ISATE 2025
TOYOTA CITY

The 18th International Symposium on Advances in Technology Education



Bridging Borders: Engineering Education with Global Citizenship

ISATE2025 CONFERENCE PROCEEDINGS

SEPTEMBER 9 – 12, 2025
TOYOTA CITY, JAPAN

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I. PREFACE

OVERVIEW

ISATE (International Symposium on Advances in Technology Education) aims to improve practice-oriented engineering and technology education through cross-institutional collaboration. It started in 2007 as an academic exchange between ten Kosen (National Institute of Technology) colleges in Japan's Kyushu and Okinawa districts and three polytechnics in Singapore. The symposium later expanded: by 2010 all Japanese Kosen joined; by 2011 two more Singapore polytechnics became co-organizers; in 2013 Nagaoka University of Technology and Toyohashi University of Technology joined; and in 2017 Hong Kong Institute of Vocational Education became an organizer. The event is co-hosted by the National Institute of Technology (NIT), five Singapore polytechnics and the Hong Kong Vocational Training Council to share education research, industry collaboration, and pedagogy.



ISATE 2025 – BRIDGING BORDERS IN TOYOTA CITY



The 18th ISATE was hosted by NIT Toyota College in Toyota City, Aichi Prefecture, Japan from **9–12 September 2025**. The conference theme, **"Bridging Borders: Engineering Education for Global Citizenship,"** encouraged participants to consider how engineering education can foster globally minded engineers capable of addressing societal challenges.

Key highlights:

- **Subthemes and Sessions:** The event organized four subthemes—engineering for welfare (e.g., assistive technologies), pedagogical innovation, artificial intelligence in teaching & learning, and engineering education for global citizenship—with workshops, oral and poster sessions that reflected these topics.
- **Participation and Program:** ISATE 2025 attracted **183 participants from 16 countries**, with a program featuring keynote speeches, institution introductions, oral presentations, poster sessions, workshops and round-table discussions. The opening ceremony and keynote sessions were held at Toyota City Welfare Center, and participants joined excursions and cultural activities.
- **Host City – Toyota:** Toyota City, known worldwide as the home of Toyota Motor Corporation, blends industry with nature. The city's history began as a silk-producing town; today it is an industrial hub with attractions such as Toyota Stadium and the expansive Toyota Ohashi Bridge over the Yahagi River. Local temples, shrines and the Obara district's four-season cherry blossoms provided cultural context for conference tours.



HISTORY

Origins and Early Expansion (2007–2013)

- **2007–2009:** The first ISATE took place at Temasek Polytechnic in Singapore (2007). Subsequent conferences were hosted by NIT Kumamoto College (2008) and Singapore Polytechnic (2009).
- **2010:** All Kosen colleges in Japan joined the symposium under the NIT's initiative. The 2010 conference was hosted by NIT Kagoshima College.
- **2011:** Two additional Singapore polytechnics became co-organizers; the 2011 conference was held at Republic Polytechnic, Singapore.
- **2012–2013:** NIT Kitakyushu College hosted in 2012; NIT Nara College hosted in 2013. Nagaoka University of Technology and Toyohashi University of Technology joined as partners in 2013.

Consolidation and Internationalization (2014–2018)

- **2014:** ISATE moved back to Singapore, hosted by Nanyang Polytechnic.
- **2015:** The theme "A New Insight for Future Engineering and Educational Systems" emphasised innovative educational systems and was hosted by NIT Nagaoka College.
- **2016:** Hosted by NIT Sendai College, the symposium celebrated its tenth anniversary under the theme "Future Prospects of Technology Education Models and Approaches," highlighting new models and approaches for practice-based engineering education.
- **2017:** Ngee Ann Polytechnic in Singapore hosted the conference.
- **2018:** The conference expanded to Hong Kong for the first time and was hosted by the Hong Kong Vocational Training Council's IVE Engineering Discipline.

Recent Editions (2019–2024)

- **2019 (Tokuyama, Japan):** The 13th ISATE in Shunan City (Tokuyama College) focused on "Engineering Education for Sustainable Development in the 21st Century." The conference provided a platform for educators to share practice-based engineering education and sustainable development initiatives.
- **2020–2021: (Online, Finland)** The COVID-19 pandemic necessitated online formats. In 2021 the event was hosted by Finland (Turku University of Applied Sciences), and the proceedings address topics such as medical technology and sustainability.
- **2022 (Online, Singapore):** The 15th ISATE was held online with Singapore acting as host. Sessions addressed technology deployment strategies for personalized learning and digital tools; examples include papers on

AI-enabled learning platforms, integrated process safety education, and virtual reality labs.

- **2023 (Matsue, Japan):** The 16th ISATE returned to Japan; held in Matsue City, it used the theme "Engineering Education After Corona" to examine post-pandemic engineering education and included keynote sessions, parallel presentations and excursions.
- **2024 (Singapore):** The 17th symposium, hosted again in Singapore, adopted the theme "Evolving Teaching and Learning in the Age of Artificial Intelligence and Sustainability." Proceedings highlight subthemes of artificial intelligence in teaching and learning, technology in education, pedagogical innovation, and stakeholder engagement.

WELCOME MESSAGE

On behalf of the National Institute of Technology, Toyota College, it is my great pleasure to welcome you to the 18th International Symposium on Advances in Technology Education (ISATE 2025), to be held in Toyota City, Japan.

ISATE has long provided an important international forum for educators, researchers, and practitioners to exchange ideas on advances in technology education. Through sustained dialogue across national and cultural boundaries, the symposium has contributed to the continuous improvement of engineering education worldwide. It is a great honor for Toyota College to host ISATE 2025 and to welcome participants from many countries.



Dr. Awaga Kunio
President, National Institute of Technology (KOSEN),
Toyota College, Toyota, Japan

Today, technology education faces both unprecedented opportunities and complex challenges. Rapid advances in digital technologies, including artificial intelligence and data-driven systems, are transforming industry and society at an extraordinary pace. At the same time, engineers are increasingly expected to address global issues such as sustainability, demographic change, and social well-being. These circumstances require us to reconsider how we educate future engineers—not only by strengthening technical expertise, but also by fostering creativity, adaptability, ethical awareness, and the ability to collaborate across disciplines and cultures.

The KOSEN (National Institute of Technology) system in Japan was established to cultivate practical and creative engineers through an integrated curriculum that combines strong academic foundations with hands-on education from an early stage. At Toyota College, we have further developed this philosophy by actively promoting international education and exchange. Each year, approximately forty of our students participate in long-term overseas interdisciplinary exchange programs lasting about ten months. In addition, many others join short-term study abroad, international internships, and overseas training opportunities. We have also established academic exchange agreements and collaborative educational projects

with partner institutions in Asia and Europe, providing our students with opportunities to learn in diverse cultural and educational environments.

In this context, ISATE 2025 is expected to contribute significantly to the further development of international projects at Toyota College. By bringing together educators and researchers from around the world, the symposium offers valuable opportunities for our students, faculty members, and staff to engage directly with global perspectives on technology education. We believe that the academic discussions and personal connections formed during ISATE 2025 will strengthen our international networks and serve as a lasting foundation for future collaboration in education and research.

Toyota City, widely known as a center of manufacturing and technological innovation, also offers a rich cultural and natural environment. I sincerely hope that your stay here will be both intellectually stimulating and personally rewarding, and that ISATE 2025 will foster lasting friendships and partnerships among participants.

Finally, I would like to express my sincere appreciation to the organizing committee, speakers, reviewers, and all those who have contributed their time and effort to the preparation of ISATE 2025. I warmly welcome all participants and wish you a productive and memorable symposium.

Dr. Awaga Kunio

President
National Institute of Technology (KOSEN), Toyota College
Toyota, Japan

II. ISATE2025 SCHEDULE

Venue: Toyota City Welfare Center (Toyota City, Aichi Prefecture, Japan)

SEPTEMBER 9TH (DAY 1)

Time	Contents	Location
9:00 - 10:00	Reception	in front of 1F Hall
10:00 - 11:00	Opening Ceremony Noh Performance GOH: Mr. Ota, Mayor of Toyota City GOH: Dr. Taniguchi, President NIT Welcome speech: Dr. Awaga, President NIT Toyota	1F Hall
11:00 - 11:15	Tea Break	in front of 1F Hall
11:15 - 12:15	Keynote Speech	1F Hall
12:15 - 13:15	Lunch	(VIP 4F room 44)
13:15 - 15:00	Institutional Speeches	1F Hall
15:00 - 15:45	Tea Break, Poster Session	4F room 41
15:45 - 17:25	Oral Session 1 (Max. 5 presents in each room)	4F room 42, 43, 45, 46
	OC/TPC Meeting	4F room 47



SEPTEMBER 10TH (DAY 2)

Time	Contents	Location
9:00 - 9:45	Reception	4F
9:45 - 10:45	Workshop 1. Active Learning: Transforming Traditional Teaching into Engaging Classrooms 2. Play to Learn: Making National Education Fun Through Game-Based Learning	4F 42, 43, 44 room 4F 46 room
10:45 - 11:00	Tea Break	4F room 41
11:00 - 12:00	Workshop 1. Active Learning: Transforming Traditional Teaching into Engaging Classrooms 2. Play to Learn: Making National Education Fun Through Game-Based Learning	4F 42, 43, 44 room 4F 46 room
12:00 - 13:30	Lunch	(VIP 4F room45)
13:30 - 15:00	Oral Session 2 (Max. 4 presents in each room)	4F room 42, 43, 44, 46, 47
15:00 - 15:45	Tea Break, Poster Session	4F room41
15:45 - 16:45	Oral Session 3 (Max. 3 presents in each room)	4F room 42, 43, 44, 46, 47
16:45 – 18:00	Move to Banquet Venue	
18:00 – 20:00	Banquet	Meitetsu Toyota Hotel



SEPTEMBER 11TH (DAY 3)

Time	Contents	Location
9:00 - 9:35	Reception	4F
9:30 - 10:30	Oral Session 4 (Max. 3 presents in each room)	4F room 42, 43, 44, 46, 47
10:30 - 10:45	Tea Break	4F room 41
10:45 - 12:15	Roundtable 5 themes	4F room 42, 43, 44, 46, 47
12:15 - 13:30	Lunch	(VIP 4F room45)
13:30 - 15:00	Oral Session 5 (Max. 4 presents in each room)	4F room 42, 43, 44, 46, 47
15:00 - 15:15	Tea Break	4F room41
15:15 - 16:45	Closing Ceremony	1F Hall

SEPTEMBER 12TH (DAY 4)

Time	Contents
8:20	Reception
8:20 - 13:00	Cultural Journey 1 (Ghibli Park)
8:20 - 14:00	Cultural Journey 2 (Toyota Commemorative Museum of Industry and Technology)
8:20 - 13:00	Cultural Journey 3 (Tie dye experience)



III. KEYNOTE SPEAKER

Mr. Beaty John	Principal and Chief Executive, Burton and South Derbyshire College, UK





IV.INSTITUTIONAL SPEAKERS

Ms. LYE Pek Ling	Lead Specialist (T&L), Nanyang Polytechnic, Singapore
Dr. SUZUKI Akihiro	President, NIT Ibaraki College, Japan
Dr. WANG Michael	Deputy Executive Director, Vocational Training Council, Hong Kong
Mr. REUNANEN Tero	Dean, Faculty of ICT and Industrial Engineering, Turku University of Applied Science, Finland
Dr. DEPAIWA Nattawoot	Director, KOSEN-KMITL, Thailand
Ms. DAGVADASH Dulmaa	Director, MUST-KOSEN College of Technology, Mongolia

V. FRAMEWORK

COUNCIL MEMBERS

Dr. TANIGUCHI Isao	(Council Chair) President, National Institute of Technology, Japan
Mr. CHAN Russell	Principal & CEO, Nanyang Polytechnic, Singapore
Mr. LIM Kok Kiang	Principal & CEO, Ngee Ann Polytechnic, Singapore
Ms. LIEW Jeanne	Principal & CEO, Republic Polytechnic, Singapore
Mr. SOH Wai Wah	Principal & CEO, Singapore Polytechnic, Singapore
Mr. LAM Peter	Principal & CEO, Temasek Polytechnic, Singapore
Dr. WANG Michael	Deputy Executive Director, Vocational Training Council, Hong Kong

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Mr. TAN Boon Liong	Academic Section Manager, Ngee Ann Polytechnic, Singapore
Mr. LONG Tien Kian	Deputy Director, Republic Polytechnic, Singapore
Mr. CHEAH Sin Moh	Master Specialist, Singapore Polytechnic, Singapore
Ms. TAN Katherina	Assistant Director, Temasek Polytechnic, Singapore
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Dr. MUTO Hiroyuki	Vice Director, Toyohashi University of Technology, Japan
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TECHNICAL PROGRAM COMMITTEE MEMBERS

Dr. TSUZUKI Keita	(TPC Chair) Associate Professor, NIT Toyota College, Japan
Dr. SHIMADA Yasuyuki	Professor, NIT Kumamoto College, Japan
Dr. KODAMA Kenji	Associate Professor, NIT Toba College, Japan
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Mr. Andy LEE Chung Hong	Senior Manager & Senior Education Specialist, Ngee Ann Polytechnic, Singapore
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Dr. NGOH Shwu Lan	Assistant Director, Singapore Polytechnic, Singapore
Mr. HALIM Tony	Assistant Director, Temasek Polytechnic, Singapore
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Dr. SUGIURA Toko	Professor, NIT Toyota College, Japan
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Ms. KOHARA Keiko	Secretariat, NIT Toyota College, Japan

And all faculty and staff members belonging to the ISATE2025 Project Steering Committee in Toyota KOSEN





VI.SUBTHEMES

OVERVIEW OF ISATE2025 SUBTHEMES

The main theme of ISATE 2025, *"Bridging Borders: Engineering Education for Global Citizenship,"* reflects the shared vision of advancing engineering education to meet global societal needs. The four subthemes explore the diverse dimensions of this mission. **Subtheme 1** emphasizes engineering's contributions to welfare, health, safety, and overall well-being, highlighting technologies and educational practices that enrich human life. **Subtheme 2** focuses on pedagogical innovation in teaching and learning, encouraging creative approaches, alternative assessments, and learner-centered methods that strengthen engagement and understanding. **Subtheme 3** examines the transformative potential of Artificial Intelligence in education, exploring AI-driven tools for adaptive learning, analytics, and ethical integration into the classroom. **Subtheme 4** promotes engineering education for global citizenship, fostering international collaboration, sustainability, and social responsibility in line with the UN Sustainable Development Goals (SDGs). Together, these subthemes invite participants to share insights and practices that connect people, ideas, and technologies across borders for a more inclusive and sustainable future.

SUBTHEME 1: ENGINEERING CONTRIBUTED TO WELFARE, FROM HEALTH AND SAFETY TO WELL-BEING



This subtheme focuses on the role of engineering in improving people's quality of life — from ensuring physical safety and health to realizing social well-being. Topics include engineering innovations for disaster prevention and emergency response, assistive and healthcare technologies, and community-based safety education. It also welcomes educational practices that integrate human-centered design, ethics, and sustainability into engineering curricula. The goal is to promote welfare-oriented engineering education that addresses real social needs, supports inclusive participation, and contributes to a safer and healthier world.

SUBTHEME 2: PEDAGOGICAL INNOVATION IN TEACHING & LEARNING



This subtheme explores forward-looking approaches that transform how engineering students learn and how educators teach. It encompasses innovative pedagogies such as project-based and active learning, competency-based assessment, flipped classrooms, and CDIO-inspired curriculum design. Presentations may highlight case studies, research outcomes, or digital strategies that empower students to think critically and creatively. The emphasis is on building resilient, learner-centered environments that respond to diverse learning styles, enhance engagement, and equip students with transferable skills required in rapidly changing engineering contexts.

SUBTHEME 3: ARTIFICIAL INTELLIGENCE IN TEACHING & LEARNING



This subtheme examines how Artificial Intelligence (AI) technologies can revolutionize engineering education. It encourages contributions that explore AI-driven analytics for monitoring learning progress, adaptive and personalized learning systems, and the ethical use of generative AI in classrooms. Research on AI-supported sustainability education, intelligent tutoring systems, and data-informed educational policy is also welcome. Through this theme, ISATE 2025 aims to deepen the understanding of how AI can augment human teaching, expand access to quality education, and inspire future engineers to harness AI responsibly and creatively.

SUBTHEME 4: ENGINEERING EDUCATION FOR GLOBAL CITIZENSHIP



This subtheme highlights the responsibility of engineering education to nurture global citizens who contribute to a sustainable and equitable society. Topics include collaborative programs among international institutions, curriculum development aligned with the Sustainable Development Goals (SDGs), and technology-enabled global learning environments. Presentations may explore intercultural competence, ethics in technology, and engineering for social innovation. By integrating global perspectives into education, this subtheme envisions engineers who can bridge cultures, address worldwide challenges, and apply their expertise for the betterment of humanity.

VII. FULL PAPERS

INTRODUCTION OF FULL PAPERS

In the ISATE 2025 Proceedings, Full Papers represent contributions that were submitted for publication as fully developed academic works. These papers were included in the Proceedings following a peer-review process conducted in accordance with the academic standards of ISATE.

The peer-review process for Full Papers was designed to evaluate the scholarly quality, originality, and relevance of each submission, as well as its contribution to the themes and objectives of the Symposium. Through this process, Full Papers were assessed to ensure that they met the expectations of rigor and completeness appropriate for peer-reviewed academic publications.

By clearly identifying Full Papers as peer-reviewed contributions, the ISATE 2025 Proceedings aim to provide readers with confidence in the academic positioning of these papers, while complementing other contribution categories that serve different purposes within the Symposium.



FULL PAPERS FOR SUBTHEME 1

ENGINEERING CONTRIBUTED TO WELFARE, FROM HEALTH AND SAFETY TO WELL-BEING

	ID	Author	Title	Affiliation	Presen-tation	Page
1	02-42-ST1-3#JP_67	KASAI Akira	Learning about SDGs from The Wisdom of Edo Period and Applying Them to The Future	National Institute of Technology (KOSEN), Fukushima College	Oral	ST1-p1
2	02-42-ST1-4#NYP_08	TOH Grace	Transforming Campus Life: Boosting Young Adult Well-being Through Play	Nanyang Polytechnic	Oral	ST1-p5
3	04-42-ST1-1#TP_04	HADIATMADJA Juniarto	Motivational and Physical Benefits of Virtual Reality Enhanced Hands-On Ideation Workflow	Temasek Polytechnic	Oral	ST1-p10
4	04-42-ST1-2#NYP_09	FIORE Federico	Exploring Open-Source Blender's Impact on Advancing Accessible and Inclusive Education in Digital Content Creation	Nanyang Polytechnic	Oral	ST1-p16
5	04-42-ST1-3#HK_03	FU Sin Pui	Application of "DriveSense" and "DriveBox" In-Vehicle Monitoring System on Wheelchair Taxi Fleet	Vocational Training Council - Hong Kong	Oral	ST1-p21
6	PP-41-ST2-01#JP_06	OHASHI Chisato	Development of a Bidirectional Health Support System for the Prevention of Frailty in COPD Patients	National Institute of Technology (KOSEN), Toyama College	Poster	ST1-p26

Learning about SDGs from The Wisdom of Edo Period and Applying Them to The Future

Akira KASAI*

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The purpose of this study is to consider the SDGs through using the wisdom of Edo period as an example. We would like to refer to the model of the Edo period to re-examine the solution for modern climate change. Modern Japan is thought to be the hottest in the past 100 years due to global warming and the effects of heat islands. However, recent research has found that the Edo period, which was considered to be a globally cold period known as the "Little Ice Age," also had years that were as hot and cold weather as now.

In the Edo period, CO_2 emissions due to human activities were limited, so it has been rarely related to global warming. It was regarded as a natural periodic fluctuation. There is also a hypothesis that "heat islands" were occurring in cities of one million people like Edo at that time. This is because the people of Edo lived in a more densely packed environment than Tokyo today, using fire under black roof tiles on hot summer days. So how did the people of Edo stand such a hot summer? In order to keep people cooling in densely populated urban areas, Edo town houses were designed to cleverly utilize the power of nature. One example is the town house of merchants were not only their home but also their shop. Most town houses had their own backyards or courtyards, where the shade of tree planted there created humidity and cooled the air as well. Besides, this cooler air was carried by the wind and circulated throughout their house. It could effectively lower the temperature in all rooms. In addition, for enduring midsummer, people in Edo would sprinkle water on the roads to lower the surrounding temperature. Sprinkling water called "Uchimizu" on the roads is a traditional helpful method to lower the temperature by utilizing the heat of vaporization that takes away heat from the surrounding area when the water evaporates. The effect can last longer if sprinkled in the morning or evening when it is relatively cool.

Humans have acquired civilization and made full use of advanced science and technology, but they have never been able to contain severe disasters or climate change in the past. Therefore, it can be said that it is more important to learn from the wisdom of the Edo period and apply it to the future.

Keywords: *SDGs, wisdom of Edo period, climate change, natural periodic fluctuation, heat islands*

Introduction

In 2023, unprecedented heatwaves were recorded around the world. In Japan, many regions saw a record number of annual heat days and midsummer days. Both Date City in Fukushima Prefecture and Komatsu City in Ishikawa Prefecture recorded temperatures of 40.0°C. Additionally, the lingering summer heat continued into autumn, with a temperature of 35.3°C observed in Kuwana City, Mie Prefecture on September 28th, and many locations in the Kanto region recorded summer-like temperatures on November 7th. Looking beyond Japan, the year of 2023 saw temperatures exceeding 45°C along the Mediterranean coast and in the southern United States. According to a report released by the National Oceanic and Atmospheric Administration (NOAA) on January 12th, 2024, the average temperature for 2023 was 1.35°C higher than the average before the industrial revolution.

While such abnormal high temperatures can be attributed to natural phenomena that have recurred throughout Earth's history, such as the El Niño event, there is no doubt that the impact of greenhouse gases, including carbon dioxide emitted from industrial activities of human beings, contributes to global warming. This viewpoint has been widely accepted by researchers in recent years. UN Secretary-General Guterres described this situation as "global boiling." The choice to use a term more extreme than global warming is intended to signal that the progress of global warming is in a crisis situation.

If global warming continues, the gradual changes we have seen until now could cross a "tipping point," leading to rapid changes. This could worsen climate change, resulting in more frequent natural disasters and making it impossible to revert to previous conditions. We are compelled to halt the progression of global warming before it reaches that point. Global warming does not only lead to rising temperatures but can also trigger various disasters. For instance, in 2023, the wildfires that occurred in Greece and on the Hawaiian island of Maui in the United States were caused by rising temperatures, and they can lead to heavy rainfall as well.

As temperatures rise, air can hold more water vapor, making it more likely for heavy rains to occur once clouds form. In Japan, from June 28th to July 16th in 2023, heavy rains swept across the country, leading to flooding in nine first-class rivers, causing damage to 3,082 homes and resulting in 14 fatalities. Additionally, Hong Kong experienced its heaviest rainfall since observations began 140 years ago.

The risks of heatstroke due to high temperatures, as well as the spread of infectious diseases, cannot be overlooked either. For other living organisms, this may also lead to the extinction of endemic species.Moreover, due to poor harvests caused by abnormal weather, issues related to the risk of food, water, and energy shortage will be likely to lead to increase the number of conflicts in the future.

Materials and Methods

The title of this study is “Learning the SDGs from Edo and Applying them to the Future.” What do we need to do in response to climate change these days? We would like to consider the Edo period as a model from the perspective of SDG 13, “Climate Action.” This is also linked to Goal 11, “Sustainable Cities and Communities.” Below, we would like to examine whether there are elements from how people spent summer during the Edo period that can be useful in coping with the modern intense heat.

Modern Japan is considered to be the hottest in the past 100 years due to global warming and heat islands. The heat and cold alternate. However, recent research has shown that even the Edo period, which was considered to be a cold period around the world, called the “Little Ice Age,” also had years as hot as today.

Climate change should not simply refer to rising temperatures, but to alternating heat and cold. With this in mind, we must take measures to combat global warming.

Although the summer temperature in modern Tokyo has been rising year by year over the long term, there were also extremely hot years in the Edo period. It should be noted that the temperature data recovered from diaries and other sources contains errors in estimation, but at least the early 1850s were warm enough to be as warm as today.

So why were extremely hot years observed in the Edo period, which was said to be cold? In the Edo period, CO_2 emissions from human activities were limited, so it was not global warming. Cyclical fluctuations of nature are conceivable. An analysis of the time-series data for the average July temperature in Tokyo (or Edo) recovered from the weather records of the diary shows the effects of solar cycles (21 years, 10.5 years), El Niño-Southern Oscillation (ENSO: 6.3 years, 50 years, 32 years), and Quasi-Biennial Oscillations. It is possible that such a natural periodic rise in temperature had an effect during the period of the end of the Edo period. Apart from this, there is also the influence of weather phenomena that are unique to smaller regions. For example, in Yamagata, it is known that high temperatures are often observed due to the "Fern phenomenon" in which dry hot air blows down from the Sea of Japan over the mountains. Besides, there is also a hypothesis that a “heat island” has been occurring in a million cities like Edo since that time.

The German physician and naturalist Philipp Franz von Siebold (1796–1866), one of the three scholars of Deshima who influenced negotiations during Commodore Perry's arrival, established this hypothesis based on observations made using thermometers at the time. In his “Diary of Siebold,” he noted during his stay in Edo in 1861 that “in July and August, it is hot in Edo Bay and in Edo and the surrounding areas. Sometimes, even in the shade, temperatures reached 94°F (about 34.4°C).” He also mentioned that “there is a constant wind blowing from the south and southeast.”

Furthermore, he explained the cause as follows: one reason is the black and thick roof tiles. “This wind is a natural result of the air on Earth being heated abnormally by the black and thick roof tiles. These black tiles cover an area that stretches for miles over the vast city.” Figure 1 is a photo of the black and thick roof tiles. This is around the first year of the Keio era (1865) View from Mt.Atago (FeliceBeato). https: // www.oldphoto-japan.com/photos/189/atagoyamatokyo#. Indeed, black tiles have a high absorption rate of sunlight, which causes them to become very hot during the day and heat the surrounding air. This is widely recognized, and even today, the use of roof materials that have high heat insulation and reflectivity properties is recommended as a countermeasure against heat islands.



Figure 1 The black and thick roof tiles

Additionally, during the late Edo period, the population of Edo was much denser, exceeding 1 million in 1721 from 60,000 in 1600, and peaking at 1.14 million in 1846. When calculated as population density, this results in approximately 23,000 people/km², far surpassing the current population density of Tokyo, which is about 6,000 people/km² (according to the 2020 census by the Ministry of Internal Affairs and Communications). The people of Edo lived a life using fire under black roof tiles in such a densely packed environment on hot summer days. Thus, imagining “Edo's heat island” may not be entirely fanciful.

How can we suppress global warming? Efforts are also being made to reduce greenhouse gases. Moreover, cities aiming for “carbon neutrality” are emerging around the world. Technologies for carbon dioxide capture and storage are being demonstrated on a large scale in Japan as well. The development of clean energy is also being promoted. For example, in wind power generation, which is expected to expand, the latest technology utilizing typhoons has also appeared. There are high expectations for such cutting-edge technologies.

However, we should also focus on what each of us can do immediately. This is precisely the wisdom and ingenuity of our ancestors from the Edo period.

Results and Discussion

It is meaningful to take a closer look at their wisdom to get over the hot summer then. As previously mentioned, the CO_2 emissions during the Edo period were not high, and there was no phenomenon of global warming. Temperature rises due to natural periodic climate changes. So, how did the people of Edo overcome the hot summers? Actually, the houses in Edo were designed to efficiently utilize natural forces to provide cooling even in densely populated urban areas. One example is the machiya, where merchants lived and operated their businesses. Most machiya had backyards or courtyards (tsuboniwa), where the shade of plants and trees generated humidity, which cooled the air. The cold air circulated throughout the house with the wind, effectively lowering the temperature in all rooms. The homes of farming families were also built to promote airflow.

Rooms that are usually separated by sliding doors can be opened up in the summer, and in this way the breeze can be flown from the beaten floor through the house to the garden beyond. The humid space of the beaten floor cools the air, making it significantly cooler throughout the house even in midsummer. Additionally, the house promotes air circulation with what is commonly known as a 24-hour ventilation system. Modern homes are highly airtight, with individual rooms separated by doors. Since July 2003, the implementation of "24-hour ventilation systems" has been mandatory in housing, and the idea of ventilating the entire home rather than each room individually is similar to the design of Edo-period homes, for example, the Air Path construction method. What are the ways to cool a house that either does not have a 24-hour ventilation system installed or does but is still warm? Opening windows and allowing the wind to flow in is one method. In the evening, when temperatures drop or after returning home, opening the windows to let in the cool outside air is effective as it exchanges the air inside. When utilizing openings for ventilation, it is effective to open windows or doors that are diagonally opposite from each other and as far apart as possible. This was also effective in countering COVID-19. For places like walk-in closets that have no windows and tend to trap heat, fans or circulators can be placed to direct airflow towards rooms with windows or ventilation features to expel the heat outside.

The deep eaves at the front entrance of a traditional Edo townhouse resembled a modern arcade, protecting the house from strong sunlight and rain. Passersby could comfortably walk under the eaves of the storefronts during hot and rainy days while shopping. Similarly, the eaves of homes were also extended outward significantly, serving to block sunlight and rain from entering spaces like the porch or workspace outside the home. As an outdoor ingenuity, the waterways intertwined throughout the town served as a natural cooling system. In the densely populated Edo urban area, the water channels and rivers crisscrossed, creating a cool breeze.

Furthermore, during the peak summer season, people would sprinkle water on the streets, a practice known as "uchimizu," to lower the surrounding temperature. Uchimizu cools the air by utilizing the heat of vaporization when the water evaporates, absorbing heat from the vicinity. However, if done when the ground is hot during the day, the sudden evaporation can lead to a rise in temperature, making it feel even more humid. Therefore, sprinkling water in the relatively cooler mornings or evenings is more effective, and it is better to sprinkle it in the shade than in the sun. Last year, in 2024, Tokyo launched a webpage named "Uchimizu Biyori" with the slogan "This summer will be boiling in Tokyo."

Also, close the curtains during the day when going out and ventilate when returning home. To reduce the amount of heat and sunlight entering through the windows, use blackout curtains inside the house. Installing outdoor bamboo blinds can block sunlight while allowing air to pass through, which is excellent. Besides, some types of awnings that can be added later, as well as insulation sheets or films that can be applied to windows, are also helpful in reducing sunlight easily.

There is also a method of borrowing the power of plants. Climbing plants, or "green curtains," which are natural curtains that soften sunlight, can cover the windows and walls of buildings to make it more difficult for sunlight to enter the room. Even placing foliage plants outside the window can reduce the amount of direct sunlight hitting the window. Herbs and evergreen perennials can serve as green curtains, providing coolness with some ingenuity.

The townhouses of Edo are practical and efficient. They are the result of creativities applied to every aspect of the building's structure and mechanisms. Even in modern times, there are various approaches to feel cool outside of just house design. Without relying on high technology, we can feel cool with just some ingenuity, relying on our own senses. Using tatami mats and rush mats is one way to stay cool. The "igusa tatami" commonly used in Edo has properties that do not conduct heat through the sponge-like parts of the igusa and the straw parts of the tatami base, has high natural moisture absorption capability, and is suitable for hot and humid conditions, making it excellent for allergy prevention. Moreover, tatami mats are soft, so they do not cause fatigue even after sitting for long periods. If there is no tatami room in the house, there are tatami mats that can be used like rugs laid on flooring. If you have a tatami room, it's comfortable to spend hot days there. Tatami rooms have a low floor and high ceiling, allowing for good air circulation and coolness. Tatami rooms typically use many sliding doors and fusuma, which block sunlight and lower the temperature inside.

You can also cool the space with colors and scents. There is a difference in perceived temperature when seeing cool colors (blue tones) and warm colors (red tones). In fact, white, blue, and green colors also help prevent radiant heat. By creatively choosing the colors of curtains and decorative items, you can create an impression of coolness visually. When smelling mint, people's bodies feel cool, and their perceived temperature drops by 4°C. (From the website of the Japan Aromatherapy Environment Association)

It is also possible to understand and utilize microclimates. The summer heat today is directly influenced by climate change, making fundamental

improvements to the overall heat in Japan difficult. Therefore, what we want to pay attention to is the concept of "microclimate." It means a climate in a narrow area.

Moreover, the "microclimate" mentioned earlier would like to be emphasized by the author. Microclimate refers to a climate in a narrow area. People in the Edo period were masters at understanding and utilizing microclimates, especially in agriculture and garden design. They intentionally made use of microclimates. Anyone in the Edo period knew that if there were trees or walls in a garden, that corner would have more shade and become cooler (and warmer in winter) than other areas for most of the year. That was why they used trees, walls, potted plants, or sunshades to create shade. They also utilized trellises or differences in elevation indoors to improve ventilation, creatively generating a microclimate. These are ideas we would like to incorporate even today. In the future, it would like to be recommended to students who want to live in a house with a garden by the author.

Furthermore, it is a helpful idea to pursue coolness through ears and eyes. For example, wind chimes, hung on the eaves and producing a refreshing tinkling sound, were regarded as a popular item to cope with the heat in the Edo period. While they didn't actually lower the temperature, the sound likely provided a sense of coolness. In the early Edo period, glass was quite precious, making wind chimes a luxury item inaccessible to the common people. However, as glass craftsmanship spread, the price of wind chimes decreased, and vendors began to sell them. Similarly, goldfish provided a visual sense of coolness. By the late Edo period, they became accessible to the common people as well. When purchasing goldfish from vendors, they were placed in small glass containers called "kingyo-tama," which people would hang from their eaves and admire at home.

Although refrigerators did not exist during the Edo period, there were specific foods and drinks that provided relief from the summer heat. Watermelon, juicy and still popular in summer today, was chilled using water from wells or tubs during that time.In summer, vendors selling cold water could be seen walking around calling out, "Hya-koi, hya-koi"! They sold cold spring water mixed with sugar and white rice dumplings for about 4 mon (approximately 100 yen today), making it an affordable way for common people to enjoy some coolness in summer. Additionally, drinks such as barley tea and loquat leaf tea were also sold. Another summer favorite was sweet sake (amazake). While today it is perceived as a winter drink, in the Edo period it was often consumed during summer to supplement nutrition and prevent summer fatigue, as indicated by its recognition as a summer term. Furthermore, there were merchants selling tokoroten, which was likely enjoyed as a snack.

The content mentioned above has been covered in the general subject called SDGs Exploration, a required subject course for 1st year students in the Advanced Courses, for the past four years in NITFC. In that subject, the students have been discussing how, in fact, until half a century ago, people were committed to discover their best way of living that could cope with modern climate change, especially the extreme heat of summer. On the other hand, when the circumstances 50 years ago were depicted by the author, they were sometimes relied on the author's own experiences as the junior high school student.

However, the stories, which may be quite distant in age from the students, seem hardly to resonated with them as much as these stories had been hoped by the author. Furthermore, it is believed that the fact that Iwaki City, where our school is located, does not have any scorching hot days may be another significant reason.

On the contrary, at the Human College hosted by Iwaki City, we have been discussing specific examples from the Edo period in the "SDGs Exploration Department" for the past five years. Many of the participants are senior citizens, so even when discussing stories from half a century ago, they can receive more empathy than the students.

Therefore, from this school year on, students started being assigned by the author to ask their grandparents about old methods to deal with heat management. They need to summarize what they learned and present it, and then have to put these old-fashioned initiatives into practice with some feasible ideas. By doing so, the author is convinced that they will understand how Japanese people in the past implemented practical solutions for warming countermeasures.

Conclusions

As mentioned above, people in the Edo period dealt with hot summers using their life wisdom, even though they did not have access to modern technology. Such knowledge and ingenuity from our ancestors can be applied immediately, as seen in practices like sprinkle water, and this should be implemented alongside the latest technology without any doubt.

Although humans have acquired civilization and made full use of advanced science and technology, they have not been capable of preventing severe disasters or climate change as before. Therefore, it can be said that it is more significant to learn from the wisdom of the Edo period and apply it to the future along with taking largescale measures against climate change.

References

Eisuke Ishikawa. (1990).The Energy Situation of Edo. Kodansha

Eisuke Ishikawa. (2003). The Ecology Situation of Edo.Kodansha

Eisuke Ishikawa. (2008). The Edo Period is an Eco-Age. Kodansha

Eisuke Ishikawa.(2009). The Energy Conservation Situation of Edo. Kodansha

Gennki Katata. (2021). Severe heat years comparable to modern times even in the Edo periodInternational. Institute for Environmental Economics.https://ieei/or.jp

Yotarō Matsuda. (2024). Boiling Earth. Newton Press

TRANSFORMING CAMPUS LIFE: BOOSTING YOUNG ADULT WELL-BEING THROUGH PLAY

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The escalating global prevalence of mental health issues among young adults is a pressing concern. Singapore, like many nations, is experiencing a growing incidence of mental health issues among this age group, which often faces high levels of stress and societal expectations to be competent and happy. and societal expectations to be competent and happy. This paper explores developing innovative physical positive psychology interventions (PPI) on campus, inviting engagement and fostering playful experiences to improve the emotional and social well-being of young adults aged 17 to 22 at a design school in Singapore. The goal is to demonstrate a tangible increase in positive emotions substantiating improvements in overall well-being after interactions with the interventions.

Using the Positive and Negative Affect Schedule - Short Form (PANAS-SF), the study assessed emotional changes among 143 participants over a six-week period. While no significant difference in positive affect was observed between intervention and control groups ($t(177) = 0.930$, $p = .353$), a significant reduction in negative affect was found among those engaging in the interventions ($t(177) = -4.506$, $p < .0001$), suggesting a beneficial effect on reducing negative emotions. The findings highlight the effectiveness of play interventions in enhancing the emotional well-being of students within educational settings by significantly lowering negative affect, while not significantly altering positive affect within the study's timeframe. These optimistic outcomes provide valuable insights into the effectiveness of the PPIs aimed at enhancing the well-being of students on campus, suggesting that playful experiences on campus can serve as a practical tool for enhancing emotional well-being, particularly by addressing negative emotions.

Keywords: *Play, positive psychology interventions, positive emotions, well-being, young adults*

Introduction

The growing prevalence of mental health challenges among young adults underscores the urgent need for innovative approaches to promoting emotional well-being, a trend also observed in Singapore (Wales et al., 2022). This issue is particularly pressing as young adults face intense academic stress and societal expectations to succeed while maintaining emotional balance (Chodkiewicz & Boyle, 2016; Ho, 2022). As Hargreaves and Shirley (2018) aptly state, “While it is heroic to keep pulling drowning people from a river, it is also important to go upstream to stop those who are pushing them in.” This perspective emphasizes the importance of addressing root causes rather than merely treating symptoms, offering a more sustainable solution to these challenges.

This study addresses the critical need to enhance the well-being of young adults, primarily those aged 17 to 22, at the School of Design & Media in Nanyang Polytechnic in Singapore. "The Playful Kit!," a physical positive psychology intervention (PPI), was designed to foster playful experiences on campus. Drawing on theoretical frameworks such as the PERMA Model (Seligman, 2011) and Self-Determination Theory (Ryan & Deci, 2000), the intervention focuses on fostering autonomy, competence, and relatedness—three essential components of intrinsic motivation and well-being. Implemented at the school, the intervention aimed to evaluate its potential for increasing postive emotions and reducing negative emotions, resulting in improved emotional well-being (Levenson, 1994).

Background and Literature Review

The "Playful Kit!" leverages play to enhance well-being, drawing on positive psychology's recognition of play's role in boosting positive emotions (Bateson, 2014; Fredrickson, 2001; Seligman, 2011). Given the extended amount of time students spend on campus, integrating play into this environment by creating a safe, engaging, and psychologically supportive space presents a promising strategy to enhance their mental and emotional health (Farley, Behr & Brown, 2021), fostering emotional resilience and reducing stress.

Csikszentmihalyi (1981) describes play as a pathway to intrinsic motivation and flow, while Fredrickson's (2001) Broaden-and-Build Theory demonstrates how positive emotions derived from play broaden cognitive and emotional resources. Conversely, the reduction of negative emotions is critical for improving overall well-being, as suggested by Levenson (1994).

This study is grounded in two complementary foundational well-being theories: the Self-Determination Theory (SDT) and the PERMA Model shown in Figure 1. Figure 2 illustrates the Self-Determination Theory (SDT), which posits three essential psychological needs for human flourishing: Autonomy, Competency, and Relatedness. These universally innate needs, when satisfied, correlate with personal well-being, individual growth, optimal functioning, and enhanced social development.

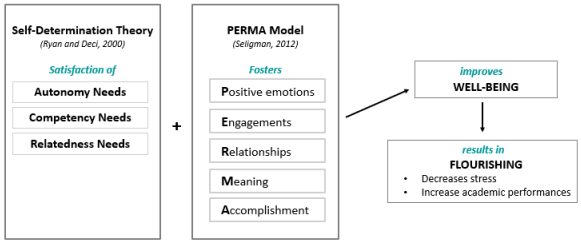


Figure 1 Well-Being Theories employed in the design of the intervention

Drawing from the Self-Determination Theory, the concept of 'Autonomy' enhances intrinsic motivation, 'Competence' involves mastering tasks tailored to users' capabilities and 'Relatedness' engages and connects players fostering social connections through play, improves psychological functioning, psychological growth and well-being. Conclusively, the play elements in the "Playful Kit!" should be enjoyable, moderately challenging, and realistically achievable, and relatable.



Figure 2 Details of the Self-Determination Theory (SDT) (Ryan and Deci, 2000)

Another widely adopted well-being model by Dr Martin Seligman is the PERMA Model presented in Figure 3. The PERMA Model identifies Positive Emotions, Engagement, Relationships, Meaning, and Accomplishment as the core building blocks of well-being (Seligman, 2011). Together, these models informed the design of "The Playful Kit!" by emphasizing activities that are intrinsically motivating, socially engaging, and emotionally enriching.

Positive Emotions	Encompass experiencing positive emotions through cultivating gratitude, forgiveness, savouring joy, practicing mindfulness, and building hope and optimism.
Engagement	Refers to complete absorption in an activity or task in which someone fully deploys their skills, strengths, and attention, often associated with the concept of 'flow' (Csikszentmihalyi, 1989) when one's skills are just sufficient for a challenging activity.
Relationships	Encompass feelings amplified through our relationships, for example, great joy, meaning, laughter, a feeling of belonging, and pride in accomplishment. The feelings of being loved, valued, and supported by others is one of the best antidotes to "the downs" of life and a good way to bounce back.
Meaning	Entails a sense of meaning and purpose can be derived from belonging to and serving something bigger than the self, such as family, religion, science, politics, work organizations, justice, the community, social causes, among others.
Accomplishment	pertains to achievements, a sense of competence, success and mastery in completing tasks.

Seligman (2011)

Figure 3 Details of the PERMA Model by Seligman (2011)

Design of "The Playful Kit!" Intervention

This design is guided by a comprehensive theoretical framework, incorporating research on play, playfulness, positive emotions, social connections, and well-being (Huizinga, 1949; Csikszentmihalyi, 1981; Ryan and Deci, 2000; Seligman, 2011). Figure 4 further elaborate the relationships and outcomes of the comprehensive theoretical framework and underpinning well-being theories as discussed in the literature review.

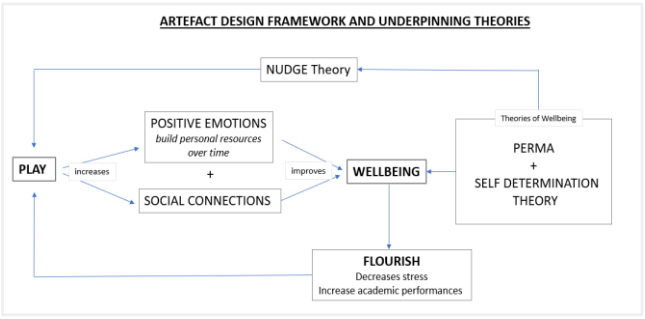


Figure 4 "The Playful Kit!" design framework and underpinning theories

Several case studies were analysed to explore the practical application of SDT and the PERMA Model. These case studies collectively demonstrate the principles of the well-being theories, which are instrumental in shaping the "Design Guidelines for Playful Kit! Elements, serving as a structured framework for creating each play element, ensuring that the interventions remain aligned to its design intentions and result in enhancing the well-being of participants.

Design Guidelines for *<insert title of play element>*		
User Needs based on Self-Determination Theory (Ryan & Deci, 2000)		
Component	**Level**	**Describe how it is achieved**
Autonomy	☐ ☐ ☐	*i.e., User decides level and depth of engagement*
Relatedness	☐ ☐ ☐	
Competency	☐ ☐ ☐	
Based on PERMA Model as analysis for Intended Outcomes (Seligman, 2011)		
Component	**Level**	**Describe what is achieved**
Positive Emotions	☐ ☐ ☐	*i.e., Encourages altruism*
Engagements	☐ ☐ ☐	
Relationships	☐ ☐ ☐	
Meaning	☐ ☐ ☐	
Accomplishment	☐ ☐ ☐	

Figure 5 Design Guidelines for Playful Kit! Elements

Two play elements, “Kindness QR” and “Toss for Better”, were implemented in classroom settings to evaluate the interventions’ impact on student well-being. The play elements were administered to the students in a classroom environment for this study. As shown in Figure 6, “Kindness QR” involved an array of QR codes, each revealing a random act of kindness when scanned. Participants had the *autonomy* to choose when and how often to engage, introducing an element of spontaneity and playfulness. Though modest, the acts varied in their levels of engagement *(competence)* and personal investment *(relatedness)*, fostering emotional and social benefits. Additionally, these random acts of kindess encouraged altruism and social connections, key contributors to well-being.

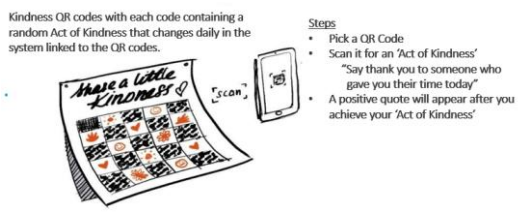


Figure 6 “Kindness QR” intervention

The second play element, “Toss for Better” as shown in Figure 7 constitutes a more structured setup. Embedded within the “Toss for Better” component is an element that contributes to the cultivation of self-compassion (Korner et al., 2015) and the cognitive re-appraisal of unfavourable thoughts. Participants are prompted to articulate their negative emotions on an activity sheet, reframed them into positive perspectives, and then physically tore off and crumpled the negative section. These were discarded into bins labeled with supportive messages, facilitating emotional release and constructive reframing. (Neff, 2021). This hands-on process enables participants to discard the physical representations of their negative emotions while encouraging constructive act of reframing, fostering a more positive mindset.



Figure 7 “Toss for Better” intervention

Methodology

The Positive and Negative Affect Schedule – Short Form (PANAS-SF) has been designated as the principal quantitative instrument to assess the effects of the play elements featured in the "Playful Kit!" given the necessity for *prompt responses immediately after engagement* with the play elements (Moskowitz et al., 2020). Participants will evaluate their emotions using a 20-item questionnaire and utilise a 5-point Likert scale for scoring, as depicted in Figure 8.

Emotions You Felt		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
PANAS 1	Interested	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 2	Distressed	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 3	Excited	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 4	Upset	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 5	Strong	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 6	Guilty	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 7	Scared	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 8	Hostile	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 9	Enthusiastic	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 10	Proud	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 11	Irritable	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 12	Alert	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 13	Ashamed	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 14	Inspired	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 15	Nervous	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 16	Determined	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 17	Attentive	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 18	Jittery	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 19	Active	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 20	Afraid	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Scoring:

Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 – 50, with higher scores representing higher levels of positive affect.

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 – 50, with lower scores representing lower levels of negative affect.

Your scores on the PANAS:

Positive:_____ **Negative:**_____

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positiveand negative affect: the PANAS scales. Journal of personality and social psychology, 54(6), 1063.

Figure 8 PANAS-SF Questionnaire

A total of 143 students from various courses and study stages from the School of Design & Media participated in this study over six weeks. They were divided into two groups: Group 1 had no exposure to the play elements while Group 2 engaged with the play elements. All participants completed a PANAS-SF pre-survey at the start of the six weeks to establish their baseline emotional states during mid-term where stress levels are usually high due to assignment deadlines. For Group 1, a survey to assess their states of emotions was conducted at the end of six weeks as controlled study. Post-engagement surveys were conducted for Groups 2 to evaluate immediate and sustained emotional effects under similar emotional and physical stress levels periods.

Data Analysis & Findings

The data analysis for this study involved conducting pooled t-tests to compare the changes in positivity and negativity scores between participants who were

exposed to the play intervention and those who were not, assuming equal variances across the groups. An increased Positive Affect (PA) and/or decreased Negative Affect (NA) will indicate efficacy of the positive psychological interventions (PPI), denoting improved overall well-being. For the first research question, which asked if there was a difference in positive affect (PA) for those exposed to play intervention compared to those who were not, the results in Figure 9 showed a t-statistic of 0.930 with 177 degrees of freedom and a p-value of 0.353. Since the p-value was greater than the conventional alpha level of 0.05, we failed to reject the null hypothesis, indicating no statistically significant difference in the change of PA scores between the two groups. This suggests that while play intervention might engage participants in positive activities, it does not significantly enhance positive emotions within the study's timeframe compared to those not exposed to the intervention.

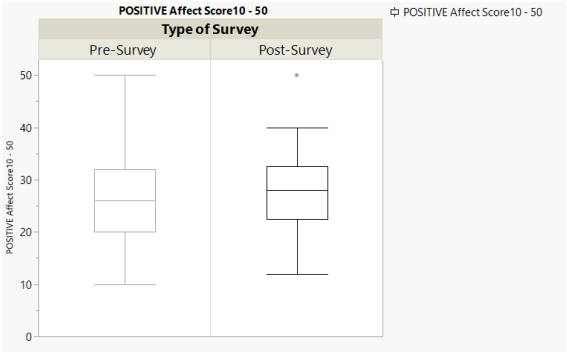


Figure 9 Effect of Play Intervention on Emotional Well-being: Changes in Positive Affect Scores (Pre- and Post-Survey)

The second research question seeks to investigate a difference in the negative affect (NA) for those who were exposed to the play intervention compared to those who did not. Figure 10 revealed a t-statistic of -4.506 with 177 degrees of freedom and a highly significant p-value of less than 0.0001. This led to the rejection of the null hypothesis, demonstrating a statistically significant difference in the change of NA scores. Specifically, those who underwent play intervention showed a significant reduction in negativity scores compared to the control group. This finding highlights the effectiveness of play intervention in reducing negative emotions, which is crucial for enhancing overall emotional well-being.

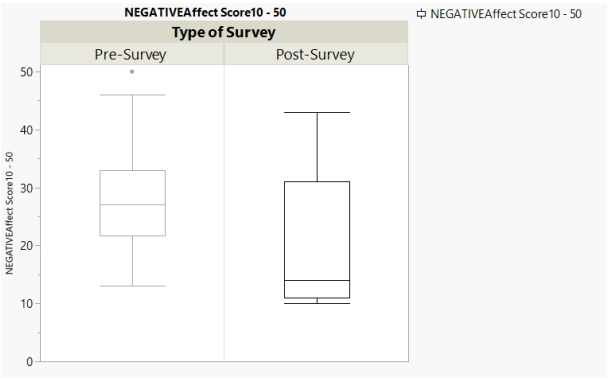


Figure 10 Effect of Play Intervention on Emotional Well-being: Changes in Negativity Scores (Pre- and Post-Survey)

In summary, the study's findings revealed distinct impacts of the interventions indicating that play intervention significantly reduces negative emotions.

Discussion

The inquiry of this research aims to explore the introduction of play using positive psychological interventions (PPI) on campus boosting the well-being of young adults in a design school in Singapore. The results underscore play's potential as an effective tool in environments like educational settings to manage and alleviate negative emotions among students. In schools, where academic pressure and social stressors are prevalent, integrating play interventions can serve as a buffer against stress, potentially leading to a decrease in anxiety, depression, and other stress-related issues. This can create a more supportive and less stressful learning environment, which is conducive to better mental health and academic performance.

However, the study, while providing valuable insights, has several limitations that must be acknowledged to contextualize the findings appropriately. Firstly, the sample size of 143 students, although sufficient for initial exploratory research, is relatively small, which could limit the generalizability of the results to broader populations of young adults, and beyond the design school. Secondly, the duration of the intervention was limited to six weeks, which might not be long enough to observe long-term changes in emotional well-being. Mental health interventions often require sustained engagement to yield enduring results. The short-term nature of this study might also not capture the full potential of the "Playful Kit!" in fostering lasting positive changes, particularly in terms of habit formation and sustained emotional resilience. Repetitive interaction with play elements over time may be considered for sustained positive outcomes (*habits*). While the study accounted for academic workload and period, factors such as personal life events or pre-existing mental health conditions were not fully accounted for, which could have influenced the results.

Conclusion

Despite its limitations, the study has significant implications for educational institutions and the field of positive psychology. The findings suggest that integrating structured, playful activities, guided by SDT and the PERMA model, into the daily routines of educational environments can reduce stress, significantly enhancing emotional well-being, and the management of negative emotions increases resilience (Levenson, 1994; Fredrickson, 2001). The study emphasizes the transformative role of play in creating supportive educational environments. By integrating immersive and interactive playful activities, institutions can promote sustained positive emotional states, strengthen social connections, and enhance community engagement. This approach has the potential to drive systemic changes, positioning play as a central element of campus culture and contributing to a holistic educational experience. Future initiatives should explore the mechanisms by which play fosters emotional resilience and evaluate the long-term impact of such interventions on student well-being.

Moreover, the incorporation of physical play elements could serve as an antidote to the pervasive digital engagement among young adults, promoting a 'digital detox' and facilitating genuine, face-to-face social interactions. Importantly, the benefits of playful engagement extend beyond those naturally inclined towards play; even those initially hesitant can experience improvements in well-being from the positive emotions generated by such activities. This research sets a foundation for further exploration into how play can be systematically integrated into educational and broader societal contexts to support the emotional and social development of young adults.

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References

Bateson, P. (2014). Play, playfulness, creativity and innovation. Animal Behavior and Cognition, 2(2), 99.

Chodkiewicz, A. R., & Boyle, C. (2017). Positive psychology school-based interventions: A reflection on current success and future directions. *Review of Education*, 5(1), 60–86.

Csikszentmihalyi, M. (1981). Some paradoxes in the definition of play. In A. Cheska (Ed.), Play as Context: 1979 proceedings of the Association for the Anthropological Study of Play (pp. 14-26). *West Point, NY: Leisure Press.*

Farley, A., Kennedy-Behr, A., & Brown, T. (2021). An investigation into the relationship between playfulness and well-being in Australian adults: An exploratory study. *OTJR: Occupation, Participation and Health*, 41(1), 56–64.

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist*, 56(3), 218–226.

Hargreaves, A., Shirley, D. (2018). What's wrong with well-being? *Educational Leadership*, 76(2), 58–63.

Ho, W. W. Y. (2022). Influence of play on positive psychological development in emerging adulthood: A serial mediation model. *Frontiers in Psychology*, 13, 1057557.

Huizinga, J. (1949). Homo Ludens: A study of the play-element in culture. (R. F. C. Hull, Trans.). London: Routledge & Kegan Paul.

Levenson, R. W. (1994) Human emotions: A functional view. In The nature of emotion: Fundamental questions (ed. P. Ekman & R. Davidson), 123–126. New *York: Oxford University Press.*

Moskowitz, J. T., Fernando, C., Zhang, W. M., Huffman, J. C., & Addington, E. L. (2020). Measuring Positive Emotion Outcomes in Positive Psychology Interventions: A Literature Review. Emotion Review. *Vol. 13 (1)*, 60 - 73.

Neff, K. D., Bluth, K., Tóth-Király, I., Davidson, O., Knox, M. C., Williamson, Z., & Costigan, A. (2021). Development and validation of the Self-Compassion Scale for Youth. *Journal of personality assessment*, 103(1), 92-105.

Ryan, M. R., & Deci. L. E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Article, American Psychologist*, Vol. 55(1), 68-78,

Seligman, M. E. P. (2011). Flourish: A visionary new understanding of happiness and well-being. *Free Press.*

Wales, M., Mårtensson, F., Hoff, E., & Jansson, M. (2022). Elevating the role of the outdoor environment for adolescent well-being in everyday life. *Frontiers in Psychology*, 13, 774592.

MOTIVATIONAL AND PHYSICAL BENEFITS OF VIRTUAL REALITY ENHANCED HANDS-ON IDEATION WORKFLOW

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Imagine architecture and interior design students sketching in 3D space rather than a 2D piece of paper. Imagine these students sculpting forms intuitively with modifiable colour and scale. Imagine students moving around as they ideate as compared to doing it as prolonged unhealthy sedentary activity on a desk. These are some potential benefits offered by a virtual reality (VR) enhanced hands-on design ideation workflow that currently have not been widely realized. A workflow that this pilot study at a polytechnic built environment studies related course in Singapore wishes to explore.

Singapore is a relevant context that provides opportunity for a rigorous litmus test for this research. This is due to the increasingly mandatory use of Building Information Modelling (BIM). It is a prominent requirement in built environment studies education in Singapore. There are clear benefits that warrant the increased adoption of BIM in Singapore. The information inherent in the models created in BIM software would be able to be used for a range of analysis on the building. These benefits range from topics such as quantity surveying, structural integrity to environmental performance. However, there is currently a major difficulty in teaching the students the use of BIM in a creative and intuitive ways for even making the building's initial form. Currently, the complex procedural and parametric workflow of BIM software is very counter intuitive for the students. Exploring a workflow that introduces the use of VR created forms as input for BIM at the conceptual design stage of a project has the potential to make a breakthrough in overcoming this major obstacle.

This paper compared the students' conceptual designs using BIM software that were done using a conventional BIM workflow with results that are achieved when forms created in VR modelling were used as input for BIM. The comparison reveals that there are tangible improvements in terms of intuitive, enjoyable as well as healthier kinaesthetic creation processes. The VR modelling inputs also expanded the range of highly exploratory forms that are achievable. However, the current research identified some current limitations that the VR created forms on specific circumstances could not be made into specific building parts. There are also, some current additional requirements needed to enable effective transfer of data from the VR Modelling to the BIM software. Future research is planned to address these limitations.

Keywords: *Virtual Reality Modelling, Building Information Modelling, Kinaesthetic Design, Hands-on Intuitive Design*.

Introduction

In the current digital age, it has become increasingly difficult for built environment design courses to dedicate sufficient training of students on basic manual, hands on intuitive skills. These range from abilities to externalise ideas by sketching on a piece of paper to roughly sculpting forms. There is constant pressure to reduce teaching hours for these fundamental skills (Patron et al, 2021; Oxman, 2008; Ranscombe et al, 2017). In its place, an increased emphasis is given to digital means of production that are increasingly required to be used in the built environment industry. (Page, 2019; Bacus, 2020).

Singapore provides a tangible context in which this shift is very evident. This is especially seen in the increasing emphasis on promoting the use of Building Information Modelling (BIM). It has become increasingly mandatory to make digital submissions for planning approval of new buildings using the BIM format (Lin et al, 2016). This trend is related to the detailed building information that can be captured in this format. Information that have a multitude of uses such as for structural calculations, building material quantification and even environmental analysis (Kirby, et al. 2017).

There is a concern that increased use of BIM could potentially undermine the creative thinking ability of future designers of the built environment. The common nature of the BIM workflow that requires prolonged, elaborate initial setup, complex procedural and numeric input makes it very counter intuitive as seen in Figure 1.

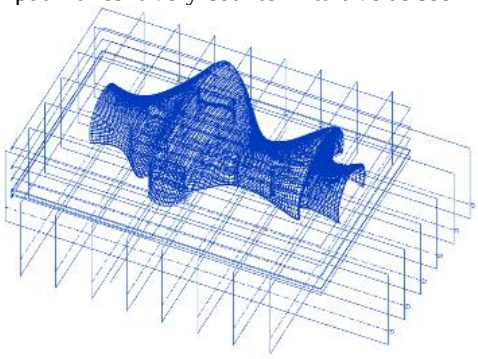


Figure 1. Example of elaborate floor level and grid reference planes arranged in initial setup before the form at the centre is created

In addition to this, Figure 2 shows an example of the various numeric inputs required in developing a common BIM model.

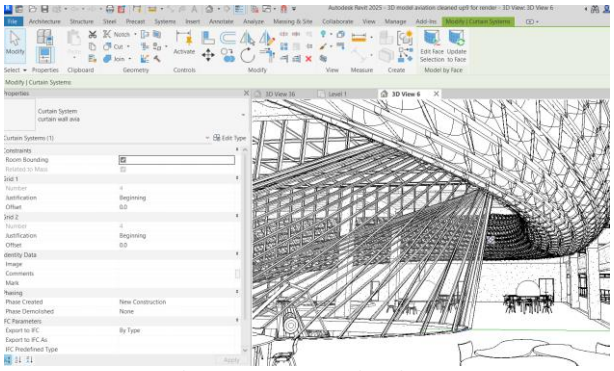


Figure 2. Example of numeric input interface for BIM

The paragraphs above show how BIM would especially be very complex to be used for the initial form ideation process at the conceptual stage of a project. A departure from creative processes traditionally focusing on the designer's agile externalisation of ideas into building forms through quick sketches and sculptures. The visual products in these traditional processes in return stimulate further creative possibilities in the designer's mind (Mc Kim, 1980).

An overview of the current conventional workflow that involves manual approaches and BIM can be summarised in Figure 3 below.

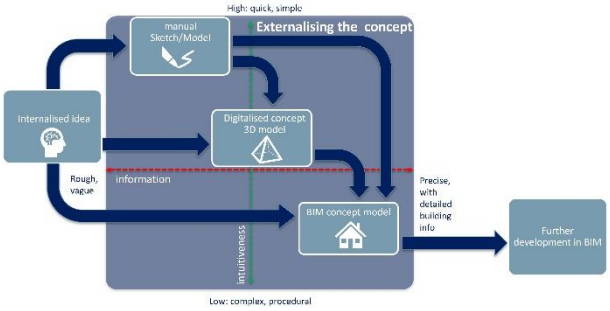


Figure 3. Overview diagram of the current conventional workflow

The diagram shows that the manual approach is extremely agile in externalising ideas and has little restraints in the forms that are possible. However, the products are limited to rough ideas that need to be digitalised in order to be further refined. There are many 3D modelling software which have varying degree of intuitiveness that could also be used to externalise the idea. As Singapore continues to promote BIM, these manual sketches or sculptures as well as products of digital modelling will in the end need to be exported into BIM software for further development.

There is a specific need to modify the current workflow to enable such an agile and creative thinking process to be incorporated in BIM. This would potentially transform the students' mindset to perceive digital modelling in BIM as part of a creative, intuitive and enjoyable ideation activity.

It is important to note that there is a generational trend that current built environment design students, born as digital natives, have higher affinity for digital means of sketching and modelling (Fakhry et al, 2021). At the same time alarming findings of negative health effects of prolonged sedentary work also highlights the importance of seeking digital means that promote rapid and kinaesthetic work activities (Gao et al, 2024). Therefore, modification of the BIM workflow should focus on enabling the students' digital preference to also become a more positively motivational and healthy endeavour.

This paper proposes this through the use of inputs of Virtual Reality (VR) modelling into the workflow. This builds on previous research that have shown the higher utility of VR modelling in comparison with other intuitive means available to digitalise sketching and modelling processes (Hadiatmadja, 2024). The research focuses on specific aspects that could enable VR modelling to support an improved workflow. Aspects that simultaneously support the health and motivational pursuits stated above. At the same time, aspects that may hinder these pursuits will also be examined.

Materials and Methods

This paper will focus on results of ongoing efforts in integrating VR modelling and BIM at a polytechnic level built environment course in Singapore. Focus was on year 3 students who have prior training in BIM using the conventional workflow. More recently, the students have been given training in VR modelling. Therefore, the student respondents would be well placed to give informed feedback to compare between the two modes. Overall, 21 students participated in this research.

The students provided feedback on the effects of VR modelling input for BIM at the conceptual design stage. The students' feedback were mostly obtained through open ended questions in an online anonymous survey. The mostly open-ended nature of the response was meant to enable students to extensively express their feedback.

In line with the research objectives to promote the students' health and motivation, a range of preparations were done. These will be further explained below.

First of this was that the lecturer provided computer hardware with specifications that had been previously proven to be effective in previous research that compared various options for intuitive modelling (Hadiatmadja, 2024). The hardware was positioned in the year 3 student's studio. This would enable easy physical access and motivate the students to use it frequently.

The research area set up, seen in Figure 4, shows an initial 3 metre by 3 metre barrier free work area. During the research it will be observed if this needs to be modified to achieve a sufficient working space.



Figure 4. Initial work area size relative to a polytechnic student.

An important hardware used for this research was a wireless VR headset that would prevent students from tripping on cables when using the headset. The wireless equipment also enables students to freely move around in developing the intended building forms in VR modelling software. This can be seen in Figure 5 below.

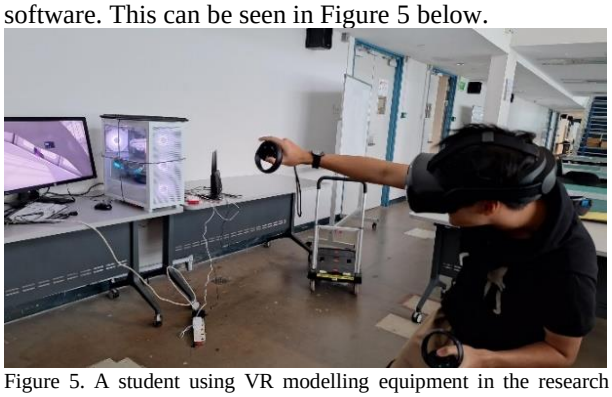


Figure 5. A student using VR modelling equipment in the research space provided.

A further safety precaution is the choice for the students to use of the 'pass through mode' feature of the VR headset. This enables the student to still see the surrounding studio environment even when they are wearing the headset. An example of a passthrough mode can be seen in figure 6 below.



Figure 6. Passthrough mode showing coloured VR modelled forms and the grey scale physical surrounding area.

The planned use of the passthrough mode also enabled students to see the position of various buttons on the actual physical VR hand controllers near its digital representation. This can be seen in the part of the view shown at the bottom right of Figure 6. The coloured digital representation of the hand controller is seen in front of the grey scale pass-through view of the actual physical hand controller. This could help students to see the effect of clicking various buttons on the model they are creating. This is a useful visual support feature for the students, especially when they are initially still getting familiar with the equipment.

As can be seen in Figure 7, there are a range of buttons that the students need to become familiar with. Being able to see the actual physical placement of the buttons in the pass-through mode will help aid the student's initial orientation of the locations of various buttons. Alternatively, the students who chose not to use the pass-through mode would have to use the sense of touch to orientate the location of the buttons.



Figure 7. Zoomed in view of the hand controllers used in this research.

The lecturer planned a system to help maintain good cleanliness and hygiene. After a student uses the headset and hand controllers, the student would have to clean the items with an antiseptic wipe. This prepares the items as a clean set ready for use by the next user. It is hoped that such a system would reduce hesitation of hygiene sensitive students to use a shared headset. During the actual research, feedback is requested from students on possible additional measures that the student feel would further help in this regard.

The study also planned for the lecturer to be able to observe the students' actions through a feature of the VR software that enables the VR view to be casted (screened) on an external monitor. This view enabled the lecturer to provide further guidance while the student is creating the model in VR space. This casted view can be seen in in the left side of Figure 5.

At the start of the research, it was established that the polytechnic has access to two VR modelling software. These are Adobe Substance Modeller and Gravity sketch (Adobe, 2024; Gravity Sketch, 2025). Comparison was done between the two options in terms of the software's compatibility as input into BIM.

The BIM software used in this research was Autodesk Revit. It was chosen because the students have been previously trained using this software. It is commonly used in Singapore (Kaneta et al, 2016).

Before involving students to participate in the research, the class lecturer conducted initial studies to enable the smooth running of VR modelling and transfer of data into BIM. First of this was a comparison between the two available VR modelling software. Both software were intuitive to use for VR modelling. However, currently only the models produced in Gravity Sketch could be exported as a format that is suitable for effective development in BIM.

Gravity Sketch files could be exported in an IGES format, which stands for Initial Graphics Exchange Specification format (Gravity Sketch 2025a). This format has a useful feature that it retains definition of curvature (Joko Engineeringhelp, 2020). A visual comparison between the surface of a model that was saved in an IGES format and a model that was not (in this example an OBJ format) is shown in Figure 8.

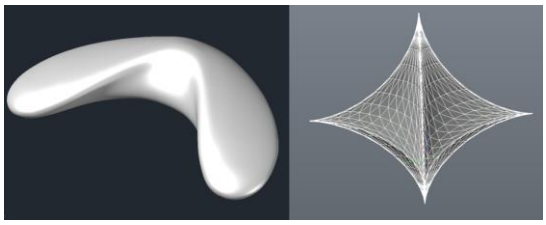


Figure 8. Comparison of IGES (left) & OBJ surfaces (right)

The model saved in IGES format will result in one or a manageable number of large smooth surfaces that can be efficiently modified in BIM. In comparison, the alternative file format (in this example an OBJ format) resulted in a large amount of small, triangulated surfaces that would require the very tedious process of individual modification. Therefore, Gravity Sketch and the IGES format were decided to be used for this research.

The class lecturer also had to overcome an additional problem that currently Autodesk Revit (as the BIM software used) cannot directly import the IGES file. As a solution, a few intermediary software that could import IGES and save it into a format that can be imported into Autodesk Revit were explored. At the end it was found that AutoCAD and Fusion 360 software had specific tools that could be used for such a purpose. Within the intermediary software, the IGES files were able to be saved as a DWG format that is importable to Autodesk Revit. The intermediary software were also useful in converting the surfaces of the IGES file to become solid forms. An important benefit of a solid form is that in Autodesk Revit the unique floor plate shape of each floor level could be automatically generated. An example is shown in Figure 9.

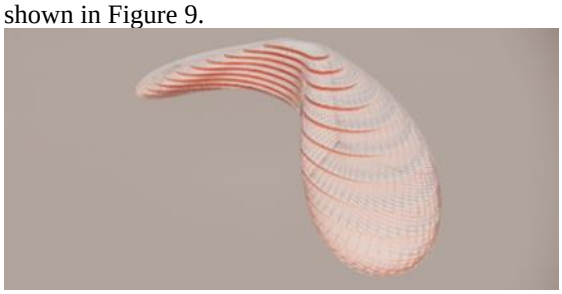


Figure 9. Example of floor levels generated from a VR model that was imported into the BIM software.

Results and Discussion

From the preparations done to incorporate VR modelling, there is an opportunity for a more efficient workflow to emerge. In place of the processes in Figure 3 a new streamlined workflow that incorporates the use of VR modelling emerges as seen in Figure 10 below.

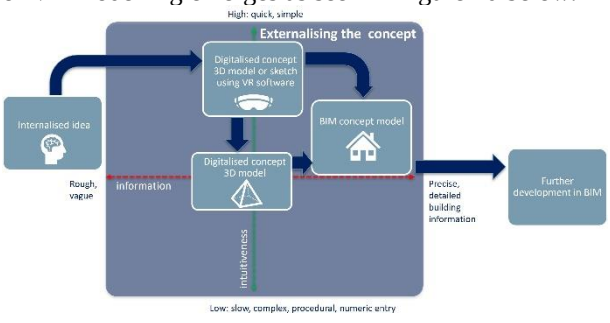


Figure 10. New workflow incorporating VR modelling

Figure 10 shows that traditional manual intuitive sketching can be digitally replicated by the similarly intuitive sketching and modelling that can be done in VR modelling software. This also automatically produces a precise digital form. The time-consuming step needed in the previous workflow to convert from manual to digital is no longer required. The VR produced digital line sketches have additional benefit of being 3D line sketches. After processed through intermediary 3D modelling software, the data is importable to BIM software for further development into building parts.

Students were invited to create forms using Gravity Sketch software and subsequently develop it further in Autodesk Revit. The students were trained on the spot to use the Gravity Sketch software as well as the processes needed to import the VR models as input to subsequently produce BIM models in Autodesk Revit. An example is shown in Figure 11. The students were also briefed on specific commands in the intermediary software for converting surfaces of an IGES file to be solid forms that can be saved as a DWG file.

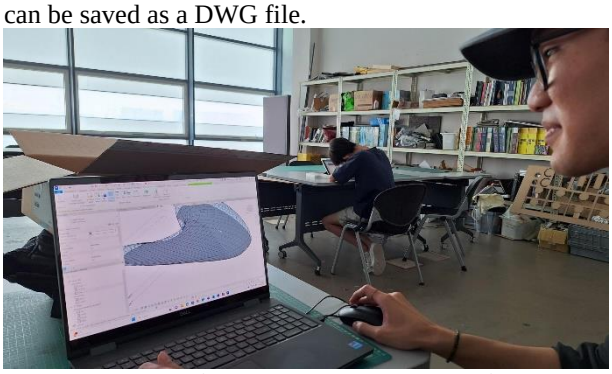


Figure 11. A student further developing a VR model form that was imported into the BIM software.

The paragraphs below will focus on the more positive results of the research that the students gave feedback on. In the online survey, some students expressed appreciation for some highly tangible physical benefits. The students contrasted the new workflow processes with their previous experience of using a mouse to rotate the view of a model on a monitor screen. Some students' feedback also revealed their awareness that the immersive VR view encouraged their entire body to frequently move around the model to view it from various angles. They also gave feedback that they were aware of the positive health implications involved.

Other students gave feedback that when using VR modelling, they focused more on creatively making the form and have less need to constantly figure out the settings of the software itself. Their previous experience in BIM software such as Autodesk Revit necessitated many presets and parameters as previously shown in Figure 1 and Figure 2. Previously, this took the students' focus away from the creative ideation process itself that is of high importance in the concept design stage.

The students provided feedback that VR modelling resulted in very dynamic forms that would have been harder to model directly in BIM software. Some students provided positive comments that the VR modelling process enabled higher freedom and flexibility. The vast

majority of students gave feedback that VR modelling was more intuitive in nature compared to BIM.

In terms of the perceived time needed to make the overall conceptual form of the building in the VR modelling software, students gave feedback that it took between 5 to 20 minutes to create a form that they feel satisfied with to be further developed in BIM software. Most students finished their model in about 10 minutes. This is very encouraging that despite the complexities of a range of buttons that the student needs to familiarize themselves with, it took a relatively short period of time for them to be up and running to start making forms in VR space.

It was also observed that a student would be able to be trained on the spot and produce VR forms that were importable to the BIM software within one day. The students were able to achieve models with all external surfaces of building components (e.g. roof, wall or curtain wall). In comparison, the time needed by the same students in their year 2 studies to develop a similar building using BIM software in a conventional workflow was more than two weeks. This represents a significant improvement in time efficiency.

This research also revealed some notable negative feedback. These will be elaborated in the following paragraphs. There seems to be some limitations in terms of importing and exporting of the VR model. These limitations also continued in the latter process of transforming surfaces into building parts in the BIM software. Not all surfaces were able to be transformed into the intended building part. For instance, some surfaces that the students wanted to transform to become a roof or wall was only possible to be transformed into curtain systems which had less potential for further modifications.

Potentially related to the of lingering problems above, there were a sizeable minority (around 35%) of student respondents who still felt that for them working fully in Autodesk Revit would still be more effective. This could be related to the longer-term comfort and familiarity with Autodesk Revit. It could also be related to the negative feedback some students provided that their initial VR forms are too abstract to be perceived as a building right away. BIM software would directly provide information related to building parts. Some students also gave negative feedback that it was harder to find the exact dimensions using the VR modelling software.

Some students felt some discomfort when using the headset. The students stated that the area of contact between their face and the headset rapidly becomes sweaty. This occurred even though they were using it in an air-conditioned studio space. Some students also expressed that the VR headset felt heavy on their head. Some students also felt that the VR screen often became blurry and they felt the screen position was too close to their eyes.

Some students gave feedback in the form of improvement suggestions for the headset related problems. For instance, one suggested the alternative use of light weight and less enclosed augmented reality (AR) glasses in the future when it can be compatible with the modelling software.

There was specific input given by students who opted out of using the pass-through mode in order to have a more focused view of the model. The students commented on the uneasiness of being in VR space while totally visually disconnected from the physical surrounding space.

This research also revealed findings related to parameters of hygiene, time and space requirements. These are useful to note for planning future VR modelling sessions. These will be elaborated in the following paragraphs.

The students appreciated the procedures put in place to sanitize the equipment with antiseptic wipes. It was also encouraging that early in the research, some students proactively suggested the option to use gloves as an extra precaution that a user can utilise.

Currently only one lecturer in the course has experience in using VR modelling software. During this research, the lecturer trained one student at a time. Although as previously stated some students claimed that with the current guidance given, they could be up and running even in 5 minutes, accumulatively it will take a relatively long time in order to train the whole class. As an illustration, for an average size class of 24 students it would take at least 2 hours for the lecturer to initially train the whole class. As not all students are fast learners, this process could be even longer.

The students gave feedback that they appreciated the care given to train students in the detailed use of the controllers on a one-to-one basis. However, the current one to one session could be made more efficient. Some students declined to wait their turn to participate. The overall session was exhausting for the single lecturer to conduct. It is planned that some ‘train the trainer’ session for other lecturers may be required. This would enable other lecturers to shoulder some of the training responsibilities. Possible video materials would also be useful to be developed as an alternative for students to train with while waiting to use the VR equipment.

Some students also expressed that there was a maximum amount of time that the students could tolerate in using the VR headset. The student feedback showed that 30 minutes was the maximum time that a student would like to continuously be using a VR headset. Most students preferred to use it for about 20 to 30 minutes at a time. A common 2-hour session should potentially be planned to involve stretches of time where the student intermittently engages with other medium. This could be used for further development of the VR model in CAD, 3D and BIM software as planned in the new workflow shown in Figure 10.

It was noticed that the initially planned work area boundary of about 3 metres by 3 metres previously shown in Figure 4 was sufficient. It was observed that such an area enabled the student to stretch their limbs maximally without obstruction. This is bigger than the area utilised by a single student who in the past were deskbound when they did 3D modelling tasks. Overall, a larger studio space would be needed for future VR modelling classes. The current individual area could potentially be useful as a standard module that can be used as part of the planning of this larger studio.

Conclusions

The student respondents stated that the use of processes and equipment as part of the new workflow shown in Figure 10 have many positive impacts that they appreciated. Overall it is a more streamlined, and enjoyably intuitive arrangement. The students were able to quickly familiarise with the use of the VR equipment and software. They were able to create unique conceptual forms more rapidly, intuitively while healthily moving around throughout the process.

Some notable negative feedback are mainly related to the enclosed nature of the VR headset which causes discomfort for some students. There are also current lingering limitations in the software used. The researcher plans to conduct further research on possible emerging alternatives that could overcome these problems.

There are findings on time and space considerations as well as training needs that were important to note from this research. These will be useful for planning future larger scale implementations. Aside from this, it is also important to note that even small gestures of promoting hygene and safety considerations that the lecturer put in place seems to also positively motivate the students. It even encouraged them to be active partners who contribute useful input for further improvement.

References

Adobe (2024, May 29) Supported file formats | Substance 3D Modeler. Retrieved February 15, 2025 from https://helpx.adobe.com/substance-3d-modeler/technical-support/supported-file-formats.html?form=MG0AV3

Bacus, J. (2020). *Digital sketching: Computer-aided conceptual design 1st edition.* Wiley.

Corenet (2015, April 15) appbca-2015-07-circular-on-deadlines-for-mandatory-bim-e-submission. Retrieved February 15, 2025 from https://corenet.gov.sg/media/1170470/appbca-2015-07-circular-on-deadlines-for-mandatory-bim-e-submission.pdf?form=MG0AV3

Fakhry, M., Kamel, I & Abdelaal, A. (2021). CAD using preference compared to hand drafting in architectural working drawings coursework. *Ain Shams Engineering Journal* 12 (2021) 3331–3338.

Gravity Sketch (2021. January 11) *How 3D sketching stimulates a more creative workflow*. Retrieved February 15, 2025 from https://gravitysketch.com/blog-post/articles/how-3d-sketching-stimulates-a-more-creative-workflow/?form=MG0AV3

Gravity Sketch (2025a, January 31) *What file formats does gravity sketch support?* Retrieved February 15, 2025 from https://help.gravitysketch.com/hc/en-us/articles/5902435883165-What-File-Formats-Does-Gravity-Sketch-Support?form=MG0AV3

Gravity Sketch (2025b, April) *Exports: from Gravity Sketch to Blender*. Retrieved May 1, 2025, from https://www.youtube.com/watch?v=xJ5P80cpT34&t=79s

Gao W., Sanna M. Chen Y. et al (2024, January 19). *Occupational sitting time, leisure physical activity, and all-cause and cardiovascular disease mortality*. Retrieved May 1, 2025 from https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2814094

Hadiatmadja J. (2024) Comparison of VR and tablet based intuitive 3D design Tools for conceptual form development of student projects: Initial findings from a built environment course pilot study in Singapore. *Proceedings of The International Symposium on Advances in Technology Education (ISATE) 2024.*

Kaneta T., Furusaka S, Tamura A. and Deng N. (2016). Overview of BIM implementation in Singapore and Japan. *Journal of Civil Engineering and Architecture 10*

Kirby, L., Krygiel & E. Kim M., (2017) Mastering Autodesk Revit 2018. Indianapolis: John Wiley & Sons

Lin Teo E; Ofori G; Tjandra, I. & Kim, H. (2016). The use of BIM in the Singapore construction industry: Opportunities and challenges. *Proceedings of the 20th CIB World Building Congress - Intelligent Built Environment for Life.*

McKim, R. (1980). *Thinking visually a strategy manual for problem solving 1st ed*. Paolo Alto: Dale Seymour Publications.

Oxman R, (2008). Digital architecture as a challenge for design pedagogy: theory, knowledge, models and medium. *Design Studies* 29(2), 99-120.

Page, T. (2019). A Comparison of haptic sketching and digital sketching: Considerations of final year design students. *International Journal of Information and Communication Technology Education (IJICTE) 15(2)*

Patron, C. & Mokhtar, M. (2021). The advantage and disadvantages of manual and digital drawing in today's institutions. *The 2nd International Conference on Design Industries & Creative Culture*.

Ranscombe, C. & Bissett-Johnson, K. (2017). Digital sketch modelling: integrating digital sketching as a transition between sketching and CAD in industrial design education. *Design and Technology Education: An Internal Journal*, 22.1, 1-15.

Thondavadi, N. (2012). *Up close at school of Architecture, role of drawing in doubt.* Retrieved May 12, 2024, from https://yaledailynews.com/blog/2012/04/06/up-close-at-school-of-architecture-role-of-drawing-in-doubt/

EXPLORING OPEN-SOURCE BLENDER'S IMPACT ON ADVANCING ACCESSIBLE AND INCLUSIVE EDUCATION IN DIGITAL CONTENT CREATION

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Digital content creation skills are increasingly crucial in the modern workforce, yet commercial software costs and technical barriers limit educational access. This paper explores how integrating Blender, a free and open-source 3D creation suite, into educational workflows can help address these challenges. Blender provides cost-effective access to industry-relevant tools, making it a powerful platform for inclusive learning. The study investigates its potential to promote accessible, inclusive education in digital content creation. These objectives align with global sustainable development initiatives for quality education and digital inclusion while also supporting industry-relevant competencies needed in an evolving digital landscape. This study adopts a qualitative case study methodology, examining four scenarios: three final-year student projects, and a situation from the Animation, Games and Visual Effects course at Nanyang Polytechnic in Singapore where a raise in costs of commercial software impacted the learning experience of students. The student projects comprise a high-end animation for Suntec Convention Centre, the collaborative short film 'Spark' and selected high-performing projects from the Independent Work Project module. For these, the research draws on project documentation, students feedback, and production analysis as primary data sources. It combines descriptive analysis of feedback with technical workflow analysis to evaluate Blender's influence on accessibility, production efficiency, and skill development. Blender's open-source framework eliminates licensing costs, ensuring equitable access to cutting-edge tools for learners and educators across diverse socioeconomic contexts. The availability of extensive free online tutorials, community support, and open educational resources fosters independent learning and interdisciplinary collaboration. Blender's real-time rendering engine, EEVEE, significantly enhances educational experiences by providing immediate visual feedback. These features align with global educational frameworks promoting accessibility, digital literacy, and industry-relevant competencies. Blender exemplifies an inclusive approach to engineering education, bridging technical proficiency with global competencies. It enables students to address real-world challenges in the digital media industry, preparing them to navigate the complexities of a technology-driven global economy. Educational institutions should prioritize integrating open-source tools like Blender to foster pedagogical innovation, promote equitable access, and cultivate the transformative competencies necessary for the future workforce. This approach ensures education systems remain inclusive and responsive to evolving industry demands.

Keywords: *Inclusive Education, Blender (3D Software), Digital Content Creation, Sustainable Development Goals, Open-Source Tools.*

Introduction

Digital content creation has become a cornerstone of modern professional competencies, transforming from a specialised skill to an essential requirement across numerous industries (National Skills Coalition, 2023). The increasing integration of digital technologies across various industries has significantly heightened the demand for professionals skilled in 3D modelling, animation, and visual effects. This surge is evident in the rapid growth of the 3D animation market, which was valued at $22.67 billion in 2023 and is projected to expand at a compound annual growth rate (CAGR) of 12.3% through 2030 (Grand View Research, 2024). However, this growing demand presents a significant challenge in educational contexts, where access to industry-standard tools often remains limited by prohibitive licensing costs and technical barriers (UNESCO, 2023; Schmitz, 2020).

This financial hurdle not only affects institutional capabilities but also impacts students' ability to practice and develop skills beyond classroom hours, potentially widening the digital divide and creating inequitable learning opportunities (Outreach International, 2024).

Blender, a free and open-source 3D creation suite, emerges as a compelling solution to these challenges. Unlike its commercial counterparts, Blender offers comprehensive functionality for 3D creation, animation, rendering, video editing, and game development without licensing fees (Blender Foundation, n.d.). This accessibility aligns directly with the United Nations'

Sustainable Development Goal 4, which emphasises ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all (United Nations, 2022).

The significance of exploring Blender's educational potential extends beyond mere cost considerations. As Industry 4.0 reshapes workplace requirements, educational institutions must adapt their approaches to develop students' technical proficiency while fostering critical thinking, creativity, and collaborative skills. These align with the OECD Learning Compass 2030's transformative competencies (OECD, 2019) and Industry 4.0's key components of agility and adaptability (World Economic Forum, 2019). This research investigates how Blender's integration into educational workflows can address these multifaceted demands.

This study specifically examined four distinct scenarios within Singapore's educational context at Nanyang Polytechnic, School of Design and Media: two final-year student projects, a high-end animation for Suntec Convention Centre and the collaborative short film 'Spark', selected high-performing Independent Work Projects (IWP) where students independently chose to implement Blender, and a broader case study of the Animation, Games and Visual Effects course's adaptation to software cost challenges. Through these cases, we explore how open-source tools can enhance educational accessibility while maintaining industry-relevant standards and examine the implications of different software adoption approaches in educational settings, from structured commercial projects to self-directed creative works.

The research aims to address one key question: how does Blender's open-source implementation advance accessible and inclusive education in digital content creation?

By examining this question, this study contributes to the broader discourse on educational technology and inclusive learning, offering insights for institutions seeking to balance educational quality with accessibility in an increasingly digital world.

Materials and Methods

This study employed a qualitative case study methodology examining four distinct scenarios at Nanyang Polytechnic, School of Design and Media. The research investigated Blender's effectiveness in educational digital content creation, focusing on accessibility, technical capability, and skill development, while providing insights into the impact of software accessibility in educational settings.

Data collection encompassed multiple sources across these four scenarios. Primary data included feedback forms completed by 17 respondents who implemented Blender: a team leader from the Suntec Convention Centre project, four team members from the 'Spark' collaborative film, and 12 students from Independent Work Projects. The forms comprised open-ended questions covering technical implementation, workflow, and output assessment. Comparative data came from the Digital Sculpting unit Learning Unit Report, which captured feedback from 74 students affected by commercial software access limitations. Technical documentation included Discord server archives tracking render logs and iteration cycles across all implementation projects

The Suntec Convention Centre client project, running for 12 weeks from 29 May 2023, involved a six-member final-year team creating a 2 minutes Deepavali-themed animation for The Big Picture, the world's largest high-definition LED video wall. This project was one of four annual animation productions typically created for Suntec using commercial software. Under their team leader's decision to implement Blender as the main lighting and rendering software, the team used EEVEE real-time rendering engine to help produce 10K resolution outputs. Data collection included feedback form and Discord server archives containing render logs and iteration cycles.

The 'Spark' Collaborative Short Film project spanned three 12-week phases with different final-year teams, beginning 27 May 2024. Originally planned for two teams over 24 weeks, the project required a third team when the second team's output did not meet the targeted quality. The first and third teams implemented Blender as the main 3D application, while the second team used commercial software. The two-minute animation was submitted to two film festivals: Tiny Mountains Film Festival (Australia) and Voronezh International Animation Film Festival (Russia). Data collection included team feedback forms, festival selection documentation, and Discord server archives containing render logs and iteration cycles.

The Independent Work Project (IWP) was a self-directed third-year module where each cohort worked for 15 weeks. The module allowed students to conceptualize and execute projects of their own choice, working individually or in pairs. Each project was scoped for approximately 150 hours of work, representing a significant milestone where students demonstrated mastery of skills developed over their previous two years through independent project management and creative decision-making. From these cohorts, twelve high-performing students who independently chose to implement Blender as their primary tool were selected for this study, with academic achievements ranging from 75 to 95 out of 100. Their self-initiated projects encompassed diverse applications including mixed media animation, character modelling, commercial visualization, and 2D/3D hybrid works. Data collection included project documentation, feedback forms, and Discord server archives containing technical discussions.

The Digital Sculpting unit within the Diploma in Animation, Games and Visual Effects faced a sudden price increase for its primary commercial software student licenses, from approximately 20 to 100 SGD per student, just weeks before the semester's start in mid-April 2024. Due to the time-consuming nature of institutional purchase procedures and budget approval processes, new licenses could not be acquired at such short notice. With individual student licenses and laptop installations no longer feasible, and a proposal to adopt Blender as alternative software rejected, the unit

implemented existing legacy software licenses restricted to shared school laboratory facilities. This arrangement involved 81 students. Data collection consisted of the Learning Unit Report, which documented personal pen tablet compatibility issues across facilities and instances of private license purchase by some of the students, highlighting the impact of limited facility access hours on student work completion.

The study employed descriptive analysis to examine feedback data through two distinct analytical lenses. The first focused on documenting implementation experiences with open-source software in two animation projects and the IWP module, examining response frequencies and thematic patterns in learning resource utilization, technical performance feedback, and workflow adaptation. The second analysed the Digital Sculpting unit as a case study, examining how commercial software licensing changes impacted the learning experience, through documented student feedback. Areas of focus included facility access limitations, technical constraints, and resource availability challenges. Data processing involved extracting direct quotes from feedback forms, Learning Unit Report responses, and Discord archives, with responses grouped and categorized to clarify both successful open-source implementation patterns and the vulnerabilities of license-dependent educational systems.

Results and Discussion

Accessibility and Inclusivity

Both animation projects and IWP implementations demonstrated high accessibility, with all seventeen respondents specifically highlighting cost-free access. As shown in Figure 1, Accessibility & Inclusivity achieved 100% positive response, indicating unanimous recognition of Blender's accessible nature. "Blender's free and so are a lot of its plugins," noted one team member, while an IWP student emphasized the practical benefit: "easier to work with when switching between different workstations without having to deal with licensing issues." Another highlighted industry potential: "advocate everyone to use it and hope the industry moves closer to Blender."

Learning resource availability emerged as a critical factor across all projects. The community aspect particularly resonated, with one FYP member noting "having fresh daring views from casual artists really expanded my perspective," while IWP students highlighted diverse learning channels including "YouTube, Reddit, Instagram, Blender community." Several IWP students specifically mentioned the advantage of Blender's large user base for troubleshooting unique problems.

Technical Performance and Production Efficiency

Technical performance data revealed strong satisfaction across both FYP and IWP projects. Figure 1 supports this finding with 82% positive response rate for Technical Performance and 76% for Production Efficiency. The Suntec project achieved 10K resolution outputs with 30-second render times, while IWP projects demonstrated diverse technical implementations from character modelling to commercial visualization. EEVEE's real-time rendering capabilities were particularly valued, with one FYP animator noting, "EEVEE made it a lot easier to visualise what was going on in the scene," while IWP students highlighted its benefits for "quick R&D to speed up my process and workflow."

Workflow advantages included comprehensive toolsets and efficient file sharing. Both FYP and IWP students praised the node system, with one IWP student noting it "felt more user friendly and less daunting." Project satisfaction ratings averaged 8/10 for FYP projects, while IWP projects consistently scored between 7-8/10, demonstrating consistent performance across different project scales.

Skill Development

Learning curve data showed notably positive trends across both FYP and IWP implementations. Despite varying levels of prior experience (from none to basic knowledge), students demonstrated successful project completion across diverse applications. IWP students particularly noted the software's adaptability, with one stating "Being able to directly draw in the 3D space with Grease Pencil... gave a more hands-on experience in production making."

Learning resource utilization demonstrated consistent patterns, with all seventeen respondents actively engaging with online tutorials and communities. The self-directed nature of IWP projects particularly highlighted Blender's capacity to support independent learning, with students successfully navigating technical challenges through community resources and experimentation. As one IWP student noted, "Open-source software like Blender lowers the barrier of entry, allowing artists freedom to create and express their own styles."

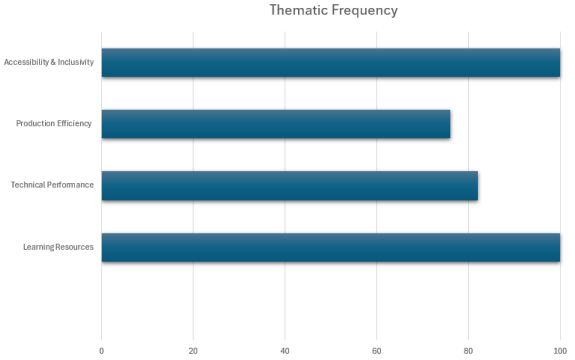


Figure 1 Thematic Frequency Chart showing key implementation outcomes. Both Learning Resources and Accessibility & Inclusivity achieved 100% positive response, while Technical Performance (82%) and Production Efficiency (76%) also demonstrated strong positive results

Digital Sculpting Unit Software Access and Resource Considerations

The Digital Sculpting unit's Learning Unit Report (n=74, 92.50% response rate) revealed significant disruption following the license cost increase. Facility access limitations emerged as a primary concern, with students reporting restricted laboratory access and weekend attendance requirements. One student noted: "Make classrooms more readily available for Zbrush, I have to go to school in the weekends sometimes."

Technical constraints compounded these challenges, with tablet compatibility issues across facilities affecting work quality. Students reported driver update needs and inconsistent hardware performance, leading to additional time requirements for basic tasks. The situation particularly impacted those without personal licenses.

Resource access emerged as a significant factor, with fifteen students addressing availability concerns. Those relying on school facilities reported challenges, with one noting: "There is an unfair playing field in terms of resources. Those who bought Zbrush was allowed to spend less time in school." Time management became a critical issue, with students reporting diverted time from other modules and increased stress levels.

Study Limitations and Future Research Directions

While this research provides valuable insights into open-source software implementation in educational settings, a few considerations present opportunities for future expansion. The study's focus on Nanyang Polytechnic's implementations offers an understanding of effective practices, particularly through high-performing final year projects that demonstrated innovative applications of Blender. Additionally, the Digital Sculpting unit case involving 81 students provided insight into the vulnerabilities of commercial software dependency in educational settings, where a sudden license price increases revealed accessibility challenges. Building upon these findings, future research could benefit from multi-institutional studies, broader student sampling and the integration of quantitative metrics to complement the existing qualitative insights. These expansions would further strengthen the growing body of knowledge around open-source tools in digital content creation education.

Conclusions

This study demonstrates how open-source software implementation in animation education supports broader educational and social objectives while meeting industry-standard technical requirements. Through examination of diverse project implementations, from high-end commercial work to independent student projects, several key conclusions emerge.

The elimination of licensing barriers through Blender's open-source framework has demonstrated tangible impacts on learning accessibility and educational equity. This becomes particularly significant considering the situation faced by the Animation, Games and Visual Effects course, where increased commercial software costs threatened to affect learning experiences. Students' ability to work seamlessly across different environments, coupled with access to extensive community resources, provides a sustainable choice while supporting continuous learning and skill development regardless of socioeconomic constraints. This aligns directly with SDG 4's objectives for inclusive and equitable quality education.

The development of transformative competencies, as outlined in the OECD Learning Compass 2030, is evidenced through students' demonstrated ability to solve complex technical challenges, collaborate across platforms, and adapt to evolving project requirements. The community-driven nature of open-source software appears to particularly enhance critical thinking and creative problem-solving capabilities.

Technical innovations, especially EEVEE's real-time rendering capabilities, have shown significant positive impact on learning experiences and workflow efficiency. This immediate visual feedback loop supports the development of agility and adaptability - crucial skills for Industry 4.0 readiness. The successful completion of professional-grade projects suggests that open-source implementation can effectively bridge educational and industry requirements while fostering these essential competencies.

These findings suggest that the integration of open-source software in animation education not only addresses immediate practical challenges but also contributes to broader educational objectives and future workforce preparation, while providing a sustainable solution to rising software costs in educational institutions.

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References

National Skills Coalition. (2023, February 6). New report: 92% of jobs require digital skills, One-Third of workers have low or no digital skills due to historic underinvestment, structural inequities - National Skills Coalition. https://nationalskillscoalition.org/news/press-releases/new-report-92-of-jobs-require-digital-skills-one-third-of-workers-have-low-or-no-digital-skills-due-to-historic-underinvestment-structural-inequities/

Grand View Research. (2024). 3D animation market size, share & trends analysis report by component, by technology, by end-use, by region, and segment forecasts, 2024 - 2030. Retrieved March 20, 2025, from

https://www.grandviewresearch.com/industry-analysis/3d-animation-market

UNESCO. (2023). Digital skills: Critical for jobs and social inclusion. Retrieved March 20, 2025, from https://www.unesco.org/en/articles/digital-skills-critical-jobs-and-social-inclusion

Schmitz, L. (2020, October 13). Education: The 4 barriers to adopting new technologies in the classroom. Ubicast. Retrieved February 14, 2025, from https://news.ubicast.eu/en/barriers-adopting-technologies-classroom?

Outreach International. (2024). The digital divide in education. Retrieved March 20, 2025, from https://outreach-international.org/blog/digital-divide-in-education/

Blender Foundation. (n.d.). Features. Retrieved March 20, 2025, from https://www.blender.org/features/.

United Nations. (2022). The Sustainable Development Goals Report 2022. https://unstats.un.org. Retrieved January 20, 2025, from https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf

OECD, (2019). Transformative Competencies for 2030. In OECD Future of Education and Skills 2030. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/transformative-competencies/Transformative_Competencies_for_2030_concept_note.pdf

World Economic Forum. (2019, December 5). Why agility is key to success in the Fourth Industrial Revolution. www.weforum.org. Retrieved January 21, 2025, from https://www.weforum.org/stories/2019/12/agility-a-book-extract

APPLICATION OF "DRIVESENSE" AND "DRIVEBOX" IN-VEHICLE MONITORING SYSTEM ON WHEELCHAIR TAXI FLEET

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According to The Government of the Hong Kong Special Administrative Region Press Releases, there are 4697 (25.9% of total taxi) wheelchair taxi in Hong Kong as at end of February 2024[1]. Rider comfort is important for the taxi passengers to feel safe and secure, and it is hugely affected by the taxi drivers' driving behavior and attitude. In this study, the wheelchair taxi driver driving behavior will be monitored, recorded and analyzed. It aims to understand the driving performance effects on the subjects of drivers' gender, drivers' age and experiences of driving wheelchair taxi.

In 2023, VTC Smart City Innovation Centre, Hong Kong Institute of Information Technology, and Hong Kong Institute of Vocational Education-Engineering co-developed "DriveSense" in-vehicle monitoring system and "DriveBox" vehicle information logger. "DriveBox" captures vehicles' motion, location and speed once the drivers start the engine. The vehicle information data is transferred to "DriveSense" system through 5G mobile network and stores in cloud-based servers. With intuitive software, vehicle information data has been visualized by presenting in the format of map, graphs and tables. "DriveSense" stands as a pioneering solution, revolutionizing the way vehicle operations are monitored and managed, while ensuring trip safety and riding comfort for taxi passengers.

In 2024, "DriveBox" vehicle information logger has been installed on 8 wheelchair taxis with different vehicle models, such as Toyota Comfort, Toyota Noah 80 and Toyota Noah 90. The barrier-free taxi operator is able to monitor the wheelchair taxi drivers by "DriveSense" in vehicle monitoring System. The analyzed results can proof that female, male or over 60 years old drivers are having capability to be empathic wheelchair taxi driver to provide safely and comfortable trip for disabled passengers.

Keywords: *Vehicle monitoring, wheelchair taxi, disabled passenger, fleet management, driving behavior*

Introduction

Taxi Driver Performance

According to data released by the Government of the Hong Kong Special Administrative Region, as of the end of February 2024, there are 4,697 wheelchair-accessible taxis, representing 25.9% of the total taxi fleet. The number of wheelchair-accessible taxis has been steadily increasing in response to the growing demand from passengers with disabilities who rely on taxis for their daily transportation needs. In 2023, a total of 5,265 taxis were involved in traffic accidents, contributing to 28,808 reported cases across all licensed vehicles, marking the highest accident rate within this category. The report identifies the top five driver-related factors contributing to these accidents as inattentive driving, tailgating, loss of vehicle control, careless lane changes, and improper or illegal turns. Research on risky driving behaviors indicates that the incidence of road traffic accidents can be mitigated through effective enforcement, continuous monitoring, and systematic evaluation. Given that many taxi fleet operators in Hong Kong manage large numbers of vehicles and employ numerous drivers, ensuring consistent and safe driving practices across all drivers presents a significant challenge.

In response to this issue, the VTC Smart City Innovation Centre, in collaboration with the Hong Kong Institute of Information Technology and the Hong Kong Institute of Vocational Education-Engineering, has developed the "DriveSense" in-vehicle monitoring system alongside the "DriveBox" vehicle information logger. These technologies aim to enhance driver oversight and improve overall taxi safety.

The "DriveSense" in-vehicle monitoring system proposes a solution that combines technologies with the existing limitations of the vehicles. It provides users with a vehicle monitoring system requiring minimal modification of the vehicle, allowing users to monitor their vehicles almost in real-time, and alerting the users about the vehicle's status and the drivers' behaviors. In this study, the wheelchair taxi driver driving behavior will be monitored, recorded and analyzed. It aims to understand the driving performance effects on the subjects of drivers' gender, drivers' age and experiences of driving wheelchair taxi.

Convert Barrier-Free Taxis to IoT Vehicles

According to information provided by the Hong Kong Government, as of the end of February 2024, there are approximately 4,700 barrier-free taxis operating in Hong Kong to cater to the transportation needs of passengers with disabilities. These barrier-free taxis are largely similar to conventional vehicles but are equipped with specific modifications, including electric wheelchair ramps, expanded interior space, and secure wheelchair mounting systems to accommodate wheelchair users. Common vehicle models adapted for this purpose include the Toyota Noah 80 Series, Toyota Noah 90 Series, Toyota Comfort, Nissan NV200, and Nissan Serena.

Notably, these barrier-free taxis currently lack integrated smart or Internet of Things (IoT) technologies. To address this gap, the "DriveSense" system has been developed, which integrates sensors, a wireless communication module, and dedicated software to enable the conversion of standard vehicles into IoT-enabled units. This system allows fleet operators to monitor their entire vehicle fleet efficiently through a web-based application. With minimal effort, operators can access comprehensive vehicle data, including real-time location information, thereby facilitating streamlined and effective fleet management.

Materials and Methods or Pedagogy

Hardware Design for Capturing data

"DriveSense" system is combined with the "DriveBox" vehicle information logger. The "DriveBox" (Figure 1) is fabricated by CSS Electronics and comprises a CANbus logger, a 12 V power supply, and a 5G wireless router. The "DriveBox" is used to capture GPS location and vehicle acceleration data. The CANbus logger is combined with the u-blox NEO-M9V-20B GNSS module, the u-blox LARA-R6001D cellular module, and the ATSAMV70N20 microchip. The GNSS module provides IMU data that includes 3-axis acceleration and 3-axis angular rate. The ANN-MS-0-005 GPS antenna is used to receive satellite signals. All captured data will be stored on an SD memory card for batch uploading to the cloud server automatically. Once the batch data file has been uploaded, the file will be deleted automatically from the SD memory card.



Figure 1 Schematic of "DriveBox"

Hardware Installation

The "DriveBox" device is powered by 12V DC through the cigarette lighter socket in the vehicle. The GPS antenna is installed and secured under the windshield for better signal reception. The device will be installed and secured under the driver's seat on a flat surface (Figure. 2). The device will follow the orientation for IMU axis calibration (Figure 3). During the testing period, three car models have been selected to install the "DriveBox" vehicle information logger and captured the driver driving performance data: 1. Toyota Comfort Hybrid (3 vehicles), 2. Toyota Noah 80 (3 vehicles), and 3. Toyota Noah 90 Hybrid (2 vehicles).

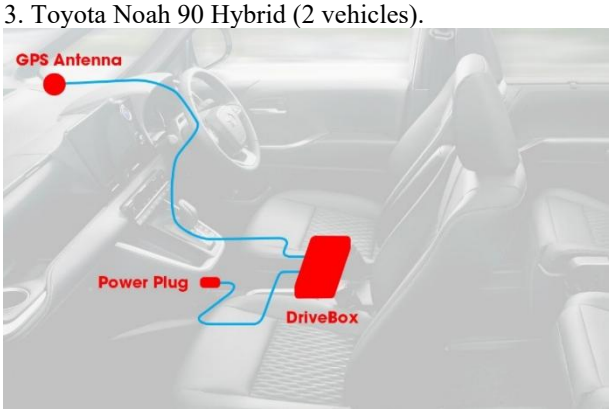


Figure 2 Installation of "DriveBox" in the Vehicles

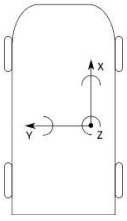


Figure 3 "DriveBox" orientation set-up

Driving Behavior Data Collection

"DriveSense" system and "DriveBox" vehicle information logger have installed on 8 wheelchair taxis, and 20 drivers have been assigned to drive specified taxis from 1 May 2025 to 15 June 2025. Table 1 shows the drivers' list for each taxi. Drivers are assigned to one vehicle only during the data collection period. All collected data will be mapped to the drivers according to the attendance records. Table 1 also lists the drivers' age range, driving wheelchair taxi experiences, accident records, and the assigned vehicles list. There are 1 driver over 70 years old, 12 drivers between 60-69 years old, 2 drivers between 50-59 years old, and 5 drivers between 40-49 years old. In the testing drivers' team, there are 1 female driver and 19 male drivers. For wheelchair taxi driving experiences, there are 8 drivers with more than 10 years of experience, 8 drivers with less than 2 years of experience, and 4 drivers with between 2-4 years of experience.

Table 1 lists of Driver Information

Driver	Cab number	Vehicle model	Age Range	Driving Wheelchair Taxi Experience (Year)	Accident Rate
Driver A	Cab 3	Toyota Noah 90	40-49	4	1
Driver B	Cab 7	Toyota Noah 90	60-69	15	0
Driver C	Cab 7	Toyota Noah 90	40-49	3	0
Driver D	Cab 5	Toyota Noah 80	70+	15	0

Driver E	Cab 5	Toyota Noah 80	60-69	15	1
Driver F	Cab 2	Toyota Noah 80	50-59	15	1
Driver G	Cab 8	Toyota Noah 80	60-69	15	1
Driver H	Cab 8	Toyota Noah 80	60-69	13	0
Driver I	Cab 8	Toyota Noah 80	60-69	1	1
Driver J	Cab 4	Toyota Comfort Hybrid	50-59	15	1
Driver K	Cab 4	Toyota Comfort Hybrid	60-69	0.5	0
Driver L	Cab 4	Toyota Comfort Hybrid	40-49	4	0
Driver M	Cab 1	Toyota Comfort Hybrid	60-69	0.5	0
Driver N	Cab 6	Toyota Comfort Hybrid	60-69	1	0
Driver O	Cab 6	Toyota Comfort Hybrid	40-49	0.5	0
Driver P	Cab 6	Toyota Comfort Hybrid	60-69	1	0
Driver Q	Cab 6	Toyota Comfort Hybrid	60-69	2	0
Driver R	Cab 6	Toyota Comfort Hybrid	60-69	1	0
Driver S	Cab 3	Toyota Noah 90	40-49	12	2
Driver T	Cab 6	Toyota Comfort Hybrid	60-69	1	0

"DriveSense" System Architecture

The "DriveSense" system consists of "DriveBox" vehicle information logger, cloud server, software design, and a user interface platform (Figure 4). The data will be captured four times per second and saved in a batch file. The batch data file, in MF4 format, will be uploaded to the Minio cloud server through a 4G mobile network. All data will be decoded automatically and stored in another cloud server, the InfluxDB database. The "DriveSense" user interface platform (Figure 5) is designed to be web-based and is able to display all the analyzed driving data on a single page.

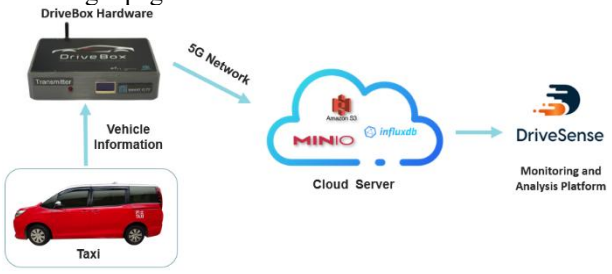


Figure 4 Schematic of "DriveSense" System



Figure 5 Design of "DriveSense" User Platform

3D Dimensional Acceleration Analysis

The IMU sensor provides three-dimensional motion measurement by converting the detected inertia. Acc-X (X acceleration) value is defined as forward and backward motion; Acc-Y (Y acceleration) value is defined as right and left; and Acc-Z (Z acceleration) value is defined as up and down. The "DriveSense" backend system has set an ACC-X exceeding value of ±3 m/s for the warning alert. The warning frequency for each alert has been set to 4 seconds to avoid repeating alerts.

Speeding Analysis

The speeding analysis uses recorded GPS ground speed values and the "Road Networks (2nd Generation)" data set from the Hong Kong Transport Department to identify the driver's speeding behavior. The speeding identification has been set if the vehicle is over 7 km/h. The speeding alert frequency for each alert has been set to 10 minutes to avoid repeating alerts.

Trip Determination and Trip Distance Calculation

Every 0.25 seconds, one set of data points will be recorded, and it will be used to calculate the distance. The total trip distance is calculated using the equation of speed x time (0.25 seconds). The total distance will only be calculated when the GPS signal is available. The total driving time will be calculated from when the GPS signal is received until it is lost. If the GPS signal is lost for more than 60 seconds, a new trip is set up.

Results and Discussion

Total Driving Distance and Total Driving Duration

Results (Figure 6 and Figure 7) show the driving records for each driver from 1 May 2025 to 15 June 2025. During the data collection period, data on the driving behavior of 20 drivers have been collected. The highest driving distance and duration are 3957.4 km and 12426 minutes by Driver A. The lowest driving distance and duration are 104.77 km and 453 minutes by Driver R. The average driving distance and duration for the drivers are 1777.0 km and 5438.95 minutesRemember the followings: do not end a page with a heading, do not start a page with an incomplete line, do not underline any part of the text, and do not forget to check the spelling.

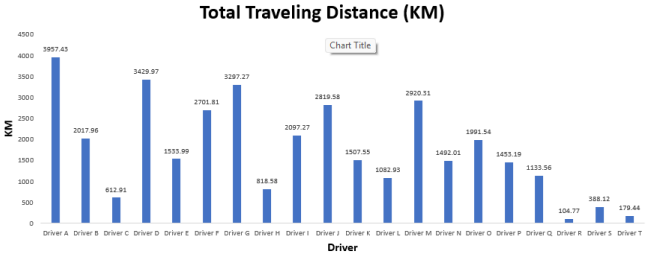


Figure 6 Results of Total Traveling Distance for Drivers

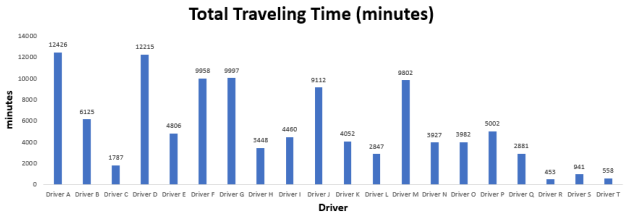


Figure 7 Results of Total Traveling Time for Drivers

Driving Behavior Analysis

"DriveSense" has captured driving behavior data from different drivers and analyzed it. Figure 8 shows the number of driving alerts for each driver along with different types of alert distribution. It has been found that Driver A has 2008 driving alerts, which is the highest. Driver R has 53 driving alerts, which is the lowest. The results do not indicate that high driving mileage corresponds with a high driving alert rate. The driving alert rate is based on the driver's driving behavior. Results also shows that the alerts are mainly due to rough steering, such as fast left turns or right turns (Figure 8). Approximately 70% of total driving alerts are attributed to rough steering. Additionally, about 20% of total driving alerts are due to heavy braking.

Results shows the frequency of driving alerts for each driver, which is the number of driving distances that will occur per driving alert (Figure 9). Higher values mean that the driver has a low driving alert frequency, and the driver is considered a safe driver. Driver H has the lowest driving alert frequency at 9.2 km per alert, while Driver L has the highest driving alert frequency at 1.25 km per alert.

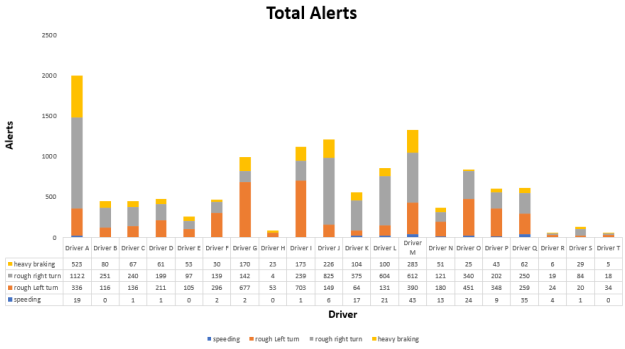


Figure 8 Results of Driving Performance Distribution for Drivers

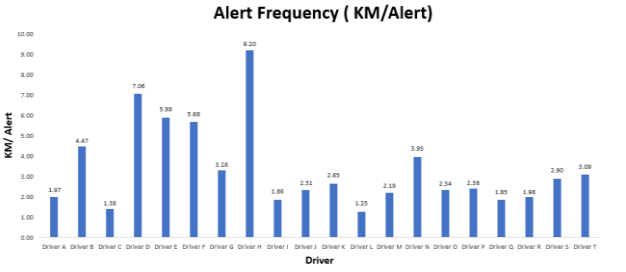


Figure 9 Results of Alert Frequency for Drivers

Gender of Wheelchair Taxi Driver

The results show that there is little difference in terms of driving behaviour for different gender. Driver F is a female driver and she has an alert frequency of 5.68 km/alert. Compared to other drivers, Driver F's frequency value is above the average value of 3.38 km/alert. The results shows that Driver F has good practice in controlling the brake panel (Figure 8). She has the lowest heavy braking alerts rate during a 2700 km driving distance, which is about 90 km per heavy braking alert. Heavy braking in a wheelchair taxi can cause serious injury for disabled passengers. Common injuries include whiplash, concussions, broken bones, and in more serious cases, traumatic brain injuries, spinal injuries, and even amputations. Many passenger transportation companies are very concerned about heavy braking, and provide training to drivers for braking control. Therefore, the results can prove that all gender can be an empathetic wheelchair taxi driver with good controlling of the vehicle.

There are 5 drivers over 60 years old who have an alert frequency value above the average value of 3.38 km/alert (Figure 9). Driver B, Driver D, Driver E, Driver H, and Driver N would be considered older empathetic wheelchair taxi drivers. It is usually the case that older drivers have more driving experience than younger drivers. However, older drivers may have a slower reaction time than younger drivers, which could increase the risk of accidents. The results can prove that older drivers can maintain a good driving attitude to avoid car accidents. A very small number of car accidents have been recorded in the past 10 years or even more. Therefore, it can be believed that if older wheelchair taxi drivers have a good driving attitude and patience, he or she could be a good empathetic and safe wheelchair taxi driver.

Over 10 Years Experienced Wheelchair Taxi Driver

Driving experience significantly influences driving performance. The findings indicate that drivers with extended driving experience demonstrate superior control over the brake pedal, accelerator, and steering. Within the study, eight individuals were classified as experienced wheelchair taxi drivers, each possessing over ten years of experience in this specific domain. These drivers include Driver B, Driver D, Driver E, Driver F, Driver G, Driver H, Driver J, and Driver S. The majority of these experienced drivers exhibited a high alert frequency rate, surpassing the average value of 3.38 km per alert as illustrated in Figure 9. Nonetheless, Drivers J and S displayed marginally lower driving performance despite their extensive experience. This suggests that multiple factors beyond experience—such as the driver's personal background, financial motivations, and personality traits—may impact driving behavior. A prevalent issue among Hong Kong taxi drivers is the pressure to increase income, which often leads to faster driving speeds in order to complete more trips within a given timeframe.

An exceptional case is Driver N, who demonstrated commendable driving performance with an alert frequency of 3.95 km per alert, despite having only one year of experience driving a wheelchair taxi. This anomaly is attributed to the transferability of driving skills from related fields; Driver N is a retired ambulance driver with over ten years of experience operating emergency vehicles. Consequently, it can be inferred that extensive driving experience, whether directly related or

transferable, contributes positively to driving performance.

Conclusions

The "DriveSense" system, in conjunction with the "DriveBox" vehicle information logger, enables comprehensive monitoring, storage, and analysis of driver behavior across eight wheelchair taxis.
This integrated monitoring framework facilitates remote management of both vehicles and drivers by taxi fleet operators. Analysis of driving performance data from a sample of 20 drivers yields several key findings: (1) gender have no effect in the capacity to provide empathetic service as wheelchair taxi operators; (2) individuals aged over 60 years can safely operate wheelchair taxis, given their physical and mental health conditions allow; and (3) drivers possessing greater driving experience exhibit superior driving performance. Looking ahead, it is recommended that the deployment of the "DriveSense" monitoring system and "DriveBox" logger be scaled up to encompass to larger fleet or other fleet vehicles. This would enhance the efficacy and quality of vehicle monitoring services available to other fleet management companies while most importantly, ensuring the health and safety for the passengers.

Acknowledgements

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Lastly, I am deeply thankful to our industry partner, Diamond Cab (Hong Kong) Limited for their unwavering support, understanding, and encouragement. Their operation arrangement in taxi greatly contributed to the success of this project.

References

1. *LCQ20: Barrier-free taxis*, The Government of the Hong Kong Special Administrative Region, 27 March 2024,https://www.info.gov.hk/gia/general/202403/27/P2024032600748.htm

2. Hong Kong Police Force (2024), Traffic Branch Headquarters, Hong Kong Traffic Report 2023.

3. Olusegun Austine Taiwo, Norashikin Mahmud, Sitti Asmah Hassan and Rahmat Bin Mohsin (2024) Influence of commercial drivers' risky behavior on accident involvement: moderating effect of positive driving behavior. Taiwo et al. *Journal of Engineering and Applied Science*, 71:68. https://doi.org/10.1186/s44147-024-00403-z

Development of a Bidirectional Health Support System for the Prevention of Frailty in COPD Patients

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COPD is a lung disease caused by long-term smoking habits and is common among the elderly. COPD is a disease that causes shortness of breath due to bronchiolitis and emphysema. In Japan, there are about 220,000 COPD patients receiving treatment, but it is reported that about 5 million COPD patients have not been examined or diagnosed. Therefore, Ministry of Health, Labour and Welfare has positioned COPD as a major lifestyle-related disease in Japan and has taken comprehensive measures. On the other hand, frailty prevention is important to extend healthy life expectancy, which is a health issue in Japan. Exercise, nutrition, and social activities are important for frailty prevention, and it has been reported that participation in social activities is especially effective for frailty prevention among the elderly.
We decided to develop a remote health support system using smartwatches and smartphones to prevent frailty in COPD patients with a very high frailty incidence. This system mainly provides the following three functions for COPD patients at home. 1) physical health management through online health observation, 2) online exercise therapy through real-time heart rate monitoring, and 3) providing opportunities for remote patient community activities. In this study, we conducted a long-term introduction experiment for six months with 2 COPD patients to verify the functionality of physical health management through online health observation. Based on the data during the system use period, we grasped changes in physical activity and physical condition that were affected by the season and the patient's lifestyle. Based on the results, this system added a function to detect an emergency when a patient is unwell and send an alert to the patient and the supporter. The alert criteria for this function can be set based on the patient's data for two consecutive weeks. In other study, we conducted an experiment to introduce online exercise therapy using a Web conferencing system for 2 healthy adults. As a result, the instructor was able to make the subjects exercise safely while grasping the pulse fluctuation during exercise in real time. The goal of the next step is to build a bidirectional health support system between the patient and supporter using ICT, instead of unidirectional health support from supporter to patient.

Keywords: *COPD, Frailty, Remote, Health Support, ICT*

Introduction

Chronic obstructive pulmonary disease (COPD) is a lung disease caused by long-term smoking habits, and its symptoms are common among elderly people [1)]. The main symptoms of COPD are dyspnea on exertion and chronic cough and sputum. It is estimated that there are 210 million COPD patients in the world. In 2020, the WHO announced that COPD is the third leading cause of death in the world after ischemic heart disease and stroke. This trend is no exception in Japan. According to a 2001 Nippon COPD Epidemiology study (NICE study), approximately 220,000 COPD patients in Japan are receiving treatment, but approximately 5.7 million patients with COPD symptoms have not been examined or diagnosed [2)]. In Health Japan 21 (the second term) Analysis and Assessment Project, implemented in fiscal 2013, COPD was positioned as a major lifestyle-related disease along with cancer, cardiovascular disease, and diabetes [3)]. In addition, the Ministry of Health, Labour and Welfare has set a goal of raising awareness of COPD to 80%, and hopes that raising awareness of the disease will lead to early detection and treatment, thereby extending healthy life expectancy and reducing mortality. However, in a survey conducted by Global Initiative for Chronic Obstructive Lung Disease Japan (GOLD Japan) in 2024, the awareness of COPD was only 32.8%, and the expected results have not been achieved [2)]. Therefore, Health Japan 21 (the third term) Analysis and Assessment Project, implemented in fiscal 2024, newly indicated the need to take comprehensive measures such as "Prevention of COPD onset, early detection and treatment intervention, and prevention of severe COPD" [3)].

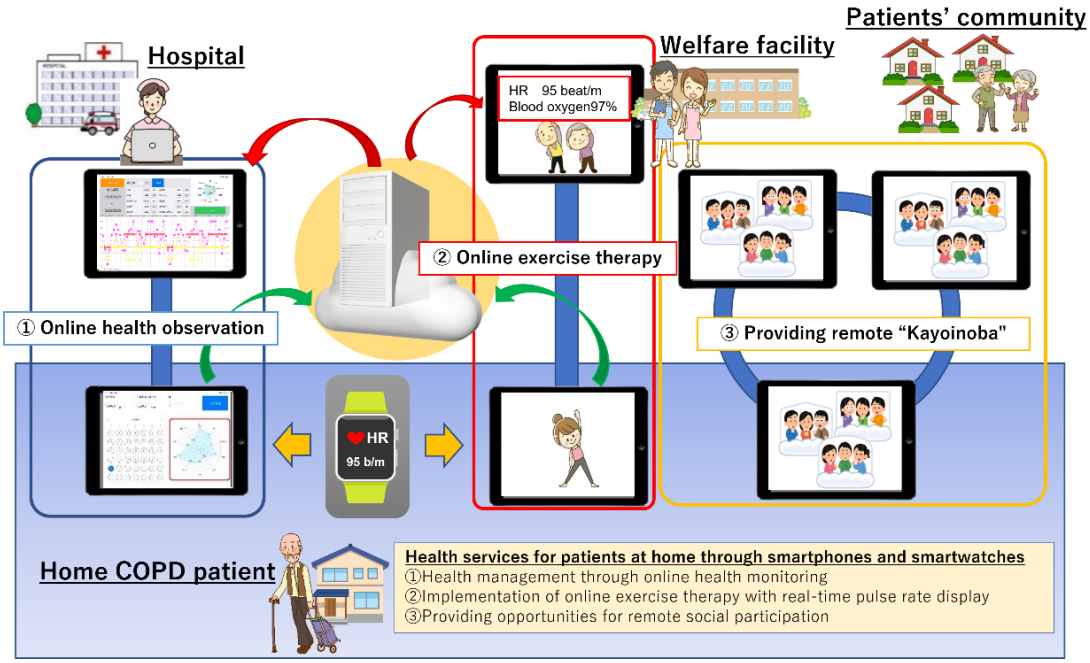


Figure 1. The Outline of the developed bidirectional health support system for the prevention of frailty in COPD patients.

On the other hand, the prevention of frailty, which is an intermediate stage between a healthy state and a state requiring nursing care, is an important issue for extending healthy life expectancy. However, it has been reported that the incidence of frailty is very high in COPD patients, who are often seen in the elderly [4]. Patients with COPD suffer from dyspnea due to the decline in lung function, which reduces their physical activity and their ability to exercise for endurance. This leads to psychological disorders such as physical limitations in activities of daily living and depressive tendencies. As a result, the development of the disease state and the onset of frailty are further promoted while forming a vicious cycle. As a result, COPD patients tend to avoid going out and have fewer opportunities to participate in society. However, it has become clear that social participation, along with exercise and nutrition, has a great impact on frailty prevention as the three pillars of frailty prevention. Therefore, securing social participation opportunities for COPD patients is a major issue.

Purpose

Exercise therapy is effective in controlling the deterioration of the condition and preventing frailty in COPD patients, but the rate of continuous exercise therapy at home is very low [5]. It is considered that the "relationship with people" has an influence as a factor. We reported that recreational activities for COPD patients, which had been held regularly, had to be cancelled due to the spread of the COVID-19, which further reduced the opportunities for patients to go out, resulting in a significant deterioration in patients' social health-related QOL [6].

From these backgrounds, we considered that it is necessary to develop an interactive health support system that realizes "relationship with people" and "connection with society" in addition to the conventional one-way health support from "supporter to patient" such as "management and guidance". Therefore, we decided to develop a remote health support system for elderly COPD patients at home using ICT devices that can realize the following three health support services (Figure 1).

1) Health management through online health observation.
2) Implementation of online exercise therapy with simultaneous display of vital data.
3) Implementation of remote "Kayoi-no-ba".

"Kayoi-no-ba" in Japanese is meant that a place where local residents, including the elderly, take the lead in activities aimed at preventing long-term care and frailty.

Development of the Health Support System

1. Measure & Send Health Condition and Physical Activity Data 'APP for Patients'

We have developed a remote monitoring system for the health status and physical activity of elderly COPD patients at home. With this system, supporters such as doctors, nurses, and caregivers can not only grasp the daily health status of the patients, but also evaluate the health status and physical activity of the patients long-term and provide health support tailored to each patient. The system in outlined in Figure 2.

In this system, an iPhone and an Apple Watch (Apple, Cupertino, California, USA) are used as patient devices. The OS used for application development was iPhone OS 14 Xcode 13.0, and Swift 5.5 was used for software development. How to operate the patient application is as follows:

1) Resting pulse rate and blood oxygen wellness (oxygen level taken into the blood) are measured

using the existing Apple Watch app, and the data is synchronized to the iPhone.

2) The six-item symptom assessment test (Cough, sputum, stuffiness, sleep, appetite, and vitality) is entered using the iPhone app, and the data is sent to the data server.
3) The results of the symptom assessment test are displayed graphically using the calendar function.

The six-item symptom assessment items are based on questions commonly used by doctors and nurses who treat COPD (Table 1). The ratings for each of the six assessment items (from 0 to 5) were added and multiplied by 20, and then divided by the number of items, i.e., six, to obtain the value of the Total Health Index.

Because the users of this system are elderly COPD patients, we designed it to minimize the amount of information displayed on the smartphone screen and to make the operation as simple as possible.



Figure 2. The Outline of the developed remote health monitoring and support system for patient.

Table 1. Six assessment items in the COPD symptoms questionnaire.

Subject	Sex	Age (y)	Height (cm)	Weight (kg)	BMI	Pulmonary Function Stage
Patient A	Male	77	162	62	23.6	II(moderate)
Patient B	Male	80	163	77.5	29.2	II(moderate)

2. Remote Check and Assessment of Patient's Health Condition 'APP for Support Staff'

First, we built a network server to store data sent from patients' iPhones. Then, we developed a remote system for monitoring the health condition and providing home health care support for elderly patients with COPD. The system in outlined in Figure 3.

The device used for this system is an iPad (Apple, Cupertino, California, USA). Supporters can use the iPad to retrieve data of the patients they manage from the network server, and check the results of their health observations and physical activity in graphs displayed on the screen. They can also download the data as a CSV file. The operation of the application for supporters is as follows.

1) Select the ID of the patient to be checked, the period for which the data is displayed, and the symptom evaluation items to be displayed.
2) The results of the health observation on the day of viewing are displayed as a radar chart.
3) The data for the specified period is displayed as a time-series graph.
4) Download the patient data as a CSV file from a PC.

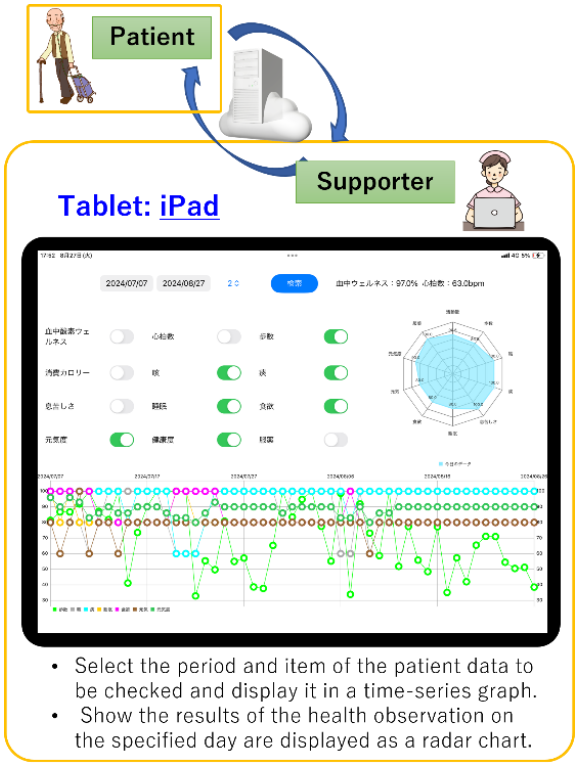


Figure 3. The Outline of the developed remote health monitoring and support system for supporters.

Table 2. Participant characteristics and stage of the patients.

Good Condition	Levels	Poor Condition
I don't have a cough	5/4/3/2/1/0	I am always coughing
I don't have any phlegm	5/4/3/2/1/0	I always have phlegm
I have no difficulty breathing	5/4/3/2/1/0	I have great difficulty breathing
I am sleeping well	5/4/3/2/1/0	I can't sleep well because of my lungs
I am eating well	5/4/3/2/1/0	I can't sleet well because of my lungs
I feel very good	5/4/3/2/1/0	I do not feel well at all

Methods of Experimental Observation and Practical Assessment of the System

This study was approved by the ethics committees of Toyama University, National Institute of Technology, Toyama College, National Hospital Organization Higashinagano Hospital, and Iizuka Municipal Hospital. A long-term implementation experiment of a remote monitoring system of health condition and physical activity using iPhone and Apple Watch was conducted for six months, from July 2024 to December 2024, with patients who were informed about the study and agreed to participate in the study. The subjects were a 77-year-old man with COPD (patient A) and an 80-year-old man

with COPD (patient B). The two patients visited the hospital once a month, but their condition was stable and there were no problems in daily life. Neither patient was receiving home oxygen therapy. The physical characteristics and stage of the patients are shown in Table 2.

In the preliminary explanation of the experiment, the patients were instructed how to operate the devices, and they were asked to wear an Apple Watch and conduct a symptom assessment test with an iPhone every day, and also to wear a Lifecorder pedometer (Suzuken, Nagoya, Japan) on their lower back every day to evaluate their daily physical activity time (Figure 4). In this experiment, the patients' data were monitored and evaluated by us using an iPad, not by their doctor, and the results were reported to their doctor once a month.



Figure 4. The photo of right side in the body of "Life Coder" (LC) and the photo of left side is a state of waring LC on side of waist.

Statistical Processing

An unpaired one-way analysis of variance was performed to compare monthly means of physical activity per day measured by the Lifecorder pedometer and the symptom assessment data by the smartphone application, followed by multiple comparisons using the Tukey method for equal variance and the Games-Howell method for unequal variance. Unpaired T-tests were used to compare mean values between days of high and low total health index. The significance level was set at 5%. IBM SPSS 28 Statistics Base was used for all statistical processing.

Results

The utilization rate of the remote health monitoring system was 134 out of 167 days (80.2%) for patient A, and 162 out of 181 days (89.5%) for patient B. Although both patients were elderly, the system utilization rate was high. For patient B in particular, the data could not be transmitted for 15 days until we checked the device due to a malfunction of the Apple Watch, so the system utilization rate would be 97.8% if that period was removed. Seasonal variations were observed in the physical activity per day and the total health index during the system utilization period (Figure 5).

Based on the average value of the total health index during the period, we classified the days with a higher value and those with a lower value than the average value, and compared the average values between the days with a higher value and those with a lower value. As a result, there was no significant difference between the days with high and low health in the item of "stuffiness" among the six symptom evaluation items for both patients, but the average value on the days with a higher value was significantly higher than the average value on the days with a lower value in the other items (Cough, sputum, appetite, sleep, and vitality). This may have been because both patients were not receiving home oxygen therapy and were in moderate condition, and their dyspnea symptoms could be controlled with inhaled bronchodilators in their normal lives.

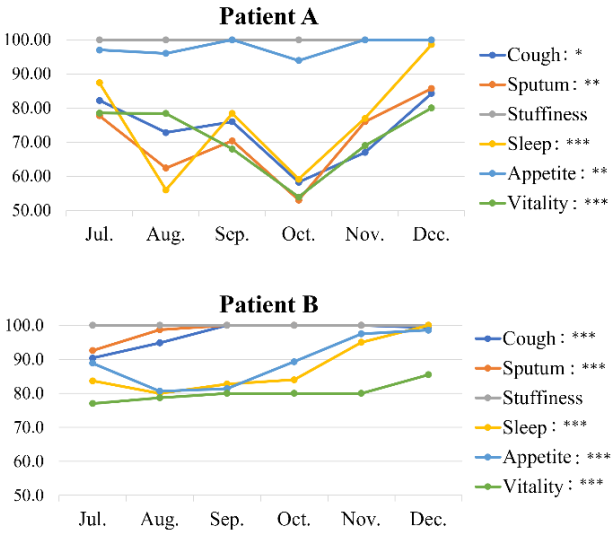


Figure 5. Seasonal changes in symptoms in COPD patients. The graph plots the monthly mean of symptom endpoints. The monthly mean of symptom endpoints was analyzed by ANOVA. *; P <0.05, **; P <0.01, ***; P <0.0001.

Discussion

In recent years, the development and spread of ICT has enabled us to enjoy various benefits in our lives. However, on the other hand, the digital divide between those who can benefit from ICT and those who cannot has become a social problem. It is said that there are four levels of the digital divide: 1) the gap in the ownership of information media, 2) the gap in the ability to use functions, 3) the gap in the use of cyberspace, and 4) the gap in the ability to process information. The users of the health support system constructed in this study are the elderly, which is the age group most vulnerable to the digital divide [7]. Therefore, in creating the application, we particularly emphasized the simplification of the application operation and the simplification of the display screen in order to eliminate the gap in 2) the ability to use functions. The implementation experiment of the system was conducted with 2 elderly COPD patients, and since their use rate of the system was high, we believe that the operability of the system was appropriate for the elderly. However, in order to promote the social implementation of this system in the future, it

is necessary to consider other solutions for the digital divide.

The patients' total health index data collected by the smartphone application were classified into high and low health days, and the six symptom evaluation items were compared. There were significant differences in five symptoms except for "stuffiness". Furthermore, when we compared each item, for patient A, the smallest difference in points between high and low health days was vitality (8.6 points), and the largest difference was sleep (28.9 points). For patient B, the item with the smallest difference was phlegm (2.1 points), and the largest difference was appetite (15.7 points). By monitoring the health status of the patients for six months, we were able to capture changes in physical activity and symptoms from a long-term perspective for each patient. Therefore, we believe that grasping the long-term changes in individual patients' symptoms can be useful information for future treatment and rehabilitation (Figure 6).

In addition, during six months of monitoring the health status of COPD patients at home, we were able to confirm days when symptoms were strong or physical activity was markedly reduced (Figure 7). Therefore, we attempted to add a new function to this remote health support system. It is a function that issues an alert to a patient's and supporters' devices when a patient feels unwell. By analyzing the pattern of individual changes in their physical condition over a long period of time, the system detects sudden unwell conditions and issues an alert, thereby providing an early response to unwell conditions such as acute exacerbations. As the population ages further in the future, we believe that telemedicine will develop to eliminate medical disparities by region and improve medical access for patients who have difficulty going to hospital. The alert function added in this study is expected to increase its utility value as a function that foresees such a future.

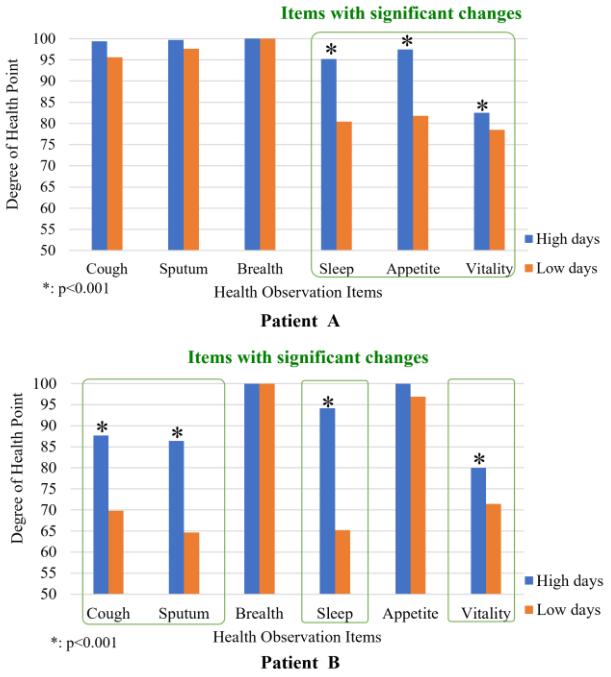


Figure 6. Individual Differences in symptom Changes in COPD patients. The graph shows the mean values of symptom evaluation items divided into days with high and low health. Comparison of mean values of symptom evaluation items was analyzed by T-test. *; P <0.0001.

Conclusions

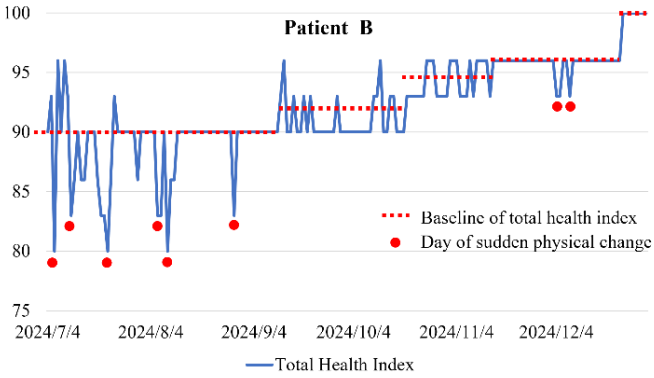


Figure 7. Days of poor health based on seasonal changes in Total health index.

In this study, we constructed a remote health support system for elderly COPD patients at home, and implemented a part of the system that remotely monitors the health status and physical activity of COPD patients at home. By accumulating patient data over a long period of time, we were able to grasp the actual condition of each patient, and found the possibility of providing health support that matches the symptoms and lifestyle of each patient. In addition, we assumed that the users of this system were elderly, and devised the device operation method and screen display method. In this six-month experiment, the use rate of the system by the patients was high, and it seems that this system also addresses the information gap regarding the ability to use the functions.

In the future, we will try to implement this system in society. And, we will aim for a society without information gap in the health promotion of the elderly at home.

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References

1. Rabe, F., Hurd, S., Anzueto, A., Barnes, J., Buist, A., Calverley, P. Fukuchi, Y., Jenkins, C., Rodriguez & R. Weel, C., et al. (2001). Global Initiative for Chronic Obstructive Lung Disease. In Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease; 2006 Report; NHLBI: Bethesda, MD, USA; WHO: Geneva, Switzerland

2. Global Initiative for Chronic Obstructive Lung Disease. Results of the 2020 COPD Awareness Survey in Japan. Available online: https://www.gold-jac.jp/copd_facts_in_japan/copd_degree_of_recognition.html (accessed on 21 December 2021). (In Japanese)

3. Ministry of Health, Labour and Welfare of Japan. A Basic Direction for Comprehensive Implementation of National Health Promotion (Ministerial Notification No. 430). Available online: https://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/0000047330.pdf (accessed on 24 December 2021). (In Japanese)

4. Marengoni, A., Vetrano, D.L., Manes, G.E., Roberto, B., Graziano, O. & Katie, P. (2018). The Relationship between COPD and frailty: A systematic review and meta-analysis of observational studies. Chest, 154, 21–40.

5. Masahiro, S. & Takanobu, A. (2007). Verification of walking-based therapeutic exercise. The Journal of the Japan Society for Respiratory Care and Rehabilitation. 17, 89–92. (In Japanese)

6. Chisato, O., Shunsuke, A. & Mineko, O. (2023). Effects of the Prolonged COVID-19 Pandemic on Physical Activity and QOL of Elderly COPD Patients. Japanese Journal of Health Promotion. 25, 1, 90. (In Japanese)

7. Jisheng, L. (2018). A Study on Methods to Solve the Digital Divide. Departmental Bulletin Review of the Division of Correspondence. 21, 85-102. (In Japanese)

FULL PAPERS FOR SUBTHEME 2

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THE IMPACT OF PRODUCTIVE FAILURE ON CULTIVATING GROWTH MINDSET IN LEARNERS

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This paper discusses the impact of productive failure (PF) interventions on cultivating a growth mindset among eighty-four second-year learners enrolled in the Diploma in Engineering with Business (DEB) who studied for a 30-hour, creative-focused learning unit during their first semester. The narrative is based on observations that most learners approach problem-solving with a "solution-first" mentality, often prioritising quick solutions and avoiding challenges owing to a fear of failure, which hinders their capacity for creativity. Previous observations indicate that fear of failure is widespread among learners and might lead to fixed mindsets, taking on a risk-averse approach in creative problem-solving. PF interventions, such as individual journals, design thinking methodologies, and collaborative activities, were implemented to motivate learners to embrace challenges and learn from their mistakes. At the end of the learning unit, the learners engaged in a reflective writing exercise employing the PEEL (Point, Evidence, Explanation, and Link) methodology to assess the effectiveness of these interventions. The learners' reflections offered evidence and explanations that highlighted the effectiveness of PF interventions in increasing their self-efficacy, motivation, and willingness to tackle innovative challenges, eventually enhancing their creative problem-solving abilities. These positive outcomes highlight the importance of cultivating a growth mindset in learners by implementing PF interventions, emphasizing the problem-solving process and reframing failure as a learning opportunity. A checklist was used to identify aspects of the learners' reflections that demonstrate the benefits of the various activities in promoting collaborative teamwork among learners with varying abilities, and how user-centric design methodology serves as the primary framework for developing the creative-focused curricula, equipping the learners with essential tools and skills necessary for creativity, as well as fostering a growth mindset crucial for lifelong learning. Future consideration may include investigating the sustained impacts of these interventions and explore their long-term influence on learners' attitudes towards failure, self-efficacy, and motivation over time. Other possibilities include the integration of PF interventions and design thinking methodology with other pedagogical approaches, such as problem-based learning and project-based learning, to uncover potential synergistic effects of combining different instructional strategies in fostering a growth mindset and enhancing creative problem-solving abilities.

Keywords: *productive failure, growth mindset, learning environment, self-efficacy*

Introduction

Singapore's Minister for Education, Mr. Chan Chun Sing, delivered a parliamentary speech in which he stated, "Each and every setback is also a learning opportunity for our children to build resilience. We must retain space for our children to try, fail, take responsibility, and bounce back from setbacks", Sing (2024). This paper closely aligns with the ministry's aim of "Reimagining the Future of Education."

This paper focuses on an Innovation & Enterprise (I&E) learning unit centered on ideation for second-year DEB learners. During the first lesson, it was observed that the majority of learners approach problem-solving with a "solution-first" mentality, often prioritising quick solutions and avoiding challenges. This is a recurring observation in numerous learning units, particularly in units that require learners to address open-ended challenges that lack a singular solution. This inherent tendency of most learners can be attributed to their fear of failure. As expressed by a learner, "Before this module, I felt scared of not finding a suitable solution. This drives my inclination to prioritise finding solutions quickly without fully understanding a problem". This tendency will subsequently impede their preparedness to address ambiguous challenges or to explore other problem-solving approaches. Another learner confirmed this tendency towards seeking for known solutions or easier options, "I went on to find problems that I already knew had a viable solution so I can feel more confident when pursuing the project. However, by doing so I did not understand the problem truly".

Pedagogical interventions were sought to shift this fixed mindset because innovation thrives on experimentation and learning from setbacks. The objectives were not merely to impart I&E competencies

but to cultivate a growth mindset that encourages learners to see challenges as opportunities and failures as integral parts of the learning process. Productive Failure (PF) interventions, where learners are encouraged to tackle challenging issues before receiving direct instruction, emerged as a promising approach. This paper reflects the effect of these interventions, and the qualitative shifts observed in the learners' approaches and reflections.

Literature Review

The challenges observed in learners, as previously described, are well-researched and documented in educational research. Whittle et al. (2020) found that post-secondary education learners frequently experience a fear of failure, which subsequently impedes their learning process. Learners will develop a fixed mindset when they view failures not as opportunities for growth but as personal flaws. They will then define themselves by academic achievement and avoid challenges, which in turn discourages creative thinking and risk-taking, as discussed in several places (e.g., Fishman and Husman, 2017; Arnett, 2022).

Yeager et al. (2019) concluded that in contrast to the expectations of individuals with a fixed mindset, those possessing a growth mindset exhibit a profound desire for self-improvement and continuous learning. They believe that creativity is not an inherent attribute but can be developed by effort. Karwowski (2014) observed that these learners display more commitment to completing creative assignments that usually result in innovative solutions. Dweck and Yeager (2021) found that academic achievements can be improved if the interventions are designed to promote a growth mindset particularly when supported by peer attitudes. Yalçın and Dinler (2022) mentioned that it is important to foster a growth mindset in learners to equip them with vital 21st-century competencies such as flexibility, adaptability, and the ability to view mistakes as learning opportunities.

The interventions aimed to support the learners to understand the process of problem-solving, the tools required to generate multiple ideas, and to explore for possible solutions without providing them with the final solution in advance. This strategy incorporates the findings of Kapur's (2008) work on productive failure, which demonstrate that learning can occur even when learners initially struggle without support structures. Kapur (2016) discussed designing tasks to "activate and elicit their prior knowledge, albeit suboptimal or even incorrect" even if learners haven't formally learned the concept yet. Buseyne et al. (2023) concluded that PF is a great way to "activate learners' prior knowledge" and form new experiences for later reflection.

Materials and Methods

In our approach, the PF-inspired interventions commenced during the initial problem-solving phase and continued through the idea creation, exploration, and solution prototyping stages. These interventions were designed to provide the following key strategies.

Emphasise divergent thinking exploration strategy: The first key strategy underpinning the PF interventions was to actively encourage exploration rather than allowing learners to seek immediate solutions. This was facilitated by providing the learning unit with open-ended challenges derived from the UN's 17 Sustainable Development Goals (SDGs). These SDGs provided an authentic context, presenting real-world issues often outside the learners' direct experience, which inherently lacked simple, pre-defined answers and this aligns with the principles of authentic learning, which argue that learning is most effective in real-world contexts as concluded by Frey et al. (2012).

The learners started their problem-solving approach by conducting exploration works, as the challenges provided by the SDGs were open-ended. The interventions were designed to encourage the learner to explore a variety of approaches rather than settling on a single “correct” one. To further prioritize exploration, the initial weeks of the learning unit deliberately enforced a "no solutions" period using techniques such as brainstorming and the 5W1H Method. This period was designed to specifically conduct broad exploration, encouraging the generation of numerous potential ideas and connections related to the SDG issues. This method requires learners to focus exclusively on comprehending the issues through user research and utilizes divergent thinking tools that encourage investigations prior to attempting to develop solutions. Consequently, the method actively opposes the tendency to converge into a “solution-first” approach.

Provide user-centric investigation tools and reflective practice: The second key strategy is to employ specific design thinking tools, including Empathy Maps, Personas, and How Might We Questions, to guide the learners with a deeper understanding of user's experience and the issues facing the user before they begin to develop solutions. McCurdy et al. (2020) concluded that design thinking activities are effective in fostering empathy and STEM integration in the classroom and that learners are more motivated and engaged in finding solutions that truly address real-world problems that they care about. Consequently, the first few lessons prioritised exploration and understanding the user’s needs, deliberately positioning them as investigation rather than immediate problem-solving approaches.

Complementing these tools, reflective practices were designed to develop the learners’ metacognition ability through learning from the process. They are, as a team, required to document their work, including team discussions and sketches captured from the whiteboard activities which formed a project journal. As individual, the learners are required to maintain a reflective journal that document their weekly progress and setbacks. Dickerson and Clark (2022) concluded that using these reflective interventions contribute to self-regulatory and self-awareness behaviours when practiced regularly because they require the learners to constantly plan, monitor, and assess their understanding and performance.

These requirements ensure that learners actively process their experiences, linking the user-centric investigation and iterative cycles back to their own

learning and mindset development which strongly aligns with the research on reflective practice that assist in developing the learners' metacognition, self-regulation, and motivation. Erickson et al. (2021) concluded that the reflection interventions work well for learners with low individual interest in developing academic motivation.

Create a Supportive Environment for collaborative work: The third key strategy focused on creating learning spaces that supports collaborative learning experiences by providing access to tools and resources for experimentation and prototyping. This is a deliberate act of moving away from traditional teaching environments, where learners are seated in front of a tutor during the lesson. Kariippanon et al. (2019) observed that group work flourishes in flexible and adaptable collaborative learning spaces that allow for ease of movements among the learners to interact and communicate and have easy access to information. Lessons were conducted in Makersnode, utilising its long whitewall. Learners must write and sketch their thoughts, ideas and points of discussion solely on the whiteboard and assess their laptops only to gather information. The whiteboard facilitates verbal and visual communication, and the resulting vigorous discussions fostered a dynamic, engaging, and productive learning environment, promoting shared ownership of ideas even among members who are more reserved. Ritchhart et al. (2011) argued that making thinking visible through writing and sketches can facilitate deeper learning and metacognition.

The learning unit curriculum provides activities that allow the learners to collaboratively identify, develop, and effectively communicate their design solutions using a low-fidelity prototype. These activities were conducted in Makerspace using the necessary tools and resources for hands-on experimentation, allowing teams to integrate personal and interpersonal skills with prototype-building skills. These activities offer learners a variety of design-implement experiences as they are required to refine their solutions iteratively through feedback and testing. In this phase, the tutors acted as facilitators, stepping away from direct instruction and adopted a facilitative role. They provided guidance by asking probing questions and empowering learners to address the challenges themselves. The environment needed for these PF interventions was created by the combination of dedicated collaborative spaces and a facilitative teaching approach.

Results and Discussion

At the end of the learning unit, each learner completed a reflective writing exercise. This exercise is to gather their responses to how they overcame challenges and failures, the crucial lessons they learnt, and their approach to problem-solving during the learning unit. The responses, supplemented by the tutors' observations, indicate that the interventions were effective in cultivating a growth mindset in the learners. They acknowledged the significant role of failure in the learning process by embracing a problem-first, user-centered approach to problem-solving.

The tutors' observations revealed some positive outcomes due to the implemented interventions, and these outcomes were categorised into six primary themes. Based on these themes, a checklist was developed to systematically analyse the learners' responses and validate the impact of the interventions. The objective of the checklist is to identify alignments between the PF intervention experiences and these observable outcomes. The analysis of the outcomes in the first two themes found evidence of shifts in mindset and approach, while the outcomes in the remaining four themes indicated increased learners' cognitive and interpersonal skills.

Reframing Failure to Increase Learner's Self-Efficacy and Motivation: The interventions produced the most significant shift observed when the learners began to reframe failure as a learning opportunity. This mindset change is crucial, as it gave the learners improved confidence and self-efficacy so they could tackle and overcome difficult and ambiguous challenges. They are then able to handle failure better whenever they experience setbacks. The observed mindset shift strongly connects to Dweck (2016) and Yeager et al. (2019) growth mindset theory, which advocates for perseverance and dedication. Crucially, learners began to articulate this value, demonstrating they were embracing failure as intended by the PF strategy.

Most of the problem-solving activities involved iterations, and they inherently involved failures or setbacks. As one learner reflected, "I understand the importance of learning and that failures are ways that we can learn... Failures can help us improve and refine our work." This iteration process provides the best opportunities for learners to use their newly founded perspective of viewing failure as learning opportunities to work towards achieving the best possible solution, as recognised by a learner that "failures provide important insights into what didn't work, allowing us to make better choices for the final solution".

A learner displayed a growth mindset trait when he valued the repetitive process of iteration to improve his potential solution and not just seek to complete the task when he remarked, "...after we found out that the solution doesn't answer the pain points of users, I then proceeded to scrap the idea... As tedious as it might sound, every time I restart, I had a better understanding of what I want in the prototype." Dorland (2023) determined that it is important to provide learners with meaningful and impactful learning experiences that are critical for developing a failure-positive mindset, and the learners' reflective thoughts resonate with Dorland's study. The learner's ability to reframe failure by turning setbacks into motivations to seek better understanding and improvement is strongly linked to increased self-efficacy.

Significant Move Towards a Problem-first Approach: Many teams began discussions regarding potential solutions before fully investigating the problem, leaning towards readily available options or reverse engineering existing solutions. This "solution-first" mentality can lead to trivial solutions that fail to address user needs as they lack the necessary depth to have a substantial influence on the issues. During the first few lessons, a "no solutions" requirement was enforced, and it was

mandatory for learners to use empathy tools in their work. These interventions were effective in fostering a significant change towards a problem-first approach and greater user-centricity. Learners explicitly reflected on this shift: "Compared to the start of the module, understanding the problem and exploring multiple ideas led me to better solutions". The traits of a growth mindset were evidence when the learners expressed understanding and willingness to explore multiple ideas. Another reflected a shift from wanting quick answers to valuing the process of understanding by writing "...it was okay not to be able to solve the complex problems as long as they tried various ways of solving them...".

Some learners demonstrated an appreciation for empathy by mentioning "...sympathising with users is crucial when creating solutions." This heightened appreciation can partly be attributed to the use of design thinking tools like empathy maps and personas. This appreciation enables the learners to have a deeper engagement with the challenges posed by the UN's SDGs, resulting in more meaningful and effective work as they work on tackling the issues. The strategy of encouraging exploration and experimentation exposed learners to an authentic and realistic experience of the design process, where setbacks and failures are common. As pointed out by Frey et al. (2012), the questions, tasks, or problems related to the SDGs have value and interest beyond the classroom and into the real world of learners' values, abilities, and motivations.

Increased Confidence in Critical Thinking and Decision-Making: The PF interventions, as previously discussed, allowed the learners to engage in a systematic problem-solving process that required them to engage deeply with complex problems. Their confidence in critical thinking and decision-making ability was enhanced by their success in collaboratively iterating on solutions. As one learner articulated, "Building a solution via a prototype with my teammates makes me feel more confident in my ability to analyse information, evaluate different options, and make informed decisions." This shift in learners having a growth mindset was built upon the first requirement of engaging in a problem-first approach, and the cycle was completed when they engaged in the impactful iterative process of collaborative prototyping.

This learning unit was designed to empower the learners to engage directly in the learning process via the various active learning methods, such as teamwork, discussions, experimentation, prototyping, and reflection. Ryan and Deci (2000) mentioned that when learners experience autonomy and ownership over their learning, they are likely to be intrinsically motivated, leading to greater engagement and persistence. As reflected by a learner, "If this was an individual project, I would not have been able to open my eyes and see the problems with my initial solutions which were made possible through the discussions with my group members." The evidence suggests the hands-on, team-based PF interventions provided a practical and effective avenue for developing and applying these higher-order thinking skills with growing confidence.

Enhanced Collaboration and Teamwork Skills: The PF intervention required the learners to work in a team where they, at times, struggled to match each other's expectations. They are forced to acquire receptive mindsets to adapt to their teammates' different perspectives. The interventions' collaborative requirements and support from a positive learning environment, like the Makerspace for hands-on work and a whiteboard for shared discussions, enhanced the learners' interpersonal skills. Learners explicitly linked the PF activities to skill development, with one stating, "working in a team and iteratively on our prototype has helped me develop valuable collaboration and problem-solving skills."

It was observed that the requirements and experience of doing collaborative iterations and problem-solving enable the teams to develop their own constructive team processes. Many teams practised different approaches when navigating challenges or when they faced negative feedback or disagreement, as reflected by one learner, "...we come together to discuss how whether to keep it or how we can work it out. This approach helped us to better understand each other." This reflection demonstrates how the PF interventions strengthened both teamwork capabilities and mutual understanding.

Improved Communication and Conflict Resolution: Ritchhart et al. (2011) concluded that the need to articulate ideas and reasoning during discussions and whiteboard use aligns with visible thinking strategies promoting more profound understanding, which in turn reduces possibilities of conflicts. Kapur (2016) mentioned that providing opportunities for explanation and elaboration is also a core principle of PF design. The PF interventions had fostered essential interpersonal skills for effective teamwork, such as active listening and constructive conflict resolution, with an increase in openness and patience in managing team dynamics. One learner highlighted this development, "A significant learning opportunity was handling my classmate's recurring ideas... I learned to value not disregarding anyone immediately. From this situation, I enhanced my skill in actively listening... This experience showed me the importance of being patient and open-minded when communicating." This mindset supported constructive approaches to disagreements, with teams learning the value of dialogue, as reflected by another learner: "...when there is bad feedback, as in someone disagrees... we come together to discuss... This approach helped us to better understand each other…."

Appreciation for Diverse Skills and Perspectives: McCrae and Costa (1997) suggested that learners in teams that work together with a high level of openness and acceptance are more willing to explore new ideas and experiences that engage their intellectual curiosity, aesthetic sensitivity, and emotional engagement. The PF interventions require learners to work together in teams with members of different abilities, perspectives and motivations. To successfully create a solution to the challenges posed by the UN's SDGs, the learners must learn from others and not just rely on their own innate ability. The successful teams were those who recognised the value diverse inputs bring to the innovation process,

which enhanced both collaboration and critical thinking and illustrated a growth mindset.

The teams learned to value the need to adapt to their peer's input and to recognise the value of different viewpoints within their team, as reflected by one learner when he wrote, "...when my teammates elaborated on why my idea may not be useful, and I heard their ideas which were more logical... it made me realise there are many ways of interpreting the problem."

Conclusions

This paper records the significant outcomes of implementing Productive Failure (PF) interventions within a creative-focused learning unit, designed to overcome the learners' "solution-first" mentality approach while working on a challenge due to their fear of failure . The learners' end of learning unit reflective writing offer valuable qualitative evidence to strongly conclude that the implemented interventions were effective in fostering a growth mindset. These interventions involve employing user-centric Design Thinking tools to prioritise exploration in addressing authentic SDGs challenges, coupled with reflective practices such as maintaining project journal, and conducting lessons in a supportive, collaborative environment with tutors acting as facilitators.

The most significant outcome of the interventions is the learners' positive shift in their attitudes towards failures and setbacks, perceiving them not as obstacles to be feared but as valuable and productive learning opportunities that enhanced their self-efficacy and motivation. This new mindset results in a significant shift in their problem-solving approach, when learners value deep understanding of the issues prior to the ideation stage. The learners worked through setbacks by conducting several iterations through the process, with the conviction that failures provide important insights. The learners also attributed their increased confidence in analytical and decision-making abilities to the various collaborative learning experiences that foster communication and conflict resolution, and appreciating diverse perspectives.

These outcomes, as documented in the learners' reflective writings, emphasize the value of PF-inspired pedagogy. The learning unit provides the learners with a safe learning environment for exploration, challenges, struggle, and reflection. The lessons learnt show that educators can move beyond traditional teaching methods to create educational practices that empower learners to embrace challenges, learn from mistakes, and develop the essential skills that align with the broader educational goals centred on lifelong learning and resilience. While future research may investigate the implementation of these interventions and assess their long-term effects on learners' mindsets and creative problem-solving abilities, this paper offers strong qualitative evidence for the significant positive effect of Productive Failure in transforming the learning experience.

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References

Arnett, T. (2022). *K-12 Value Networks: The Hidden Forces That Help or Hinder Learner-Centered Education.* Clayton Christensen Institute for Disruptive Innovation.

Buseyne, S., Vrijdags, A., & Raes, A. (2023). Productive Failure as a Method for Learning about Effective Collaborative Problem Solving. *International Journal of Designs for Learning,* 14(1), 43-58.

Dickerson, S. J., & Clark, R. M. (2022). Use of SPICE Circuit Simulation to Guide Written Reflections and Metacognition. *IEEE Transactions on Education*, 65(3), 471–480.

Dorland, A. M. (2023). *Failing to learn: Design thinking and the development of a failure-positive mindset in the university classroom. Collected Essays on Learning and Teaching, 14(1).* Retrieved from https://doi.org/10.22329/celt.v14i1.7155.

Dweck, C. (2016). What having a "growth mindset" actually means. *Harvard Business Review*, 13, 213-226.

Dweck, C. S., & Yeager, D. (2021). Global mindset initiative introduction: Envisioning the future of growth mindset research in education. *Available at SSRN 3911564.*

Erickson, M., Wattiaux, M. A., Marks, D., & Karcher, E. L. (2021). Brief, Written Reflections Improve Interest of Introductory Animal Science Undergraduates. *CBE - Life Sciences Education*, 20(2).

Fishman, E. J., & Husman, J. (2017). *Extending attribution theory: Considering learners' perceived control of the attribution process. Journal of Educational Psychology*, 109(4), 559. Retrieved from https://doi.org/10.1037/edu0000158.

Frey, B. B., Schmitt, V. L., & Allen, J. P. (2012). Defining authentic classroom assessment. *Practical Assessment, Research, and Evaluation*, 17(1), 2.

Kapur, M. (2008). *Productive failure. Cognition and Instruction, 26, 379–424*. Retrieved from https://doi.org/10.1080/07370000802212669.

Kapur, M. (2016). *Examining productive failure, productive success, unproductive failure, and*

unproductive success in Learning. Educational Psychologist, 51, 289–299. Retrieved from https://doi.org/10.1080/00461 520.2016.1155457.

Kariippanon, K. E., Cliff, D. P., Lancaster, S. J., Okely, A. D., & Parrish, A. M. (2019). Flexible learning spaces facilitate interaction, collaboration and behavioural engagement in secondary school. *PloS one*, 14(10), e0223607.

Karwowski, M. (2014). *Creative mindsets: Measurement, correlates, consequences. Psychology of Aesthetics, Creativity, and the Arts, 8(1), 62–70.* Retrieved from https://doi.org/10.1037/a0034898.

McCrae, R. R., & Costa Jr, P. T. (1997). Conceptions and correlates of openness to experience. In *Handbook of personality psychology* (pp. 825-847). Academic Press.

McCurdy, R. P., Nickels, M. L., & Bush, S. B. (2020). Problem-based design thinking tasks: Engaging learner empathy in STEM. *The electronic journal for research in science & mathematics education*, 24(2), 22-55.

Ritchhart, R., Church, M., & Morrison, K. (2011). *Making thinking visible: How to promote engagement, understanding, and independence for all learners*. John Wiley & Sons.

Sing, C.C. (2024, September 9). *Minister for Education Mr. Chan Chun Sing's Reply to Adjournment Motion – Reimagining the Future of Education.* Retrieved from https://www.moe.gov.sg/news/speeches/20240909-minister-for-education-mr-chan-chun-sing-reply-to-adjournment-motion-reimagining-the-future-of-education.

Whittle, R., Brewster, L., Medd, W., Simmons, H., Young, R., & Graham, E. (2020). The 'present-tense'experience of failure in the university: Reflections from an action research project. *Emotion, Space and Society*, 37, 100719.

Yalçın, V. & Dinler, H. (2022). *Growth mindset in early childhood: why and how? Inonu University Journal of the Faculty of Education, 23(1), 584-598.* DOI: 10.17679/inuefd.1076292.

Yeager, D. S., Hanselman, P., Walton, G. M., Murray, J. S., Crosnoe, R., Muller, C., ... & Dweck, C. S. (2019). A national experiment reveals where a growth mindset improves achievement. *Nature*, 573(7774), 364-369.

TRADITIONAL CHINESE MEDICINE IDENTIFICATION WITH ARTIFICIAL INTELLIGENCE IN TEACHING AND LEARNING

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Chinese medicine practitioners (CMP) have a long historical standing. Nowadays, they become important in treating diseases apart from General Practitioner. Unlike western medicine, CMP uses Traditional Chinese Medicine (TCM), which are herbal products from the nature. The herbal products can be roots, stems, barks, leaves, flowers, fruits, seeds and whole herbs. The functions of a plant with roots and stems can be different. In addition, there are many easily confused TCM, for instant, there are leaves from two different plants and their shapes are similar. However, their functions can be completely opposed. It may cause poison to the patients and lethal if wrong TCM was used.

Many universities in China and Hong Kong wants to make TCM in scientific management. To identify a TCM, there are few steps. Firstly, it is an original identification by naked eye or touching them. In the second step, macroscopic authentication can be used and further by microscopic identification. Finally, physical & chemical authentication by operating HPLC and LCMS. Lastly, molecular biology identification can be used, such as polymerase chain reaction (PRC). Ultimately, a large scientific bases are built for the identification of TCM which can be used in the future. Nevertheless, it is difficult to identify by layman or public in the first step.

Artificial Intelligence, machine learning and deep learning has emerged in our daily life, such as the analysis of consumer behaviours or using crime prevention by police force. AI identification of TCM can offer an innovative solution to identify the similar TCM. In our institute, students have to learn modules about TCM, like, Principles of Chinese Medicine, Medicinal Botany, Authentication in Chinese Materia Medica. However, the methods they learnt are traditional, as mentioned above, chemical analysis, microscopic observation. Our institute try to introduce and apply Chinese Herbs Identification App which is a protype for students and teachers, in order to enhance the teaching and learning effectiveness. The App can help users identify Chinese herbs with deep learning technology and analyzes images of Chinese herbs. This can accurately determine the type and information.

Keywords: *Deep learning, Chinese Medicine, identification App, Chinese Herbs*

Introduction

Traditional Chinese medicine (TCM) refers to a holistic medical system for the pathophysiology, diagnosis, treatment, and prevention of diseases. (Liu et al., 2021; Xu et al., 2013). As one of the oldest traditional medicine systems in the world, TCM was formed more than 2000 years ago and developed with the accumulation of knowledge and practice in the following centuries (Lu et al., 2021; Raja et al., 2015; Tang et al., 2008; Lu et al., 2004; Wang et al., 2018). Nowadays, the evolution of technologies is exponentially growing. Deeping learning, artificial intelligence (AI), augmented reality (AR), virtual reality (VR) and mixed reality (MR) are merged in our daily life. For example, they can be used in computer games or home video game consoles for entertainment. In addition, they also can be used for learning and teaching purpose. For instance, medical students can use it to learn human anatomy and perform virtual surgery which can be beneficial to patients. ChatGPT and Deepseek turn over a new leaf in this century, which start to change our life. Many App related to the above technologies can be downloaded and used easily with user-friendly Graphical user interface (GUI). Back to TCM, although it can be used to treat disease, the principle is different from western medicine. Herbal products from the nature are used. The herbal products can be roots, stems, barks, leaves, flowers, fruits, seeds and whole herbs. For example, *Periostracum Cicadae* (蟬蛻) is an expensive TCM while *Periostracum Cicadae Flammatae*is (金蟬蛻) is a common TCM, which is cheaper (Figure 1). Moreover, *Campsis Flos* (凌霄花) is a non-posion TCM, while *Daturae Flos* (洋金花) is poison TCM, which contains tropane alkaloid. (Figure 2). In order to help our students to identify similar TCM, a Chinese Herbs Identification App is still under developing which serves internally only. Leveraging advanced Deep Learning technology, the App analyzes images of Chinese herbs to accurately determine their type and provides detailed information such as the herb's name and characteristics.



Figure 1. *Periostracum Cicadae* (left) and *Periostracum Cicadae Flammataeis* (right)



Figure 2. *Campsis Flos* (upper) and *Daturae Flos* (lower)

Number	Name of Chinese Medicine (English)	Name of Chinese Medicine (Chinese)
1	*Eupolyphaga sinensis*	土鱉蟲
	Opisthoplatia orientalis Burm.	金邊土鱉
2	*Cordyceps sinensis (Berk.) Sacc.*	冬蟲夏草
	Cordyceps hawkesii Gray	亞香棒蟲草
3	*Ficus hirta Vahl*	五指毛桃
	Gelsemium elegans (Gardn. Et Champ.) Benth.	斷腸草
4	*Lygodium japonicum* (Thunb.) Sw.	海金沙
	Pinus massoniana Lamb.	松花粉
5	*Amomum kravanh Pirre ex Gagnep.*	豆蔻
	Alpinia katsumadai Hayata	草豆蔻
6*	*Periostracum Cicadae*	蟬蛻
	Periostracum Cicadae Flammataeis	金蟬蛻
7*	*Campsis Flos*	凌霄花
	Daturae Flos	洋金花
8	*Curcuma wenyujin*	鬱金
	Curcuma phaeocaulis	莪朮
9	*Dryopteris crassirhizoma*	綿馬貫眾
	Brainea insignis	蘇鐵蕨貫眾
10	*Acanthopanax gracilistylus*	五加皮
	Hedyotis hedyotidea	牛白藤
11	*Pseudolarix kaempferi*	土荊皮
	Cleistocalyx operculatus	土槿皮
12	*Apocynum venetum* L.	羅布麻葉
	Apocynum pictum	白麻葉
13	*Lonicera japonica Thunb.*	金銀花
	Lonicera macranthoides	山銀花
14	*Buddleja officinalis*	密蒙花
	Edgeworthia chrysantha	結香花
15	*Coixlacryma-jobi*	製薏苡仁
	Sorghum bicolor	製高粱
16	*Malva verticillate* L.	冬葵果
	Abutilon theophrastii Medic.	苘麻子
17	*Cynanchum atratum Bge.*	白薇
	Gerbera piloselloides (L.) Cass.	白眉草
18	*Artemisia anomala* S. Moore	劉寄奴
	Artemisia lactiflora Wall.ex DC.	鴨腳艾
19	*Hedyotis diffusa Willd.*	白花蛇舌草
	Hedyotis corymbosa (L.) Lam.	水綫草
20	*Ephedra sinica*	草麻黃
	Cinnamomum cassia Presl	桂枝

Table 1. Chinese Medicine proposed in our cloud library (some of them are under development)
*Chinese Medicine mentioned in this paper.

Methodology

Our App is designed to recognize 20 types of similar Chinese medicines (Table 1). In this paper, 4 types of them are taken as examples, which have been tested and gave the best performance. They are *Periostracum Cicadae*, *Periostracum Cicadae Flammataeis*, *Campsis Flos* and *Daturae Flos* which were mentioned in the introduction. The solution architecture of the App is shown in Figure 3. These TCM images dataset (100 images for each TCM) are partitioned into three distinct subsets: training, validation, and testing. After undergoing data pre-processing. A process that entails the refinement of data through format adjustments, value modifications, and structural alterations in the training and validation datasets are harnessed to build and train the classification model. This model leverages a deep learning technique known as MobileNetV3Large.

Upon the completion of the classification model's construction, the testing dataset was utilized to evaluate its performance. The images contained within the testing dataset were unique and separate from those found in the training and validation datasets, and they did not contribute to the model's training process. This arrangement enabled the model to be exposed to completely new images, thereby simulating real-world situations that users might encounter.

Model deployment constitutes the integration of a deep learning model into an established production environment, thereby enabling data-informed business decisions. This pivotal final phase, frequently characterized by its intricacy and time-consuming nature, essentially involved the incorporation of the model's outcomes into the application. For hosting the trained model, Microsoft Azure was utilized as cloud server. The open-source tools were used to develop the App, which were Python, Keras, Kotlin and Microsoft Azure respectively.

After deploying the model, a mobile application had been developed for real-world users to interact with the deployed model. This app allows users to capture photos of TCMs they encounter in their daily lives and upload them to the cloud server for analysis. Subsequently, the application provides information about the herb depicted in the image, enriching users' understanding of the herb.

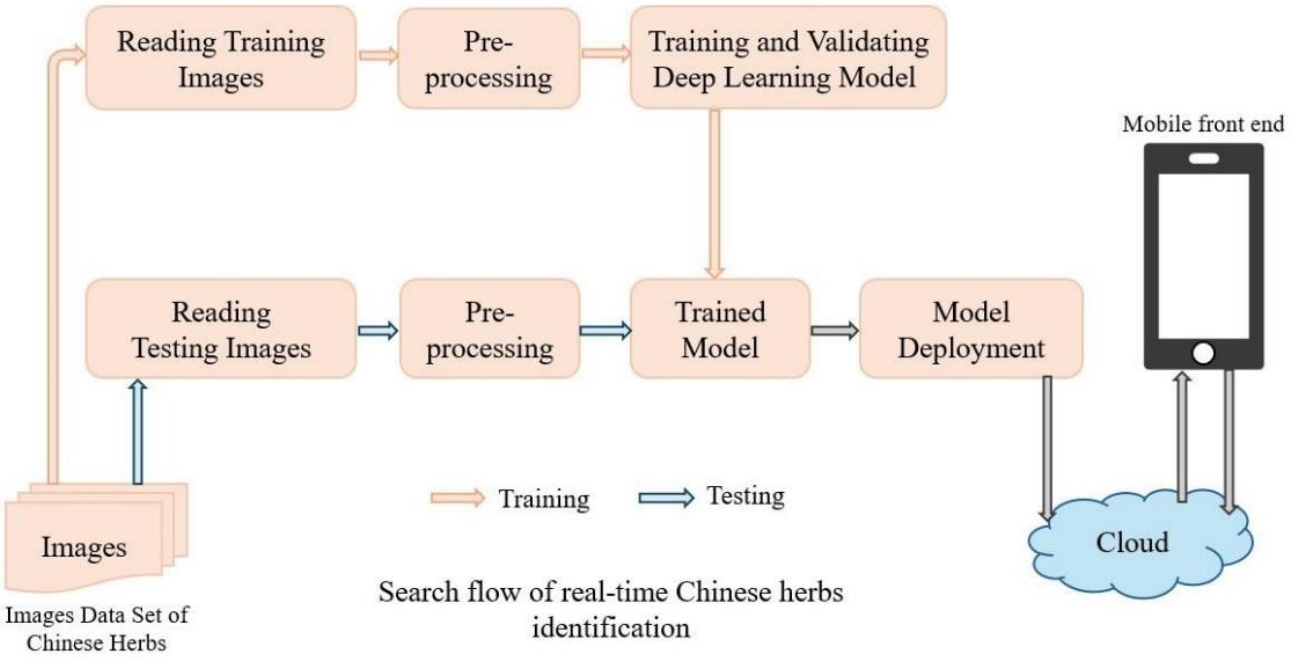


Figure 3. The solution architecture of App

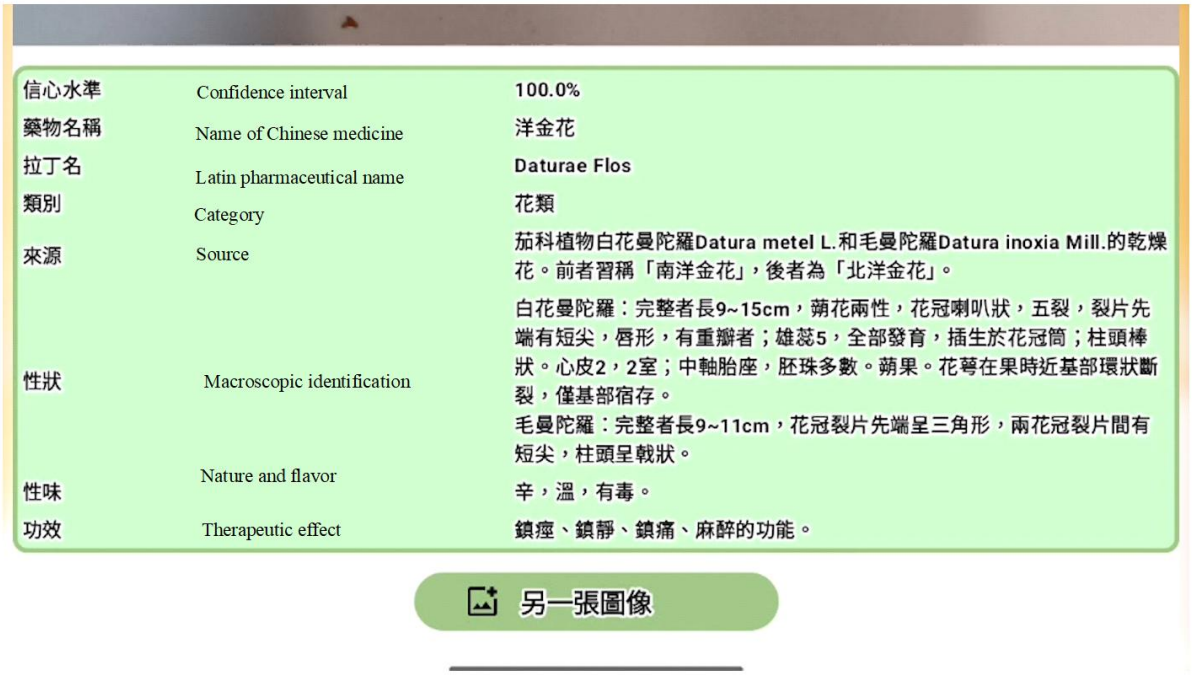


Figure 4. The detail information of Chinese medicine, *Daturae Flos* (洋金花)

Results and Discussion

Our App can show the detail information after scanning the Chinese Medicine, they are confidence interval, name of Chinese medicine, Latin pharmaceutical name, category, source, macroscopic identification, nature and flavor, therapeutic effect respectively. Taking *Daturae Flos* (洋金花) as an example, after scanning, the detailed information are shown in the App (figure 4) while the user can read the information easily. For confidence interval, it showed how the scanned picture matched our photos in our cloud library. Secondary, it also showed name of Chinese medicine (**洋金花**) with its Latin pharmaceutical name (*Daturae Flos)*. In addition, the category, such as, flower, seed, stem were also listed. Here, *Daturae Flos* was flower. Besides, the sources which *Daturae Flos* came from a flower named *Datura metel* L. and *Datura inoxia* Mill. Importantly, the information of macroscopic identification was given to the users. Finally, the nature and flavour and therapeutic effect were also shown to the users.

Miao et al., 2023 mentioned that deep learning technology is used to complete the recognition of traditional Chinese medicine, which not only effectively solves the problems of misjudgment and low efficiency caused by human factors, but also has high detection and recognition rate, convenient operation, and greatly saves time and labor costs. The is the objective of our App. However, the performance of our App can be further enhanced. The reasons are lack of publicly available datasets for traditional Chinese medicine, and the relatively high requirement for dataset size in deep learning classification tasks (Miao et al., 2023; Krizhevsky et al., 2012). In deep learning, image quality affects recognition accuracy, and the number of images affects network generalization performance (Miao et al., 2023). Furthermore, the angles and degree of distance of taking photos can also affect the accuracy to identify TCMs. During processing of the TCMs images, it is inevitable that they will be affected by various intensity signals, which will affect the quality of the image and disrupt the correlation between the content structure and pixels in the image, which is not conducive to further analysis of the image (Han et al., 2022).

Conclusions

In conclusion, our Chinese Herbs Identification App improve the the teaching and learning experience of both students and teachers. It offers valuable insights into the potential benefits and challenges of identifying similar TCMs.

References

Han, M., Zhang, J., Zeng, Y., Hao, F., and Ren, Y. (2022). A novel method of Chinese herbal medicine classification based on mutual learning. Mathematics 10 (9), 1557. doi:10.3390/math10091557

Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). ImageNet classification with deep convolutional neural networks. Communications of the ACM, 60(6), 84–90. https://doi.org/10.1145/3065386

Liu, X. H., Jin, F., Hsu, J., Li, D. N., & Chen, W. (2021). Comparing smartphone App for traditional Chinese medicine and modern medicine in China: Systematic search and content analysis. JMIR Mhealth and Uhealth, 9(3), e27406. https://doi.org/10.2196/27406

Lu Ai-Ping, Jia Hong-Wei, Xiao Cheng, & Lu Qing-Ping. (2004). Theory of traditional Chinese medicine and therapeutic method of diseases. 10(13), 1854–1856.

http://www.cqvip.com/QK/84123X/200413/11074193.html

Miao, J., Huang, Y., Wang, Z., Wu, Z., & Lv, J. (2023). Image recognition of traditional Chinese medicine based on deep learning. Frontiers in Bioengineering and Biotechnology, 11. https://doi.org/10.3389/fbioe.2023.1199803

Raja Ikram, R. R., Abd Ghani, M. K., & Abdullah, N. (2015). An analysis of application of health informatics in Traditional Medicine: A review of four Traditional Medicine Systems. International journal of medical informatics, 84(11), 988–996. https://doi.org/10.1016/j.ijmedinf.2015.05.007

Tang J, Liu B, Ma K. (2008). Traditional Chinese medicine. Lancet. Dec;372(9654):1938–1940. doi: 10.1016/s0140-6736(08)61354-9.

Wang, J., Wong, Y. K., & Liao, F. (2018). What has traditional Chinese medicine delivered for modern medicine?. Expert reviews in molecular medicine, 20, e4. https://doi.org/10.1017/erm.2018.3

Xu, Q., Bauer, R., Hendry, B. M., Fan, T. P., ZHAO, Z., Duez, P., Simmonds, M. S. J., Witt, C. M., LYU, A., Robinson, N., Guo, D. A., & Hylands, P. J. (2013). The quest for modernisation of traditional Chinese medicine. BMC Complementary Medicine and Therapies, 13, Article 132. https://doi.org/10.1186/1472-6882-13-132

A PILOT STUDY ON THE USE OF SCENARIO-BASED SIMULATION AS A PEDAGOGICAL TOOL IN MENTAL HEALTH EDUCATION FOR TERTIARY HEALTHCARE STUDENTS

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Aim: This pilot study aimed to explore the preliminary impact of using scenario-based simulation as a pedagogical tool to enhance mental health literacy, satisfaction and self-confidence among tertiary healthcare students. Methods: This pilot study utilized a cross-sectional design with a purposive sample of 20 tertiary healthcare students enrolled in a Mental Health Nursing module. Data were collected using a questionnaire comprising two instruments: the Mental Health Literacy (MHL) scale and the Student Satisfaction and Self-Confidence in Learning (SSCL) Scale. The collected data were analyzed using SPSS (Version 29.0). Results: The findings revealed that students' mental health literacy was low (M=109.0, SD=8.0). Conversely, high levels of student satisfaction (M=21.1, SD=4.5) and self-confidence (M=32.0, SD=6.3) with the scenario-based simulation learning activity were observed. Furthermore, a positive correlation was identified between student satisfaction and self-confidence in learning (r=0.83, p<0.001). Conclusion: The present study offers preliminary evidence that scenario-based simulation serves as an effective pedagogical tool for fostering both satisfaction and self-confidence within tertiary mental health education. Nevertheless, the result of low mental health literacy among students indicates that extended scenario-based simulation activities should be considered. All these findings advocate for the broader integration of simulation into the health sciences curriculum.

Keywords: *scenario-based simulation, pedagogical tool, mental health education, tertiary healthcare student*

Introduction

Traditional pedagogical approaches in mental health education are increasingly recognized for their limitations. Historically, curricula have emphasized theoretical instruction and didactic learning strategies, prioritizing knowledge acquisition over the development of essential practical skills (Chen et al., 2023). This discrepancy between classroom learning and clinical application has resulted in a well-documented theory-practice gap (El Hussein and Osuji, 2016; Greenway et al., 2019; Scully, 2011). Such conventional methods are often criticized for their effectiveness in cultivating the critical thinking and psychomotor skills essential for effective patient care (Li et al., 2025; Niu et al., 2023).

In response to these challenges, scenario-based simulation has emerged as a transformative alternative (Mulyadi, et al., 2021; Shin et al., 2015). This experiential approach offers a solution by mirroring the complexities of mental health practice in a controlled environment. Research consistently demonstrated that simulation-based training increased satisfaction and self-confidence (Alexander et al., 2023; Hall, 2017; Jeffries and Rizzolo, 2006; Schlairet and Fenster, 2012). Specifically, within mental health, studies confirmed that simulations provided a secure setting for students to practice and amplify real experiences with guided experiences without risk to actual patients (Alexander et al., 2023; Hall, 2017). Furthermore, students in simulation cohorts showed significant improvements in mental health literacy, as reported in studies by Liu (2021) and Murphy et al. (2023), demonstrating the importance of incorporating simulation exercises into nursing pedagogy (Al-Qerem et al., 2025).

This pilot study aimed to explore the preliminary impact of using scenario-based simulation as a pedagogical tool to enhance mental health literacy, satisfaction and self-confidence among tertiary healthcare students. Accordingly, this study sought to answer the following research question: How does participation in a scenario-based simulation activity influence the mental health literacy, satisfaction and self-confidence of tertiary healthcare students?

Methodology

Research Design and Sampling: This pilot study employed a cross-sectional design using purposive sampling. The entire cohort of first-year higher diploma healthcare students enrolled in the Mental Health Nursing module at the Institute of Vocational Education (Kwai Chung) was invited to participate. From this cohort, a final sample of 20 students voluntarily consented to complete a survey. No exclusion criteria were applied for participation.

Assessment Instruments: The data collection instrument was a three-part survey. The first section collected demographic data. The second section comprised the Mental Health Literacy Scale (MHLS; O'Connor and Casey, 2015), a 35-item instrument designed to evaluate multiple dimensions of MHL, including disorder recognition, risk factors and causes knowledge, self-treatment knowledge, help-seeking knowledge, and attitudes. Its response format included: 13 questions on a 4-point Likert scale (1=very unlikely to 4=very likely), with items 10 and 15 being reverse-scored; 2 questions on a 4-point Likert scale (1=very unhelpful to 4=very helpful), with item 12 being reverse-scored; 13 questions on a 5-point Likert scale (1=strongly disagree to 5=strongly agree), with items 20 to 28 being reverse-scored; and 7 questions on a 5-point Likert scale (1=definitely unwilling to 5=definitely willing). This scale demonstrated good internal consistency with a Cronbach's alpha of 0.87. The third section was the Student Satisfaction and Self-Confidence in Learning (SSCL) questionnaire (Jeffries, 2007; National League for Nursing, 2005). This 13-item instrument measures student satisfaction (5 questions) and self-confidence (8 questions) using a 5-point Likert scale (1=strongly disagree to 5=strongly agree). This instrument reported a high level of internal consistency, with a Cronbach's alpha of 0.90 for both the original version. Higher scores are associated with better performance on both scales.

Data Collection: Data were collected between July 3 and July 15, 2025, during the third semester of the 2024/2025 academic year. Prior to the study, prospective participants were briefed on its objectives and procedures. It was emphasized that participation was voluntary, confidential, and would have no impact on their academic performance. Following this briefing, written informed consent was obtained from each student. Upon completion of the simulation activity, participants were invited to complete the questionnaire. The process took approximately 10–15 minutes per participant, and completed forms were returned directly to the investigator.

Data Analysis: All data were analyzed using SPSS version 29.0. The analysis involved both descriptive and inferential statistics. Quantitative variables are presented as means (M) and standard deviations (SD), and the threshold for statistical significance for all inferential tests was set at $p<0.05$.

Ethical Considerations: Prior to commencing the study, administrative approval was obtained from the principal of the institute. All potential participants were then informed of the study's aims and procedures. They were assured that participation was voluntary, all data would be kept confidential and used solely for study purposes, and they could withdraw at any time without penalty.

Results

Demographic Data: The study involved 20 first-year tertiary healthcare students, with a gender distribution of 65% male and 35% female. As shown in Table 1, 70% of the participants were aged between 18 and 21 years.

Table 1 Sample Characteristics

Study Sample (n=20)	%	N
Gender		
Female	65	13
Male	35	7
Age		
18 – 21	70	14
22 – 25	20	4
26 – 29	10	2

Summary of Main Result: Nearly all participants (95%) found the simulation-based learning activity to be useful. For Mental Health Literacy, only 10% achieved an average score (119–136), while almost all (90%) had scores below average (35–118). Regarding Satisfaction with Current Learning, around 70% scored between 20 and 25, while only 30% scored below 20. For Self-Confidence in Learning, at least half (65%) scored between 31 and 40, around 30% scored between 21 and 30, and only 5% scored below 20 (Table 2).

Table 2 Summary of Main Result

Study Sample (n=20)	%	N
Usefulness of Simulation-based Learning Activity		
Yes	95	19
No	5	1
Mental Health Literacy		
35 – 110	55	11
111 – 118	35	7
119 – 136	10	2
137 – 143	0	0
144 – 160	0	0
Satisfaction with Current Learning		
0 – 9	0	0
10 – 19	30	6
20 – 25	70	14
Self-Confidence in Learning		
0 – 10	0	0
11 – 20	5	1
21 – 30	30	6
31 – 40	65	13

Result of Mental Health Literacy: Regarding mental health literacy, students demonstrated a low overall mean score of 109.0 (SD=8.0), as shown in Table 3. The item with the highest mean score (M=3.9, SD=0.6) indicated that students were confident about where to seek information concerning mental illness. In contrast, the item measuring the extent to which avoiding all activities or situations that made someone feel anxious would be helpful when experiencing difficulties managing emotions had the lowest mean score (M=2.1, SD=0.8) (Table 4).

Table 3 Mean Score of Mental Health Literacy

	M	SD
Mental Health Literacy	109	8.0

Table 4 Mean Score of Mental Health Literacy Items

Mental Health Literacy Items		M	SD
12	To what extent do you think it would be helpful for someone to avoid all activities or situations that made them feel anxious if they were having difficulties managing their emotions?	2.1	0.8
16	I am confident that I know where to seek information about mental illness	3.9	0.6

Result of Student Satisfaction: The participants reported a high level of satisfaction with the simulation-based learning activities, achieving an overall mean score of 21.1 (SD=4.5) (Table 5). The highest-rated items on the satisfaction subscale, both with a mean score of 4.3 (SD=0.9), pertained to the teaching materials used in the simulation, which participants found motivating and helpful for learning, and the instructor's teaching style, which was considered suitable for student learning (Table 6).

Table 5 Mean Score of Student Satisfaction with Current Learning

	M	SD
Student Satisfaction with Current Learning	21.1	4.5

Table 6 Mean Score of Student Satisfaction with Current Learning Items

Student Satisfaction with Current Learning Items		M	SD
1	The teaching methods used in this simulation were helpful and effective.	4.2	1.0
2	The simulation provided me with a variety of learning materials and activities to promote my learning the medical surgical curriculum.	4.2	1.0
3	I enjoyed how my instructor taught the simulation.	4.2	1.0
4	The teaching materials used in this simulation were motivating and helped me to learn.	4.3	0.9
5	The way my instructor(s) taught the simulation was suitable to the way I learn.	4.3	0.9

Result of Student Self-confidence: As presented in Table 7, students demonstrated high self-confidence in their learning, with an overall mean score of 32.0 (SD=6.3). The highest-scoring item (M=4.2, SD=0.8) highlighted that instructors utilized helpful resources for simulation instruction (Table 8).

Table 7 Mean Score of Student Self-confidence in Learning

	M	SD
Student Self-confidence in Learning	32.0	6.3

Table 8 Mean Score of Student Self-confidence in Learning Items

Student Self-confidence in Learning Items		M	SD
1	I am confident that I am mastering the content of the simulation activity that my instructors presented to me.	4.0	0.9
2	I am confident that this simulation covered critical content necessary for the mastery of medical surgical curriculum.	4.1	1.1
3	I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting.	3.8	1.0
4	My instructors used helpful resources to teach the simulation.	4.2	0.8
5	It is my responsibility as the student to learn what I need to know from this simulation activity	3.9	0.9
6	I know how to get help when I do not understand the concepts covered in the simulation.	4.0	0.9
7	I know how to use simulation activities to learn critical aspects of these skills.	3.9	0.9
8	It is the instructor's responsibility to tell me what I need to learn of the simulation activity content during class time.	4.1	0.9

Correlation between Student Satisfaction and Self-confidence: A significant positive correlation was reported between satisfaction levels and self-confidence levels ($r=0.83$, $p<0.001$) (Table 9).

Table 9 Correlation between Student Satisfaction and Self-confidence (n=20)

		Satisfaction	Self-confidence
Satisfaction	Pearson correlation	1	.83**
	p-value		<0.001
Self-confidence	Pearson correlation	.83**	1
	p-value	<0.001	

**Significant at $p<0.01$.

Discussion

This pilot study demonstrated the preliminary impact of using scenario-based simulation as a pedagogical tool to enhance satisfaction and self-confidence among tertiary healthcare students. The findings indicate that even a single simulation session can contribute significantly to improvements in these key areas. Specifically, students reported a high level of satisfaction with the learning activity, achieving an overall mean score of 21.1 out of a possible 25 (SD=4.5). This high satisfaction was driven by positive perceptions of the

teaching materials, which were found to be motivating and helpful, and the instructor's teaching style, deemed suitable for student learning (both with a mean score of 4.3, SD=0.9). Concurrently, students exhibited high self-confidence in their learning, evidenced by an overall mean score of 32.0 out of 40 (SD=6.3), with particular appreciation for instructors' use of helpful resources for simulation instruction (M=4.2, S=0.8). The observed strong positive correlation between satisfaction and self-confidence ($r=0.83$, $p<0.001$) further underscores that a positive and engaging learning experience directly contributes to students' belief in their abilities. This conclusion aligns with the extensive literature that consistently confirms the positive impact of simulation on satisfaction, self-confidence and skills development within healthcare education (Aebersold and Tschannen, 2013; Bdiri Gabbouj, et al., 2024; Hall, 2017).

These positive outcomes directly address the core weaknesses of traditional teaching methods, which criticized for their effectiveness to develop critical thinking and psychomotor skills vital for patient care (Alexander et al., 2023; Guerrero, et al., 2022; Hall, 2017; Li et al., 2025; Niu et al., 2023).

However, it is important to note the findings regarding mental health literacy. Despite the positive gains in satisfaction and self-confidence, students exhibited a low overall mean score of 109.0 (SD=8.0) on the mental health literacy scale. While students reported self-confidence in knowing where to seek information concerning mental illness (M=3.9, SD=0.6), the overall low MHL score suggests that a single simulation session may not be sufficient to significantly enhance comprehensive mental health literacy. This highlights a potential area for further development in curriculum design, perhaps requiring more extended simulation exposures, or integration with other pedagogical strategies specifically targeting knowledge acquisition in mental health.

As a pilot study, this research is subject to several limitations. First, the small sample size (n=20) and the single-institution setting restrict the generalizability of these findings. Furthermore, the single-group, cross-sectional design could not establish causality and measure change over time. Future research should aim to address these limitations by employing a larger, multi-institutional sample and a randomized controlled trial design that includes a control group to more robustly assess the impact of scenario-based simulation on both affective and cognitive learning outcomes, including a more detailed exploration of mental health literacy improvement.

Conclusion

This pilot study provides preliminary evidence that scenario-based simulation is a valuable and feasible addition to mental health nursing education. It significantly enhances students' knowledge and self-confidence while providing a deeply valued learning experience that bridges the gap between theory and practice. The results strongly support the strategic adoption of simulation as a core pedagogical tool to better prepare the next generation of health care professionals.

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References

Aebersold, M., & Tschannen, D. (2013). Simulation in nursing practice: The impact on patient care. *The Online Journal of Issues in Nursing*, *18*(2), Manuscript 6.

Alexander, L., Coyte, B., Evans, A., Dickson, J., Guinea, S., & Foster, K. (2023). The educational value of mental health simulation in undergraduate bachelor of nursing education: An integrative review. *Clinical Simulation in Nursing*, *84*, Article 101459. https://doi.org/10.1016/j.ecns.2023.101459

Al-Qerem, W., Jarab, A., Eberhardt, J., Alasmari, F., Hammad, A., Alfarajat, A. M. I., Hour, S. A., Al-sa'di, L., AlKhateeb, R., & Ashran, W. (2025). Mental health literacy among Jordanian nurses: a cross-sectional study and scale validation. *BMC Nursing*, *24*(1), Article 750. https://doi.org/10.1186/s12912-025-03278-4

Bdiri Gabbouj, S., Zedini, C., & Naija, W. (2024). Nursing students' satisfaction and self-confidence with simulation-based learning and its associations with simulation design characteristics and educational practices. *Advances in Medical Education and Practice*, *15*, 1093–1102. https://doi.org/10.2147/AMEP.S477309

Chen, L., Chen, Y., & Yu, J. (2023). Analysis and application of mental health education strategies for college students: A positive psychology perspective. *SHS Web of Conferences*, *157*, 01012. https://doi.org/10.1051/shsconf/202315701012

EL Hussein, M. T., & Osuji, J. (2016). Bridging the theory-practice dichotomy in nursing: The role of nurse educators. *Journal of Nursing Education and Practice*, *7*(3).https://doi.org/10.5430/jnep.v7n3p20

Greenway, K., Butt, G., & Walthall, H. (2019). What is a theory-practice gap? An exploration of the concept. *Nurse Education in Practice*, *34*, 1–6. https://doi.org/10.1016/j.nepr.2018.10.005

Guerrero, J. G., Ali, S. A. A., & Attallah, D. M. (2022). The acquired critical thinking skills, satisfaction, and self confidence of nursing students and staff nurses through high fidelity simulation experience. *Clinical Simulation in Nursing*, *64*, 24–30. https://doi.org/10.1016/j.ecns.2021.11.008

Hall, K. (2017). Simulation-Based learning in Australian undergraduate mental health nursing curricula: A literature review. *Clinical Simulation in*

Nursing, *13*(8), 380–389. https://doi.org/10.1016/j.ecns.2017.04.002

Jeffries, P. R. (2007). *Using simulations in nursing education: From conceptualization to evaluation.* New York, NY: National League for Nursing.

Jeffries, P. R., & Rizzolo, M. A. (2006). *Designing and implementing models for the innovative use of simulation to teach nursing care of ill adults and children: A national, multi-site, multi-method study*. National League for Nursing.

Li, M., Hong, Y., Wu, A., Ou, W., Yang, J., Lin, G., Ruan, Y., Chen, Z., Lin, C., & Liang, Y. (2025). The effectiveness of blended learning in nursing and medical education: An umbrella review. *Nurse Education in Practice*, *86*, Article 104421. https://doi.org/10.1016/j.nepr.2025.104421

Liu, W. (2021). The effects of virtual simulation on undergraduate nursing students' mental health literacy: A prospective cohort study. *Issues in Mental Health Nursing*, *42*(3), 239–248. https://doi.org/10.1080/01612840.2020.1793248

Mulyadi, M., Tonapa, S. I., Rompas, S. S. J., Wang, R.-H., & Lee, B.-O. (2021). Effects of simulation technology-based learning on nursing students' learning outcomes: A systematic review and meta-analysis of experimental studies. *Nurse Education Today*, *107*, Article 105127. https://doi.org/10.1016/j.nedt.2021.105127

Murphy, K. L., Klug, K. B., & Kasimatis, M. D. (2023). Strengthening mental health literacy in interprofessional health science students utilizing mental health first aid and simulation. *Education in the Health Professions, 6*(1), 22–26. https://doi.org/10.4103/EHP.EHP_1_23

National League for Nursing. (2005). *Student Satisfaction and Self-confidence in Learning ©.*

Niu, Y., Xi, H., Liu, J., Sui, X., Li, F., Xu, H., Zhao, L., Li, Y., Zhang, S., & Guo, L. (2023). Effects of blended learning on undergraduate nursing students' knowledge, skills, critical thinking ability and mental health: A systematic review and meta-analysis. *Nurse Education in Practice*, *72*, Article 103786. https://doi.org/10.1016/j.nepr.2023.103786

O'Connor, M. & Casey, L. (2015). The Mental Health Literacy Scale (MHLS): A new scale-based measure of mental health literacy. *Psychiatry Research, 229*(1-2), 511-516. https://doi.org/10.1016/j.psychres.2015.05.064

Schlairet, M. C., & Fenster, M. J. (2012). Dose and sequence of simulation and direct care experiences among beginning nursing students: A pilot study. *The Journal of Nursing Education, 51*(12), 668–675. https://doi.org/10.3928/01484834-20121005-03

Scully, N. J. (2011). The theory-practice gap and skill acquisition: An issue for nursing education. *Collegian (Royal College of Nursing, Australia), 18*(2), 93–98. https://doi.org/10.1016/j.colegn.2010.04.002

Shin, S., Park, J.-H., & Kim, J.-H. (2015). Effectiveness of patient simulation in nursing education: Meta-analysis. *Nurse Education Today, 35*(1), 176–182. https://doi.org/10.1016/j.nedt.2014.09.009

Web Application for Personalised Learning of Object Oriented Programming

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Object Oriented Programming is a module taken by all Year 2 students from Electronic & Computer Engineering, Aerospace Engineering and Engineering Science Diploma courses, in Ngee Ann Polytechnic (NP). This module builds on the programming fundamentals taught in the Year 1 Programming module.

Object Oriented Programming is difficult to learn as students must shift their thinking to conceptualize real-world objects in code, understand relationship between objects and master complex concepts like classes, encapsulation, inheritance, and polymorphism.

Student programming competencies within a class can vary significantly. When uniform material and exercises are assigned, less experienced students struggle and require additional support, while advanced learners find the content insufficiently challenging. This one-size-fits-all approach often leads to learning dissatisfaction across different competency levels.

A web application, CSHARPY, is developed to teach Object Oriented Programming in C#. CSHARPY offers a personalized learning approach which allows students to choose how to learn. CSHARPY features two distinct learning modes. The first mode provides line-by-line guidance, supporting less experienced students to complete the exercises successfully while building their motivation to continue learning. The second mode is designed for students with stronger programming foundations, who can complete the exercises on their own. This advanced mode also analyses students' entire programs and provides feedback on their mistakes, allowing proficient students to complete more challenging exercises and further develop their skills.

A survey in BrightSpace (NP's Learning Management System) is conducted and the results show that most students found CSHARPY helpful. This module adopts a Constructivist learning pedagogy, where students build their own understanding through hands-on programming experience. Instead of lectures, each lesson engages students in active learning through writing code, testing and debugging the programs. The module follows an incremental learning progression where students write a first program to create a class, followed by a second program to create a class and property, and a third program to create a class, property and method. Each program illustrates real-world application of Object Oriented Programming, encouraging students to connect new concepts with their existing knowledge and incrementally build their understanding.

Keywords: *Programming, Constructivism, Personalised Learning*

Introduction

Object Oriented Programming can be challenging to learn and understand, primarily due to its abstract nature, the shift in mindset from procedural programming, and the need to conceptualize real-world entities as code (Kolling, 1999). Key concepts such as inheritance, polymorphism, and encapsulation often intimidate beginners, and applying design patterns effectively is a skill that takes both time and experience to develop. Object Oriented Programming demands a higher level of cognitive ability, particularly in abstract reasoning and complex problem-solving. A solid foundation in core programming principles, algorithms, and data structures is crucial for understanding and mastering Object Oriented Programming concepts.

At Ngee Ann Polytechnic, Year 2 students from Diploma of Electronic & Computer Engineering, exhibit a broad range of strengths and skill levels, with many lacking a strong understanding of fundamental programming principles, possibly due to lack of practice. These students may struggle significantly when learning Object Oriented Programming, requiring close guidance and step-by-step assistance in writing even basic lines of code. Given that Object Oriented Programming involves learning new syntax and tackling lengthy, intricate programs, it can be especially difficult

for instructors to provide effective support in traditional classroom settings.

On the other hand, some students demonstrate advanced programming capabilities and can independently complete exercises. These students benefit from immediate feedback on their work, allowing them to refine their skills efficiently. To maintain their engagement and stimulate critical thinking, these students require more challenging problems and advanced exercises.

Given the diverse proficiency levels among students, a one-size-fits-all teaching approach is ineffective. Differentiated instruction methods can better cater to individual students.Personalized Learning, which has shown promising results in programming education (Junus, 2017), offers a potential solution by enabling students to choose and engage with the material according to their individual needs. Recognizing that each student has unique learning preferences and abilities, research indicates that adapting teaching approaches to accommodate different learning preferences and abilities can improve student outcomes. Hence, wo distinct learning paths were developed while covering the same core concepts, allowing students to progress at their own pace.

CSHARPY: Design and Implementation

CSHARPY is a web application designed to teach Object Oriented Programming based on C#. The CSharpy web app is published to cloud services. It communicates with the Google Gemini AI model using the Google Gen AI SDK. The system implements a personalized learning approach grounded in constructivist educational theory. The CSHARPY web application presents users with a landing page (Figure 1) that offers two distinct learning modes to cater to students with varying levels of programming proficiency and confidence. This initial interface allows students to choose between independent practice with immediate feedback (Mode 1) or step-by-step guided learning (Mode 2).

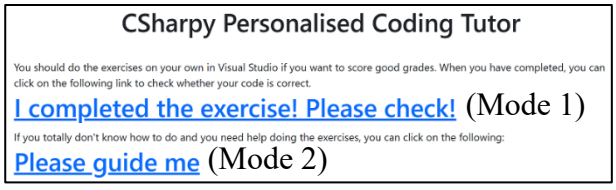


Figure 1: CSHARPY Web Application's homepage showing the two learning mode options

Mode 1: Independent Practice with Immediate Feedback

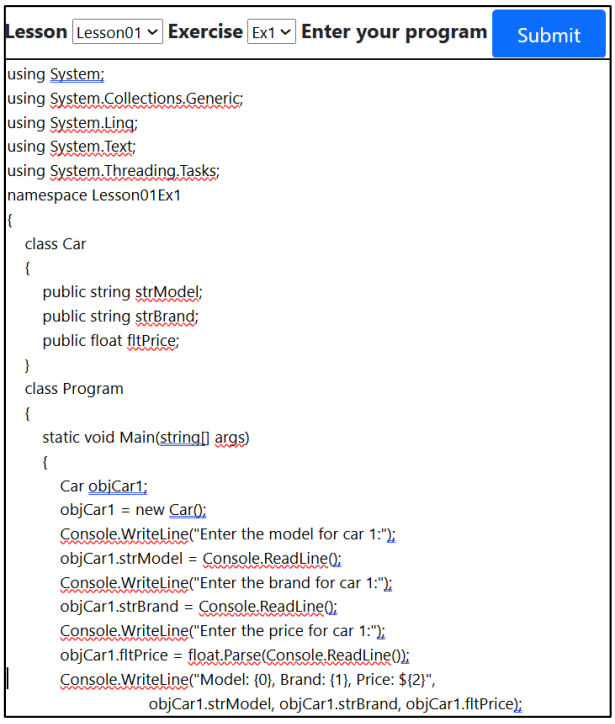


Figure 2 CSHARPY Mode 1

This mode supports students who can complete coding exercises independently and would like immediate feedback from CSHARPY. In this mode:

- Students paste their completed code into the provided text area in CSHARPY (Figure 2) and click **Submit**.
- CSHARPY utilizes the Google Gemini AI model to analyse the submitted code, performing both syntactic and logical error detection.
- When errors are detected, the system provides **detailed, targeted feedback** that explains the issue and suggests specific corrections.

Example 1: Logical Error – Incorrect Object Reference

```
Car objCar2 = new Car();
Console.WriteLine("Enter the model for car 2:");
objCar1.strModel = Console.ReadLine();
// Incorrect object reference
```

CSHARPY Response:

The program contains the following mistake:
On line 40:
objCar1.strModel = Console.ReadLine();

should be

objCar2.strModel = Console.ReadLine();.

Example 2: Constructor Argument Order

```
public Computer(string brand, string shopname) : base(shopname)
    {
       strBrand = brand;
    }

objCom = new Computer(shopname, brand);
// Incorrect argument order class
```

CSHARPY Response:

The student program has one mistake:
In the `Program` class, inside the `Main` method, the `Computer` object is instantiated incorrectly. The arguments passed to the `Computer` constructor are in the wrong order:

```
objCom = new Computer(shopname, brand);
```

It should be:

```
objCom = new Computer(brand, shopname);
```

Example 3: Flexibility in Coding Style

CSHARPY recognizes and accepts semantically equivalent code variations for tasks like object declaration and instantiation.

C#

```
// Two-line approach

Car objCar1;

objCar1 = new Car();

// One-line approach

Car objCar1 = new Car();
```

CSHARPY accepts that both single-line and two-line approaches are semantically equivalent in C#. Both approaches achieve the same outcome and the system refrain from flagging either one as an error.

The system's immediate feedback mechanism aligns with established principles of constructivist learning. By enabling rapid error identification and correction, it allows students to progressively tackle more challenging exercises and deepening their understanding of Object Oriented Programming concepts.

Mode 2: Step-by-step Guided Learning

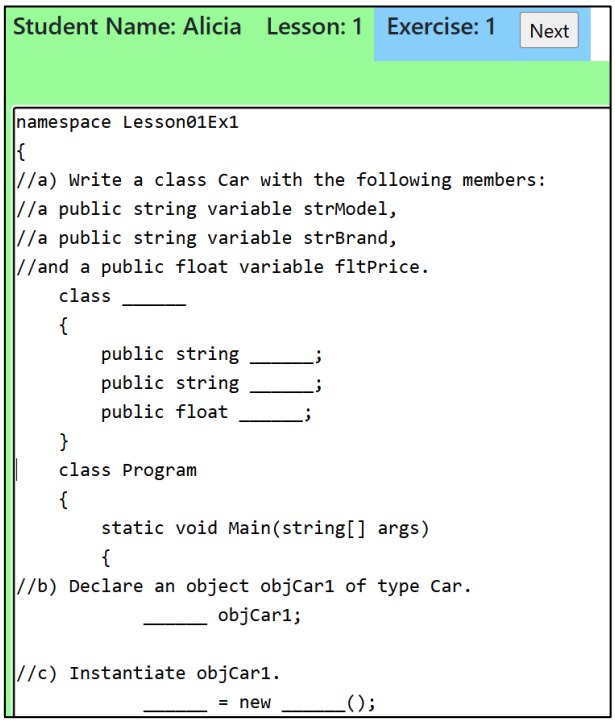


Figure 3 CSHARPY Mode 2

This Guided Learning Mode provide structured support for students through an interactive, **step-by-step approach** to programming instruction. This mode implements a scaffolded learning strategy through the following features:

- When a lesson is selected, CSHARPY displays partially completed code with **blanks** for students to fill in (Figure 3). This template maintains sufficient program structure while leaving key concepts for student completion.

- If a student enters incorrect code or leaves a blank unanswered, CSHARPY automatically provides a **mini-video tutorial** (Figure 4) focusing specifically on the concepts needed for that code segment.

- This just-in-time instructional approach significantly reduces cognitive load compared to traditional methods that require students to absorb lengthy video tutorials before attempting practical exercises. By integrating learning and practice, students engage actively with programming concepts while receiving immediate, relevant support.

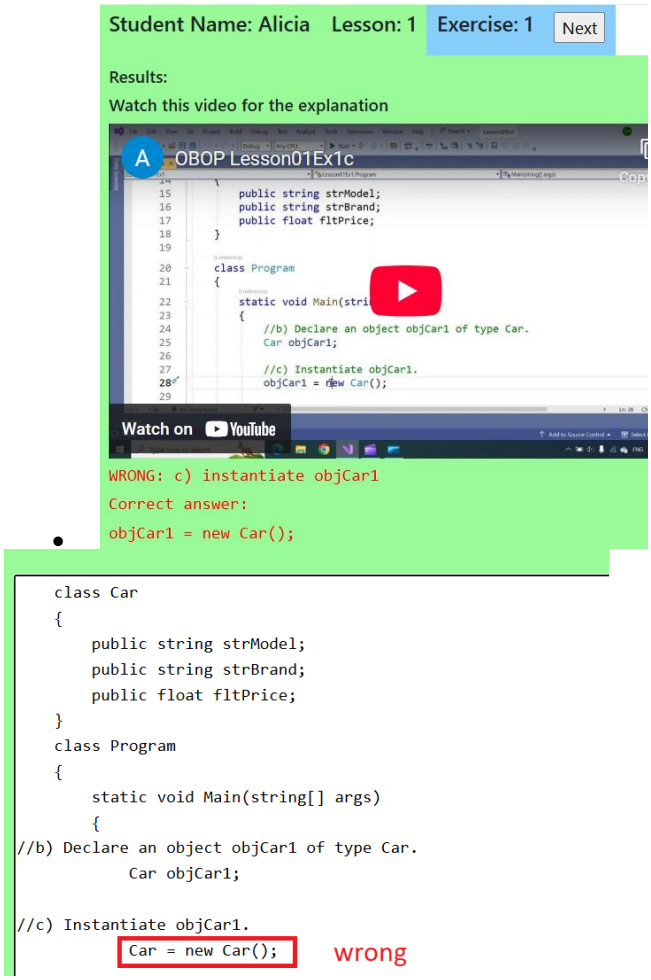


Figure 4 CSharpy mini-video

This scaffolded learning approach facilitates progressive skill development through structured support mechanisms. Rather than emphasising rote memorisation of syntactical elements, the system employs strategic code completion exercises that enable students to develop both structural understanding and logical reasoning skills.

This pedagogical approach aligns closely with contemporary software development practices, where developers primarily work on maintaining, enhancing, and modifying existing code rather than creating new applications from scratch. By emphasising code comprehension and providing contextualised assistance, CSHARPY creates an authentic learning environment that reflects real-world programming practice. This approach particularly benefits novice programmers who might otherwise find traditional programming instruction intimidating, thereby fostering a more accessible and inclusive learning environment.

CSHARPY comprises 15 lessons, each containing one to four scaffolded exercises. This progressive structure allows students to build confidence and understanding through guided practice, starting with fill-in-the-blank tasks before advancing to complete program writing. When ready, student can transition to independent coding using "I have completed the exercise. Please check" mode.

The system's approach reflects real-world software development, where programmers typically modify existing code rather than writing programs from scratch. By emphasising code comprehension and providing targeted assistance, CSHARPY creates a supportive environment that helps students overcome initial programming anxiety while developing practical skills.

Constructivism

Constructivism posits that learners actively construct knowledge through experience and reflection, rather than passively absorbing information. This module embraces a Constructivist learning pedagogy by immersing students in hands-on activities centered around Object Oriented Programming. Instead of relying on traditional lectures, each lesson is designed to engage students in writing, testing, and debugging code—promoting a cycle of experimentation, failure, and refinement that deepens conceptual understanding.

This approach is further enriched by principles drawn from Vygotsky's Zone of Proximal Development (ZPD), which highlights the difference between what a learner can achieve independently and what they can achieve with guidance. Within this framework, learning activities are scaffolded to provide structured support as students take on increasingly complex programming challenges. Initially, guidance is provided through example-driven tasks, collaborative coding exercises, and targeted feedback. As learners build confidence and competence, this scaffolding is gradually removed, encouraging autonomy and mastery. Through this guided, active engagement, students internalize not just the syntax and structure of Object Oriented Programming, but also its underlying principles and practical applications in software development.

Lessons 1 to 3 below illustrate the step-by-step nature of the proramming exercises.

Lesson 1: Introducing Classes and Objects

Lesson 1 introduces students to fundamental Object Oriented Programming concepts as they create their first class. Students learn to define a class and instantiate objects, establishing the foundational understanding of class structure that underpins subsequent lessons.

Lesson 1 programming exercise:

a) Define a class named Car with the following public members: strModel (string), strBrand (string), fltPrice (float) b) Declare an object named objCar1 of type Car. c) Instantiate objCar1. d) Prompt the user to input the model, brand, and

price for objCar1.
e) Display the model, brand, and price of objCar1 on the console.
f) Declare and instantiate a second object named objCar2 of type Car.
g) Prompt the user to input the model, brand, and price for objCar2.
h) Display the model, brand, and price of objCar2 on the console.

Lesson 2: Encapsulation with Properties
Lesson 2 advances students' understanding of class design by introducing data encapsulation. Students learn to protect class data using private members and control access via properties, implementing fundamental Object Oriented principles of information hiding.

Lesson 2 programming exercise:

a) Define a class named Employee with the following members: strName (public string), fltSalary (private float)
b) Implement a public property named Salary that provides controlled access to the private fltSalary variable. The set accessor should only allow values greater than zero to be assigned to fltSalary. The get accessor should return the current value of fltSalary.
c) Declare and instantiate an object named empObj of type Employee.
d) Prompt the user to enter the name and salary for empObj.
e) Display the name and salary of empObj on the console.

Lesson 3: Constructors and Methods
Lesson 3 introduces constructors, methods, and read-only properties through the implementation of a Circle class. Students apply Object Oriented principles while working with mathematical concepts, strengthening their understanding of both domains.

Lesson 3 programming exercise:

a) Define a class named Circle with a private float variable fltRadius.
b) Implement a read-only public property named Area that calculates and returns the area of the circle using the formula: Area=π×fltRadius2 (Use 3.1416f for π).
c) Write a constructor for the Circle class that accepts one float parameter representing the radius and initializes the fltRadius member with this value.
d) Implement a public method named Circumference that calculates and returns the circumference of the circle using the formula: Circumference=2×π×fltRadius (Use 3.1416f for π).
e) Declare two objects, c1 and c2, of type Circle.
f) Prompt the user to enter the radius for both c1 and c2.
g) Instantiate c1 and c2 using the provided radii.
h) Calculate and display the total area of both circles.
i) Calculate and display the total circumference of both circles.

Each exercise demonstrate Object Oriented principles model real-world entities and their behaviour, allowing students to solve real-world problems through code. Building incrementally on previous lessons, students construct their understanding by connecting new concepts to existing knowledge. This constructivist approach fosters deeper comprehension and retention of Object Oriented Programming principles.

Results and Discussion

A CSHARPY user experience survey was taken by 82 students during the October 2024 semester. The survey results are presented in Figures 5 to 8.



Figure 5 Question 1: CSharpy helps me to find and correct mistakes in my programs efficiently



Figure 6 Question 2: CSharpy provides personalised feedback when I am writing my programs

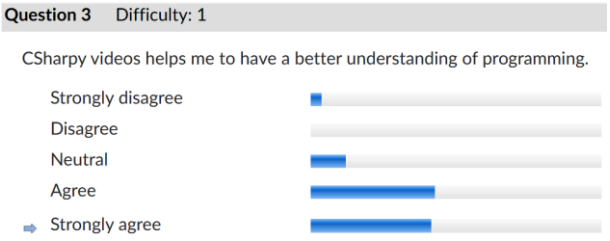


Figure 7 Question 3: CSharpy videos helps me to have a better understanding of programming.



Figure 8 Question 4: I feel more motivated to do my programming exercises when using CSharpy

Question 5: Do you have any comments for the CSharpy Personalised Coding Tutor?

Students' comments:

1	CSharpy is useful towards helping me in my education.
2	I feel that this is very important and effective and will help me in my learning
3	it is very well designed, and particularly helps the students who require a bit more help
4	Its actually genius, I genuinely have nothing bad to say about it
5	the app is well created
6	No comments but i think the CSharpy is really good
7	Well made website that aids in my OAL at home, and I can rely on it to teach me and it is manageable and not difficult to use.
8	You have done a great job to help all students who struggle to finish their code. Thank You!!
9	Really appreciated Csharpy, helped me in my tutorials to better understand where I made syntax or logical errors in my code which would have taken up more time if not for Csharpy.
10	Csharpy and the notes given to us to help us understand the module
11	csharpy was pretty cool and helpful, lesson vids were detailed and helpful
12	nice program which helps students learn the key pointers (CSharpy)
13	The notes and Csharpy helped alot when doing the exercises.

The survey results demonstrated strong student satisfaction with CSHARPY across multiple dimensions:

- **Debugging Support**: 89% of students agreed that CSHARPY helps them identify and correct programming errors effectively.
- **Instructional Guidance**: 84% reported that the integrated video tutorials enhanced their understanding of programming concepts.
- **Targeted Support**: 80% valued the platform's provides personalised feedback on their code submissions.
- **Motivation**: 75% experienced increased motivation to complete programming exercises when using CSHARPY.

Qualitative feedback reinforced CSHARPY's effectiveness as a learning tool. Students particularly valued its intuitive interface, clear instructional videos and comprehensive syntax and logical errors detection capabilities. These comments establish CSHARPY as an essential learning tool and reliable resource for programming education.

Conclusions

CSHARPY demonstrates an innovative and effective solution for teaching Object Oriented Programming in a personalized and adaptive manner. Its dual-mode approach accommodates diverse learning needs, supporting both guided practice and independent learning. The platform's constructivist design, emphasizing on hands-on coding practice and targeted feedback, enables students to progressively develop their competence in Object Oriented Programming concepts, while building confidence.

The positive feedback from students underscores the platform's effectiveness, with many highlighting its usefulness in providing targeted assistance and reinforcing key programming principles through practical exercises. The platform's combination of interactive feedback and hands-on coding exercises addresses traditional challenges in teaching Object Oriented Programming. From October 2024 semester survey results, students reported increased motivation and deeper conceptual understanding, validating CSHARPY's scaffolded learning approach. By effectively supporting learners at different proficiency levels, the system creates an inclusive environment for learning Object Oriented Programming.

In the future CSHARPY will also be used for other programming modules such as the Data Structures and Algorithms module for Year 2 students from Engineering Science Diploma course.

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The author thanks Mr. Kwek Lian Chong, Senior Lecturer at Ngee Ann Polytechnic for his continuous support in implementing CSHARPY.

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References

Peters, J., Le Cornu, R. & Collins, J. (2003). Towards Constructivist Teaching and Learning

Bada, S. O. (2015). Constructivism Learning Theory: A Paradigm for Teaching and Learning

Allen, A. (2022). An Introduction to Constructivism: Its Theoretical Roots and Impact on Contemporary Education

Application of Robotics Education through the Collaborative Class between the Robot SIer Company and National Institute of Technology, Kushiro College

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This paper presents the application of education on robotics through collaborative courses jointly conducted by a robotics company and the National Institute of Technology, Kushiro College. The increasing demand for robotics engineers, driven by recent societal changes, highlights the urgent need for specialized training of robot system integrator (SIer) professionals.

Robotics is playing an increasingly vital role in addressing societal challenges, such as shortages of laborers, owing to population decline. Society needs to foster robot SIers who can apply engineering skills with a focus on robotics. Higher education institutions are actively implementing education on robotics. However, few educators possess sufficient experience with industrial robotics to deliver practical instruction. Therefore, our institution has adopted social-implementation-based education through joint classes with a local robotics company. This is unique in that it emphasizes hands-on experience in teaching tasks utilizing cooperative robots. In addition, this educational initiative stands out owing to its collaboration with a robotics SIer company. The course centers on the use of a cooperative robot. Students design robotic hands using 3D CAD software. The designed hand is manufactured using a 3D printer and can handle materials. The design concept and operation are evaluated by engineers from the local company, and students are advised on effective learning. These corporate engineers conduct evaluations and provide advice for improvement accordingly. In this paper, we discuss the details of the practical application. Our research identifies areas for improvement in current pedagogical approaches and directions for future developments.

Keywords: *education on robotics, PBL education, industrial robot, collaborative robot*

Introduction

1. Social Necessity and Situation of Industrial Robots

Japan is a well-known “robot powerhouse.” According to a report titled “Trade and Industry"[1)] by the Ministry of Economy, Japan accounted for approximately 90% of the global sales volume until the 1990s. Japan was among the first countries to introduce and utilize industrial robots in factory automation, contributing significantly to the global dominance of its electronics and automobile sectors during the 1980s. China has since become the largest producer of robots globally; however, as of 2019, over 60% of its robots were manufactured by Japanese firms. The robotics industry of Japan still holds the second largest share of the global market in terms of robot shipments.

However, Japan faces a declining birth rate and an increasing shortage of production laborers owing to the substantial retirement of postwar baby boomers. Wider deployment of industrial robots is anticipated to address this labor gap. In addition, robotics is an effective means of addressing problems in industries as well as in an aging society[2)].

Although several world-class robot manufacturers exist in Japan, the diffusion of robots into small- and medium-sized manufacturing enterprises has been limited.

A significant barrier is the shortage of system integrators (SIers) who can effectively implement this technology, as also noted in the aforementioned “Trade and Industry"[1)] report.

2. Research Trends and Objectives

Several studies have addressed education on robotics. For instance, Toyama et al.[3)] implemented robotics education across academic departments. The content focused on the practice of problem-based learning (PBL) education through student group works. Sato et al.[4)] recently developed training programs for skills related to smart industrial robots, assigning students the task of autonomous robot teaching. However, to the best of our knowledge, no prior studies have reported practical applications using the equipment provided by local companies.

Therefore, we initiated robot SIer education for social implementation in FY2021 to foster robot SIer professionals[5)]. The program involved collaboration with

local companies and joint classes using the robotics education facilities of these companies. In this paper, based on the experience of implementing this program, we propose a novel educational model through industry academia collaboration. In addition, we identify areas for improvement in current pedagogical methods and discuss directions for future developments.

COMPASS5.0 (Robotics Field) and Kushiro College Robot SIer Education

The Cabinet Office launched the 5th Science and Technology Basic Plan and proposed Society 5.0[6] as an ideal future society. In response, the National Institute of Technology launched COMPASS5.0[7] (Curriculum Development of Next-Generation Fundamental Technology Education) as a nationwide project for the National Institute of Technology in 2020. COMPASS5.0 comprises five fields, one of which is robotics. The Kitakyushu and Tokyo colleges are the core colleges pursuing this field. Eighteen participating colleges, including ours, are implementing this educational model.

This initiative involves the development of an educational package that combines the following five elements: (1) goal formulation, (2) curriculum, (3) syllabus, (4) material development, and (5) educational practices. This includes original initiatives that exploit the strengths of each technology college. A distinctive feature of the efforts of our institution is the robot SIer education that is provided through joint classes with a local robotics company.

Robot Education Facility and Education Schedule

1. Robot Education Facility

The local company, which supports education on robotics, leveraged its track record to open Hokkaido Robot Laboratory[8] (HRL), which is the first corporate-integrated industrial education on robotics facility in Hokkaido, in April 2022, as a solution for human resource development.

This facility was established to develop human resources for robot SIer, which is in high demand within the industrial sector, and one of the services that it offers is “classes for students using industrial robots.” A distinctive feature of this initiative is that, among the various types of equipment owned, industrial parallel-link and SCARA robots are used in student classes. Figure 1 shows a student class at this facility.

2. Robotics-Related Subjects

This article describes our institution’s curriculum regarding the main devices used in industrial robots.



Figure 1 Student class at
the Hokkaido Robot Laboratory facility

“System control devices” are studied in the first semester of the fifth-year undergraduate course in control engineering. “End effectors” and “safety education” are studied in the second semester of the fifth year in the “Digital Design Competition” subject (a compulsory subject with 15 lectures). This subject is introduced to fifth-year students in the field of mechanical engineering.

Other robotics-related subjects are listed in Table 1. First-year students learn the basic operation of a computer in the “Information Literacy” subject. Second-year students learn how to operate a robotic car using interactive programming in the “Basic Creative Engineering Exercises” subject. Third-year students learn how to program and run line-trace cars using PIC in the “Mechanical Engineering Experiments and

Table 1 Robotics-related subjects in the field of mechanical engineering

Grade	Subject	Contents	Classes
1	Information Literacy	Computers	6
2	Basic Creative Engineering Exercises	How to operate a robotic car using interactive programming	6
3	Mechanical Engineering Experiments and Training	How to operate line-trace cars using PIC	12
4	Composite Fusion Exercises	How to operate a robotic car using Arduino and how to handle various sensors	8
5	Control Engineering	Fundamentals of control engineering	30
5	**Digital Design Competition**	Joint classes with local companies	30

Training" subject. Fourth-year students learn how to operate a robotic car using Arduino and manage various sensors as one of the themes of the "Composite Fusion Exercises" subject. Fifth-year students learn robotics in the aforementioned "Control Engineering" and "Digital Design Competition" subjects.

Robotics Education Contents in "Digital Design Competition" Subjects

1. Schedule

The Digital Design Competition course comprised 15 classes (two school hours each). Eight of these were joint classes with a local company. The class schedules are presented in Table 2.

The first and second classes were overviews presented by the local company. They explained the environment surrounding robots, types of robots, and key points for designing end effectors. The end effector in this project is a robotic hand for transporting cups. From the third to sixth classes, students were introduced to the robotics laboratory of the local company, "HAL," for an overview of industrial robots and to gain experience in operating a robot. In addition, they formulated specifications for a robotic hand.

From the 7th to 9th classes, each student created a concept sheet for a robotic hand and designed it employing CAD. During the 10th class, each student presented a robotic hand concept. Subsequently, they selected the robotic hand to be used in machining and formed teams. During the 11th class, an engineer from the local company with expertise in designing robotic hands evaluated the robotic hands that were created by the students. This practical approach is a distinctive feature of this educational program.

During the 12th–14th classes, the created robotic hands were mounted to the collaborative robot of the institution. The students performed teaching tasks on the robot. During this process, the students acquired the relevant knowledge necessary for robot teaching, including programming. In the 15th class, a robot operation competition was organized for the teams using the robotic hand created by the students.

Table 2 Digital design competition course schedule

Class	Contents	Remarks
1st–2nd	Overview explaining key points for designing robotic hands	Joint classes
3rd–6th	Experience in operating an industrial robot	Joint classes
7th–9th	Creating a concept sheet for a robotic hand and designing it using CAD	Our institution
10th	Presenting the robotic hand concept and dividing into groups	Our institution
11th	An engineer from a local company evaluates the robotic hands created by the students	Joint classes
12th–14th	The robotic hands created will be attached to the collaborative robot, followed by robot teaching	Our institution
15th	A robot operation competition will be organized in teams using the robotic hand created by the students	Joint classes

2. Collaborative Robots

As shown in Figure 1, industrial robots must be enclosed within safety fences or other devices to separate them from the worker space completely. Therefore, small- and medium-sized enterprises with small factory floor spaces cannot easily introduce robots. However, in recent years, collaborative robots have been included as a new category of industrial robots. This is owing to the incorporation of safety functions based on the technical specifications for collaborative robots published by ISO/TS15066. Furthermore, with the issuance of a notice (Kihatu-1224 No. 2, dated December 24, 2013) and the revision of the Industrial Safety and Health Act, workers and robots can currently coexist in the same space. Thus, collaborative robots are becoming increasingly widespread in industry.

This positive impact also extends to the educational field. Academic faculties are still required to undergo a special training course of approximately three days, as stipulated in Article 36 of the Industrial Safety and Health Regulations. However, as opposed to conventional industrial robots, collaborative robots are equipped with a function that detects overload and stops the servomotor. Therefore, fences and partitions are not required (Figure 2). This facilitates the installation of collaborative robots. Collaborative robots do not require safety measures and can be operated efficiently. For this reason, cooperative robots are suitable for use in educational settings.



Figure 2 Collaborative robot installed at our institution

3. Robotic Hand Production Project for 2023

In 2023, a project was launched to create a robotic hand that can transport paper cups. The robotic hand is operated by an actuator using air pressure. Details of the

project are shown in Table 2. Company engineers directly presented an overview and discussed issues surrounding industrial robots with the students. Subsequently, students were trained on how to operate industrial robots in the robotics laboratory of the company (Figure 1).

Thereafter, each student designed a robotic hand using CAD (Figure 3). During the design process, company engineers provided online support to students to update their progress and address any questions regarding assignments.

The deliverables were a concept document and CAD model, which were evaluated using the evaluation criteria presented in Table 3 that were prepared by company engineers.

After selecting four or five robotic hands from the completed CAD models for production, the robotic hands were modeled using a 3D printer. We actively selected new structures that did not exist in previous years.

The created hand was attached to an industrial robot, and a performance test was conducted (Figure 4). At this point, the obtained results could be predetermined when the created hand moved an object. Changing the picking speed of an object could result in it being missed or the robotic hand breaking. Students were surprised when they witnessed this. Thus, we could infer the possibility of achieving educational benefits from a student perspective.

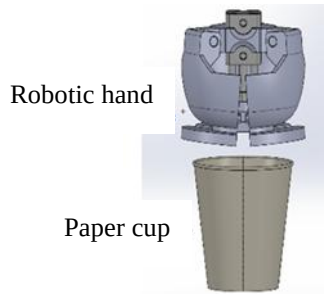


Figure 3 End effector (robotic hand) and transported object (paper cup)

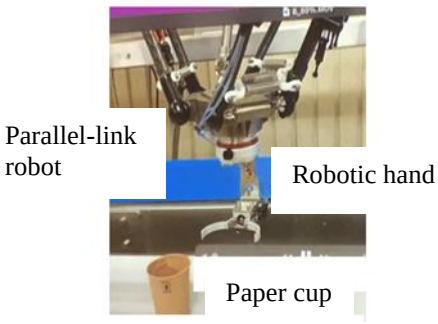


Figure 4 Robotic hand created by a student using a printer attached to a parallel-link-type industrial robot

Table 3 Robotic hand evaluation criteria

Items	**Points**		**Evaluation contents**
Restrictive	30		Gripping strength is the most important factor
Concept	20		Emphasis on thought process
Submission deadline	20		Delivery dates are important to companies
Others	30		"Others" are as follows:
-Accuracy		5	No interference during operation
-Strength		5	Durability after repeated operations
-Practicality		5	Realism
-Versatility		5	No restrictions on grip
-Design		5	Good appearance, functionality, and creativity
-Challenging		5	Proactive and open to new challenges
Total	**100**		

4. Robotic Hand Production Project for 2024

Nikko Co., Ltd., a local company with which we have been conducting joint classes, is primarily involved in the manufacturing of robots for transporting food such as seafood and vegetables. By 2024, chicken wings were transported instead of paper cups. Because handling raw meat in class was not realistic, we used models made from paper clay (Figure 5). However, as opposed to paper cups, each food item has different dimensions. To retain the characteristics that rendered transportation challenging, models with variations of several millimeters were used. Therefore, a hand that can accommodate variations in the shape of a target object should be developed.

Students could choose between swing- or piston-type pneumatic actuators to move the robotic hand. The flow of the assignment was the same as that in 2023, in that the design was created using CAD, evaluated by company engineers, manufactured using a 3D printer (Figure 6), and attached to an industrial robot for testing. The difference was in the type of robot used. Unlike the previous year, the introduction of a collaborative robot (Figure 2) allowed students to assist easily with robot-teaching tasks. As a result, students could safely conduct direct robot teaching (Figure 7). This made learning about robotic operations more in-depth than that in the previous year. The robot program is illustrated in Figure 8.



Figure 5 Chicken wing model made from paper clay



Figure 6 Creating a robotic hand for transporting chicken wings



Figure 7 Direct robot teaching

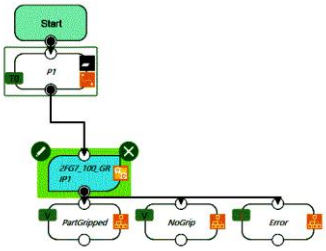


Figure 8 Example of robot teaching data

Issues and Future Prospects

Areas for improvement become noticeable when implementing robot SIer education in collaboration with local companies. A major challenge associated with robotic hand design is insufficient time. Even if company engineers identify flaws in students' work from a professional perspective, they cannot take measures to improve the robotic hand. Consequently, students may not feel a sense of accomplishment. The suggestions of the company engineers are reflected in the design and improvements are made to reproduce the product. This will hopefully further improve the ability of the company to render the product usable. One means of achieving this would be to task students with assignments related to design modifications outside of class time.

Through the initiative described in this paper, the teaching materials were almost completed. Awareness of robotics technology can be further enhanced by utilizing them in events of the institution (such as experience classes in College Festival and Open-College).

As a future effort, we will conduct a survey on the types of skills (e.g., technical, practical, and problem-solving skills and attitude changes) acquired by the students obtained. This should validate the effectiveness of the education.

It is important to attempt to visualize the education by quantitatively evaluating the satisfaction of students and corporate engineers. Therefore, after the survey, we will review the evaluation criteria for the robotic hands.

Improved teaching materials, as well as revised evaluation criteria, will be subject to an additional questionnaire survey. This will allow for further revision and improvement of the teaching materials in the following year. Thus, longitudinal tracking of educational effectiveness is important.

Conclusions

The current labor shortage has increased the demand for the widespread operation of robots. Therefore, training robot SIer engineers who can implement system integration in industrial contexts is imperative. The presented initiative is unique in that education on robotics is held in collaboration with a local food processing machinery company.

Social implementation has gained significance recently, and engineers with expertise in production systems that incorporate robots evaluate the student-designed robotic hands. Furthermore, these robotic hands are mounted to industrial robots and tested in realistic conditions, rendering this course highly practical. As opposed to evaluations that are conducted solely by an academic faculty, assessments conducted by experienced engineers provide students with more credible and application-oriented feedback. This collaboration significantly enhances the educational experience and introduces professional rigor that is rarely found in traditional classrooms. The course is structured as a PBL-style exercise, in which students are assigned engineering tasks that are subsequently examined from multiple perspectives to address a specific problem. Through this experience, students gain exposure to both the technological competencies and business operations of the partner company. We aim to continue to leverage this collaborative environment and improve our educational materials further.

Acknowledgments

We would like to thank Nikko Co., Ltd. for providing us with their robotics laboratory for the joint classes to train the robot SIer. We also thank Mr. Yasunaka from the Human Resources Department and various company engineers for their lectures on robotics and evaluation of the robotic hand.

References

1) Ministry of Economy. (2019). Changes in the environment surrounding robots and the direction of future policies 8120190724_report_01.pdf. Trade and Industry: July 2019 Robot Social Change Promotion Conference.
Retrieved from https://www.meti.go.jp/shingikai/mono_info_service/robot_shakaihenkaku/006.html.

2) Yusuke Aoki, Takumi Onuma, Susumu Kotani, Shinji Ushimaru, and Masato Kagawa. (2021). Practical

implementation of robotics education in society with the theme of life with robots. Journal of the Robotics Society of Japan, 39(9), 870–873.

3) Ken Toyama, Shigeoki Hirai, Yusuke Ohta, Yoshimi Ui, Hiroki Sato, Masaya Ando, Toshihiro Ioi, and Hiroshi Kubo. (2015). Social implementation robotics education across disciplines. Engineering Education, 63(1), 31–36.

4) Takashi Sato, Takuo Kikuchi, and Koji Takahashi. (2020). Proposal and implementation of education and training for robot technicians in smart factories. Engineering Education, 68(1), 75–80.

5) Susumu Tarao, Keiichi Asano, and Tomomasa Sato. Analysis of the process of social implementation of robotics education. Engineering Education, 63(1), 62–67.

6) Cabinet Office: society5_0. (2023). Retrieved from https://www8.cao.go.jp/cstp/society5_0.

7) National Institute of Technology. COMPASS5.0 Development Project. Retrieved from https://www.kosen-k.go.jp/about/profile/gear5.0-compass5.0.html.

8) NIKKO Co., Ltd. Hokkaido Robot Laboratory. Retrieved from https://www.k-nikko.com/robo-lab.

A Structured Pair/Trio Model for Collaborative Learning in Computer Programming: A Novel Approach for Adult Learners

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This study explores the impact of a structured pair/trio programming model on adult learners in Computer Programming Continuing Education and Training (CET) lessons, using a social constructivist approach. The model was designed based on Dillenbourg's (1999) requirements for collaborative learning, with structured pair/trio programming exercises created to enhance adult learners' programming skill acquisition. The study employed a mixed-method approach to evaluate the efficacy of the model. Mid-Semester Assessment (MSA) scores between control and experimental groups were compared while quantitative and qualitative insights through survey questionnaire, interviews, and independent lesson observation were also gathered. Although MSA score comparisons showed no statistically significant difference between groups, survey responses from the experimental group highlighted the benefits of structured pair/trio programming. Learners reported improved error detection, enhanced peer learning, and increased confidence in programming. Motivation and engagement were high, though some challenges emerged, such as group compatibility and varying participation levels. Notably, most respondents were willing to recommend this approach to others. In the student interviews conducted, further benefits of structured pair/trio learning such as real-time feedback, reduced anxiety, and deeper conceptual understanding through structured discussions were uncovered. Staff interviews supported these observations, noting increased peer problem-solving and engagement in CET lessons. An independent lesson observation confirmed high student participation and the application of social constructivist principles. Despite these positive outcomes, challenges like skill mismatches and participation inconsistencies indicate areas for improvement. The study's limited sample size and institutional setting constrain generalizability. Future research should explore best practices for group formation, rotation strategies, and long-term effects on student retention and post-course learning. These insights provide valuable guidance for educators seeking to enhance collaborative programming education.

Keywords: *Structured pair/trio, Social constructivism, Programming education, Mixed-method research*

Introduction

Computer programming is a difficult field that requires a deep understanding of programming practices and concepts. Teaching programming is a complex process which is difficult for novice learners (Gomes & Mendes, 2007). The high failure and drop-out rates associated with introductory programming courses are a common issue, prompting many researchers to suggest various tools and methodologies aimed at improving the learning experience for students in programming (Ma, Ferguson, Roper, & Wood, 2011). Recent educational research has focused a great deal of attention on the study of successful computer programming teaching methods, especially pair programming. Traditional pair programming, particularly the driver-navigator model, has proven effective in enhancing performance, teamwork, and learning outcomes in computer science courses (Cliburn, 2003; McDowell et al., 2002). Incorporating pair programming in computer science classrooms has been shown to enhance student learning, increase satisfaction, and reduce common frustrations. This approach also alleviates the burden on educators, as students begin to tap on their peers for technical support rather than depending solely on the teaching staff (Williams & Upchurch, 2001). Studies show that students who work in pairs on programming create better programs, have increased motivation toward programming and have more confidence in their coding skills than those who work alone (McDowell et al., 2002). Despite its benefits, pair programming presents limitations like the failure to foster genuine collaboration, with students sharing a machine without engaging in meaningful interaction (Bevan et al., 2002).

Goel and Kathuria (2010) introduced a framework for pair programming that integrates Dillenbourg's four conditions for collaborative learning. Their approach focuses on ensuring both students in a pair contribute equally to the task, thus promoting collaboration through clearly defined roles. Their study found that this method significantly improved problem-solving skills, the quality of work, trust, and teamwork, particularly helping inexperienced programmers perform at the same level as their more experienced peers. The framework highlights the importance of structured collaboration in enhancing both technical and soft skills in programming education. The study was conducted with undergraduate students, specifically tested in an introductory computer programming course offered to first-year engineering students.

The effectiveness of these collaborative methods remains underexplored for adult learners. Our study aims to fill that gap by providing empirical insights that can inform educators and practitioners about the potential advantages of structured collaborative learning environments in developing essential programming skills of adult learners.

In this study, a model based on Dillenbourg's (1999) set of four conditions was adapted to establish an active learning context for a CET class in Computer Programming. The four conditions include setting up initial conditions such as group formation, over-specifying roles within the collaboration, scaffolding effective interactions through structured activities, and monitoring and regulating interactions to ensure engagement and focus throughout the learning process. The study was conducted from a social constructivist perspective in CET, rooted in the four social constructive principles of knowledge construction, zone of proximal development, collaborative learning and contextual learning. The social constructivist approach emphasizes the value of social interaction and collaboration in the learning process. According to Vygotsky's theory, learning occurs most effectively through social engagement and active participation within a community of practice (Vygotsky, 1978). In the context of this study, structured pair/trio programming activities were designed to foster knowledge construction through individual and peer interaction, supporting both cognitive development and the acquisition of programming skills in adult learners. Table 1 illustrates how Dillenbourg's (1999) four conditions for collaborative learning were applied in the study, aligning each condition with the corresponding social constructivist principle to guide the implementation of structured pair/trio programming in the CET Computer Programming class.

Table 1: Dillenbourg's Set of Conditions (1999) and Social Constructivist Principles

Dillenbourg's Set of Conditions (1999)	Social Constructivist Principles
Set up the initial conditions: Pair/Trio arrangement fixed at the start of the semester and followed for all lessons in the module	*Knowledge construction*: Learners engage in collaborative programming tasks, constructing knowledge together through discussion and problem-solving
Over-specify the collaboration contract with scenario based on roles: Mixture of academically strong and not-so-strong members in each Pair/Trio	*Zone of proximal development*: Pair/trio programming offers opportunities for learners to work within their zone, challenge themselves, and learn from peers
Scaffold productive interactions by encompassing interaction in medium: Deliberate activities for individual, Pair/Trio, and Team discussions	*Collaborative Learning*: Pair/trio settings foster collaboration and communication between learners
Monitor and regulate the interactions: Trainer monitors and regulates the interaction face-to-face as well as with EdTech tools like Padlet and Kahoot	*Contextual learning*: Learners engage in relevant programming tasks, allowing them to construct knowledge within meaningful, real-world contexts.

The purpose of this study is to investigate the effects of a structured pair/trio approach on the adult learners' computer programming skills based on a social constructivist perspective in CET.

The research questions that drive this investigation are:

- What are the perceived effects of structured pair/trio programming on adult learners' computer programming skills?
- How does the social constructivist approach influence the learning outcomes of adult learners in structured pair/trio programming?

By answering these questions, this study seeks to enhance understanding of how social constructivist teaching methods might improve CET learning outcomes.

Methods

The study involved forty-four learners from Part-time Diploma in Engineering (Electrical and Electronics) who enrolled on a foundational Computer Programming course. These learners were split into two classes: Class A and Class B. Nineteen learners from Class A were placed in the control group, while twenty-five learners from Class B were placed in the experimental group. Based on their cumulative Grade-Point Average (cGPA), learners in the experimental group were grouped in a structured team of pair or trio to work on the individual and group work in the class. The grouping ensured a deliberate mix of academically strong and weak learners. The class was conducted in a lab with 5 desks, each equipped with 5 chairs, where each desk accommodated one pair and one trio for collaborative learning. Learners in the control group followed the usual classroom setting. In the first lesson, learners were briefed about the seating arrangement and instructed on how to interpret the various icons, as shown in Figure 1, used in the lesson materials, which indicated when to work individually, collaborate in pairs/trios, or engage in class discussions. The arrangement was continued for all lessons in the module. Mid-Semester Assessment (MSA) results for both groups were compared to evaluate the effectiveness of the collaborative learning approach. Additionally, interviews and surveys were conducted with participants from the experimental group, as well as staff, to gather insights into the teaching and learning experiences, providing a deeper understanding of the impact of the structured pair/trio setting. An independent staff was invited to observe the learners during one of the lessons

to provide an unbiased, external perspective on the effectiveness of structured pair/trio approach. and identify challenges, assess student engagement, and ensure that the teaching methods aligned with the intended learning outcomes.

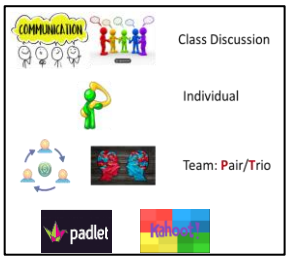


Figure 1: Icons used for activities

The lesson flow for the computer programming lessons is depicted in Figure 2. The learning outcomes and sequence of the key activities were identical for both classes. The hands-on activities for Class B were conducted at various levels—individual, pair/trio, and whole-class sharing—each represented by distinct icons to indicate the corresponding level. Padlet served as a collaboration platform for every lesson. Quiz activities at the end of each lesson were conducted using team-based Kahoots.

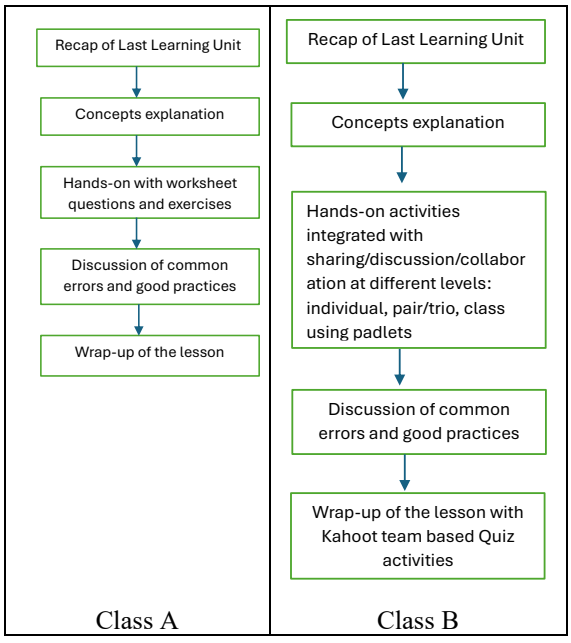


Figure 2: Lesson flow

The study adopted a mixed-method approach comprising of surveys to measure the perceived effects of structured pair/trio programming on learners' computer programming skills, interviews of learners and lecturers as well as class observation by an independent lecturer to gain deeper understanding of the adult learners' experiences. The MSA scores for the two classes were compared at the middle of the course using a two-sample t-test assuming unequal variance. The survey questionnaire was administered to the learners of experimental class B. Three learners and two staff members were interviewed to gather insights on the perceived effects of structured pair/trio programming. The interviews followed a semi-structured format, allowing participants to elaborate on their experiences and perspectives. The learner interviews focused on their experiences with collaboration, challenges, and learning outcomes, while the staff interviews explored their observations of student engagement and effectiveness of the approach. An independent lecturer was invited to observe a lesson and provide an unbiased view on the class dynamics. The qualitative data was analyzed using inductive thematic analysis adopting a semantic approach (Caulfield 2023).

Results and Discussion

Quantitative Statistical Insights

Independent samples t-test was conducted to investigate the effect of a structured pair/trio learning approach on adult learners' computer programming skills, as measured by MSA scores. The results of this analysis are presented in tabular format in Figure 3.

t-Test: Two-Sample Assuming Unequal Variances		
	MSA Scores	
	Class A	Class B
Mean	30.05263	30.92
Variance	77.16374	93.91
Observations	19	25
Hypothesized Mean Difference	0	
df	41	
t Stat	-0.31022	
P(T<=t) one-tail	0.378984	
t Critical one-tail	1.682878	
P(T<=t) two-tail	0.757967	
t Critical two-tail	2.019541	

Figure 3. Independent samples t-Test to compare MSA scores

The mean MSA score for Class A (control group) was 30.05 (SD = 8.78), while the mean MSA score for Class B (pair/trio learning) was 30.92 (SD = 9.69). There is a slight trend towards experimental group (Class B) having higher grades than control group (Class A). However, the independent samples t-test revealed no statistically significant difference between the mean MSA scores of the two groups ($p = 0.76$). This suggests that, in this sample, the structured pair/trio learning approach adopted in class B did not lead to a statistically significant improvement in MSA scores compared to the class A learning approach. This non-significant finding may be attributed to the relatively small sample size, which could have limited the power to detect a statistically significant difference, even if one existed. Furthermore, the wide range of student scores in both groups, as indicated by the standard deviations, highlights the potential influence of other factors, such as prior programming experience, learning styles, or the dynamics within the learning pairs and trios. Future research with larger samples and more detailed measures of these potential moderating factors is warranted.

A survey questionnaire, based on 5-point Likert scale, was administered to the learners of experimental class B in the middle of the course before the mid-semester assessment to measure the perceived effects of structured pair/trio programming on learners' computer

programming skills. Table 2 shows the descriptive statistics for the survey items, which highlight both the strengths and challenges of structured pair/trio programming in enhancing programming skills among adult learners. The survey results indicate that learners had moderately positive perceptions of structured pair/trio programming in their computer programming course. The highest-rated category was Recommending This Approach (M = 3.57, SD = 0.79), suggesting that most learners found it effective and would endorse its use. Identifying and Correcting Mistakes (M = 3.52, SD = 0.85) was also highly rated, reinforcing the role of collaborative approach in debugging and problem-solving. However, learners encountered Challenges (M = 3.17, SD = 0.83), indicating that while beneficial, the approach posed difficulties for some learners. Motivation (M = 3.35, SD = 0.83) and overall Learning Experience (M = 3.35, SD = 0.78) suggest a generally positive impact, but with variations across individuals.

Table 2: Summary table (M and SD of each question)

Survey Item	M (Mean)	SD (Standard Deviation)
Learning Experience	3.35	0.78
Motivation	3.35	0.83
Identifying and Correcting Mistakes	3.52	0.85
Contributing to the Learning of Others	3.48	0.95
Encountering Challenges or Difficulties	3.17	0.83
Recommending This Approach	3.57	0.79

In addition to the statistical analysis, qualitative insights were gathered from learner and staff interviews to provide a deeper understanding of their experiences. The lecturer's independent observations further enrich the findings, offering additional context on the structured pair/trio programming approach. Next, we discuss the qualitative analysis of the data gathered through interviews and lesson observation.

Qualitative insights – Thematic analysis of interviews

Thematic analysis of learner and staff interviews revealed four key themes regarding their experiences with structured pair/trio learning, with a snapshot of the analysis shown in Table 3. The benefits of pair/trio learning emerged as a significant theme in the student interviews where learners highlighted how peer discussions helped in debugging errors, reinforcing understanding, reducing anxiety and increasing confidence in programming. Learners valued the opportunity to see multiple perspectives, learn from and support one another, particularly when encountering challenges that they might not have resolved independently. However, some learners also expressed challenges in pair/trio learning, noting that differences in skill levels and communication issues sometimes slowed their progress, and stronger learners occasionally felt burdened by excessive questioning. Another recurring theme was the potential to apply the pair/trio approach in other modules, particularly in subjects requiring complex calculations or conceptual understanding, such as Circuit Analysis and Control and Mathematics. Learners emphasized that peer verification and structured collaboration could reduce errors and improve accuracy in these modules. Additionally, classroom engagement was identified as a crucial factor, where tools like Kahoot and Padlet were seen as valuable resources to recap key learning points, facilitate discussion, and extend collaborative learning beyond immediate group members. Finally, the theme of learning preferences and group size considerations surfaced, where learners reflected on their preferred working styles, with some favouring independent learning while others found the structured environment more beneficial. Learners also suggested that pair/trio sizes of two to three members reviewed at regular intervals were optimal, whereas larger groups could become less effective due to limited participation. These insights collectively underscore the value and limitations of structured peer collaboration in programming education and highlight the role of interactive engagement strategies in enhancing the learning experience.

Thematic analysis of staff interviews revealed key perspectives on the effectiveness and classroom dynamics of structured pair/trio in programming lessons. Staff emphasized that pair/trio settings enhanced classroom interactions, providing a structured platform for learner-learner and learner-trainer engagement. They noted that this format encouraged peer discussion, immediate clarification of doubts, and collaborative problem-solving, allowing learners to address misconceptions in real time. Additionally, staff identified time efficiency as a major benefit, particularly in CET lessons, where structured collaboration helped learners manage their learning within limited class hours. Pair/trio learning was perceived as a natural and effective approach, promoting deeper discussions and increased participation compared to independent learning. Staff also highlighted that some learners naturally extended their collaboration beyond assigned groups, engaging with peers across teams to solve problems collectively. While no specific challenges were mentioned, staff acknowledged that factors such as workload, module content, and logistical considerations influence whether a pair/trio or a larger group of 4-5 learners would be more suitable for other modules. These insights suggest that structured pair/trio arrangement is a valuable approach that can be adapted to different learning contexts based on instructional needs and logistical factors.

Table 3: *Snapshot of how the thematic analysis was done on learner, and staff interviews to generate the themes*

Raw data (excerpts)	Open code	Themes	Cluster themes
Working in pairs/trio helps as we can counter more problems, more people so we can discuss (student)	Collaborative problem-solving	Effectiveness of Pair/Trio Learning	Benefits of Structured Pair/Trio
CET lesson is limited time so having a Pair/Trio setting helps in the learning. (staff)	Pair/Trio is beneficial for time-constrained lessons	Structured Peer Support in Time-Limited Sessions	Benefits of Structured Pair/Trio
I take the analogy of say bubblegum, see the bubble gum you put in your mouth, it sticks everywhere, right. So this pair/trio is something so unique that it can connect the facilitator to the student. (staff)	Encourages discussion and resolving contradictions instantly	Real-Time Clarification of Concepts	Benefits of Structured Pair/Trio
Sometimes we are afraid to ask a question or also if it is the right time to ask a question, but in pair/trio we are more open and freely ask questions (student)	Pair/trio format encourages open questioning	Confidence in Asking Questions	Classroom Engagement
In pair/trio setting students work more closely as they know that this is a pair so more discussion instead of independently. (staff)	Pair/Trio promotes deeper engagement in discussions	Collaboration and Active Participation	Classroom Engagement
If more knowledgeable, then it may hinder as friends might keep asking questions. (student)	More knowledgeable students may feel burdened by constant questions	Unequal Cognitive Load in Groups	Challenges of Structured Pair/Trio
Sometimes pair/trio are not communicating well. (student)	Communication issues in pair/trio settings	Challenges in Peer Interaction	Challenges of Structured Pair/Trio

Lesson observation and triangulation of findings

To gain non-biased insights into the delivery of a lesson using a structured pair/trio setting in a programming module, an independent lecturer was invited to observe a session on Strings. The observer noted that the class was highly interactive, with learners actively participating in team-based activities and whole-class discussions, particularly during exercises involving hexadecimal and ASCII values. Collaborative learning was evident, as learners engaged in peer discussions, worked together on coding problems, and supported one another in debugging and troubleshooting. The observer also highlighted that the learning environment was safe, allowing learners—especially the more vocal ones—to freely share ideas, contribute to coding activities on the whiteboard, and experiment with different coding approaches. Real-world coding exercises in Visual Studio, where learners independently coded, sought clarification from their peers, and engaged in cross-team discussions to compare solutions reinforced the authenticity in learning. The observer further noted that the lesson promoted self-directed learning, as learners were encouraged to attempt exercises independently before engaging in team discussions. Additionally, reflective learning was incorporated, with learners summarizing key learning points at the end of the session. The observer suggested that encouraging peer movement across teams could further enhance collaboration and emphasized the importance of ensuring logistical readiness, such as reminding learners to bring laptops for coding activities.

The findings from the lesson observation helped to triangulate the insights gathered from student and staff interviews, reinforcing the benefits of structured pair/trio learning in fostering peer collaboration, engagement, and knowledge-sharing. Like the perspectives shared by learners and staff, the observer noted that learners leveraged peer interactions to clarify doubts, troubleshoot coding errors, and reinforce their understanding of key concepts. This alignment across multiple data sources strengthens the validity of the study's findings on the effectiveness of structured peer collaboration in programming education.

Recommended Next Steps

Educators should consider a structured process for introducing and sustaining pair/trio learning. We propose the following five-step approach, as illustrated through a flowchart in Figure 4 below.

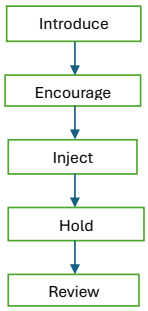


Figure 4: Flow-chart on recommended next steps

The process begins with deliberately introducing structured Pair/Trio settings in the class instead of letting it happen by chance. Once implemented, it is essential to encourage learners to work in their pairs and trios during their lessons. Worksheet Questions/ Exercise Questions are recommended to be injected in the lessons for

pair/trio and class discussions to reinforce engagement and peer exchange. The learners are to be held accountable to work with their pair/trio for their submissions. Finally, the grouping should be reviewed periodically, allowing educators to reassess and adjust groupings to maximize learning effectiveness and accommodate student compatibility. This structured approach provides a practical framework for integrating pair/trio learning into the curriculum, ensuring that collaboration enhances student engagement, knowledge construction, and problem-solving skills.

Conclusions

The qualitative analysis of student interviews, staff interviews, and lesson observations provided valuable insights into the perceived effects of structured pair/trio learning in a programming module. Findings from learners highlighted the benefits of peer collaboration, such as improved problem-solving, enhanced engagement, and increased confidence in programming. Staff interviews reinforced these perspectives, emphasizing how structured peer interactions enhanced classroom dynamics and time efficiency, particularly in time-constrained CET lessons. Additionally, the lesson observation by an independent lecturer validated these findings, showcasing active student participation, peer-driven knowledge-sharing, and self-directed learning in a socially constructivist environment. The triangulation of these data sources strengthens the study's conclusions, demonstrating that while structured pair/trio learning fosters engagement, collaboration, and knowledge construction, its effectiveness depends on group formation strategies, logistical considerations, and the nature of the learning tasks.

Limitations and Challenges

This study has certain limitations and challenges that must be considered. Skill level mismatches and compatibility issues in pair/trio were noted. The findings cannot be generalized due to the small sample size and learner-centric teaching context of the higher education institution. To draw more definitive conclusions, future research should collect data from a larger population of adult learners to ensure broader applicability of findings. Additionally, decisions regarding pair/trio work should consider individual needs, learning preferences, and course context to provide a more effective learning experience. Regular review and reorganization of pair/trio groups are recommended to ensure compatibility and sustained engagement among learners. Future research should also examine how structured Pair/Trio programming influences attrition rates in adult learning programs to assess its long-term impact. These insights offer practical implications for educators seeking to optimize collaborative learning structures in programming education and beyond.

Acknowledgements

The authors are thankful to the cooperation and support extended by Ms Shri Latha and Dr Jiang Lijun in conducting the lessons. The first author is grateful to Dr Abdul Kahlid and Dr Jeeva Periasamy for their insightful and enriching discussions. The inputs given by reviewers and Dr Jolly Parikh also need a special mention.

References

Bevan, J., Werner, L., & McDowell, C. (2002). *Guidelines for the use of pair programming in a freshman programming class*. Conference on Software Engineering Education and Training (pp. 100-107). KY: IEEE Computer Society.

Cliburn, D. C. (2003). *Experiences with pair programming at a small college*. Journal of Computing Sciences in Colleges, 19(1), 20-29.

Caulfield, J. (2023, June 22). *How to do thematic analysis | Step-by-step guide & examples.* Scribbr. Retrieved January 31, 2024, from https://www.scribbr.com/methodology/thematic-analysis/

Dillenbourg, P. (1999). What do you mean by collaborative learning? *Collaborative-learning: Cognitive and computational approaches.*, 1-19.

Goel, S., & Kathuria, V. (2010). *A novel approach for collaborative pair programming*. Journal of Information Technology Education Research, 9, 183–196. https://doi.org/10.28945/1290

Gomes, A., & Mendes, A. J. (2007). *Learning to program - difficulties and solution*. Conference paper in proceedings of International Conference on Engineering Education, Coimbra, Portugal.

Ma, L., Ferguson, J., Roper, M., & Wood, M. (2011). *Investigating and improving the models of programming concepts held by novice programmers*. Computer Science Education, 21(1), 57-80. doi:10.1080/08993408.2011.554722.

McDowell, C., Werner, L., Bullock, H., & Fernald, J. (2002). *The effects of pair programming on performance in an introductory programming course*. Proceedings of the Thirty-Third Technical Symposium on Computer Science Education (SIGCSE 2002), pp. 38-42. ACM Press.

Vygotsky, L. (1978). *Mind in Society: The development of higher psychological processes*. https://ci.nii.ac.jp/ncid/BA03570814

Williams, L., & Upchurch, R. L. (2001). *In support of student pair-programming.* ACM SIGCSE Bulletin, 33(1), 327–331. https://doi.org/10.1145/366413

Practical Programming Education through Game Development with Unity

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This paper discusses the implementation and evaluation of practical programming education using Unity, which is one of the most popular game development engines. Programming education is the most important engineering skill for students, regardless of their field of study in KOSEN education. The curriculum of programming education in the Department of Computer Engineering (CE) at KOSEN-KMITL is designed so that students learn Python in their 1st and 2nd years in the courses Programming 1-4. Then, in their 3rd year, they begin studying C language in Programming 5 and 6. In addition to those programming subjects, students in their 3rd year take a course called PBL, where they gain experience applying their programming skills to develop specific software in groups based on requirements provided by partner companies. Programming 7 is the final programming subject in the curriculum, offered to the 4th year students. It is a 100-minute class that runs for 15 weeks in the first semester. During the first four weeks, the class aimed to review C programming with various algorithms and was conducted as a review session of C language programming from the previous year. In the following six weeks, students learned how to develop a simple game using C# in Unity. We referred to the textbook for class material and created handouts with 43 assignment questions. By allowing students to share their progress on the assignments via a Google Sheet, students can track their progress in the class, and teachers can manage the class's overall progress. In the last five weeks, students have worked on a mini project, choosing one topic from three options: (1) customizing the simple game by adding some original functions; (2) developing a maze-solving simulator; (3) creating an original game from scratch. The number of students who chose each option was as follows: (1) 20, (2) 7, and (3) 15. In the mini project, students created a short video clip with their own narration. The evaluation was conducted using a rubric that was presented in class. Before the final submission of the video, we held a showcase presentation, where students gave feedback to each other. The results of a survey in both the first and final class, which asked 42 students whether they like programming, find it fun, and consider themselves good at it, showed that about 13% of students developed a more positive opinion by the final class.

Keywords: *Practical Programming Education, Unity, Active Learning, Game, Computer Engineering*

Introduction

KOSEN-KMITL was established in 2019 by the Thai KOSEN project, under an ODA loan agreement of the Japan International Cooperation Agency (JICA) with the Government of the Kingdom of Thailand (Aburatani et al. 2020). KOSEN-KMITL has three departments, the Mechatronics Engineering Department (ME), Computer Engineering Department (CE), and Electrical and Electronics Engineering Department (EE), and they were established in 2019, 2021, and 2023, respectively. In March 2024, the first batch of ME students graduated, and in 2025, it is the first year that the CE department has students in all grades from 1st to 5th year. The education provided at KOSEN-KMITL is equivalent to KOSEN education in Japan (Kobayashi et al. 2023). Additionally, the ME program at KOSEN-KMITL was accredited by KIS (KOSEN International Standard) in 2024.

Similar to KOSEN education in Japan, programming education is a core topic at KOSEN-KMITL, and programming skills are considered the most important engineering skill for students. In the curriculum of CE at KOSEN-KMITL, students start learning programming with Python in their 1st year in the courses Programming 1 and 2, continue their studies in 2nd year in the courses Programming 3 and 4, and learn C programming in the 3rd year in courses Programming 5 and 6. In addition to their programming courses, students in their 3rd year take a course called PBL (Project-Based Learning) (Oo et al. 2024), where they apply their knowledge and skills to developing specific software systems based on requirements provided by partner companies (Toyota Tsusho (Thailand) Co., Ltd., Neural Group (Thailand) Co., Ltd., and MapQuestAsia Corp., Ltd.). Programming 7 is the final subject offered to the 4th-year students in the programming curriculum of CE. It was a newly introduced subject of CE in 2024. Since students have already acquired basic programming skills through Programming 1-6 and the KOSEN's MCC achievement levels of the major subjects should be considered, Programming 7 needed to be designed to focus on practical applications using programming skills,

	Evaluators will be treated as anonymous, so please rate accurately.						
Session No	Choose the presenter ID	Nick Name	That presenter was explaining in their own words.(not reading written texts.) (Yes: ✓)	The presenter has a good understanding of the algorithm. (Yes: ✓)	There are no problems with the presentation attitude, voice volume, eye contact, etc. (Yes: ✓)	Choose the most excellent presenter with ✓. (Choose only ONE student.)	Comments (What you learned from the presentation.) (Required)
1	649xxxxx		✓	✓	✓		
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Figure 1: Report template that students submit after the presentation session.

including analysis, evaluation, and creativity. Based on this background, Programming 7 was designed using Unity, one of the most popular game development engines.

This paper discusses the implementation and evaluation of practical programming education using Unity in Programming 7. The remainder of this paper is organized as follows: Section 2 describes the structure of Programming 7 and the evaluation method. Section 3 presents the student outcomes, and Section 4 shows the survey results. Finally, Section 5 concludes the paper.

Structure of Programming 7 and Evaluation Method

Programming 7 is a compulsory subject for 4th-year students in CE. It is a 100-minute class held once a week over 15 weeks in the first semester. In 2024, forty-two students enrolled in the course. In this section, the structure of the course and the evaluation methods of students' achievements in the course are explained. Furthermore, the evaluation methods of the subject itself based on how students changed their attitude and mindset toward programming are described.

(1) Structure of Programming 7

The course is divided into three parts: Part 1: Review session of C language for 4 weeks; Part 2: Basic study of Unity for 6 weeks; Part 3: Mini project for 5 weeks.

Part 1 (4 weeks) consisted of review sessions in C language, including assignments that involved creating programs using various algorithms. The topics of each week were as follows:

- Week 1: Calculating a factorial number using recursion
- Week 2: Finding approximate solutions of polynomials by bisection and Newton Raphson methods
- Week 3: Finding optimal solutions under specific conditions using the greedy algorithm
- Week 4: Presentation for three topics

In the presentation of Week 4, three sessions of a gallery walk-style presentation were conducted. During each presentation session, audience students were assigned to make a report for each presentation based on the format shown in Fig. 1.

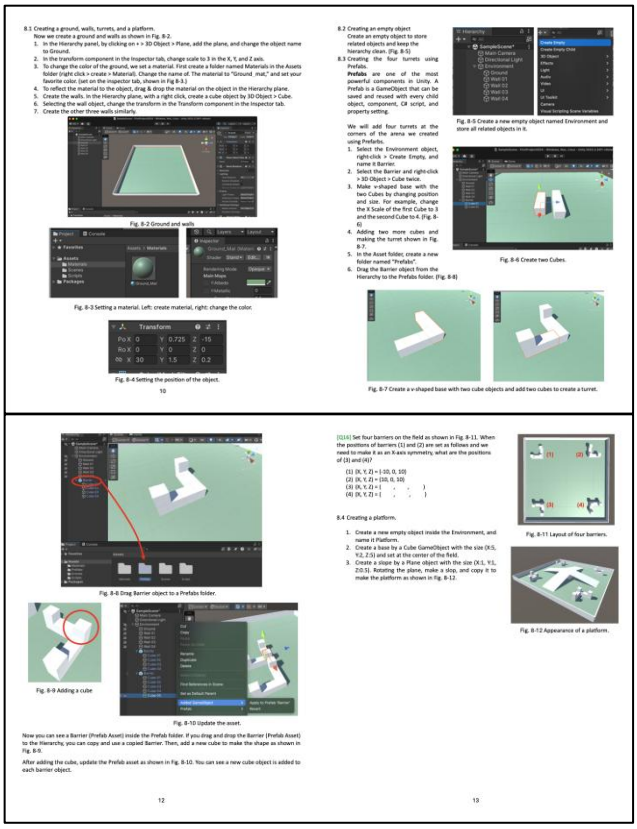


Figure 2: Part of the handout to explain how to develop a sample game.

In Part 2 (6 weeks), students learned how to develop a simple game using C# in Unity and studied the basic functions of Unity. First, they set up the environment by installing Unity on their laptop or on a desktop computer in the computer lab. The class materials were based on a textbook (Ferrone 2022), and we also created 42 pages of a handout containing 43 assignment questions. Figure 2 shows the part of the handout. The questions are grouped into 5 assignments and students submit them by each due date. Students shared their progress using a Google Sheet as shown in Fig. 3, which allowed them to track their own progress and enable teachers to monitor the overall progress of the class.

In Part 3 (5 weeks), students worked on a mini-project, choosing one topic from three options: (1) customizing the simple game by adding original features; (2) developing a maze-solving simulator; (3) creating an

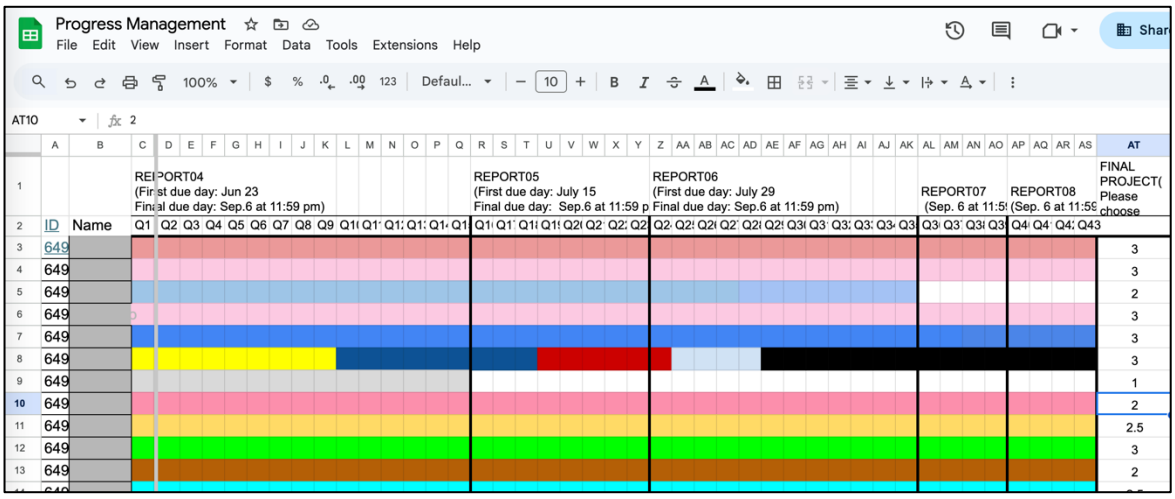


Figure 3: Progress management sheet.

	Excellent (10, 9)	Good (8, 7)	Fair (6, 5, 4)	Poor (3, 2, 1)
About requirements	Requirements for the game are specifically analyzed and designed in detail. The development are excellently achieved.	Requirements for the game are analyzed and designed. The development are achieved.	Requirements for the game are analyzed. The development are achieved.	Requirements for the game are not analyzed. The development are achieved only some parts.
Report	The format is appropriate. Including concept, gameplay, interface, and art style. The description is clear and logical. The game idea is unique and nice.	The format is appropriate. Including concept, gameplay, interface, and art style. The description is clear and logical.	The format is appropriate. Including concept, gameplay, interface, and art style.	The format is not appropriate. Not Including concept, gameplay, interface, or art style.
Presentation (Short video)	Presentation is logical and appropriately explained. Duration is less than 1 min. and not too short.	Presentation is logical and appropriately explained. Duration is less than 1 min.	Presentation is good.	Delay due day.

Figure 4: The rubric for the mini project: development of an original game from scratch.

original game from scratch. We provided these three options because students' progress varied depending on their programming skills and their familiarity with tools like Unity. Although we allocated 6 weeks for developing a simple game (Part 2) and 5 weeks for a mini project (Part 3), it was supposed that some students would be unable to complete Part 2 within the given time, while others finished it in less than 5 weeks. Students who needed more time to complete Part 2 were encouraged to choose option (1), which required less time compared to options (2) and (3). On the other hand, students who completed Part 2 quickly could move on to Part 3 early and were encouraged to choose option (2) or (3), which allowed for more detailed and creative development. Regarding option (2), students had previously learned various maze-solving algorithms in a subject titled Introduction to Artificial Intelligence. The purpose of this option was to allow students to implement those algorithms in the form of a game application.

In the 5th week of Part 3, a showcase session was held to review all games currently in development and to provide mutual feedback. In the class, three sessions were held, and students were divided into nine groups for each session. The group members were arranged in such a way that no group had the same members across different sessions. For the mini-project, students were required to submit a Final Report including a report of the mini-project, a one-minute video of their game, and the exported project file from the Unity engine.

The submission deadline for the mini project was set for two weeks after the showcase session, giving students enough time to revise or continue their development based on the feedback received from classmates and teachers during the session.

(2) Evaluation methods of students' achievements

The evaluation of students' achievements in Programming 7 is based on five criteria: an examination (20%), quizzes (10%), mutual evaluations between students (20%), reports (30%), and other components (20%).

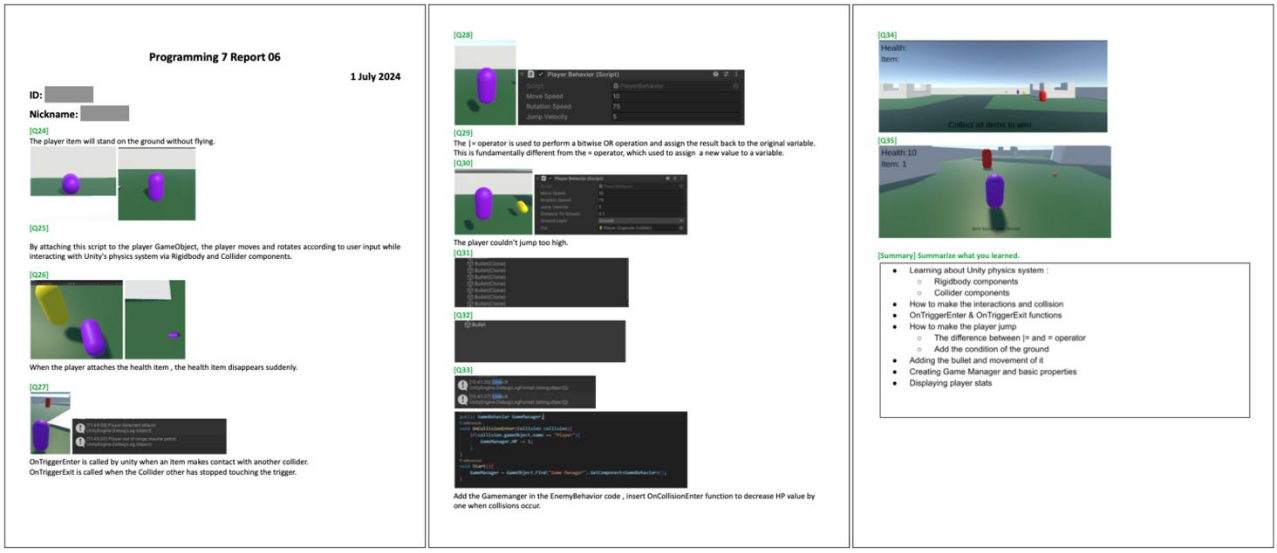


Figure 5: Examples of reports submitted by a student.

Regarding the examination, only a midterm exam was conducted, which tested students on the basic review topics of C programming covered in class, as well as fundamental knowledge of Unity. As for the quizzes, only one was administered at the end of the course during this term.

Mutual evaluation is related to the presentation session in Part 1 and the showcase session in Part 3. During the presentation and showcase sessions, students voted for the most valuable presenter in each session or group, the results were used for mutual evaluation.

In this course, students were assigned a total of 10 reports, consisting of three reports in Part 1, one activity report in the presentation session in Part 1, five reports in Part 2, and the Final Report in Part 3. Except for the Final Report, reports were evaluated based on whether they were submitted because the contents are explained in the class and the reports are just the evidence that students worked on the development of each step. However, if a report is deemed unacceptable, for example, it is almost blank, uses an inappropriate format, or includes some problems, students must revise and resubmit it. If a report was not perfect but it was acceptable, it was accepted with a few point deductions. The Final Report, consisting of a report of the mini-project, a one-minute video of their game, and the exported project file from the Unity engine, was evaluated by the rubric presented in the first class of Part 3. Since three options for the mini project were offered, three rubrics were prepared. Figure 4 presents the rubric for the option (3): creating an original game from scratch.

As for other components, we considered students' behavior based on whether students submitted assignments on time or late. A 10-point deduction was applied when students submitted each assignment late.

(3) Evaluation methods of how students changed their attitude and mindset toward programming

To evaluate how students' attitudes and mindsets toward programming changed after taking Programming 7, we conducted surveys at both the beginning and end of the course. In the first survey, students were asked four questions: "Do you like programming?", "Do you think programming is fun?", "Are you good at programming?", "What do you think is the reason for learning programming?" The first three are closed-ended questions with three response options: "Yes.", "No.", and "I am not sure." The fourth is an open-ended question that requires a free-writing response. In the last survey, in addition to the same four questions from the first survey, an open-ended question, "Do you like Unity programming?", was added, which required a free-writing response.

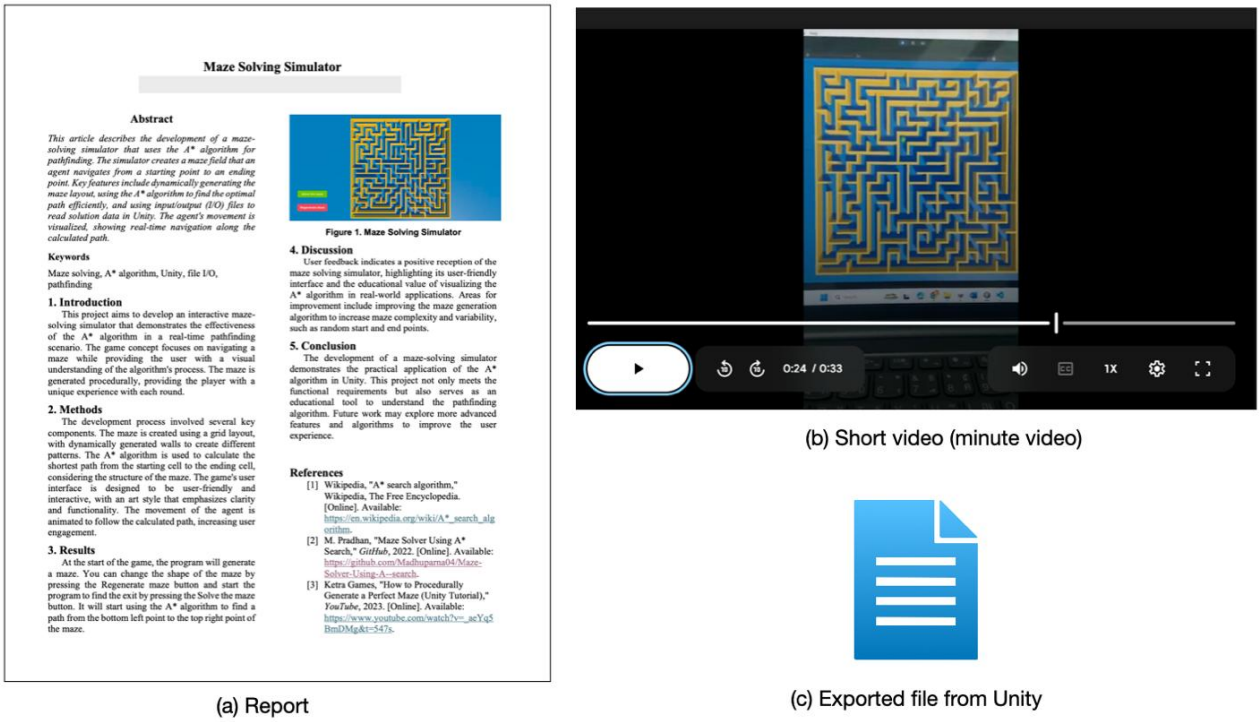
To analyze the results, we focused on the three closed-ended questions and created a state transition diagram with four states: "Yes," "No," "Not sure," and "N/A." The results are presented and discussed in the Survey Results section below.

Student Outcomes

Figure 5 shows an example of reports submitted by a student about developing a simple game using Unity (Part 2). As for the report template, blank formats are prepared, and students can use the template and make a report while creating a sample game by following the handouts. As mentioned in the previous section, the student's progress in the creation is monitored by the progress management sheet shown in Fig. 3, and some students whose progress is delayed can be identified and guided by teachers.

Figure 6 shows the three items, a report, a minute video, and a exported files from Unity, that students had to submit as the outcomes of the mini-project (Part 3). Figure 7 shows the situation during the showcase session held in Part 3. Students gave a feedback each other.

In the mini project, the number of students who chose each topic from three options was (1) 20, (2) 7, and (3) 15. About topic (1), students successfully added multiple functions to the original game studied in Part 2, for example, changing the shape of the game field and adding multiple characters. Regarding topic (2), only 7 students worked on the topic. However, the quality of their work was very high, and all students could



(a) Report

(b) Short video (minute video)

(c) Exported file from Unity

Figure 6: Assignment for the mini-project: (a) report, (b) short video of a mini-project, and (c) exported file from Unity.

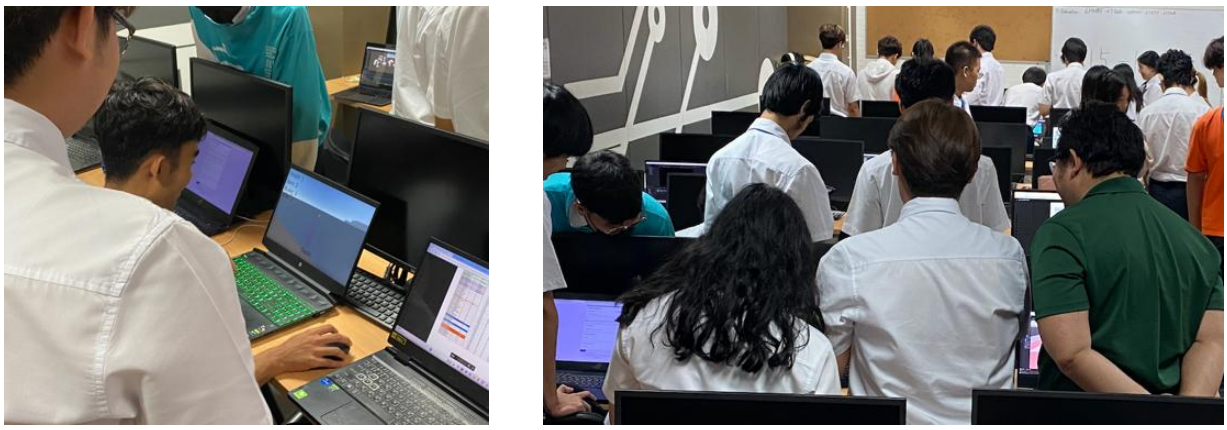


Figure 7: Situation during the showcase session.

implement A* algorithm that is one of the maze-solving algorithms they have learned in other class. About topic (3), some students created a game which has several advanced functions that were not taught in the previous classes of Part 2. Among those students, some students tried to create 3D models with Blender to use them in their developing game and used a head-mounted display in their presentation. It can be said that these students actively learned more on their own than the knowledge provided in the class.

Survey Results

Table 1 summarized the results of surveys that were conducted at both the beginning of and end of the course, focusing on the three closed-ended questions. In the first survey, all 42 students answered, however, 38 students answered at the end survey. To analyze the results, we use a state transition diagram with four states: "Yes,"

Table 1: Summary of the survey results. 42 and 38 students answered to the first and last surveys, respectively.

Q1: Do you like programming?

	First Survey	Last Survery
Yes.	28	28
No.	3	2
I am not sure.	11	8

Q2: Do you think programming is fun?

	First Survey	Last Survery
Yes.	25	27
No.	4	2
I am not sure.	13	9

Q3: Are you good at programming?

	First Survey	Last Survery
Yes.	5	8
No.	11	10
I am not sure.	26	20

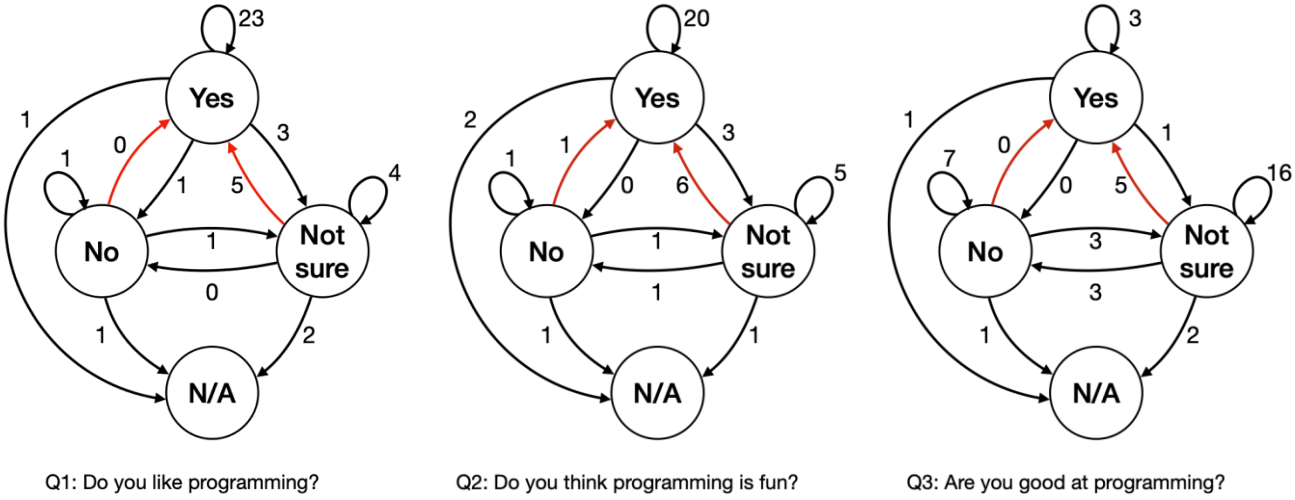


Figure 8: State transition diagrams based on students' responses to three closed-ended questions. The number labeled on each arrow indicates the number of students.

"No," "Not sure," and "N/A." Figure 8 shows a state transition diagrams about each question. In Fig. 8, the number labeled on each arrow indicates the number of students. Although there are 12 types of transitions, such as from "No" to "Yes" and from "Not sure" to "No", we consider only from "No" to "Yes" and "Not sure" to "Yes" are positive changes in students' attitude toward programming, as indicated by the red arrows in Fig. 8. From the analysis, we found that an average of 13.4%, calculated from 11.9% (Q1), 16.7% (Q2), and 11.9% (Q3), of the 42 students developed a more positive opinion by the final class. Especially, about the question, "Q2: Do you think programming is fun?", the ratio of positive change was highest. It can be concluded that students who found creating a game enjoyable and had fun developing their game with Unity though Programming 7 showed a positive change in their attitude and mindset toward programming.

Conclusions

This paper discussed programming education conducted in the Programming 7 for the fourth-year students in the Department of Computer Engineering at KOSEN-KMITL. Unity, one of the most popular game development engines, was used as the programming platform. In the Programming 7, after taking classes of reviewing C language and learning basic usage of Unity, students worked on the mini project, creating a game based on a theme they selected from three options. Students' achievement in the mini project was evaluated using a rubric that was presented in the class. Most students worked proactively on the project and presented their games during the showcase session. To evaluate how students' attitudes and mindsets toward programming changed after taking Programming 7, we conducted surveys at both the beginning and end of the course and analyzed the results of three closed-ended questions, focusing on the change in students' responses. Based on the analysis, we found that an average of 13.4% of the 42 students developed a more positive opinion toward programming by the final class of Programming 7. We concluded the reason of this results is that students who experienced enjoyment in creating games developed a more positive perception of programming.

This programming course was implemented for only one academic year so far. Therefore, the survey results might not be enough to discuss the effectiveness of the course. To allow for more accurate discussion, survey results over multiple years should be collected and analyzed. In this study, although we asked an open-ended question, "What do you think is the reason for learning programming?", only three closed-ended questions were analyzed. Investigating the responses to the open-ended question remains a task for the future.

References

Aburatani, H., Sittichivapak, S., Kano, S. and Uehara., N. (2020). Curriculum and Implementation of KOSEN Eengineering Education at KOSEN-KMITL, Thailand, Proceedings of the 16th International CDIO Conference, hosted on-line by Chalmers University of Technology, pp. 54-63, Gothenburg, Sweden, 8-10 June 2020.

Kobayashi, H., Pawasopona, T., Tangsuknirundorna, P., Keatsamarna, T., Rittiplanga, A., Srithanasarna, K., Oo, S.H.P., Paraa, M., Yoshikawa, Y. and Doi, S. (2023). Modifying a "Reverse Engineering" Class for the Department of Computer Engineering at KOSEN-KMITL. Proceedings of 16th International Symposium on Advances in Technology Education (ISATE) (pp. 324-327), September 12-15, 2023, Matsue City, Japan.

Oo, S.H.P, Pawasopon, T., Tangsuknirundorn , P., Keatsamarn, T., Srithanasarn, K., Su Wai Myo, S.W., Shah, S., Kobayashi, H., Kobayashi, M. and Yoshikawa, Y. (2024). Establishing Automated Attendance Checking Systems through Project-Based Learning in KOSEN-KMITL. Proceedings of 17th International Symposium on Advances in Technology Education (ISATE) (pp. ST3-136-ST3-141), September 24-27, 2024, Singapore.

Ferrone, H. (2022). Learning C# by Developing Games with Unity: Get to grips with coding in C# and build simple 3D games in Unity 2023 from the ground up 7th ed. Edition, Packt Publishing.

Exploring Team-Based Learning in a Year 1 Programming Module

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In Singapore's polytechnics, a sector-wide transition to Flipped Learning is being implemented to foster students' self-directed learning abilities. Central to this approach are Online Asynchronous Lessons (OAL), where students engage with pre-reading materials to familiarise themselves with key concepts before attending face-to-face classes (In-Person Lessons, IPL). During these in-person sessions, students seek clarification and delve into more complex ideas.

This paper explores the integration of Team-Based Learning (TBL) within the Flipped Learning framework for a Year 1 common engineering module, Programming, at Ngee Ann Polytechnic during the Academic Year 2024/25 Semester 1. As part of OAL, students complete an Individual Readiness Assurance Test (iRAT), which is then followed by a Team Readiness Assurance Test (tRAT) during IPL. After discussion and completion of tRAT, a tutor-facilitated review takes place and students embarks on practical exercises in the application phase.

The student cohort comprises 944 individuals from a range of engineering diplomas with diverse academic backgrounds and abilities. The use of TBL leverages on this diversity and enriches discussions, allowing high-achieving students to deepen their understanding by teaching peers, while students with lower abilities gain support in mastering fundamental concepts.

Consistent with existing TBL research, students generally perform better in group tRATs compared to individual iRATs. In addition, preliminary results from our study indicate that more students completed end-of-chapter competency tests earlier in the semester than previous cohort. This suggests that TBL's collective knowledge-building approach facilitates quicker mastery of key topics. Student survey results, along with peer lesson observations by teaching staff reveal mostly positive outcomes, with some areas identified for further improvement. Specifically, the structured preparation and discussion inherent in TBL encourages the sharing of diverse perspectives, fostering deeper, collective learning. However, careful attention to the facilitation of TBL is necessary, as deviations from its core principles may affect outcomes. These challenges will be addressed in future recommendations to refine the pilot implementation.

Keywords: *Team-based Learning, collective knowledge-building, Flipped Learning, Programming, engineering*

Introduction

Conventional educational approaches typically involve direct transmission of curriculum content from teachers to students in classroom settings. This teacher-centric model, characterised by lecture-style delivery can lead to passive learning behaviours, where students rely heavily on explicit teacher instructions regarding what and how to learn. Dudley-Marling (2018), Mason (2021), has demonstrated the limitation of this approach, particularly in developing critical thinking and independent learning skills. In response to these limitations, several studies have advocated for student-centred, active learning strategies.

One such approach is flipped learning, a pedagogical model popularised by Bergmann and Sams (2012). This approach reverses the traditional instructional sequence, by moving initial content delivery outside the classroom through various means including pre-recorded video lectures, allowing students to engage with the material at their preferred pace and revisit complex concepts as needed. Classroom time is then repurposed for higher-order learning activities such as problem-solving exercises, peer discussions, guided practice with lecturers facilitating rather than lecturing. , Research by Keengwe et al. (2014) demonstrated that this restructuring of learning time, fosters deeper engagement and promotes active learning.

Another effective active learning strategy is Team-Based Learning (TBL). TBL is a structured methodology where students complete pre-class preparatory independently, followed by in-class Individual Readiness Assurance Tests (iRATs) and Team Readiness Assurance Tests (tRATs). The teacher then provides targeted clarification addressing specific conceptual gaps identified during the RATs. . Subsequently, students collaborate in teams to solve complex application problems that require higher-order thinking skills. The process often concludes with peer evaluation to encourage individual accountability (Michaelsen, 2008). Although TBL has been predominantly used in medical education, recent research by Parappilly et al. (2021) from Flinders University has demonstrated its successful application across STEMM disciplines (Science, Technology, Engineering, Mathematics, and Medicine).

Studies by Burgess et al. (2019, 2021) have shown that TBL promotes both individual accountability and collaborative learning, learning to enhanced knowledge construction.

Nevertheless, as Johnson (2013) argues, the success of these approaches is significantly dependent on students' intrinsic motivation. Students need to be self-directed during the pre-class preparation phase to prepare for their in-class activities and learning. Lack of preparation can result in reduced participation in discussions, compromised team performance and poorer learning outcomes.

This study examines a pilot implementation that integrates flipped learning and TBL methodologies in a foundational programming module for first-year engineering students at Ngee Ann Polytechnic. The integration of these two pedagogical approaches aims to enhance student engagement through pre-class preparation, deepen understanding through team-based problem-solving, and improve learning outcomes.

Materials and Methods or Pedagogy

Programming is a core module taken by close to 1000 first year engineering students in Ngee Ann Polytechnic. The 15-week module syllabus introduces fundamental programming concepts using the C programming language. The curriculum progresses systematically through key foundational concepts such as variables and data types, advancing to flow control structures with branching and iteration, lastly culminating in function development. This structured sequence helps students to build a strong foundation in computational problem-solving, essential for their engineering careers.

As part of the Flipped Learning pre-class preparation phase, students are expected to acquire foundational content knowledge via Online Asynchronous Lessons (OAL) which comprises of bite-sized instructional videos and structured guided exercises including formative quizzes and short programming tasks. These activities are designed based on experiential learning principles. For example, students engage with quiz questions require them to execute and observe code outputs. This is followed by reflection on the underlying principles, culminating in guided hands-on programming tasks where students apply their understanding. These carefully sequenced OAL activities ensure students arrive at In-Person Lessons (IPL) with foundational knowledge and practical experience that can allow for in depth application of concepts in class .

TBL is infused into Flipped Learning via Feedbackfruits (FBF),a digital learning platform that enables interactive online assessment. In this modified TBL approach, iRATs are incorporated into the pre-class OAL phase, allowing students to demonstrate their understanding immediately after engaging with the OAL content. This adaptation allows for more efficient use of in-class time while maintaining core TBL principle of individual accountability. The TBL learning sequence comprises of four interconnected phases (Figure 2) as follows:

Phase 1: **Individual Preparation Through OAL**
Prior to each face-to-face session, students engage with preparatory materials through OAL.

- Bite-sized instructional videos and simple exercises to introduce core programming concepts.
- iRAT, which is embedded within the Learning Management System (LMS) as part of OAL allows students to self-assess their understanding and identify knowledge gaps.
- FBF analytics on iRAT enable instructors to monitor student engagement and identify common areas of difficulty before the face-to-face session.

Phase 2: **Team-Based Assessment and Collaborative Learning**
Conducted during the IPL, this phase emphasizes on collaborative learning and problem-solving.

- Tutors provide a brief overview and highlight key concepts to focus on, often guided by iRAT performance.
- Students complete the tRAT in pre-assigned teams of 4-5 members, by answering the same conceptual questions from their iRAT. During this process, team members share their individual perspective and reasoning from their individual preparation phase, engaging in structured dialogue to reach consensus on their team's solution.
- The classroom is specially configured with clustered seating arrangements and interactive display screens to facilitate team discussions.
- The FBF platform provides immediate feedback on team responses in tRAT; while incorrect answers incur minor point deductions, teams can discuss and resubmit their answers,promoting deeper analysis and collaborative learning.
- The weightage for the RAT is evenly split, with 50% allocated to the iRAT and 50% to the tRAT.



Figure 1. Groups having discussion during tRAT

Phase 3: **Facilitated Feedback**
Following the tRAT, the tutors facilitate a structured review session to synthesize key learning points and address emerging conceptual challenges. This critical transition phase bridges collaborative team learning with instructor-guided knowledge transfer.

Tutors utilize FBF analytics to identify specific questions that warrant detailed review, based on patterns of student responses from both iRAT and tRAT. TBL process continues with students sharing their team's reasoning and problem-solving approaches to the entire class. This allows tutor to provide targeted feedback. For instance, tutor might highlight cases where different teams arrived at correct solutions through varying approaches or address persistent misconceptions revealed in teams' sharing or through the FBF analytics. This example is further elaborated as follows:

- The tutor uses FBF analytics to plan and focus the class discussion on specific questions.
- Significant learning takes place when:
  - students who initially answered incorrectly in the iRAT but corrected their conceptual understanding during tRAT, and
  - contrasting answers across teams were analysed, enabling knowledge exchange and promoting cross-team learning.
- The tutor provides targeted explanations/feedback and corrects misconceptions based on student's sharing.
- The tutor offers further insights into the topic by building upon student's contributions.

This structured feedback phase facilitates knowledge transfer at multiple levels:

i) through peer collaboration within groups,
ii) cross-pollination of ideas between groups, and
iii) expert guidance from tutors to individual, group or entire class.

Phase 4: **Application**

The TBL learning sequence concludes with an application phase where students demonstrate their understanding through hands-on programming tasks. During IPL, students work on their individual programming exercises that reinforce the concepts covered or relevant components of their ongoing programming projects. When IPL time constraints arise, these practical exercises are assigned as bridging activities, strategically positioned between current IPL and the next OAL, ensuring continuous engagement with programming concepts.

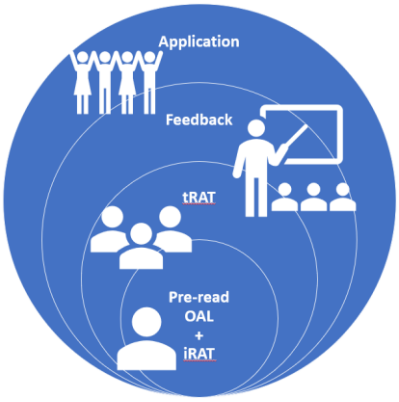


Figure 2. Illustration depicting the 4 phases in a typical TBL

Results and Discussion

Qualitative feedback from tutors indicated increased student participation and deeper collaborative discussions in TBL sessions compared to traditional teaching methods. Tutors consistently reported that TBL support students in clarifying key concepts and facilitated stronger conceptual understanding. Key insights from tutor feedback included:

"*Incorporating TBL highlighted the importance of student-centred learning, encouraging teamwork, and effectively using technology to enhance the learning experience*."

"*Holding students accountable for iRAT and tRAT sets clear expectations and promotes responsibility*."

Students echoed similar sentiments:

"*We can share our own ideas and learn from our mistakes*."

"*The team-based quizzes helped us understand topics better through discussion and peer explanation*."

Students responded positively to the TBL approach, particularly valuing peer-learning opportunities, as some may feel more at ease speaking with peers and able to understand better from their perspective. The survey was conducted anonymously to encourage unbiased responses; however, the sample size was limited, with only 73 students participating, which should be considered a limitation when interpreting the results. Below (Figure 3, 4) shows a pie-chart response from survey open to students.

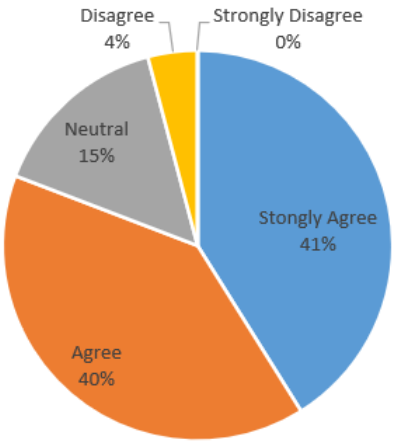


Figure 3. "TBL helped me to obtain a better understanding of the topic"

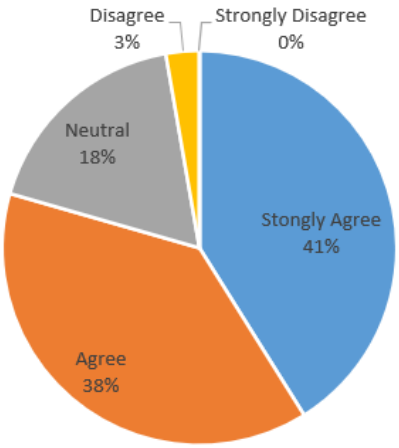


Figure 4. "TBL had a positive impact on my learning experience"

Quantitative analysis revealed consistent improvement in student performance from iRAT to tRAT scores (see Figure 5), suggesting effective knowledge sharing within teams.

Name	Take individual test for 50%	Take team test for 50%	Optional grade adjustment	Pub Brig	Overall grade
38PROG_TE08 - 4	40	46.2			
38PROG_TE08 - 2	38.3	46.2			
38PROG_TE08 - 1	39	47.5			
SIM BOON KIAT NP	45	47.5		✓	92.5 %
CHAN JENSON NP	35	47.5		✓	82.5 %
KELTON LIEW TZE HUA NP	40	47.5		✓	87.5 %
ZOU JINTAO NP	35	47.5		✓	82.5 %
TAN PIK HENG NP	40	47.5		✓	87.5 %
38PROG_TE08 - 3	38.3	50			
ANG CHER MENG JAIRUS NP	50	50		✓	100 %
ALIF ANAQI BIN MOHAMAD ...	35	50		✓	85 %
BASKAR KISHORE NP	25	50		✓	75 %
SYAHRUL ANUAR BIN ALI NP	40	50		✓	90 %
COLLIN REYES VINCENT HA...	40	50		✓	90 %
KARTHIKESAN HARIHARAN ...	40	50		✓	90 %

Figure 5. Students achieving higher/comparable tRAT score than iRAT

Additionally, completion rates for end-of-chapter competency programming tests (Figure 6) showed earlier mastery of core concepts compared to previous cohorts, suggesting that the structured TBL environment enhanced the quality of learning.

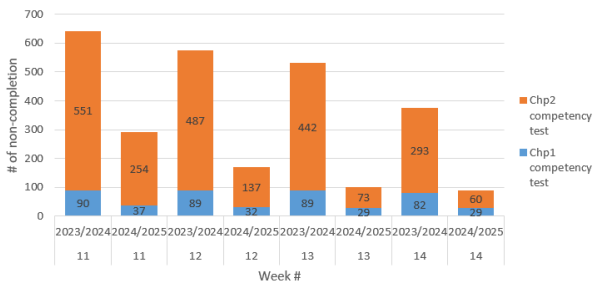


Figure 6. Comparison of non-completion 2023/2024 [before TBL pilot] vs 2024/2025 [TBL pilot year]

While the findings indicate positive outcomes overall, the implementation of TBL also surfaced several challenges:

- **Variability in Class Dynamics**: Observation on some classes revealed varying levels of engagement, with some groups remained reticent despite tutor's best effort in facilitation. This limited participation affected the quality of peer learning.
- **Insufficient Preparation before IPL**: Students who demonstrated inadequate preparation in Phase 1 were less likely to benefit from subsequent learning phases. This preparation gap created disparities in team contributions and impeded individual learning progression.
- **Learning Approach Preferences**: A minority of students expressed preference for traditional didactic instruction, indicating challenges in adapting self-directed and peer-driven learning methodologies. This resistance has negatively impacted their engagement with collaborative learning activities.
- **Group Dynamics**: Observations revealed imbalanced participation patterns within teams, where more confident students occasionally dominated discussion and decision-making which led to passive acceptance of solution by other team members. This occasionally resulted in group tension, especially when collective decision on tRAT answers turned out to be incorrect.

To address these challenges, implementing a hybrid instructional model offers a promising approach. This model alternates between traditional teaching and active learning weeks, allowing systematic content delivery while creating space for TBL. Instructors should also receive training in discussion facilitation techniques such as wait time management and inclusive questioning strategies, as well as methods for fostering balanced group dynamics and encouraging contributions from all students.

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Conclusions

This pilot study demonstrates the feasibility and potential benefits of integrating flipped learning with Team-Based Learning in a large-scale foundational programming module. The use of iRATs within the OAL framework resulted in learning accountability and engagement during the individual preparation phase. The structured TBL phases promote active participation, peer learning, and conceptual understanding.

However, effective TBL implementation requires careful planning, adaptability, and continued support for both instructors and students. Future work should examine broader application of this hybrid approach in other engineering disciplines, particularly those with similar computational thinking requirements, as well as

longitudinal studies to assess the impact on student's problem-solving capabilities, programming proficiency and motivation.

References

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach Every Student in Every Class Every Day*. International Society for Technology in educ.

Burgess, A., Haq, I., Bleasel, J., Roberts, C., Garsia, R., Randal, N., & Mellis, C. (2019). Team-based learning (TBL): a community of practice. *BMC medical education*, *19*(1), 369.

Burgess, A., Matar, E., Roberts, C., Haq, I., Wynter, L., Singer, J., ... & Bleasel, J. (2021). Scaffolding medical student knowledge and skills: team-based learning (TBL) and case-based learning (CBL). *BMC Medical Education*, *21*(1), 238.

Dudley-Marling, Curt. (2018). *Does direct instruction work?: A critical assessment of direct instruction research and its theoretical perspective.* Journal of Curriculum and Pedagogy. 16. 1-20. 10.1080/15505170.2018.1438321.

Johnson, G. (2013). *Flipped classrooms not beneficial to all*. University Wire, Nov 2013, 1 (1).

Keengwe, J., Onchwari, G., and Oigara, J. (2014). *Promoting Active Learning Through the Flipped Learning Model.* Hershey, PA: IGI Global.

Mason, L., & Otero, M. (2021). *Just How Effective is Direct Instruction?.* Perspectives on behavior science, 44(2-3), 225–244. https://doi.org/10.1007/s40614-021-00295-x

Michaelsen, L. K., & Sweet, M. (2008). *The essential elements of team‐based learning.* New Directions for Teaching and Learning, 2008(116), 7‐27. https://doi.org/10.1002/tl.330

Parappilly, M., Woodman, R. J., & Randhawa, S. (2019). *Feasibility and effectiveness of different models of Team-Based learning approaches in STEMM-Based disciplines*. Research in Science Education, 51(S1), 391–405. https://doi.org/10.1007/s11165-019-09888-8

KOSEN's Capstone Project: Fostering Engineers through Software Design and Implementation

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The curriculum at the National Institute of Technology (KOSEN) in Japan is designed to be completed in five years. The KOSEN's curriculum has features that enable students to acquire knowledge and skills at or above the same level as those at university by the time they graduate. In the graduation research project that the authors conduct, we intend to foster students as innovative and practical engineers so that we provide them with the opportunity to set their own goals and learn by overcoming complex tasks that integrate the knowledge of the software field with technical skills and problem-solving skills by themselves under the teacher's qualitative support according to each student's progress. As the number of students accepted in the laboratory each year is small, each student can set their field of interest and theme, and by deciding how to design and implement the program, teachers can provide learning support based on engineering design.

In this report, we will provide the students' project theme, "Development of a wayfinding system using AR in the complex structures of the building," which has been improved and expanded by multiple students over a long period of consecutive years. Through assisting the students of this project, we have observed the students and found how and what the students involved in the project learned from the information they obtained from academic papers and introductory computer language books, how they selected the appropriate technology by themselves, how they developed the practical software system, how they managed the software development life cycle, and how they overcame technical difficulties. Specifically, the students learned to build user interfaces based on augmented reality, route search algorithms, and server-client software system architecture, and those technologies could not have been taught in the class. The students also gained soft skills such as the ability to make proposals and answer questions about how to improve the project, the ability to discuss with their peers and teachers, and the ability to write reports.

Furthermore, the characteristics of this educational program will be discussed based on the observation of each student's actions and attitude to conduct the project from the educator's perspective, and through a questionnaire after the students finish the project.

Keywords: *capstone project, self-directed learning, self-regulated learning, skill-oriented learning, engineering design*

Introduction

Colleges of Technology (KOSEN) in Japan are five-year institutions where students enter after graduating from junior high school at age 15 and learn general and special subjects for 5 years. The National Institute of Technology (NIT) Headquarters, an independent administrative institution in Japan, organizes 51 KOSENs across 55 campuses. Their primary mission is to foster engineers ready to contribute to the workplace in each special engineering field. As with ordinary general high schools, students begin with general education, such as Japanese language, English, social studies, mathematics, and physics in the lower grades. Then, they gradually acquire specialized knowledge and skills related to their departments. KOSENs also offer advanced courses, which provide more than two years of education for students who graduate from the regular courses to acquire a bachelor's degree.

National College of Technology (KOSEN), Toyota College, where the authors belong, is the only KOSEN in Aichi Prefecture, located in Toyota City. Toyota College has five departments, and the authors belong to the Department of Electrical and Electronic Engineering, emphasizing foundational courses such as electrical circuits, electromagnetism, electronics, automatic control engineering, and so on. However, graduates are also expected to obtain skills in developing computer software for microcontrollers, data analysis using a computer, and how to use a computer simulator.

To become engineers, students must acquire essential engineering design skills, including planning, problem investigation, and project scheduling. To support this development, graduation research is offered as a mandatory capstone project in the final academic year. This capstone project serves to confirm the students' mastery of specialized knowledge and skills, comparable to the level expected of a university bachelor's degree graduate. This paper describes the approach taken in the

author's laboratory at Toyota KOSEN to foster software design and implementation skills through graduation research following the department of electrical and electronic engineering curriculum.

Pedagogy

Beppu (2011) emphasized the necessity of providing engineering students with a fundamental understanding of the engineering design process and then proposes an integrated curriculum that incorporates design theory and creativity exercises before conducting graduation research over multiple academic years. The author also argued that engineering students must understand the theoretical principles of design and apply them to practical manufacturing processes to study and implement engineering design effectively.

Shurin et al. (2021) surveyed about the benefit of the capstone project against four stakeholders (academia, industry, students, and advisors) and concluded that the capstone project plays a central role in developing engineering students' readiness for industry by fostering the most important and significant skills, such as independent learning, ability to adjust to change, multidisciplinary, and adaptability to the industries.

L.F. CAPRETZ (2024) developed an engineering design course for senior-level students enrolled in the software engineering program and described that students engage in the full design process. The author concluded that the most critical aspects of the student experience was the soft skills, such as recognition of the importance of team efforts and group dynamics, the practice of cooperation and appreciation of different talents, the exposure to the complete cycle of design from concept to final production in the form of prototype, and the integration of economic, legal, and human factors into the design decisions.

Methods

1. Curriculum of the Department

The Department of Electrical and Electronic Engineering offers a curriculum focused on electrical and electronic engineering from the first through the fifth years. Table 1 shows the special subjects provided in this department at Toyota College in 2024. The curriculum comprises several parts: theoretical subjects related to electrical and electronic engineering, mathematics practice, experimental laboratories, Problem-based Learning, Learning, English for engineering, and software subjects.

2. Software Subjects

To graduate from NIT, Toyota College students are also expected to acquire skills in developing computer software for microcontrollers, data analysis using a computer, and utilizing a computer simulator. Therefore, the department offers software subjects such as Microcomputer Engineering in the second year, Basic Programming in the third year, and Programming Techniques in the fourth year.

Table 1. Curriculum of the Special Subjects in the Department

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td></td><td colspan="2">Basic English for Electrical Engineering</td><td colspan="2">English for Electrical Engineering</td></tr>
<tr><td colspan="2">Mathematics for Electrical Engineering</td><td colspan="3">Practice of Basic Mathematics, Physics, Electrical and Electronic Engineering</td></tr>
<tr><td>Fundamental Electrical Engineering</td><td colspan="3">Electrical Circuit Theory</td><td>Digital Circuit Theory</td></tr>
<tr><td colspan="3"></td><td>Electromagnetism</td><td>Power Electronics</td></tr>
<tr><td colspan="3"></td><td>Electronics</td><td>Semiconductor Theory</td></tr>
<tr><td colspan="3"></td><td>Electronic Circuit Theory</td><td>Automatic Control Engineering</td></tr>
<tr><td colspan="3"></td><td>Energy Transfer</td><td>Electrical Power</td></tr>
<tr><td colspan="3"></td><td>Electrical Measurements</td><td></td></tr>
<tr><td colspan="3"></td><td>E.E. Eng Seminar</td><td></td></tr>
<tr><td>Information Literacy</td><td>Microcomputer Engineering</td><td>Basic Programming</td><td>Programming Technique</td><td>Software for Electrical Engineering</td></tr>
<tr><td colspan="2"></td><td colspan="2">PBL for Electrical Engineers</td><td rowspan="2">Graduation Research</td></tr>
<tr><td colspan="4">Electrical Engineering Laboratory</td></tr>
</table>

In the second year, students study discrete mathematics, logic circuits, and embedded microcontroller programming using loops and conditions. The third year focuses on C language syntax, including input/output on a terminal, functions, array variables, input/output through the file system, and pointers. The fourth year curriculum addresses modular programming and introduces data structures and numerical calculation methods for general-purpose applications.

In the third-year PBL, students create a line-tracking robot and design a program to acquire values from a light-detecting sensor and change the speed of toy motors. In the fourth year PBL, students create soccer robots using LEGO Mindstorms EV3 and design programs to compete with the robots their classmates created.

Additional subject, Software for Electrical Engineering, is conducted in the fifth year, though programming language education is limited to Microcomputer Engineering, Basic Programming, and Programming Technique.

3. Pre-research Activities

In the second semester of the fourth year, students are assigned to laboratories through a course called Electrical and Electronic Engineering Seminar as a pre-research. Each laboratory conducts about four seminar sessions for the students, and the students can prepare for fifth-year research activities. One of the authors' laboratories develops software applications for various purposes using advanced techniques that students don't learn from the curriculum the department provides, so it provides short lectures and practical exercises about the topics below.

- Fundamentals of object-oriented programming in C++
- Event-driven programming
- Collaborative application development in a team

Object-oriented programming and event-driven programming are not included in the department curriculum. However, they are practical and fundamental techniques for developing the practical software products described later in this paper. Therefore, the author introduces concepts such as classes and inheritance in the pre-seminar, which are not available in C and are common in modern languages but difficult to self-learn.

In the department curriculum, in programming classes, each student creates the same program by himself/herself on the assignments. However, engineers work as a team in the practical workplace to develop software products. So, the purpose of collaborative application development in a team is to provide students with experience in developing software. At the same time, they communicate with their teammates, share the problems that they face, and confirm their solutions.

4. Graduation Research as a Capstone Project

As a capstone project, all KOSENs conduct graduation research for the fifth-year students based on what they have learned so far, deepening their understanding under faculty supervision while learning to manage research projects independently and continuously. Students conduct graduation research for three hours a day, twice a week, for nine months in the authors' department. They also learn how to write a research thesis and give a presentation in class. In addition, advanced course students engage in further research during Special Research I and II in their first and second years.

Fifth-year regular course students are typically 20 years old. Advanced course students are 21 to 22 years old, corresponding to second and fourth year university students. Each laboratory accepts 3 to 6 students. Each faculty member in the department provides research guidance for the students, which varies by special field.

Both graduation and special research involve mid-year poster sessions and final oral presentations. Students also must submit a graduation thesis (or a completion thesis for Advanced Course second-year students).

5. Laboratory Operation

One of the authors' laboratories conducts software-based research on educational support and image processing using webcams. Figure 1 shows students studying in the laboratory.

The laboratory's policy is "independent problem-solving and project management skills." Based on this policy, the laboratory requires the students to improve their independent problem-solving and project management skills. Students are expected to define research themes, plan systems, and identify necessary knowledge independently, wherever possible.



Figure 1. Students studying in the laboratory

Students can choose previous projects to update or propose new ideas and finalize topics through discussion with faculty. Innovation is not strictly required in graduation research, and students are encouraged to pursue interesting topics personally and engage in the engineering design process by themselves. In the laboratory, we hold one-on-one progress reports and discussions on direction approximately once a month.

The past projects conducted in the laboratory are as follows.

- Development of a 3D scanning system using a webcam
- Exercise form evaluation and improvement using pose estimation
- Fashion coordination recommendation using machine learning

6. Laboratory Projects

One long-term laboratory project involves developing an indoor way guidance system. This project was initiated in 2012. Visitors often get lost when assuming guidance within buildings with complex structures and layouts. To address this, students created a system where users set destinations on smartphones and scan markers placed at intersections. AR techniques overlay arrows on the screen to guide users.

Students proposed the system, and its design and architecture were decided through discussions with the laboratory professor. Initially, the server handled arrow rendering and pathfinding, while the client displayed results. Students independently researched pathfinding algorithms like Dijkstra's method.

In subsequent years, students improved the system by addressing issues and incorporating new features made possible by smartphone performance improvements. Improvements included UI, server-client structure, libraries used, and system operation, which are not taught in the department curriculum. Figures 2 and 3 show the students' proposed and updated architecture and interface.

7. Skills Acquired

Although the department curriculum emphasizes C programming, various other languages are used in the laboratory depending on the project, such as JavaScript for browser interfaces and Python for data processing and machine learning. Typical libraries, such as Three.js for 3D graphics and AR.js for augmented reality, are also used. Due to frequent library updates, online resources are commonly used.

As each project uses different tools, students are expected to learn them independently rather than in organized lectures conducted during the four-year seminar.

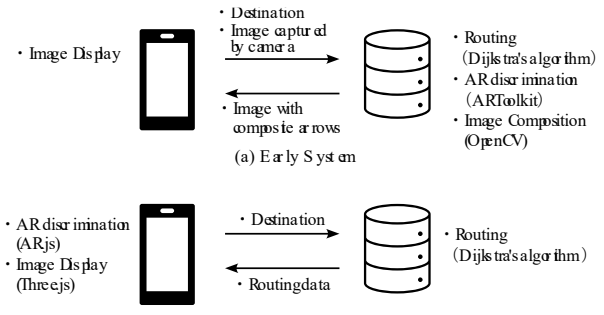


Figure 2. System Structure Diagram of the Student's Capstone Project of the Way Guidance System

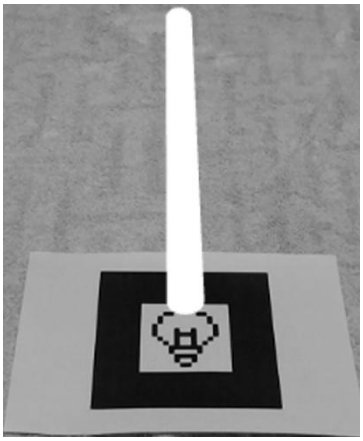


Figure 3. Example of the Screen of the Way Guidance System

8. Role of Faculty

Faculty conduct meetings with students once or twice a month when requested to review progress and provide guidance. In addition to checking progress, faculty members use this meeting to confirm that there are no research problems, and to check for necessary equipment, software, books.

Students independently select learning resources, request book orders, and share information, autonomously fostering a collaborative laboratory environment.

In some cases, students change the software components already implemented by former laboratory members due to limitations in solving the development problems. For instance, in 2023, a student switched from A-Frame to Three.js after finding the former insufficient. Faculty members support specification planning, but implementation is the students' responsibility.

Results and Discussion

At the end of the academic year 2024, an anonymous questionnaire titled "Survey on Independent Implementation of Graduation and Special Research" was conducted to assess whether the laboratory provides students with a self-directed, self-oriented, and self-regulated learning environment. The survey targets are small in this report, though four laboratory members—one second-year advanced course student and three fifth-year regular course students—answered. The questionnaire was administered on March 17 and completed by March 18, 2025, using Microsoft Forms.

The questions assessed students' perceptions of the laboratory's policy of "independent problem solving and project management skills." The survey questions include the following.

Q1. Were you able to schedule and meet goals independently?
Q2. How often did you engage in productive discussions with your supervisor?
Q3. Did you feel these discussions were conducted on equal footing between the supervisor and student?
Q4. Was your supervisor available to consult when you needed?
Q5. If yes to 4, was the advice helpful?
Q6. Did you improve your ability to make decisions independently?
Q7. Did you become more proactive in self-learning skills for computer programming?
Q8. Did the collaborative laboratory environment support your personal growth?

Table 2 shows the questionnaire results. The responses were anonymous, and the order of respondents does not reflect their academic year or other factors.

The results were generally positive. All respondents answered that discussions were equal (Q3), and Q6 responses showed improvement in independent decision-making.

Table 2. The Results of the Questionnaire

#	A	B	C	D
Q1	Somewhat agree	Agree	Somewhat disagree	Somewhat agree
Q2	Once per month	Once per month	Once per month	twice per month
Q3	Agree	Agree	Agree	Agree
Q4	Yes	Yes	Yes	Yes
Q5	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree
Q6	Agree	Agree	Agree	Agree
Q7	Somewhat agree	Agree	Somewhat agree	Somewhat agree
Q8	Somewhat disagree	Agree	Somewhat agree	Somewhat agree

Students were also asked: "If future students take on the same topic, what should be improved to enhance learning?" Responses are shown below.

- More frequent progress checks would help.
- While AR navigation systems exist, documentation is limited. Early AR programming instruction would be helpful.
- Opportunities for system testing in the real world should be arranged (students cannot organize it alone).
- Guidance on searching academic resources would be beneficial.

These responses clarified that some students needed faculty to provide explanations and assistance related to their research at the beginning. At the start point of the graduation research, considering the wide range of computer programming skills among students, some students likely felt some stress in conducting their research independently. The authors recognize that these issues are future challenges to be addressed for fostering students through a capstone project to have students address self-directed and skill-oriented learning. The survey by questionnaire is something we started this year, and we plan to take similar surveys in the future to provide material for improvement regarding the management of the laboratory.

Conclusions

This paper describes how the authors organized and conducted the software development laboratory in the Department of Electrical and Electronic Engineering at a National College of Technology (KOSEN), in Japan. The laboratory's policy is "independent problem-solving and project management skills." Based on this policy, the laboratory requires the students to improve their independent problem-solving and project management skills. It also introduces a long-term project, and students take initiative in learning and decision-making based on the self-directed/self-oriented/self-regulated learning pedagogical methods. A survey confirms that the laboratory environment supports autonomous research development. However, the authors recognize challenges that must be addressed for fostering students through a capstone project to have students address self-directed and skill-oriented learning.

References

Beppu, T. (2011). Engineering design education for Japanese Tertiary Education (in Japanese). *Journals of Japanese Society for Engineering Education*, 59(4), 72-79.

L.F. Capretz (2024), Bringing the human factor to software engineering, *International Journal of Advances in Electronics and Computer Science*, 11(8), 92-94.

Shurin, A., Davidovitch, N., & Shoval, S. (2021). The role of the capstone project in engineering education in the age of Industry 4.0 – A case study. *The European Educational Researcher*, 4(1), 75–91.

THE FEATURE OF EDUCATIONAL PROGRAMS OF TRAINING MARITIME CADETS AT FIVE MARITIME KOSENS

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Abstract

The collaboration of training international cadets and developing a global internship program was implemented by Japanese maritime KOSEN. There are many international exchange programs: the Singapore Maritime Academy program, the Kaua'i Community College program, and the international exchanges with Maritime Academy in the Philippines. In this work, we are going to report the international exchange programs prepared in collaboration with five maritime KOSENs and Japanese international organizations of shipping.

Keywords: *Collaboration, Maritime English, Maritime cadet, Maritime KOSEN, STCW*

Introduction

As for international maritime officers, a deep knowledge of theory, operating skill and maintenance for the ship are a very important requirement for them. Aside from that, they need keen English communication skills for internal or external communication between ship to ship or ship to shore. Most of Japanese international shipping company hires many foreigners as a ship crew. It is necessary for international maritime officer to have daily communication with each other who have different nationalities. They need to communicate with SMCP (*Standard Marine Communication Phrases*) based on STCW (*Standards of Training, Certification and Watchkeeping for seafarers*).

Five maritime departments under the National Institute of Technology (KOSEN) in Japan namely Toyama, Toba, Hiroshima, Yuge and Oshima College have been working together to nurture the maritime officers and to enhance the professional English communication ability without any trouble (2013). "All maritime college study method improvement project" in 2006 - 2011, "Maritime Human Resources Development project" in 2012 – 2017 and "2nd phase of Maritime Human Resources Development project" in 2017 – 2019 supported by Japanese government have been carried out to achieve this goal.

There are two international internship programs for five Japanese maritime KOSENs: Singapore Maritime Academy (SMA) program and Kaua'i Community College (KCC) program. The international internship program in SMA and KCC will be encouraging that the maritime KOSEN students can put in practice the English training from now on.

Over the last decade or so, the international exchange with the Marime Academy in the Philippines has become increasingly active. Firstly, Maritime Academy of Asia and the Pacific (MAAP) has developed the global educational programs since 2012. We have invited English instructors and requested them to conduct the Maritime English Seminar in Japan. Recently, MAAP's students have visited Japan on their training ship M/V KGO (Kapitan Gregorio Oca) supported by International Mariners Management Association of Japan. Secondly, between 2015 and 2019, the English study and training program have been performed at NYK (Nippon Yusen Kaisha) - TDG (Transnational Diversified Group) Maritime Academy (NTMA) in the Philippines. We have been joining the program with Japanese students and instructors every year. And, NTMA members have visited Japanese maritime KOSENs every year. Thirdly, Mol Magsaysay Maritime Academy (MMMA) was established in 2018 and is one of the maritime higher education institutions accredited by the Philippine Higher Education Authority. The first international internship from the Oshima college, which is one of the five maritime KOSENs, to the MMMA took place in March 2024. We conducted the maritime educational program in English based on STCW. A survey questionnaire was conducted when the program was over amongst the students. This paper reviewed how the international exchange programs worked for training maritime cadets.

Training at SMA through MEL Camp

This international internship program will take place at the MEL (Maritime Experiential Learning) camp organized by SMA. In particular, by embarking on a cruise ship departing from or arriving in Singapore, students are trained in a situation where English is the only language available for communication. The purpose of the program is to give students the opportunity to realize that the intercultural understanding and English communication skills are necessary for their future. This internship also aims to develop the meaningful reciprocal relationships through interaction with SMA students and staff.

When implementing the MEL Camp, first, as soon as the program schedule is finalized, the application guidelines for participants is posted on campus. At the same time, we announce the recruitment to the five maritime KOSENs. The prospective participants should submit an essay in Japanese which contains their motivation for participating in the program, and in English with personal eagerness. Then, interviews will be conducted in both Japanese and English, and participants will be prioritized.

At SMA, the students are given an orientation including a field trip and campus tour with the help of SMA students and faculty members to understand Singapore, before participating in the MEL camp. In addition, the introduction of short-term intensive language courses provides students with the opportunity to become familiar with English as it is spoken in Singapore (See Figure 1). We also have coordinated a way to increase the effectiveness of the internship by incorporating visits to Japanese companies in the area, and the entire program is set to last 11 to 12 days to ensure a full training program.

The onboard training is a 4-day/3-night program in which all students from different countries attend lectures and participate in workshops in the same program (See Figure 2 and 3). Japanese students will be assigned to separate groups as much as possible to encourage communication in English. They meet daily under the guidance of the faculty members who lead the meeting to monitor their physical condition and check their level of understanding.



Figure 1. Language Training at SMA



Figure 2. Group work on board



Figure 3. Onboard Lectures

After returning to Japan, they should make a presentation on the program and its results to other students and faculty members at an international exchange debriefing session on campus. Through participating the program, some students are interested in other overseas training programs. We take this as an indication that the program has fostered an awareness of the need to look overseas. In this way, this internship program has steadily produced effective results.

Training at KCC

Students of five maritime KOSENs study modern navigation techniques in the colleges and the training ships. They learn how to navigate the open seas using a variety of modern navigational instruments (e.g., magnetic compass, sextant, chronometer, RADAR, GPS, etc.). It is considered that these instruments are essential for voyaging today, yet it is also known that in ancient times there were people who voyage the Pacific Ocean without such instruments.

In 1975, a small vessel was built in Hawaii and named “Hokulea”. The “Hokulea” is a reconstruction of an ancient style of double-hulled sailing vessel. This style of vessel (called “voyaging canoe”) had been used by ancient peoples to travel throughout Polynesia (a large area of the Pacific Ocean that includes the Hawaiian Islands, New Zealand, and Easter Island). Along with this vessel, the ancient style of navigation was also revived. The Polynesian traditional navigation techniques (called “wayfinding”) consists of special skills to recognize one's position and course in the open seas, by integrating

information directly sensed from the nature, such as the movement of stars, birds, and waves. The “Hokulea” sailed 4,000 kilometers from Hawaii to Tahiti with the traditional navigation techniques in 1976, to demonstrate that it is possible to navigate the ocean without any modern navigational instruments.

In 2007, the “Hokulea” sailed from Hawaii to Japan. At that time, educators at Japan and Hawaii initiated a plan to give Japanese maritime KOSEN students an opportunity to learn the Polynesian traditional navigation. For this purpose, the international exchange program “Ikena Kahua” (this program name means “to seek one's foundation” in Hawaiian language) was launched in 2010. And a comprehensive exchange agreement was concluded between five Japanese maritime KOSENs and University of Hawaii - Kauai Community College (KCC).

This “Ikena Kahua” is a three-week program in Hawaii. During the first and second weeks, Japanese students stay together in an accommodation and commute to the KCC campus by public bus. In the mornings, students attend classroom lectures and group works on the Polynesian traditional navigation. They discuss with local students in English and plan voyages on a chart together. Japanese share their knowledge of modern navigation with locals while locals share their knowledge of traditional navigation with Japanese. They can compare the traditional one with the modern one and rediscover the most common and fundamental elements of the navigation. In the afternoons, students work outdoors. They work on building a voyaging canoe (Figure 4), practice survival skills at sea, and experience traditional Hawaiian agriculture.

Evening times in the accommodation are also special experiences. They cook and eat dinner together, present to each other what they have learned in the day, and work on homework together.

During the third week, students participate in a training camp of traditional navigation for students from various colleges and universities in the Hawaiian Islands. They work together in each group consisted of few Japanese students and many local students. In the days, they engage in practical training that apply what they have learned in the previous two weeks, on a voyaging canoe. In the evenings, they learn traditional Hawaiian songs, chants, and dances, and listen to stories told by elders who have worked to revive the traditional navigation. At nights, they sleep outdoors under the stars.

This program with travel to Hawaii was offered every spring from 2010 to 2019. 110 students in total have participated in the program. Then, due to the COVID-19 pandemic, it was cancelled in 2020 and an online exchange program without travel was started in 2021. The online program was held for three times from 2021 to 2023, and 49 students in total have joined (2022). After that, in the summer of 2023, the “Ikena Kahua” program with travel was resumed and 14 students have participated in the program.

Many of the KOSEN students who have participated in this program in the past have gone on to work for global maritime shipping companies or study at universities after graduation. It is considered that their experience in this program has motivated the students to learn more practical English and to become global maritime professionals who operate merchant ships with foreign crews.



Figure 4. A “voyaging canoe”, one of the reconstructions of ancient Polynesian double-hulled sailing vessels.

MAAP's Maritime English Seminar

Of the approximately 1.2 million seafarers working on the world's merchant ships, Filipinos account for the largest number at approximately 230,000. The same is true in Japan's commercial shipping industry, where Filipinos account for more than 70% of the approximately 56,000 crew members employed by Japanese merchant shipping companies. Due to this situation, there are many schools in the Philippines where you can study merchant marine.

The Maritime Academy of Asia and the Pacific (MAAP) was founded by the Associated Marine Officers’ and Seamen’s Union of the Philippines (AMOSUP) in 1998. The following year saw the establishment of a new campus (JSU-IMMAJ Campus), which is affiliated with the All Japan Seafarers’ Union (JSU), the International Mariners Management Association of Japan (IMMAJ) and AMOSUP.

JSU, which is one of the stakeholders in our maritime human resources development project, advised us to visit MAAP, which produces world-class seafarers and provides global education. As a result, starting in 2013, MAAP dispatched teachers to hold maritime English seminars at five maritime colleges (KOSENs).

Japanese-registered ships are not only manned by Japanese people. On board the ship are not only Japanese people, but also Filipinos, Koreans, Croats, Indonesians, Indians, and other people whose native languages are various. The common language is, of course, English. You must communicate with all ships overseas in English. However, as mentioned above, not all sailors from all countries are fluent in English. And, communication between ships is essential for safe navigation. If each other's English is unclear, there is a risk of mistakes and confusion. So it is important for them to eliminate this language barrier as much as possible. In other words, standard maritime communication terminology called SMCP is used.

We conducted English program based on verbal communication using the SMCP (Figure 5 and 6). The SMCP, which is a set of key phrases in English, is supported by the international maritime community for use at sea and developed by the International Maritime Organization (IMO) in 2001.



Figure 5. The Maritime English Seminar

The SMCP constituted by the Maritime English is accepted as a common working language for safety operation at sea and in port in order to avoid misunderstandings on verbal communication caused by English locality of each seafarer coming from various non-English speaking world. It consists of a set of terms, phrases used on board ships. And it is a standardized safety language, precise, concise, simple and unambiguous so as to avoid confusion and error.



Figure 6. The training ship with MAAP students

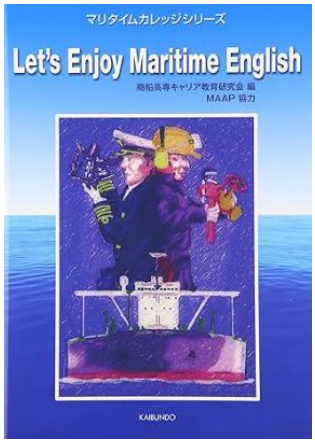


Figure 7. Textbook based on the SMCP

MAAP and teachers from the five schools have created a textbook containing the content of this seminar so that each school can continue to provide this type of English education. It was created mainly by teachers from each school who attended these seminars for teachers (Figure 7). Based on this SMCP, we created a textbook that complies with the International Convention on STCW. These are still used so far.

Training on MAAP's training ship KGO

Students and professors from five maritime KOSENs in Japan participated in a cultural exchange program with students of the Maritime Academy of Asia and the Pacific (hereinafter, MAAP). The program was held on board a MAAP training ship, M/V Kapitan Gregorio Oca (hereinafter, KGO). The International Mariners Management Association of Japan provided and operated the program.

MAAP is located in the Philippines, and the MAAP students aim to become ocean-going seafarers working in Japanese merchant ships. This was a program in which the maritime KOSEN students got on board a training ship with MAAP students, trained and spent shipboard life together, and deepened mutual understanding, including differences in culture and ways of thinking.

A similar project was held in 2019 when KGO was newly built; this program was the second time. This program was held to coincide with KGO's docking in Shimizu.

22 students (1st and 2nd year) and five professors from five maritime KOSENs. 38 MAAP students (19 deck cadets and 19 engine cadets) and four MAAP faculty members (not including the seafarers for operation) participated. In addition, two people from the International Mariners Management Association of Japan were on board and took care of us. Originally, the plan was to board the ship at Kobe Port at 13:00 on March 8, 2024, and disembark at Shimizu at noon on March 11, but due to bad weather during the KGO's voyage from the Philippines to Japan, the embarkation at Kobe Port was on the 10th and the disembarkation at Shimizu was on the 12th. The schedule was changed to 2 nights and 3 days.

An opening ceremony was held at the beginning of the program on the first day. After that, "A buddy system was used to pair the students for the three-day activities". In this program, Japanese students and MAAP students worked as partners on a one-to-one (sometimes one-on-two) basis, and all programs were conducted on a partner-by-partner basis. Buddy shared the room and ate meals together. As the Japanese students who participated were 16 or 17 years old, whereas the MAAP students were 21 years old, the MAAP students had built good relationships with the Japanese students as good seniors.

The participants observed the training ship facilities with their buddies. Afterward, an evacuation drill was held for all the passengers on board before leaving the port. Japanese students also participated by asking the buddy questions about things they didn't understand. Japanese students were gradually finding ways to communicate through various efforts. They were divided

into two groups and given a lecture after the evacuation drill. During that time, the ship departed from the Kobe Port.

The second day was the main part of this program. In the morning, the students were divided into three groups. Then they had training on the bridge, engine room, safety equipment, and a lecture on the importance of communication and reporting on board. All programs were held in partnership with the buddy, so anything that the Japanese students could not understand from the instructor's explanations was supported and re-explained by the MAAP students as the buddy. The MAAP students actively communicated with the Japanese students and explained things over and over until the Japanese students correctly understood. We felt it was such a good point in this program. After the day-long practical training was completed, a game competition called "Cultural Night" was held. The students played the *message games* in Tagalog and Japanese to transfer the message each other. The event was a great success. It was such a fun time, in contrast to the atmosphere during the day training. After the game, the students deepened their friendships at karaoke until late at night.

On the third day, after breakfast, they observed the entrance of the ship dock. Afterward, they disembarked and toured the dock. After lunch, a closing ceremony was held, and the group dispersed, regretting a farewell to the buddy.

One week later, we took a questionnaire survey to the participating students. The participating students responded positively to all questions. In the comments section, participants included comments about the ships such as "Participating in this program has greatly changed the way I recognize the world of ships." Most of them stated about English such as "I found that the partner can understand what I said, if I try to actively communicate with others, even if I am not good at English," "I found that MAAP teachers' English accents and difficult words were difficult to understand, so I was able to understand them by rephrasing things with the buddy." Some of them mentioned their cultural exchange such as "Through these exchanges, we not only talked about hobbies and friends, but also deepened our understanding of each other's cultural backgrounds, including the social situation, religion, and history of our hometowns."

One of the noteworthy student's comments was, "This program was a memory that I will never forget for the rest of my life." The program was a positively influenced experience for all the students' consciousness. We believe most of the participating students will become deck officers and engineers of ocean-going vessels. We would like to express our deep gratitude to the International Mariners Management Association of Japan for providing this great opportunity.

We would like to express our deep gratitude to the International Mariners Management Association of Japan for providing this great opportunity.

Training at NTMA

The English training and international internship programs were performed at NYK-TDG Maritime Academy (NTMA) in the Philippines as "NYK MIRAI Project". An official agreement between KOSEN and NYK (Nippon Yusen Kaisya) for this program entered into force in November 2015. Number of participant of students and schools for this program were gradually increased until 2019. Then, due to the COVID-19, it was cancelled in 2020, and the NTMA program is scheduled to start again in 2024.

Buddy system which makes a pair between KOSEN and NTMA student was employed to take care these students. Students engage in an immersive communal experience where they attend classes together, share meals in the canteen, reside in quadruple dormitory rooms, and participate in morning exercises as a group. Table 1 shows the time schedule of program in NTMA. And the statistical results about buddy system is shown in Figure 8.

Just choose one number from listed below for each question.
1. very disagreeable, 2. disagreeable, 3. neither disagreeable nor agreeable, 4. agreeable, 5. very agreeable.

<u>About buddy</u>

Q. 1 Can you understand your buddy's English?
Q. 2 Can you ask a question to your buddy in English?
Q. 3 Can you perform the program in harmony with buddy?
Q. 4 Can you enhance your understanding for your buddy?
Q. 5 what kind of topic is easy to communicate?
1:Hobby 2:Dayly dormitory routine 3:Maritime technical 4:General subject 5:Social system 6:Culture
Q. 6 what kind of topic is difficult to communicate? 1:Hobby 2:Dayly dormitory routine 3:Maritime technical 4:General subject 5:Social system 6:Culture

Table 1. Time schedule of program in NTMA

0500H	Reveille (fellow Cadet's daily) Routine
0800H	Attend classes of 3rd year cadets
1200H	Lunch with NTMA Cadets at Cafeteria
1300H	Attend classes of 3rd year cadets
1700H	Attend English oral communication activities
2100H	Administrative time
2200H	TAPS (sleeping time)

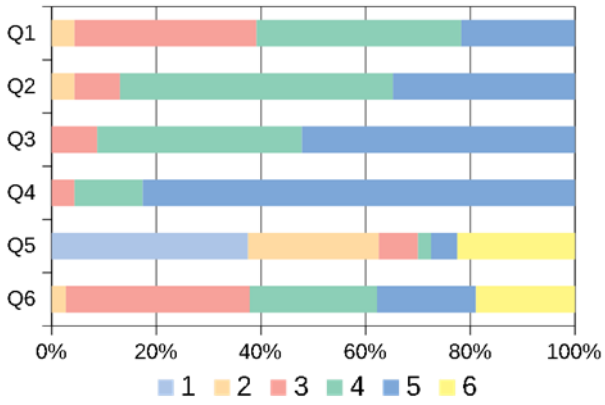


Figure 8. Statistical results about buddy system in percentage of the questionnaire survey by KOSEN students for the program at NTMA

Figure 8 shows the statistical results in percentage of the questionnaire survey for KOSEN students for the

program at NTMA. KOSEN students can communicate with NTMA buddy even though their poor English. KOSEN students have difficulty to understand English at the class. However, the new teaching styles help to understand English thought giving additional environmental information. All sector shows remarkable motivation enhancement.

English training and internship program in NTMA in the Philippines which is affordable for all students was developed. Host NTMA give a chance to many KOSEN students to study English without any extra personal cost. It is very important to learn maritime English and to understand inter-cultural background to be able to communicate with international colleagues in future work on ships. Maritime English classes on board the training ships are very effective. We conclude the program is successful to enhance student's motivation to be seaman.

Teaching in English on technical subjects at MMMA

An international internship program was conducted for five Japanese students from Oshima college to promote student and faculty research exchange with the MMMA (Mol Magsaysay Maritime Academy) in the Philippines. MMMA is one of the maritime higher education institutions recognized by the Philippine Higher Education Authority (CHED), established in 2018.

During the students' maritime training, a non-native English speaker from KOSEN gave lectures in maritime technical subject such as Marine Auxiliary Machinery engineering in English at regular class for the Japanese students and Filipino students. Also, a KOSEN instructor gave a presentation of Japanese culture and geography in English for MMMA students. They listened intently to the class discussion, and there was an exchange of ideas. They raised questions and participated in the class discussion.

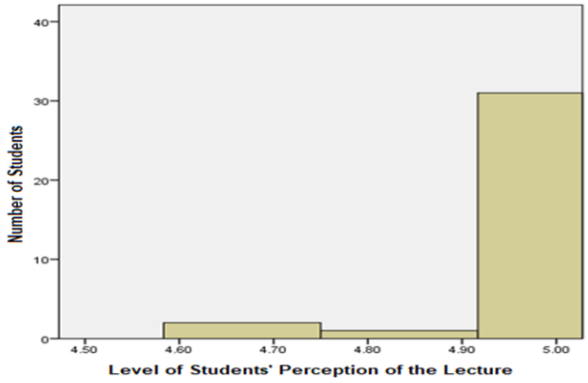


Figure 9. Non-normal Distribution of the Level of Students' Perception of the Lecture

The result spoke the learnings of students from the lecture (2017): Out of 34 students including Japanese and Filipinos, 22 (64.71%) learned auxiliary machinery. Also, 20 (58.82%) and 12 (35.29%) students learned the types of pumps, and force and pressure, respectively. The overall mean of 4.98 (/5.00) indicates a very high level of students' perception of the lecture. The standard deviation implies that the levels of perception are close to the mean. Some are as high as 5, while some are as low as 4. As shown in Figure 9, the level of students' perception of the lecture concentrated on 5.00, showing a non-normal distribution.

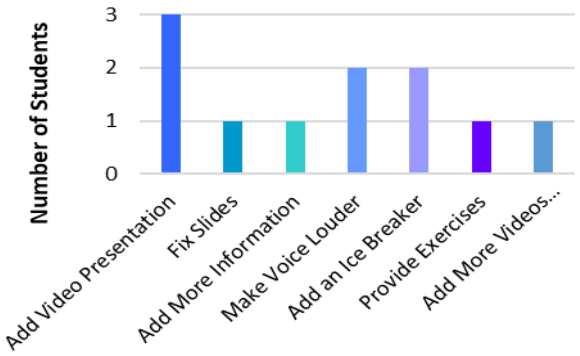


Figure 10. Students' Suggestion for Lecture Improvement

Figure 10 shows students' suggestions for the improvement of lecture. Out of 34 students, 3 (8.82%) suggested the addition of video in the lecture. While few students suggested making the voice louder (5.88%), including ice breaker (5.88%), fixing the slides (2.94%), adding more information (2.94%), providing exercises (2.94%) and adding more videos about the Japanese culture (2.94%). For the purpose of variation, the teacher should use different teaching methods so that students will not get bored in the class.

Conclusions

The collaboration of training international cadets and developing a global internship program have clearly showed improvement in both of students' English proficiency and communication skills in English.

We concluded that the collaboration programs to train international cadets for maritime English education was successful to enhance Japanese students' motivation and professional English communication ability for the future seafarer.

References

Makoto Endou, (2013), "An approach to study method easy to understand and to fix in maritime department - all maritime college study method improvement project", *Proceedings of Education forum for all colleges in Japan*, AP4 3 2.

Ikeda-chun, K., Mukose, K., Homae T., Murakami T., Ikeda S., Hashizume N. & Kameya T. (2022). Co-Creating Meaningful Online Program Under COVID Pandemic. *Research reports of Toyama National College of Technology*, 9, 14

Jongdoc Park and et al., (2017), "International Maritime Education and Training in Collaboration with Philippines Maritime Academy", *Proceedings of the International Symposium on Marine Engineering (ISME)*, Tokyo, Japan, D20-201, pp 507-510.

"SMART HOSPITALITY EXPRESS" – WORK INTEGRATED LEARNING & PROJECT BASED LEARNING ON WHEELS

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This paper presents an innovative mobile learning platform developed by the Hospitality Discipline of the Vocational Training Council (VTC), Hong Kong that combines Work-Integrated Learning (WIL) and Project-Based Learning (PBL) for students of the Higher Diploma in Sports Studies with Smart Technology. The Smart Hospitality Express (SHE) Project transforms a mini-truck into a mobile techno-fitness laboratory, creating unprecedented opportunities for hands-on vocational training while promoting health and wellness across Hong Kong. Through its first three academic years (2021/22-2023/24), SHE has engaged over 9,000 participants across 90+ schools, demonstrating the effectiveness of this novel approach to vocational education. The paper examines the pedagogical framework, implementation strategies, learning outcomes, and community impact of this initiative, while exploring its potential for replication in other vocational disciplines.

Keywords: mobile learning, work-integrated learning, project-based learning, vocational education, smart sports technology

Introduction

The integration of smart technology into sports studies presents unique opportunities for enhancing vocational education. Traditional methods often lack the dynamic, real-world application necessary to fully prepare students for careers in this evolving field. Recognizing this, the Hospitality Discipline at VTC developed the "Smart Hospitality Express (SHE)" Project, offering a mobile learning platform that brings education directly to communities, fostering both student development and public health engagement. SHE allowed the students to outreach to different schools, sports associations, and community centers to actively engage stakeholders in the sports, health and education sectors while students are conducting Work-Integrated Learning (WIL) and Project-Based Learning (PBL) by organizing smart health and sports day and workshops. The SHE Project also aligns with the Smart City Blueprint 2.0 (Hong Kong SAR Government, 2020), which emphasizes innovation in education and community services. In addition to enhancing students' learning, the SHE serves to increase community engagement and promotes health and fitness awareness, similar goal as stipulated in the Global Action Plan on Physical Activity (WHO, 2022).

Conceptual Framework for Pedagogical Innovation

SHE integrates three key educational paradigms:

1. Mobile Learning: Bringing education directly to communities (Billett, 2014)
2. Work-Integrated Learning (WIL): Following Billett's (2014) structured WIL model, where students develop professional competencies through real-world tasks
3. Project-Based Learning (PBL): Student-driven problem-solving (Kolmos, 2017)

SHE (Figure 1) represents an innovative approach to vocational education by creating a mobile classroom for sports and related programmes. This innovative platform enables students to engage with diverse populations including school children, elderly community members, and elite athletes through comprehensive data collection and analysis activities. The WIL and PBL approaches enable students to achieve intended learning outcomes in a structured way.

Figure 1: Smart Hospitality Express



SHE is a health and fitness classroom on wheels, serving as a mobile classroom in smart sports, e-health, and fitness assessment. It promotes smart sports data analytics and aligns with VTC's strategic "Digital Future"

initiative, facilitating multi-disciplinary and innovative project collaborations. Equipped with health and sports equipment, SHE functions as a mobile smart sports coach and supports various planned purposes.

The primary objectives of SHE include:

1. Providing students with hands-on experience in smart sports technology applications
2. Collecting and analyzing health data from diverse demographic groups
3. Revitalizing sports participation through data-driven exercise and diet recommendations
4. Training students in emerging professional roles, such as:
   - Sports assessors
   - Sports data architects
   - Techno fitness coaches
   - Sports administrators
   - Smart living planners

SHE Project Implementation

Prior to operation, the SHE was required to obtained Special Purpose Vehicle License from Transport Department before completing exterior design and painting and installation of portable and fixed digital fitness equipment.

The equipment features:

- Boditrax body composition analyzer
- NURVV Run smart insoles for gait analysis
- Technogym smart exercise bikes with VR integration
- PostureScan digital mirror
- Myzone heart rate tracking system

SHE mainly operated through outreaching to primary and secondary schools, athlete academies, and sports associations. Students were arranged to conduct smart sports demonstrations and data collection, provide health assessments and improvement recommendations. Through conducting real fitness assessments using professional equipment with diverse client groups (students, athletes, elderly), students were able to develop professional competencies in:

- Sports assessment
- Data analysis
- Client communication
- Training program design

Project-Based Learning Methodology

Students participate in complete project cycles:

1. Needs Assessment: Identifying community health needs
2. Program Design: Creating tailored fitness tests and workshops
3. Implementation: Conducting mobile outreach sessions
4. Evaluation: Analyzing data and providing recommendations

This approach develops critical thinking, problem-solving, and teamwork skills while addressing real community health challenges. Students gain hands-on experience with industry-standard equipment while learning data analytics skills.

Industry Collaborations

The SHE Project has fostered significant industry partnerships:

1. Tanita Health Equipment: Students serve as Sports Assessors for Physical Fitness Assessment Days
2. CUHK & Department of Health: Collaboration on Hong Kong Growth Study (20,000 samples)
3. Elderly Care Programs: Resistance training for sarcopenia prevention (300-450 participants)
4. Hong Kong Korfball Association: Development of digital trainer passports
5. Hong Kong Housing Society: Smart rehabilitation programs for elderly

Funding Support

VTC has provided funding for initial setup of the min-truck, equipment and time-limited operation cost. In addition, the project has demonstrated strong sustainability through external funding such as the SYNC Foundation funding.

Results and Impact

The Table 1 below shows the quantitative outcomes covering the period from AY2021/22 to AY2023/24).

Table 1 Quantitative Outcomes (AY2021/22 – AY2023/24)

Metric	Result
Schools Reached	90+
Participants Engaged	9,000+
Fitness Tests Developed	70+
Student Satisfaction	92%
Community Satisfaction	93%

Discussion

The SHE offered a good opportunity for students to be trained as sports assessors, sports data architects, techno fitness coaches, sports administrators, and smart living planners, at the same time provided a platform for community to enjoy the smart sports and activities and promote healthy lifestyle. During AY2021/22 – AY2023/24, the SHE has outreached to over 90 secondary and primary schools in Hong Kong, with more than 9,000 participants experienced over 70 smart fitness tests designed by the students. The SHE project showcased an innovative and versatile way of vocational and professional education and training that created a

win-win outcome for students and the community. Further exploration is therefore suggested in extending the same WIL and PBL mode for other study areas.

Unlike traditional WIL or PBL models, SHE extends students' learning and practices to a broader and more diverse range of populations. By operating in various community settings. The integration of a mobile platform sets SHE apart by offering students flexibility and interactive learning opportunities. This modern approach keeps students engaged, encourages self-directed learning, and aligns with the digital preferences of today's learners, ultimately boosting motivation and participation.

SHE also enhances its presence within the community by actively engaging in real-world health initiatives. This increased visibility not only strengthens partnerships but also raises awareness about the program's contributions, fostering trust and collaboration with local stakeholders.

Conclusions

The Smart Hospitality Express (SHE) initiative represents a transformative approach to vocational education, combining mobile learning with real-world application to benefit both students and communities. By fostering skills in sports technology and promoting health and wellness, SHE sets a precedent for innovative educational models that can be replicated across various disciplines.

References

Billett, S. (2014). Integrating learning experiences across tertiary education and practice settings. Springer International Handbooks of Education.

Kolmos, A. (2017). PBL curriculum strategies. Wiley Handbook of Problem-Based Learning.

Hong Kong SAR Government. (2020). Smart City Blueprint 2.0.

VTC. (2021). Digital Future Strategic Initiative Framework.

World Health Organization. (2022). Global Action Plan on Physical Activity.

Establishing a Framework for Social Implementation Education in Collaboration with Regions of Kochi Prefecture

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National Institute of Technology, Kochi College aims to cultivate human resources who can contribute to society by collaborating with the local community. The college emphasizes entrepreneurship education, which guides students through problem identification to solution implementation. Through a five-year " Social Implementation Education" program, the institution works with local companies and municipalities to provide practical learning opportunities, allowing students to engage progressively in entrepreneurship and regional problem-solving.

By utilizing ICT (Information and Computer Technology), the initiative expands its activities to cover the entire Kochi Prefecture (All-Kochi) and fosters collaboration between students and faculty (All-Kochi KOSEN) to address regional issues. This approach aims to broaden students' perspectives and increase their engagement with local businesses, government agencies, and community organizations through collaborative learning.

Starting in the 2024 academic year, the "Regional Collaborative Practice" course will be a mandatory subject, extending its scope across the entire prefecture. The course will recruit companies, municipalities, and organizations willing to provide information on regional issues and collaborate on solutions. Furthermore, a support system integrating both general and specialized subjects will be established to expand students' horizons and promote collaborative learning.

In 2024, 40 teams participated in activities, with 28 teams collaborating with external organizations, including 17 local companies, government agencies, and community groups. This initiative enabled the college to address issues in remote and mountainous areas. At the results presentation meeting, all first- to third-year students attended as part of their career education, and 20 representatives from businesses, government, and educational institutions also participated, providing positive feedback.

Additionally, the course led to an increase in the number of students seeking the "Regional Revitalization Practitioner" certification—a title awarded to those aspiring to contribute to regional development through hands-on experience.

Through a comprehensive educational program focusing on discovering and solving regional issues, students deepen their understanding and affection for the local community while enhancing their commitment to contributing to regional development. This initiative fosters the growth of local innovators who will drive future regional innovation.

Keywords: *Social Implementation, Career Education, Regional Collaboration, Entrepreneurship, Technical Education, Local Innovator*

Introduction

Technical education must evolve to address not only technological advancements but also the complex challenges faced by local communities. As regional revitalization becomes a national agenda in Japan, institutions such as KOSEN are uniquely positioned to train students who can identify and solve real-world problems. Kochi KOSEN has established a career education program centered on entrepreneurship and regional collaboration, aiming to cultivate young professionals who can drive sustainable innovation in local areas. This paper reports on our efforts to establish a sustainable framework for social implementation education through entrepreneurship-based learning and regional collaboration activities. We also present results and discuss future challenges

Objectives and Background

To foster students at Colleges of Technology who can contribute to society in a new era, it is essential for educational institutions to collaborate with local industries and communities, engaging in co-creative educational development. At Kochi National College of Technology, we have been promoting education that aims to nurture students capable of contributing to society through active collaboration with the local community.

Particularly, we place strong emphasis on entrepreneurship education that encompasses the full cycle from identifying problems to implementing solutions. As illustrated in Figure 1, our five-year career education program is structured to gradually develop

these capabilities. Through collaboration with local companies and government offices, we provide students with practical learning experiences.

Specifically, 1st- and 2nd-Grade students participate in introductory and foundational courses on social design and entrepreneurship. In the 3rd-Grade students learn from the experiences of local entrepreneurs in a regional studies course. In the 4th-Grade, they engage in hands-on problem solving through the "Regional Collaborative Practice" course, and in the 5th-Grade, they apply their knowledge and skills in graduation research projects, some with the goal of launching their own ventures.

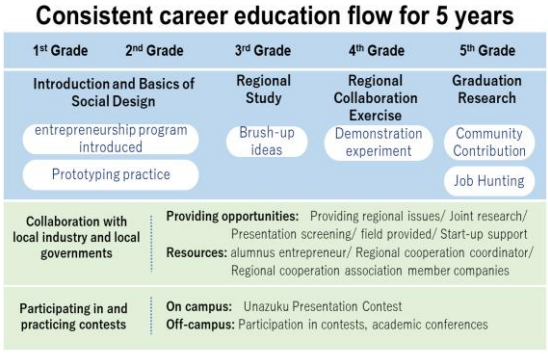


Figure 1 Consistent career education flow for 5years.

In order to expand our efforts to include remote areas within Kochi Prefecture—regions that have been difficult to support in the past—we are utilizing ICT to extend our activities across the entire prefecture ("All-Kochi"). This initiative is implemented jointly by faculty and students ("All-Kochi KOSEN"). Through this approach, we aim to broaden students' perspectives and increase their engagement with local issues by fostering collaborative learning with local businesses, government entities, and community organizations.

Enhance Educational Program

In 2024, our program was enhanced through a series of initiatives aimed at deepening collaboration with local communities and industries in the context of problem-based learning. The major components are as follows:

1. Broadening Regional Engagement for Problem-Based Classes

We actively invited local communities and companies to provide real-world issues that students could engage with in two key courses:

- 2nd Grade course: Fundamentals of Social Design – Local and regional organizations shared current social issues, offering students opportunities to understand and analyse community needs.
- 4th Grade course: Regional Collaborative Practice – Students worked in collaboration with local partners to tackle real problems through year-long team projects.

2. Enhancement of the 4th-Grade "Regional Collaborative Practice" Course

Significant improvements were made in 2024:

- The course was restructured from an elective to a mandatory subject, accompanied by an increase in faculty assigned to each student group.
- Teams of students collaborated with local companies and municipalities on issue-based research and development projects throughout the academic year, concluding with a formal presentation of outcomes at a final review session.

3. Institutionalization of the Company Research Seminar in Kochi as a Career Education Program

The Company Research Seminar in Kochi was officially integrated into the school calendar as a career education event. the 2024 event required participation from all students in Grade 1 through 4.

4. Strengthening Partnerships with the Regional Collaboration Support Council

To enhance long-term collaboration, companies that participated in or contributed to initiatives (1) through (3) were encouraged to join the school's Regional Collaboration Support Council.

Member companies that joined were granted access to the school's digital signage system, allowing for internal information dissemination and further visibility on campus.

Results and Achievements

1) Broadening Regional Engagement

Table 1 shows the annual transition in the number of student teams and collaborating organizations involved in the "Regional Collaborative Practice" course between 2022 and 2025.

Academic Year	No. of Students	No. of Teams	No. of Collaborative Teams	No. of Partner Organizations	No. of Support Teacher
2022	125	31	19	10	21
2023	123	31	23	10	14
2024	142	40	28	17	36
2025 (planned)	175	45	28	26	37

Table. 1 Number of participating teams and partner organizations in regional collaborative exercises

In 2024, significant growth was observed in both the number of students and collaborative teams. The number of partner organizations increased from 10 to 17, and the number of faculty advisors was more than doubled, ensuring sufficient support for each student group. For 2025, further increases are expected, particularly in the number of partner organizations, indicating a strengthening of regional engagement and institutional commitment.

These projects included collaboration with remote and mountainous communities that had previously been difficult to reach, enabled by web-based communication and on-site fieldwork. Figure 2 shows an online meeting with partner organizations in remote areas using digital collaboration tools.



Figure 2 Web discussions with remote community

Figure 3 depicts a pilot project of a mobile “third place” conducted in a remote location.



Figure 3 Fieldwork with remote community organizations

Figure 4 illustrates a programming workshop for elementary school students in a remote area. Through these initiatives, students gained opportunities to engage with communities that had previously been difficult to access.



Figure 4 Programing workshop with remote community

2) Dissemination of Results and Educational Impact

At the end of the academic year, a "Regional Collaborative Practice Presentation Day" was held. All first- to third-year students participated as part of their career education. Faculty reported that this event provided meaningful insights into real-world applications of classroom learning. Additionally, 20 representatives from companies, government agencies, and educational institutions attended and expressed strong interest in the students' presentations (see Figure 5).



Figure 5 Regional Collaborative Practice Presentation Day

3) Increase in Interest in Local Contribution

The course has had a notable impact on students’ attitudes toward their communities. There has been an increase in students aspiring to obtain the “Regional Revitalization Practitioner” certification, a title awarded to those who demonstrate a commitment to local problem-solving and contribution through hands-on activities. Figure 6 presents the results of a survey regarding the acquisition of this certification, conducted among fourth-year students enrolled in the Regional Collaboration Seminar. Responses were collected from 70 students, revealing that 5 students (7.1%) expressed a strong desire to obtain the certification, and 8 students (11.4%) indicated a positive intention to pursue it.

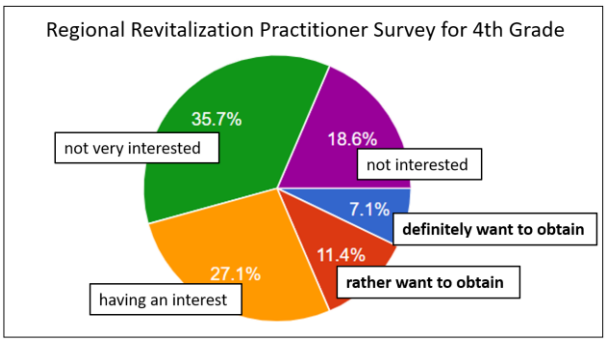


Figure 6 Regional Revitalization Practitioner Survey

4) Integration of Company Research Seminar in Kochi into Career Education

The 7th Company Research Seminar in Kochi was held on November 19, with a record-breaking

participation of 70 local companies. Starting this year, the seminar was officially recognized as part of the school's "career education" program and designated as a school-wide event. All 1st to 4th-Grade students participated (Total participants: 640) The event was redesigned to match students' career development stages, allowing each participant to envision their future through direct dialogue with representatives from regional companies (see Figure 7).

This initiative has significantly expanded opportunities for students to learn about local industries and strengthened ties between the school and the regional economy. By institutionalizing the seminar as part of career education, students are increasingly motivated to explore local career pathways and entrepreneurship.



Figure 7 The 7th Company Research Seminar in Kochi

5) Strengthening Partnerships with the Regional Collaboration Support Council

To strengthen ties with the Kochi KOSEN Regional Cooperation Association, a digital signage system was introduced. It displays information about participating local companies, their social initiatives, and their collaboration with students. 9 member companies actively participated in the program and were granted access to the school's digital signage system to promote their activities and opportunities to students (see Figure 8).



Figure 8 Installed Digital Signage system

As a result of these collaborative efforts, the number of member companies in the Regional Cooperation Council increased from 24 in FY2023 to 29 in FY2024, including 5 newly joined companies. This growth reflects the deepening relationship between the institution and local industries, as well as heightened interest in contributing to educational programs aimed at regional revitalization.

This has:

· Encouraged donations and support from partner companies.

· Enhanced student awareness of local industry activities.

· Fostered long-term, mutually beneficial partnerships.

Discussion

This initiative has not only fostered student growth but also influenced faculty perspectives and community engagement. A multi-stakeholder collaboration framework has emerged—one in which schools, students, and regional actors jointly design and implement learning experiences. Moving forward, the challenge will be to institutionalize this framework and ensure its sustainability through ongoing dialogue with local stakeholders and flexible curricular design.

Additionally, external support, including contributions from member companies of the Kochi KOSEN Regional Cooperation Association, has enabled us to introduce digital signage systems on campus. These systems promote local businesses and their collaboration with the college, thereby reinforcing the connection between students and the regional economy.

Conclusions

By offering students a progression of educational experiences—ranging from problem discovery to solution implementation—Kochi KOSEN has succeeded in promoting social implementation education that resonates with the needs of local society. The "All-Kochi" framework empowers students to engage deeply with real challenges, transforming them into motivated contributors to regional innovation. Future efforts will focus on strengthening the institutional foundation, expanding cross-sectoral collaboration, and enhancing the scalability of this model.

References

Takuo FUJITA, Motoki SATOH, Fuyuko EGUCHI, Shihoko ONAGA, Maiko MATSUURA, Harunori FUJITA, Kiyoshi ISE and Shigenori AKAMATSU (2021). Regional Collaborative Education Fosters Future-minded Engineers, *14th International Symposium on Advances in Technology Education (ISATE2021)*

ENHANCING SYLLABUS DEVELOPMENT THROUGH AI-DRIVEN ASSISTANCE

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Developing a subject syllabus is a critical component of curriculum design, yet it remains a complex and time-consuming process for academic staff. At Temasek Polytechnic, syllabus development must adhere to outcome-driven institutional standards set by the Academic Programme Validating Committee (APVC), while also incorporating feedback from multiple stakeholders. Staff often find the iterative nature of drafting, refining, and aligning syllabus components, such as subject aims, synopsis, learning outcomes, teaching methods, and assessment structures, both demanding and challenging. These difficulties are compounded by the need to ensure clarity, compliance with accreditation requirements, and adherence to educational best practices.

To address these challenges, a Generative Pre-trained Transformer (GPT) was introduced as an AI-powered assistant to support staff in syllabus drafting. The tool was designed to provide structured, template-aligned guidance and real-time feedback, helping staff produce well-structured and coherent syllabus documents more efficiently. By integrating AI into this process, the institution aimed to reduce drafting time, enhance clarity, and foster consistency across course documentation.

The implementation was carried out through APVC representatives, who facilitated the rollout and supported staff adoption of the tool. Feedback from users highlighted several key outcomes: a noticeable increase in drafting efficiency, improved clarity and consistency in subject syllabi, and enhanced staff confidence in syllabus development. The AI tool's ability to streamline the process also contributed to a more productive and less burdensome curriculum development experience.

This initiative illustrates the value of AI-driven tools in supporting higher education institutions' administrative and academic functions. Beyond saving time, the GPT tool empowers educators to focus more on content quality and less on formatting and structural concerns. Looking ahead, future iterations will explore refined feedback capabilities and expanded application to other academic documents, including course reviews and learning guides.

Overall, the integration of GPT into syllabus drafting demonstrates a practical and scalable approach to improving curriculum design through technology-enhanced academic support.

Keywords: *Pedagogical Innovation, AI in Education, Syllabus Development, Curriculum Design, Academic Standards*

Introduction

The development of subject syllabi is a cornerstone of curriculum design in higher education. At Temasek Polytechnic, this process is structured around rigorous institutional requirements, including alignment with outcome-based education (OBE) principles, accreditation and curriculum standards. Drafting syllabi entails defining subject aims, synopsis, intended learning outcomes (ILOs), learning and teaching strategies, and assessment methods—all of which must exhibit internal consistency and pedagogical coherence. However, the iterative nature of syllabus drafting, coupled with limited staff training and evolving educational standards, often renders the process burdensome. To mitigate these challenges, a GPT-based AI tool was introduced, providing real-time feedback and structured guidance in syllabus writing. This paper evaluates the tool's effectiveness and potential for broader adoption.

Syllabus Design Process

In current practice, this process is typically undertaken with limited support beyond standard templates and brief guidelines. There is minimal scaffolding provided to help staff make informed pedagogical decisions when crafting ILOs or aligning assessments.

The absence of real-time feedback mechanisms often results in prolonged back-and-forth among reviewers, further delaying finalisation.

Moreover, new or industry-based staff often experience uncertainty when interpreting educational standards, leading to inconsistent quality in early drafts. The reliance on manual vetting by academic committees adds an administrative burden and may dilute the time available for content enhancement.

Literature Review

In recent years, AI has also been increasingly integrated into curriculum design systems. Empirical studies by Kukulska-Hulme et al. (2021) have suggested that AI tools not only streamline administrative tasks but also encourage reflective practice among educators. The effectiveness of AI-supported curriculum design is particularly evident in contexts where educators are transitioning from industry roles and require scaffolding to interpret pedagogical expectations. AI interventions serve as an adaptive tool in facilitating the crafting of materials efficiently.

Furthermore, the relevance of AI in addressing misalignment in curriculum elements is echoed in research by Abbasi, Wu & Luo (2025), who argue that intelligent systems can act as mediators to bridge gaps in pedagogical coherence. They further contend that curriculum tools must be contextualised to fit specific institutional frameworks—a point highly pertinent to this study's application of GPT at Temasek Polytechnic.

The complexity of curriculum design has long been acknowledged in pedagogical literature. Harden (2001) highlighted the "spiral curriculum" as a reflective, iterative model requiring continuous revision. More recently, Biggs and Tang (2011) advanced the principle of "constructive alignment," emphasizing coherence between learning outcomes, pedagogy, and assessment.

Studies by Leask (2015) and Toohey (1999) affirm that academic staff often struggle to translate industry expertise into formalized curriculum documents. Literature underscores the importance of institutional support and capability building in curriculum writing (Barnett & Coate, 2005). Furthermore, Boud and Falchikov (2007) emphasize the necessity for continuous feedback loops during syllabus development. Yet, these processes are time-intensive and demand high cognitive engagement.

With the rise of artificial intelligence in education (AI), tools like ChatGPT and other large language models (LLMs) have shown promise in assisting educators with administrative and cognitive tasks (Zawacki-Richter et al., 2019). AI-powered writing assistants are increasingly being explored in higher education for their potential to streamline complex tasks, support formative feedback, and enhance instructional design quality (Luckin et al., 2016). However, empirical research on their application to syllabus development remains limited.

Research Methodology

This study employs a qualitative methodology to evaluate the AI GPT's implementation at TP. Data were collected through individual interviews with curriculum writers from multiple schools within the institution. In total, 18 academic staff members who engaged with the GPT tool were interviewed. Semi-structured interviews were used to gather insights into user experiences, perceived benefits, and areas for enhancement.

Artefacts generated during the GPT usage—such as annotated syllabi drafts, feedback loops, and revision histories—were also analysed to triangulate findings. A simple thematic analysis (Braun & Clarke, 2013) was employed to identify recurring patterns in user feedback and to infer implications for curriculum design support.

Development of the AI-Enabled Tool

The GPT tool was tailored using multiple institutional and pedagogical resources. This includes:

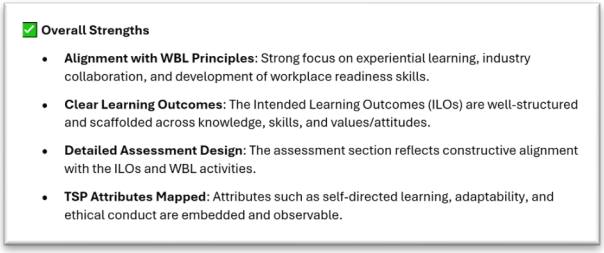
- Temasek Polytechnic's official curriculum writing guidelines
- Bloom's Taxonomy, including verb lists for ILO articulation
- Syllabi and course overview templates
- School-specific curriculum guidelines, instructional strategies and assessment philosophies

The tool was designed to function interactively, whereby users input draft content, and the AI provides suggestions, flags inconsistencies, and recommends improvements. These may include rewriting ILOs, suggesting alternative assessment methods, and/or learning and teaching strategies or ensuring alignment between learning strategies and subject outcomes.

Findings and Analysis

Benefits Identified by Users

Feedback from interviewees highlighted a strong appreciation for the AI tool in supporting the syllabus writing process. Drafting a syllabus independently, especially without comprehensive knowledge of academic conventions, has traditionally been a challenging task for many staff. The GPT tool alleviates this burden by offering immediate, structured feedback on early drafts. This enables staff to consider revisions that align both with academic standards and industry relevance, an area in which they possess strong familiarity. Key benefits reported by interviewees are summarised and discussed below.


✅ **Overall Strengths**

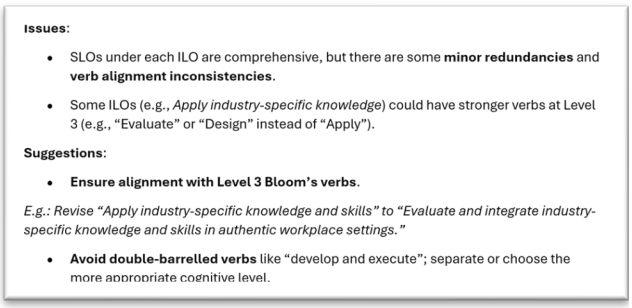
- **Alignment with WBL Principles**: Strong focus on experiential learning, industry collaboration, and development of workplace readiness skills.
- **Clear Learning Outcomes**: The Intended Learning Outcomes (ILOs) are well-structured and scaffolded across knowledge, skills, and values/attitudes.
- **Detailed Assessment Design**: The assessment section reflects constructive alignment with the ILOs and WBL activities.
- **TSP Attributes Mapped**: Attributes such as self-directed learning, adaptability, and ethical conduct are embedded and observable.

Figure 1 – A sample GPT response highlighting the strengths

Efficiency Gains:

The GPT tool substantially reduced the time required for drafting and revising syllabi. Staff who previously

needed weeks to complete initial drafts reported doing so within a matter of days. Industry-informed content in early drafts was efficiently adapted to meet the academic and curriculum standards of the School and Institution. A key point of reassurance expressed by interviewees was the immediate feedback provided by the tool, which helped guide meaningful enhancements to their syllabus drafts as shown as a sample in Figure 2 below.



Issues:

- SLOs under each ILO are comprehensive, but there are some **minor redundancies** and **verb alignment inconsistencies**.
- Some ILOs (e.g., *Apply industry-specific knowledge*) could have stronger verbs at Level 3 (e.g., "Evaluate" or "Design" instead of "Apply").

Suggestions:

- **Ensure alignment with Level 3 Bloom's verbs**.

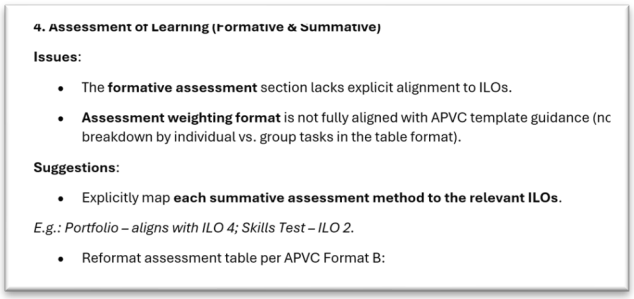
E.g.: Revise "Apply industry-specific knowledge and skills" to "Evaluate and integrate industry-specific knowledge and skills in authentic workplace settings."

- **Avoid double-barrelled verbs** like "develop and execute"; separate or choose the more appropriate cognitive level.

Figure 2 – Suggested changes to SLOs and educating on principles of verb usage in accordance with guidelines.

Improved Constructive Alignment:

The GPT tool supported the logical alignment of subject aims, intended learning outcomes (ILOs), teaching strategies, and assessments—an essential aspect of syllabus coherence. A sample of this is shown in Figure 3 below. Previously, achieving such coherence required multiple iterative revisions. With the GPT, feedback on constructive alignment is provided promptly, allowing for more cohesive drafts from the outset. As a result, syllabus documents submitted for stakeholder review now demonstrate greater internal consistency and align more closely with the institution's quality expectations



4. Assessment of Learning (Formative & Summative)

Issues:

- The **formative assessment** section lacks explicit alignment to ILOs.
- **Assessment weighting format** is not fully aligned with APVC template guidance (nc breakdown by individual vs. group tasks in the table format).

Suggestions:

- Explicitly map **each summative assessment method to the relevant ILOs**.

E.g.: Portfolio – aligns with ILO 4; Skills Test – ILO 2.

- Reformat assessment table per APVC Format B:

Figure 3 – Constructive alignment being emphasised and reference to institutional standards

Clarity and Language Quality:

Previously, repeated reviews and drafting cycles often led to fatigue, which affected grammatical accuracy and clarity in syllabus documents. The GPT tool mitigated this issue by providing feedback that enhanced both grammatical precision and sentence structure. This resulted in higher-quality drafts and was identified as a notable benefit by users of the tool.

Staff Confidence:

Writers reported increased confidence in sharing their drafts with peers and stakeholders after refining them using the GPT tool. There was assurance that foundational elements—such as alignment across key components of the syllabus—had been adequately addressed. This enabled subsequent discussions to focus more meaningfully on curriculum scope, academic level, and the integration of relevant content from diverse stakeholder perspectives. Such constructive exchanges are now facilitated by the improved quality of syllabus drafts

Areas for Improvement

Despite the positive feedback, several areas for improvement in the GPT tool were identified. These will be discussed in the following section.

School-Specific Customisation:

As reflected in Abbasi, Wu & Luo (2025) there is a need to contextualise the guidelines for the desired curriculum, learning and teaching methods and assessment in accordance to the respective School's needs. The tool requires further refinement to accommodate the varied practices and pedagogical priorities across different Schools. Given the distinct guidelines and requirements set by each School, there is a clear need to customise the tool's inputs to reflect both school-specific and institutional standards.

Revision Integration:

The current version of the GPT tool offers feedback and suggests changes for various components of the syllabus. However, users expressed a desire for an integrated re-drafting feature that could iteratively refine the syllabus based on accepted revisions.

Discussion

The GPT-based syllabus writing tool bridges an important capability gap in curriculum design. While institutional guidelines provide foundational training, many staff, especially those from industry backgrounds, lack the pedagogical expertise to articulate outcomes and assessments effectively. The tool supports novice and experienced writers alike by automating checks, providing feedback, and encouraging best practices in educational design.

The integration of AI in syllabus development also redefines the curriculum writer's role. Rather than acting as sole authors, staff become collaborators with intelligent systems. This transformation aligns with the broader shift toward AI-supported work environments, where human–AI collaboration enhances productivity and quality (Holmes et al., 2022).

Conclusion and Recommendations

This paper demonstrates how AI-driven tools like GPT can significantly enhance the syllabus development

process in higher education. At Temasek Polytechnic, the tool has improved efficiency, increased staff confidence, and fostered better alignment in curriculum documentation. To maximise its impact, future efforts should focus on:

- Refining AI models to reflect school-specific pedagogical philosophies
- Integrating drafting and feedback cycles more seamlessly
- Expanding AI support to other academic writing domains (e.g., lesson plans, assessment blueprints)

As curriculum design becomes increasingly complex, AI tools offer scalable, intelligent support mechanisms to uphold educational quality and innovation.

References

Abbasi, B. N., Wu, Y., & Luo, Z. (2025). Exploring the impact of artificial intelligence on curriculum development in global higher education institutions. *Education and Information Technologies, 30*(1), 547–581.

Barnett, R., & Coate, K. (2005). *Engaging the curriculum in higher education*. McGraw-Hill Education.

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). Open University Press.

Boud, D., & Falchikov, N. (2007). *Rethinking assessment in higher education: Learning for the longer term*. Routledge.

Braun, V., & Clarke, V. (2013). *Successful qualitative research.* London, England: SAGE Publications Ltd.

Harden, R. M. (2001). AMEE Guide No. 21: Curriculum mapping: A tool for transparent and authentic teaching and learning. *Medical Teacher*, 23(2), 123–137.

Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.

Kukulska-Hulme, A., Bossu, C., Coughlan, T., Ferguson, R., FitzGerald, E., Gaved, M., Herodotou, C., Rienties, B., Sargent, J., Scanlon, E., Tang, J., Wang, Q., Whitelock, D., Zhang, S. (2021). Innovating Pedagogy 2021: Open University Innovation Report 9. Milton Keynes: The Open University.

Leask, B. (2015). *Internationalizing the curriculum*. Routledge.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed: An Argument for AI in Education.* Pearson Education.

Toohey, S. (1999). *Designing courses for higher education*. Open University Press.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, 16(1), 1–27.

DESIGN AND IMPLEMENTATION OF A HYDROGEN ENERGY ENGINEER EDUCATION PROGRAM UTILIZING FIELDWORK IN MIE PREFECTURE

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In Japan, the world's first national strategy for hydrogen, the Basic Hydrogen Strategy, was formulated in 2017, and research and development efforts have been undertaken to realize a hydrogen society. However, challenges such as insufficient hydrogen infrastructure, the high cost of hydrogen fuel, and a shortage of professionals specialized in high-pressure gas safety remain significant obstacles. To address these challenges, fostering public understanding of a hydrogen society is essential. While awareness of hydrogen has been increasing, interest in hydrogen as a future energy source remains low.

This study implements a hydrogen education program for second-year KOSEN students to foster the advancement of social infrastructure for a hydrogen-based society. The program includes specialized lectures on hydrogen-related topics delivered by KOSEN faculty members, along with site visits to observe local initiatives promoting carbon neutrality and hydrogen energy. Building on this knowledge, students create educational materials for elementary school students and conduct outreach lectures to enhance public understanding of hydrogen energy.

First, fieldwork was conducted at the Suzuka Circuit to explore carbon neutrality initiatives. Formula 1 has announced a plan to achieve net-zero carbon emissions by 2030, and various efforts are underway to realize this goal. During their visit, the students toured the Suzuka Circuit facilities and deepened their understanding of carbon neutrality through direct discussions with engineers. Next, they conducted fieldwork at a mobile hydrogen station, where they learned about the challenges of operating a hydrogen station, the human resources needed to promote a hydrogen society, and the importance of encouraging hydrogen utilization. Additionally, they attended specialized lectures on hydrogen technology given by a faculty member engaged in hydrogen research at the National Institute of Technology. Through these lectures, students gained insights into the challenges associated with "producing," "transporting," and "storing" hydrogen, the necessity of building a supply chain for a hydrogen society, and the technological research challenges related to hydrogen infrastructure.

Based on the knowledge they learned, the students deepened their understanding of hydrogen energy by giving delivery classes. The students were provided with opportunities to deepen their understanding of hydrogen energy through both instruction and hands-on experience, including explanations of basic concepts of hydrogen energy and a hands-on class using a hydrogen rocket learning kit.

Keywords: Realization of hydrogen society, STEAM education, Practical education, Engineering education, PBL

Introduction

Hydrogen has been receiving increasing attention as an environmentally friendly energy source. Since hydrogen does not emit CO_2 during combustion, it does not contribute to global warming. In 2017, the Japanese government formulated the world's first national strategy, the Basic Hydrogen Strategy, to promote the utilization of hydrogen. This strategy was revised in 2023, setting a target of introducing 12 million tons of hydrogen annually by 2040.

However, progress toward establishing a hydrogen-based society has been hindered by the high costs associated with hydrogen infrastructure. In order to support governmental policies and corporate initiatives aimed at promoting hydrogen utilization, it is essential to enhance public understanding of hydrogen energy. Moreover, the successful realization of a hydrogen society depends on the widespread public acceptance of hydrogen as a viable energy source. From this standpoint, the importance of educational programs that provide experiential learning opportunities and foster a deeper understanding of hydrogen energy has been increasingly emphasized. Concurrently, Japan's education sector has been actively promoting Project-Based Learning (PBL),

which encourages students to engage in solving real-world social issues through interdisciplinary approaches.

In this educational research, a project was implemented within the second-year course Design Fundamentals at the National Institute of Technology, Suzuka College in which three students were assigned to develop hydrogen energy learning materials intended for use at local community events.

Program Design and Implementation

This study was carried out through the following six steps:

1. Students engaged in fieldwork to learn about efforts toward realizing a hydrogen-based society.
2. Students attended a lecture delivered by a subject-matter expert.
3. Students gave a poster presentation on what they had learned.
4. Students developed educational materials to facilitate learning about hydrogen energy.
5. Students organized a public workshop.
6. A presentation venue was arranged to exhibit the outcomes of their activities.

1. Students learned about efforts toward realizing a hydrogen society through fieldwork.

The objective of the fieldwork was to help students understand the functioning of hydrogen energy systems and the broader societal initiatives aimed at addressing global warming, including carbon neutrality. This experience served to enhance their motivation for the project and to provide them with foundational knowledge.

1.1 Fieldwork at Suzuka Circuit

In the motorsports industry, environmental sustainability has become an urgent concern, and automakers are actively working toward carbon neutrality, including by entering vehicles equipped with hydrogen-powered engines. On September 28, 2024, fieldwork was conducted at Suzuka Circuit as shown in Figure 1. A wide range of vehicles participated in the Super Taikyu race held at the venue, from those with conventional engines to those using carbon-free powertrains. Learning about each company's initiatives in this competitive and experimental racing environment provided students with a valuable opportunity to gain deeper technological insight and develop the mindset needed to forge their own paths toward the future.



Figure 1. Students observing carbon-neutral initiatives during a field visit to the Suzuka Circuit.

First, the students visited the racing gallery at Suzuka Circuit, where they observed various machines and engines and learned about the technological evolution over time.

Next, they toured the Formula 1 pit area to view the vehicles participating in the race and received explanations from engineers regarding the objectives and mechanics of the race, as well as the challenges involved in enhancing the environmental performance of race cars.

Finally, they engaged in a discussion with a former Suzuka Circuit official and learned about ongoing initiatives aimed at achieving carbon neutrality in Formula 1 racing.

1.2 Observation of a Mobile Hydrogen Station

On November 5, 2024, the students visited a mobile hydrogen station. One of the key challenges in realizing a hydrogen-based society is the slow progress in the deployment of hydrogen infrastructure. Through this fieldwork, the students gained insights into the technical and societal issues associated with building such infrastructure. It is estimated that between 1,000 and 2,000 hydrogen refueling stations will be required nationwide to support the realization of a full-scale hydrogen society. At present, however, only about 30 mobile hydrogen stations exist across Japan, and these are expected to be gradually replaced by permanent facilities in the coming years.

Figure 2 shows the students' visit to the Mobile Hydrogen Station. During the visit, the station staff explained that there are legal regulations governing the allowable amount of hydrogen storage, that the service life of compressed hydrogen fuel containers used in fuel cell vehicles is 15 years, and that it costs approximately 15 million yen to dispose of two such containers. Through this experience, the students gained a clearer understanding of the practical challenges associated with hydrogen infrastructure, which helped them develop a greater awareness of the specific issues that must be addressed in realizing a hydrogen society.



Figure 2. Fieldwork visit to a mobile hydrogen station.

2. Students Attended a Lecture by an Expert

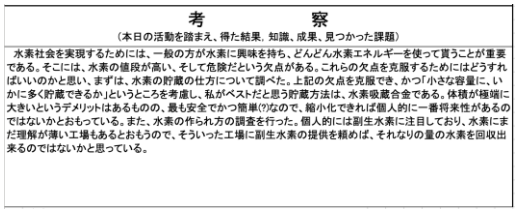
On October 11, 2024, a specialized lecture on hydrogen energy was delivered by Associate Professor Nishiguchi from the National Institute of Technology, Sasebo College. The lecture covered technologies related to hydrogen production and utilization, as well as current technical challenges in the field.

Figure 3 shows the students attending the lecture. The students learned about various methods of hydrogen storage, including metal hydrides, compressed hydrogen gas, ammonia, liquid hydrogen, and toluene. They also gained deeper insights into hydrogen embrittlement, which is Associate Professor Nishiguchi's area of expertise. In the domain of hydrogen production, the lecture addressed multiple sources such as renewable energy, by-product hydrogen, and fossil fuels. With respect to hydrogen applications, students studied its use in fuel cell vehicles and hydrogen engines, as well as its potential role as an emergency power source. In addition, advanced topics were discussed, including the importance of financing and other key elements required to build a hydrogen supply chain.

Figure 4 shows a student's project report. As part of this educational program, students submitted short reports after each session. These reports served both as a means for students to consolidate their understanding and as a tool for instructors to track their learning progress. The student developed a strong interest in metal hydrides and explored the possibility that this method could be one of the most effective approaches for hydrogen storage. In the report, the student examined both the advantages and potential challenges of the method, with a particular focus on its future applicability.



Figure 3. Students attending the lecture delivered by Associate Professor Nishiguchi.



考　　察

（本日の活動を踏まえ、得た結果、知識、成果、見つかった課題）

水素社会を実現するためには、一般の方が水素に興味を持ち、どんどん水素エネルギーを使って貰うことが重要である。そこには、水素の値段が高い、そして危険だという欠点がある。これらの欠点を克服するためにはどうすればいいのかと思い、まずは、水素の貯蔵の仕方について調べた。上記の欠点を克服でき、かつ「小さな容量に、いかに多く貯蔵できるか」というところを考慮し、私がベストだと思う貯蔵方法は、水素吸蔵合金である。体積が極端に大きいというデメリットはあるものの、最も安全でかつ簡単(?)なので、縮小化できれば個人的に一番将来性があるのではないかとおもっている。また、水素の作られ方の調査を行った。個人的には副生水素に注目しており、水素にまだ理解が薄い工場もあるとおもうので、そういった工場に副生水素の提供を頼めば、それなりの量の水素を回収出来るのではないかと思っている。

Figure 4. A report written by a student as part of the learning project.

3. Students Presented Their Learning in a Poster Session

On November 1, 2024, the students gave a poster presentation at the KOSEN Hydrogen Forum 2024 held in Kurume. The presentation was based on the content covered during the learning activities conducted in October 2024. In preparing the presentation materials, the students reflected on their prior learning and summarized the key points. Figure 5 shows a portion of the poster they created. The presentation process provided a valuable opportunity for the students to organize and consolidate their understanding of the topics studied.



Figure 5. A portion of the poster created by the students.

4. Students Created Teaching Materials to Help Others Learn About Hydrogen Energy

As a culmination of their learning, the students began developing educational materials on hydrogen energy targeted at elementary school students. Figure 6 shows a slide created by the students to explain the differences between fossil fuels and hydrogen fuel.

They considered how to explain the principles of hydrogen-based power generation, the reasons why hydrogen energy is attracting attention, and how to effectively demonstrate its real-world applications.

Figure 7 shows an instruction manual created by the students for operating this kit. Subsequently, the students focused on a commercially available hydrogen rocket learning kit. This kit enables hydrogen generation using a hand-powered generator and launches a small rocket by igniting the produced hydrogen.

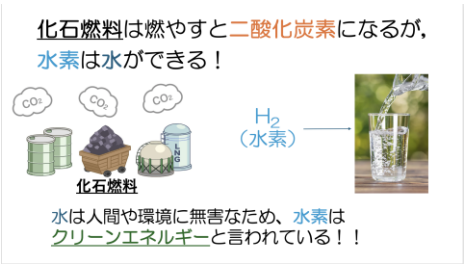


Figure 6. A slide created by the students to illustrate the differences between fossil fuels and hydrogen fuel.

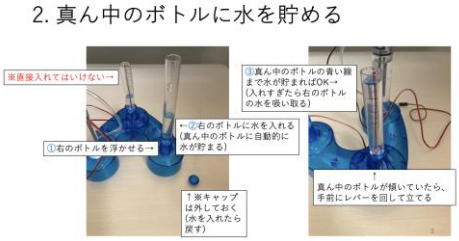


Figure 7. An instruction manual created by the students for operating a hydrogen rocket learning kit.

5. Students Conducted a Public Workshop

In March 2025, the students conducted a public workshop for elementary school students using the educational materials they had developed. The target participants were sixth-grade students, and the college students assumed the role of instructors. Figure 8 shows a poster created to promote the workshop. During the session, the students explained the utilization of hydrogen energy and carried out a hands-on

demonstration by launching a hydrogen-powered rocket as a tangible example of its application.

Figure 9 shows elementary school students engaging with the hydrogen rocket activity. The participating students were able to enjoyably learn that hydrogen can be applied in practical ways.



Figure 8. A promotional poster created to advertise the workshop.



Figure 9. Elementary school students engaging with the hydrogen rocket activity.

6. A Presentation Venue Was Arranged to Exhibit the Outcomes of Their Activities

To broadly disseminate the outcomes of these student-led activities to the public, a presentation venue was organized. An exhibition booth utilizing hydrogen rockets as educational tools is scheduled to be featured at Super Formula Rd11–12 in Suzuka on November 11–12, 2025. The target audience is the general public, with the aim of raising awareness of and interest in hydrogen energy across a wide demographic. Figure 10 shows the announcement of the Suzuka Circuit event distributed to technical colleges across Japan.



Figure 10. A promotional announcement for the upcoming Suzuka Circuit event featuring the hydrogen energy outreach booth.

Results and Discussion

The program enhanced students' understanding of hydrogen energy through fieldwork, expert lectures, and hands-on activities. At the KOSEN Hydrogen Forum, students effectively presented key concepts such as hydrogen production and storage. In the public workshop, elementary school participants responded positively to the hydrogen rocket activity, indicating the materials were engaging and accessible. The scheduled exhibition at Super Formula further demonstrates the outreach potential of student-led initiatives.

While the educational kit effectively demonstrated the process of generating hydrogen from water and utilizing it as an energy source through combustion, it did not explore the conversion of hydrogen into electrical energy. In the future, to expand hydrogen education more broadly, it will be necessary to develop additional teaching materials that take into account cost and safety considerations.

Conclusions

This study implemented a PBL-based hydrogen education program that effectively integrated technical learning with community outreach. Through real-world activities, students not only deepened their understanding of hydrogen energy but also developed essential communication skills. The program was uniquely designed by aligning the social challenges of hydrogen energy and motorsports with the regional characteristics of Suzuka City in Mie Prefecture. Given that the development and utilization of hydrogen infrastructure remain limited on a national scale, there is a pressing need to cultivate an educational foundation that supports the widespread implementation of fieldwork-based learning. By capitalizing on the scale and collaborative network of KOSEN institutions and partnering with companies and local governments engaged in hydrogen-related initiatives across Japan, the fieldwork component of this program could be further expanded. Such efforts would enhance the program's transferability and promote its adoption in diverse educational contexts.

The results suggest that programs of this kind can play a vital role in fostering future engineers and raising public awareness of hydrogen energy on a broader scale.

Acknowledgements

We would like to express our sincere gratitude to Mr. Yamaji for guiding us through the mobile hydrogen station.

References

Ministerial Council on Renewable Energy, Hydrogen and Related Issues(2023). Basic Hydrogen Strategy.

The High Pressure Gas Safety Institute of Japan (2022). *Review of Regulatory Frameworks under the High Pressure Gas Safety Act and the Road Transport Vehicle Act Pertaining to Fuel Cell Vehicles and Related Applications, and Future Policy Considerations.*

PROMOTING MULTICULTURAL UNDERSTANDING AND GLOBAL EXCHANGE USING CALL IN EFL CLASSES AND CLUB ACTIVITIES AT A RURAL KOSEN COLLEGE

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Since the end of the COVID-19 pandemic, the return to in-person international exchange programs has been unexpectedly slower than it was before 2020. Although the interest remains for highly motivated students, taking the first step in participating in overseas study abroad programs remain the hardest to take for rural National Institute of Technology (henceforth referred to as Kosen) students. In this study, we observe English as a Foreign Language (EFL) Classes taught using computer-assisted language learning (CALL), as well as members in an after-school club activity which aims at fostering students in learning more about other cultures and languages. It is also observed if the intrinsic motivations of these participating students can be pushed into a more proactive participation in overseas study abroad programs, as well as learning more about and understanding foreign cultures, even if on their own free time. In the EFL classes, high school level students (aged 15 to 18) were tasked with presenting in groups as a major task of their annual syllabus. First year students had to introduce Japanese culture to first time visiting foreigners to Japan in English, second year students created their own short movies, with scripts that were completely written originally by the members, and third year students were tasked with creating promotional tourism videos of various locations and attractions of their prefecture. Whereas in the international club, exchange students and foreign-born professors and staff taught about their home country, culture and language, where not only club members were invited to participate, but also students who were not part of the club but were still interested and wanted to attend. It was seen that student membership in the club increased as part of these activities, but there was no connection seen to increases in participation in overseas programs. Students responded to surveys based on their class and club activities, as well as those who participated in exchange programs. Some positives mentioned were that students were able to learn and experience different cultures from the comfort of their own school campus. However, one source of concern that will be discussed is the contents and context of currently organized study abroad programs, and how they do not always necessarily reflect the needs, goals, and points of interest in their programs to attract motivated students. Discussion about ideal study abroad programming based on students' perspectives and from previous research will also be reviewed.

Keywords: *multicultural understanding, global exchange, student motivation, computer-assisted language learning (CALL), English as a Foreign Language (EFL)*

Introduction

Before the start of the COVID-19 pandemic, the push for international exchange in Japan was increased with likely correlation to the incoming Tokyo Olympic and Paralympic games. However, with border closures quickly becoming commonplace around the world, the future of many students who were planning on studying abroad had disintegrated in front of their eyes, with no concrete prediction of when it would again be possible.

While the world switched to online and distance learning to keep up with the times, it was hard at first to find ways to relate this international exchange. As easy as it is to communicate to anywhere in the world in the internet age, the analogue concept of having to physically go abroad to experience things in person as being the be all end all was hard to shake off at first.

In retrospect, the concept of these online exchange programs was discussed before the pandemic hit, such as the discussion of 'virtual exchanges' brought forward by O'Dowd (2019) in their research. Collaborative online pedagogical projects done in and out of real time with cooperating institutions in foreign language learning showed promise, but also some limitations. The predicted future outcomes did come true during the pandemic, and some were even attempted in this study as well.

The subjects of this study were all National Institute of Technology (henceforth referred to as Kosen) students, which is a polytechnic adjacent kind of educational institution unique to Japan, in which students aged 15 to 20, and sometimes to 22 if they choose to stay and complete their respective advanced course, study various fields of engineering with the goal of being future global engineers, able to use their unique educational background and communicative competence to work and help others anywhere around the world.

Methods and Pedagogy

The students in question were observed in two kinds of situations. The first was as part of their mandatory English communication classes – 90-minute classes once a week for 15 weeks in the first and second terms. Students are divided by their field of engineering, which in this case were 4; mechanical, electric and electronic, computer, as well as civil and environmental engineering. There was no division by level or linguistic ability in these classes. Some students were confident in their English abilities, others had studied abroad before, and some also disliked learning the language or about other cultures entirely. They were marked across various assignments, like presentations, to receive credits.

The mandatory classes observed were first through third year students, all having a major summative presentation assignment as a significant (20% or more) portion of their final marks. First year classes had to present on an aspect of Japanese culture they want visiting foreign tourists to know more about before or when they arrive. Next, second year classes were tasked with creating an original short film, including a script from scratch and having to record and edit the final product themselves, based on a unit in the textbook that could be used as supplementary material in future years.



Figure 1, A unit of the textbook which students would base off for their original storied video presentations

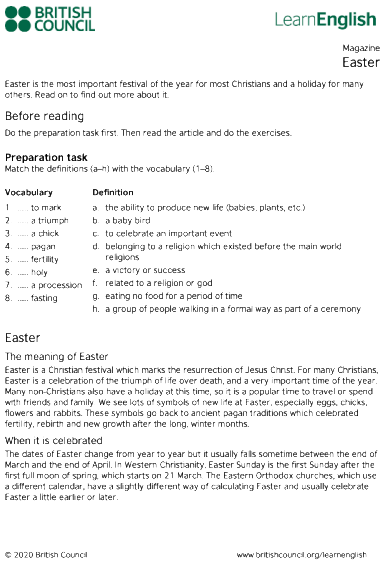
Finally, third year students (the newest addition to the current mandatory communication English classes) were tasked with presenting local tourism videos, based on their unique perspectives of youth brought up in the prefecture, targeting the increased number of inbound visitors to the prefecture post pandemic.



Figure 2, third-year students gathering to watch their finalized original local tourism videos made in English

Each grade of students was then asked to fill out a survey anonymously at the end of the school year to observe their rates of satisfaction with the presentation projects, their sources of satisfaction and concern, as well as reflections on how it may have potentially changed their perspectives of this unique kind of global promotion from a local scale.

The second group of observed students was made of members of the international club of the Kosen college. The club was formerly known as the English club, which focused mostly on English language activities, and participating in speech and presentation contests. However, over the years, the club members showed more interest in other languages and cultures other than just English, and thus the club was re-named to the international club, and the activities expanded to learn many other languages and cultures, including English.


BRITISH COUNCIL LearnEnglish

Magazine
Easter

Easter is the most important festival of the year for most Christians and a holiday for many others. Read on to find out more about it.

Before reading

Do the preparation task first. Then read the article and do the exercises.

Preparation task

Match the definitions (a–h) with the vocabulary (1–8).

Vocabulary	Definition
1 ..... to mark	a. the ability to produce new life (babies, plants, etc.)
2 ..... a triumph	b. a baby bird
3 ..... a chick	c. to celebrate an important event
4 ..... pagan	d. belonging to a religion which existed before the main world religions
5 ..... fertility	e. a victory or success
6 ..... holy	f. related to a religion or god
7 ..... a procession	g. eating no food for a period of time
8 ..... fasting	h. a group of people walking in a formal way as part of a ceremony

Easter

The meaning of Easter

Easter is a Christian festival which marks the resurrection of Jesus Christ. For many Christians, Easter is a celebration of the triumph of life over death, and a very important time of the year. Many non-Christians also have a holiday at this time, so it is a popular time to travel or spend with friends and family. We see lots of symbols of new life at Easter, especially eggs, chicks, flowers and rabbits. These symbols go back to ancient pagan traditions which celebrated fertility, rebirth and new growth after the long, winter months.

When it is celebrated

The dates of Easter change from year to year but it usually falls sometime between the end of March and the end of April. In Western Christianity, Easter Sunday is the first Sunday after the first full moon of spring, which starts on 21 March. The Eastern Orthodox churches, which use a different calendar, have a slightly different way of calculating Faster and usually celebrate Faster a little earlier or later.

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Figure 3, An example of a cultural learning mini lesson in English about Easter as an international club activity

These students were more highly motivated than the average of those in the mandatory communication classes and had shown previous interest in studying abroad as well. Unfortunately, a cohort meant to study abroad to New Zealand was cancelled just days before the planned departure due to border closures from both countries at the very start of the pandemic, so there was clear frustration and disappointment for those who has paid for and planned to go, but had their dreams shot down by something that was unpredictable at that time.

However, despite the pandemic keeping these students at home, and later domestically, there was interest shown by a previous collaborative institute of higher education in the United States, that suggested participating in online exchange activities to make up for the lack of being able to visit in person like they would have before. A previous study by Hiroike & Yokomizo (2022) about using Flipgrid, at the time also known as

Flip, detailed their original program of online exchange with students at an American university that was incorporated into one of their lessons, in which students were regularly tasked with short video message-like presentations that would act as international exchange between the physically far distanced students, and making them interact like friends by cross-posting as well as interacting with the posts of others as well.

This activity was mimicked as the first main endeavour for the international club students at this Kosen college with the previously in-person interacted university. Conveniently, the partner institution had previous experience in such exchange using Flip, so each month, students were tasked with posting on a specific topic – from self-introductions and general small talk, to slowly but surely progressing to more detailed and increasingly difficult topics, such as describing their hobbies one month, and then the next going into detail about the historical significance of their local festivals.

As part of this video exchange activity, students were tasked to post once a month, and to comment on three other posts from the partner institution as part of their monthly exchange activity. Participation was not mandatory for all members, but most members did show interest when first hearing of this new kind of activity.

At the end of each semester, international club students who had participated, and those who chose to refrain from the online international exchange, were surveyed about their perceptions and satisfaction of this kind of activity, and if they found it to be a valuable option (or temporary substitute) of studying abroad.

Results and Discussion

First, to begin with the presentations tasked in CALL based EFL classes, the student satisfaction rate was high across all grades, which was reassuring due to their varying levels of English abilities, and the lack of previous experience in somewhat formally presenting in English to an audience of their peers for most of the first-year students. Some of the students mentioned that having the topic about introducing Japanese culture let them choose a topic they were familiar with, which made them feel more at ease presenting, but also that they learned more about the specifics of their chosen topic by researching it in more detail, as opposed to just going off of common knowledge and practice in their daily lives.

Table 1, Results of student satisfaction surveys regarding their designated presentation task and theme

	1st year	2nd year	3rd year
Very satisfied	73%	81%	13%
Satisfied	12%	14%	60%
No strong opinion	9%	4%	11%
Unsatisfied	6%	1%	8%
Very unsatisfied	0%	0%	8%

Overall, all years had over 70% satisfaction rate (‘satisfied’ and ‘very satisfied’ combined) which reassured the validity of the task assigned. Some of the students mentioned in their anonymous free feedback that they ‘wished they would be able to do an in-person information session for new visitors’ based on their presentations and wanted to ‘show’ their presentation to ‘athletes that are staying in the Tokyo 2020 athletes village, so they can experience local Japanese culture even under lockdown’.

Second year students tasked with the originally scripted short movies had their highest levels of satisfaction, likely due to the freedom of creativity of their final products. Even if they were marked on a specific criterion in their rubric, detailed in Figure 4, the comments in the free feedback showed that the biggest struggle was with the actual editing and finishing the video, as they had not previously done tasks like these before in any of their other classes.

	FAIL (1)	POOR (2)	OK (3)	GOOD (4)	GREAT (5)
SPEECH MESSAGE					
Was the English fluent?					
Was the speaking natural?					
Was the vocabulary correct?					
PHYSICAL MESSAGE					
Was the student confident?					
Was the acting believable?					
Did the script seem real?					
VISUAL MESSAGE					
How was the video quality?					
Were the subtitles correct?					
Were non-talk scenes valid?					
SUITABILITY					
Did the content follow unit's?					
Was the teamwork balanced?					
Is it appropriate for class?					

FEEDBACK	/ 20

TEAM NAME _____ TEAM MEMBERS _____

Figure 4, Rubric for the second-year video presentation

Finally, the third-year students tasked with local promotional tourism videos showed the lowest level of satisfaction, even if it totaled at 73%. One of these discrepancies are thought to include it being the first time the students were given this kind of task and not having their school seniors be able to give advice or suggestions on how to succeed in the task, like previous years.

Figure 5, QR code to see the top 8 local tourism videos produced by the third-year students as voted on by peers

However, even with having the lowest rate of satisfaction from the students, the feedback was the most reassuring of its validity in global exchange from a local perspective, including one group of students commenting ‘We were not sure what kind of higher-level of

presentation we would have to do in our third year after the short movies we did last year, but doing local tourism videos seemed like a natural step from last year'. Another group of commented that 'Being able to talk about local spots that only we know as youth, as opposed to the often overly focused standard tourist traps, made it feel like our voices were actually being heard to people overseas'.

Regarding the international club activities, the number of active members almost doubled during the pandemic, with a portion of the members participating in post-COVID study abroad programs, but there was no significant correlation found to the rate of total participants in the in-person programs to those of students being active members of the international club. In fact, some students mentioned greater dissatisfaction than non-club member participants, stating their 'expectations were probably too high for the study abroad program', showing a unique paradoxical situation that may jeopardize the status of the international club.

As for the participation in monthly online Flip-based video interactions, the club started off strong but then decreased their proactivity very quickly with some students choosing to keep masks on during their videos, or just not showing their faces at all in their videos. The more students would shy away from exposing themselves even to the restricted online group (purposely made so that people without the link could not see their videos for privacy reasons), the more their peers would follow suit.

This is likely due to cultural differences in the Japanese and American students, who have unique perceptions in their online presence. The American students would often be very outgoing and show a lot more of themselves, whereas international club students tended to be shier and more reserved, including in their video responses to each other. Written comments did not show much difference however, which was somewhat reassuring, but also showed that the visual aspect of showing their faces online still is a big hurdle for Kosen students, especially voluntarily, unlike in the study the activity was based on (Hiroike & Yokomizo, 2022).

Conclusions

The presentation tasks given to students in their mandatory English communication classes has a high level of satisfaction, and also student feedback reassuring that they were able to promote their local Japanese culture (especially for first years), and also give back to their communities by promoting local tourism hot spots in their newly designated third-year presentation task. The full details of the third-year local tourism presentation activity and feedback of the project as a whole will be published at a later date this academic year.

It can thus be concluded that regardless of students having varying levels of English and confidence in their skills, students appreciate having an outlet to express themselves and their culture through presentations, even if mandatory and marked on as part of their course. These unique presentation ideas will now further be promoted to the international club, to hopefully give students a greater creative outlet to create newer annd more uinque presentations, detailing their areas of interest more fully.

However, what was expected to be a great interactive activity for the perceived higher motivated international club students, did not necessarily reflect their genuine interests. Even if they were given an outlet to meet, mix and mingle with peers their own age and with similar interests from around the world, the interpersonal communication was still a barrier for the club students.

The concept of simultaneous, real-time interaction can especially be considered effective in reducing the communication barriers Japanese KOSEN students feel due to prevention of over-preparation that is often seen as a barrier for speaking. Students often show confidence only if they thoroughly prepare and memorize a script translated from Japanese, but simultaneous interaction is a more realistic and spontaneous skill-based output task.

Although domestically, it is often considered that interpersonal communication with strangers for Japanese students is a hurdle, it can be greater for Kosen students, who are often quite shy to begin with. One suggestion could be simultaneous interactions in real time, instead of having to record videos of themselves talking and then posting it onnline and waiting nervously for a response. The only barrier to real-time interaction would be time zones, with which the collaborative American institution being a full 13 to 14 hours difference with Japan.

Perhaps geographically closer locations, such as those in southeast Asia would be seen as a more practical area, also with similar cultural understanding and standards, which may lead to more openness in communication between the international student body.

Acknowledgements

The researched would like to acknowledge and thank the other institutions around the globe that agreed to collaborate in these experimental online exchange efforts over the past few years, even in keeping their anonymity.

References

Hiroike, S. & Yokomizo, H. (2023). Online International Exchanges with Flipgrid. *Journal of JSEE, 71*(1), 62-65.

Lee, J., Leibowitz, J. & Rezek, J. (2021) The Impact of International Virtual Exchange on Participation in Education Abroad. *Journal of Studies in International Education, 26*(2), 202-221.

O'Dowd, R. (2020). A transnational model of virtual exchange for global citizenship education. *Language Teaching, 53*(4), 477-490.

Swanson, N. W., & Duncan, N. T. Understanding the "new normal": The internationalization of education and study abroad during the COVID-19 era. *Susan Bulkeley Butler Center for Leadership Excellence and ADVANCE Purdue Center for Faculty Success Working Paper Series, 4*(1), 33-55.

Ziemba, T. (2016). Ideal processes for studying abroad: An ethnographic approach. *Memoirs of National Institute of Technology, Oita College, 53*, 11-16.

WHAT DO PHYSICAL EDUCATION TEACHERS IN KOSEN TEACH IN HEALTH AND PHISICAL EDUCATION CLASSES? [A review of the relevance of the model core curriculum based on previous research]

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Abstract

In 2017, the National Institute of Technology established the Model Core Curriculum (MCC), providing specific goals for the knowledge and skills that students should acquire before graduation. In the original version, Health and Physical Education (P.E.) was categorized under "attitudes and orientation (human abilities)," considered cross-disciplinary competencies that engineers should have. However, the 2023 edition of the MCC does not specify the learning area for P.E. Minami et al. (2024) raised concerns that the P.E. curriculum at colleges of technology (KOSEN) may include content corresponding to the "core (basic skills)" outlined in the MCC.

This study aims to examine the nature of KOSEN P.E. education by reviewing previous research and discussing the potential positioning of P.E. in the MCC framework.

The keywords "KOSEN physical education" and "KOSEN health" were used to identify 57 articles related to P.E. classes at KOSEN in the CiNii research article database. Analysis showed that some articles addressed multiple learning areas, 60 classifications. The article content was analyzed, focusing on the learning areas of the MCC, especially the core (basic skills) to which they correspond.

Figure 1 illustrates the article distribution across MCC learning areas. The top three categories were as follows:

Engineering Ethics: Many P.E. classes emphasized safety management and injury prevention, likely contributing to students' understanding of ethical responsibilities in engineering.

Physics: Practical exercises in P.E. often require an understanding of mechanics and motion, thereby reinforcing foundational physics knowledge.

Globalization and Cross-Cultural Understanding: Some P.E. classes incorporated activities such as English-language instruction, physical disability simulations, and exposure to uncommon foreign sports. Instructors' flexibility in designing classes based on their areas of expertise facilitated this.

Several studies described interdisciplinary approaches in P.E. classes integrating content from physics experiments, biology, or even corporate understanding, reflecting an educational framework consistent with engineering training at KOSEN.

This study suggests that P.E. classes at KOSEN align not only with the development of students' attitudes and orientations (human abilities) but also with the core (basic skills) competencies defined by the MCC. Consequently, the MCC should be revised to reflect the multifaceted educational contributions of P.E. at KOSEN more accurately.

Keywords: *physics, project-based learning, creativity, engineer education,*

1. Introduction

The National Institute of Technology established the Model Core Curriculum (MCC) in 2017, which outlines the specific knowledge and skills students should acquire before graduation. This version categorized Health and Physical Education (P.E.) under "attitudes and orientation (human abilities)," a cross-disciplinary competency expected for engineers. However, the 2023 edition of the MCC does not indicate a learning area for P.E. Minami et al. (2024) questioned whether P.E. content at colleges of technology (KOSEN) aligns with the "core (basic skills)" section of the MCC.

In contrast, high schools, which enroll students of the same age group as those attending KOSEN, P.E. is officially recognized subjects in the National Course of Study. Its objective is to cultivate students' physical well-being not only through P.E. classes but also as a component of their overall educational experience

(Ministry of Education, Culture, Sports, Science and Technology, 2018). Furthermore, the Organization for Economic Co-operation and Development (OECD) introduced the OECD Learning Compass 2030 (OECD, 2019), outlining the future direction of education systems in member countries. This framework identifies physical and mental well-being as foundational to student learning. Most OECD member countries have incorporated P.E. or an equivalent subject into their national education systems.

Thus, P.E content is regarded as a fundamental component of general education, both domestically and internationally. However, neither the MCC nor the International Standard Accreditation System for National Colleges of Technology Education, launched in 2022 by the Japan Society of Engineering to ensure quality assurance under the KOSEN International Standard, refer to P.E. (Japan Society of Engineering, n.d.).

2. Purpose

The purpose of this study is to examine the characteristics of P.E. provided by P.E. departments at KOSEN, based on a review of previous research, to explore the role of P.E. in the MCC.

3. Methods

The keywords "KOSEN physical education" and "KOSEN health" were used to search CiNii Research, an academic article database, yielding 57 articles on P.E. classes at KOSEN. The article content was analyzed to determine the MCC learning areas to which they corresponded, with a particular focus on the "core (basic skills)" category. Some articles were relevant to multiple learning areas, resulting in 60 classifications in total. Figure 1 shows the distribution of articles across MCC learning areas.

4. Results and Discussion

4.1. Relevance of MCC to previous research

Figure 1 illustrates the learning areas of the MCC addressed in the selected papers. Owing to space limitations, this study focused on the top three areas. Physics is considered a foundational subject for understanding physical movements and exercises involving equipment in practical P.E. classes (e.g., Matsui & Azuma, 2019). Globalization and multicultural understanding are reflected in the ability of P.E. classes at KOSEN to be conducted in English (e.g., Nigo & Ito, 2023), include simulated experiences of people with disabilities (Ichiya et al., 2018), and feature uncommon foreign sports (Watanabe & Sato, 1998). Instructors have flexibility in designing courses based on their areas of expertise, enabling these practices.

4.2. P.E. Leading to Engineer Education

The details of P.E. classes reported in previous studies reveal that some were designed to contribute directly to engineering education at KOSEN. These include classes integrating P.E. content with subjects such as physics, physics experiments, biology, and corporate understanding of safety management and injury prevention (Hirama, 2010).

Sakata et al. (2012) described a hurdle-running class utilizing a video delay display device at their affiliated KOSEN. Students practiced 20-meter hurdle runs and used delayed video playback to review their form immediately after each attempt. The time and motion of their hurdle runs were recorded before and after practice and compared from a biomechanical perspective. The results showed that students' hurdle times and motion improved, which was attributed to the use of the device. Furthermore, students' written reflections indicated that analyzing their hurdling form helped them overcome athletic challenges. This class not only demonstrated the effectiveness of using a video delay system for efficient skill acquisition but also highlighted the educational value of developing students' problem-solving skills by analyzing physical performance from a biomechanical perspective, reflecting a promising outcome for engineering education.

Kato and Tamura (2018) conducted a project-based learning (PBL) exercise class in collaboration with industry and academia. This was part of the "Advanced Health Science" course at Toyota KOSEN and aimed to enrich liberal arts education for engineering students through practical P.E. content. Students worked in groups on a defined task and presented their findings to a company representative in the final week. The presentations included ideas and suggestions for future applications based on the effects observed in an exercise intervention conducted during the course. This format of group work, result presentation, and peer voting resembles the hackathons often held in the IT field. Furthermore, a questionnaire survey indicated that this hands-on project deepened students' interest in health science and encouraged active engagement. Including a presentation to an external party (i.e., the company representative) added a sense of realism that appeared to boost student motivation. Moreover, over 80% of the students expressed a desire to continue these types of learning experiences, suggesting that PBL-style classes incorporating practical P.E. elements may effectively enrich liberal arts education for engineering students.

Shibayama (2020) designed a P.E. course titled "Creative Sports Practicum" that aimed to foster creativity among fifth-year students at the KOSEN where he teaches and reported the practical outcomes. Students were encouraged to take an active role in planning and managing P.E. sessions based on three core elements of creativity: novelty, ingenuity, and problem-solving (Figure 2). The effectiveness of the class was evaluated using a creativity assessment administered during the first and final sessions, and the students provided written reflections after each class to document changes in their perceptions of their creativity. The results demonstrated that students improved the novelty and ingenuity of their ideas, their ability to solve problems during class, and their overall understanding of the concept of creativity.

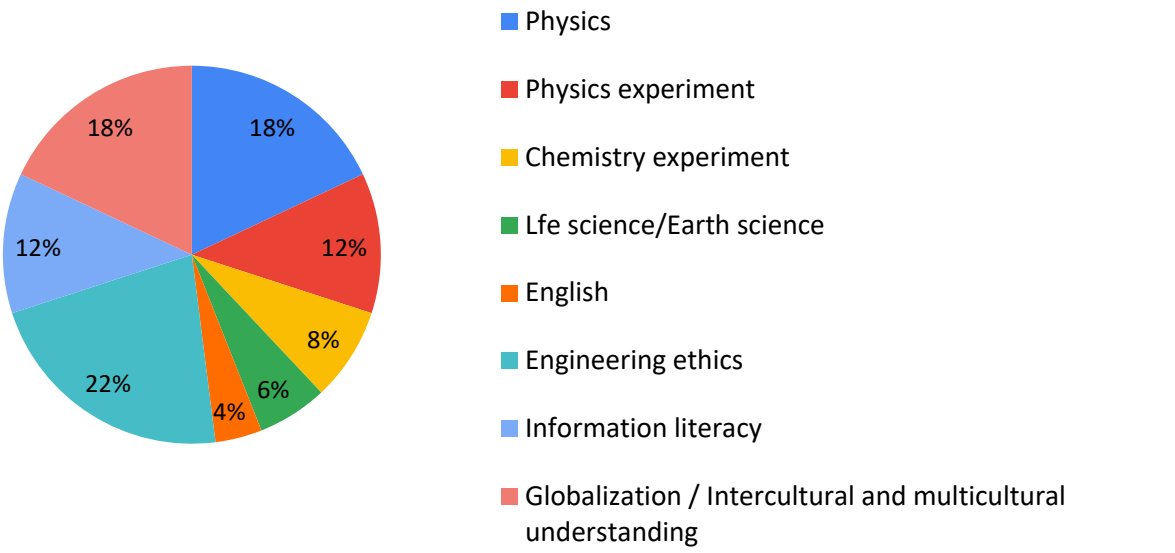


Fig.1 The relationship between P.E. course content and the learning areas of the MCC based on previous research.



Fig.2 The conception and implementation of a snowball fight in a creative sports practicum.

In addition to aligning with the findings from previous research on creativity education in P.E., the study highlighted the importance of incorporating activities tailored to KOSEN students' unique characteristics, such as the design and use of original instructional tools. Thus, the study made a valuable contribution by suggesting that creativity, a foundational element of KOSEN education, can be effectively nurtured through P.E.

4.3. Position of P.E. in the MCC

A review of previous studies on KOSEN P.E. classes indicates that P.E. may contribute to learning outcomes such as "independence," "self-management skills," "responsibility," "teamwork skills," "leadership," and "ethics," as defined by the MCC (National Institute of Technology, 2017), as well as areas such as "chemistry experiments," "life science," "earth science," "English," and "globalization, cross-cultural and multicultural understanding." Furthermore, some instructors are actively integrating P.E. content classes into engineering education. Given these findings, the absence of P.E. in the current MCC for KOSEN overlooks the educational and research contributions that P.E. instructors have made. Therefore, based on the above, as a proposal to position P.E. in the MCC core (basic skills), "II-E Life Science, Earth Science" in "II Natural Science" could be changed to "II-E Life Science, Earth Science, Health Science (Table 1)." Thus, in the future, it will be necessary to consider clarifying the unique learning content of P.E. at KOSEN in the MCC.

Ohara et al. (2024) surveyed students at one institution to examine the significance of P.E. classes at KOSEN. Based on the results, they highlighted the importance of redefining the role of P.E. in each academic year and intentionally modifying the form and content of classes. These suggestions consider the unique educational challenges at KOSEN, such as the prevalence of dormitory life and wedge-shaped curricula, when designing an MCC for P.E As a reference from other fields, the MCC for medical education explicitly includes "sports medicine," with examples of classes designed to enable students to assess an individual's physical functioning and life activities and plan exercise support based on the person's values and behavioral science (Ministry of Education, Culture, Sports, Science and Technology, 2017). This demonstrates the feasibility of integrating sports and professional education within an

MCC. Similarly, clarifying how P.E. can be linked to engineering education in the MCC for KOSEN should be possible. However, in applying this system, it is necessary for each school to devise ways to utilize the expertise of health and physical education teachers and to collaborate with teachers of specialized departments, etc.

Finally, KOSEN institutions claim to cultivate "doctors of society" who contribute to building a sound and sustainable future (Organization of National Colleges of Technology, online). Foundational knowledge of physical and mental health is indispensable

Table.1 Abilities KOSEN students should acquire

【In current, model of MCC (core)】

Basic skills that all engineers should have
Ⅰ Mathematics
Ⅱ Natural science Ⅱ-A Physics Ⅱ-B Physics experiments Ⅱ-C Chemistry Ⅱ-D Chemistry experiments Ⅱ-E Life science, Earth science
Ⅲ Humanities/Social Sciences Ⅲ-A Japanese Ⅲ-B English Ⅲ-C Social
Ⅳ Engineering basics Ⅳ-A Engineering experiment technology Ⅳ-B Engineer ethics Ⅳ-C Information Literacy Ⅳ-E Globalization and mulitcultural understanding

【Revised model of MCC (Core) based on the results of this study】

Basic skills that all engineers should have
Ⅰ Mathematics
Ⅱ Natural science Ⅱ-A Physics Ⅱ-B Physics experiments Ⅱ-C Chemistry Ⅱ-D Chemistry experiments Ⅱ-E Life science, Earth science, **Health science**
Ⅲ Humanities/Social Sciences Ⅲ-A Japanese Ⅲ-B English Ⅲ-C Social
Ⅳ Engineering basics Ⅳ-A Engineering experiment technology Ⅳ-B Engineer ethics Ⅳ-C Information Literacy Ⅳ-E Globalization and mulitcultural understanding

Position of P.E.

(The National Institute of Technology, 2023, p.13; modified by the authors)

to the basic qualities and competencies required by such individuals. Building on this foundation, students should be equipped to make healthy and meaningful contributions to society.

Conclusion

P.E. classes at KOSEN encompass the learning area of core (basic) skills and students' attitudes and orientation (human abilities). Given the potential for P.E. to contribute to engineering education, the MCC should be promptly revised to reflect these aspects.

Furthermore, although this study is based on previous research, more extensive and detailed investigations, such as surveys and interviews with P.E. instructors at KOSEN, are necessary to gain a deeper understanding.

Acknowledgements

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References

Hirama, T. (2010). A report on practical measures to prevent accidents during Judo classes and the results. *Research reports / Sendai National College of Technology, Natori Campus*, 46, 69-76.

Ichiya, F., Moriyama, Y., Morita, M., Fujishima, N. & Maruyama, K. (2018). The influence of simulated experiences of the elderly in physical health education classes on students at a college of technology. *Journal of the Japan Association for College of Technology*, 23 (3), 1-6.

Japan Society of Engineering. (online). *International Standard of Education for National Colleges of Technology (2022-) Commentary on Accreditation Criteria.* Retrieved from https://www.jsee.or.jp/jsee/wp-content/uploads/2024/03/77acb35104545d3a3355f3c6391dd517.pdf(2025-5-9.)

Kato, T. & Tamura, T. (2018). Effect of project-based-learning with industry-academia collaboration in physical education-related liberal arts classes. *Bulletin of Toyota Technological College of Technology*, 51, 44-49.

Matsui, K. & Azuma, A. (2019). A study on self-analysis of the movement using a strobe picture: its effect on college male students' long jump performance. *Research Reports of National Institute of Technology, Fukui College. Natural Science and Engineering*, 53, 29-34.

Minami M., Shibayama T., Sakata Y. & Takatsu H. (2024). Raising problems of health and physical education class contents (1~3 years) in national colleges of technology from the viewpoint of current situation: Focusing on comparison between Model Core Curriculum and Courses of Study in colleges of technology. *Proceedings of the 50th Annual Meeting of the Japan Curriculum Research and Development Association*, 276-277.

Ministry of Education, Culture, Sports, Science and Technology. (2018). *General Guidelines for High School Course of Study*. Kyoto: Higashiyama Shobo.

Ministry of Education, Culture, Sports, Science and Technology. (2017). *Model Core Curriculum for Medical Education, revised in 2022*. Retrieved from https://www.mext.go.jp/content/20240220_mxt_igaku-000028108_01.pdf(2025-5-9)

Nigo, Y & Ito, K. (2023). The potential of physical education CLIL for first-year students of technical colleges (5) - a case study of badminton class using English. *JACET Chugoku-Shikoku Chapter Research Bulletin*, 20, 73-90.

Ohara, Y., Ichiya, F., & Nagata, T. (2024). The significance of physical education classes as considered by technical college students: A study of one college. *Japan Journal of Physical Education, Health and Sport Sciences*, 69, 565-582.

Organization for Economic Co-operation and Development. (2019). *Core Foundations for 2030.* Retrieved fr

om https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/concept-notes/Core_Foundations_for_2030_concept_note.pdf(2025-5-9.)

Sakata, H., Tamiuchi, T., & Seino, T. (2012). Verification of effectiveness of the video delay display device in the physical education class -For hurdle race learning-. *Kosen Kyoiku*, 35, 239-243.

Shibayama, K. (2020). Empirical research of physical education lessons to foster creativity in technical colleges-taking advantage of the characteristics of the subject-. *Bulletin of the Graduate School of Humanities and Social Sciences, Hiroshima University. Studies in Education*, 1, 568-577.

The National Institute of Technology. (2017). *Model Core Curriculum: Guidelines*. Retrieved from https://www.kosen-k.go.jp/wp/wp-content/uploads/2024/04/2017_Model-Core-Curriculum-Guidelines.pdf(2025-2-25.)

The National Institute of Technology. (2023). *Model Core Curriculum: Guidelines.* Retrieved from https://www.kosen-k.go.jp/wp/wp-content/uploads/2023/12/2c383e29-7e20-4b20-af19-ca3737450665.pdf(2025-5-7.)

The National Institute of Technology. (online). *Greetings from the Chairman of the Board of Directors.* Retrieved from https://www.kosen-k.go.jp/about/president_message(2025-2-25)

Watanabe, S. & Sato, M. (1998). A Study on physical education classes in Numazu National College of Technology using new sports - the case of 4th grade students at Numazu National College of Technology. *National Institute of Technology Numazu College Research Annual*, 33, 163-174.

MICROSOFT TEAMS SPEAKER PROGRESS: WHY AND HOW TO USE IT

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Speaker Progress is the latest Learning Accelerator in Microsoft Teams. It is a combination of Teams' Reading Progress and PowerPoint's Reading Coach. To use Reading Progress, the teacher gives students a text to read. Students get AI feedback on word-level pronunciation, reading speed, intonation. This is a fantastic tool for getting students to read a text before class or reinforce pronunciation after class. On the other hand, PowerPoint's Reading Coach allows students to practice saying their own presentation content and gives additional feedback including eye contact. Speaker Progress has elements of both programs. Speaker Progress can be used with video to practice and record a presentation, and with audio only to have students read out loud their own writing. Using Speaker Progress to have students record and submit video assignments is a smooth process for both students and teachers. Using other recording methods, students record a video on their device and upload it to the assignment. This method sometimes has issues with file size and uploading based on device type. Speaker Progress is a simpler process because the recording is made directly in the assignment, removing the need to upload files. Another advantage is that students can receive real-time AI feedback. This immediate feedback means that students can learn what to do to improve their presentation, re-record the assignment, and submit a better recording. Speaker Progress is also useful as a tool for having students read out their own written assignments, submitting the audio along with the written assignment. Recently, when writing reports in a second language, students often use machine translation. When used correctly, machine translation is a valuable tool which can also deepen students' language abilities. However, when machine translation is used incorrectly, students turn in assignments that they do not understand, and they do not have the ability to verify whether the information is correct. Based on observations in both presentations and written assignments, if students are unable to say the words they have submitted, they do not understand the meaning. Using Speaker Progress along with written assignments is one way to gauge students' understanding of their work.
Speaker Progress uses AI to generate immediate feedback for students. However, the AI feedback is not 100% accurate, so teachers cannot rely on it exclusively to determine students' grades, but it can help teachers save time when assessing students' work.

Keywords: *AI, assessments, feedback, Teams assignments, Speaker Progress*

Introduction

Back in 1985, Steve Jobs was prescient when he said, "Computers themselves, and software yet to be developed, will revolutionize the way we learn." Technology is forever changing the way teachers teach and the way students learn. It is changing the way we give and accept assignments. It is changing the way students complete those assignments. AI is accelerating the revolution.

Technology, particularly AI, often makes things easier for both teachers and students, but it also brings new sets of problems. Two crucial issues that arise are originality and accuracy. Is content created with the assistance of AI original and authentic, and to what degree? This is a question that many people are still debating and having a difficult time reaching consensus on. Even if we cannot agree on the proper usage of AI, I think we can agree that AI still has real and serious issues with accuracy. As long as teachers keep this accuracy issue in mind, AI can be useful for both teachers and students. In this paper, I am not going to try and answer these questions, but they are always in the back of my mind as I use AI and teach my students to use AI.

What this paper is going to look at is the usage of AI in Microsoft Teams, which has been incorporating AI into its learning tools since 2021, when it introduced Reading Progress, a fun and easy way to give students reading practice outside of class using teacher-assigned texts. Also in 2021, Microsoft introduced PowerPoint's Rehearse with Coach, which was fantastic for students to get feedback on their presentations and pronunciation. However, Rehearse with Coach had limitations. It was only available in the English mobile version of PowerPoint, and because of this there was no good way to assign it to students to practice their own presentations. It seemed to be a really cool bit of software that was stealthily slipped into certain versions of PowerPoint. Then in 2023 Microsoft rebranded its AI in Teams assignments as Learning Accelerators, adding new accelerators for math and online searching. In August 2024, Speaker Progress was finally added. Essentially, it is PowerPoint's Rehearse with Coach added to

assignments as a Learning Accelerator. As an English teacher, the combination of Reading Progress and Speaker Progress opened up new possibilities for assignments, feedback, and assessment.

Pedagogy

In this section I will explain some important aspects of Teams Learning Accelerators Reading Progress and Speaker Progress, assignment purposes, and what students are taught regarding AI usage.

First, in Reading Progress, the content is determined by the teacher, so all the students are reading the same content. The AI provides numerical data about pronunciation markers and an overall accuracy score. However, students cannot see the AI feedback until after the teacher checks the content and returns the assignment with a score. Because the feedback is based solely on the audio file, I do not require video for Reading Progress assignments. Results from an average recording might look something like Figure 1.



Figure 1. Average Reading Progress AI result (purple: mispronunciations, pink: omissions, green: insertions, blue: repetitions, grey: self-corrections)

In the assignment directions, students are instructed that the assignment is worth 2 points. If their AI score is 50% or better, they can get the full 2 points. If it is less, they will get 1 point. 50% is a relatively low bar, so most students do get the full points, with an average of 3-4 students out of 40 getting only 1 point. One reason that students only get 1 point is that they need to practice reading the text a few times before recording. In this case the AI has correctly judged their accuracy as less than 50%. Another reason has to do with recording quality and background noise. Some students speak too quietly in the recording while others record in a place that is too noisy for AI to accurately pick up their voice. Unfortunately, students cannot see the AI feedback before submitting the assignment. But they can listen to their own recording before choosing to use it. Students are encouraged to do this to check their recording quality. If the AI assessment does not fit into normal patterns, I more closely check the listening. Figure 2 is an example from a student who was speaking too quietly in the recording so the AI could not pick out the individual sounds and words. However, when I listened to the recording, I could pick out the words, even though they were a bit quiet, so the student received 1 point on the assignment.

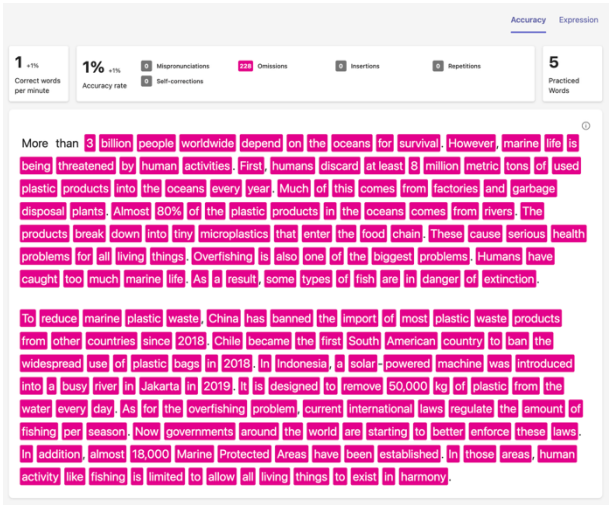


Figure 2. Poor Reading Progress AI result (pink: omissions)

However, there have been issues with a few students' Reading Progress recordings. On at least 2 occasions, students have tried to pass off an AI reading of the text. A more common issue is students reading the first sentence followed by a minute or two of either gibberish or silence. In these cases, the AI results may show 1 or 2%, and then all pink "omissions", so their AI results are also similar to the results in Figure 2. In these cases, the students get 0 on the assignment and are informed about the reason through assignment feedback.

I use Reading Progress assignments for two different purposes. The first is to practice pronunciation that we have already done in class. In these assignments I want to encourage spaced repetition and get students to practice the pronunciation a bit more outside of class. Students generally score fairly high because they have already had some practice reading the text out loud during class. The second purpose is to introduce them to a text, usually from their textbooks, before class. In an ideal situation, students would read the text as requested and check the words they do not know – most of which are in a class Quizlet. However, in reality it is very difficult, almost impossible, to get the majority of students to do this level of studying before a class without some kind of graded assessment. A Reading Progress assignment where they read the text aloud guarantees that they have read through the text at least once before coming to class. Some students clearly practice reading the text before recording, while others do not. Overall students have lower scores on assignments introducing a text before class, but at least they have seen and read the text once before class even if their comprehension may be low. Reading Progress has been a great tool for introducing new content before class and reviewing pronunciation skills after class.

Table 1. Comparison of Reading Progress and Speaker Progress

	Reading Progress	**Speaker Progress**
Content	Teacher-assigned texts All students read the same text.	Student-generated text Each student reads/presents different text.
Medium	Voice/Video	Voice/Video
Purpose of Assignments	- Review/practice pronunciation (voice only okay) - Enforce reading of text before class to prepare (voice only okay)	- Submit presentation videos (video required) - Check for misuse of AI (translation software/Chat GPT) when writing a report (voice only okay)
AI Feedback Timing	Later, when the graded assignment is returned by the teacher	Immediate, before submitting
AI Feedback Content	Accuracy - Correct words per minute (number) - Accuracy rate (mispronunciations, omissions, insertions, self-corrections, repetitions) (percentage) Expression - Monotone score (period, exclamation, question, extended pause, rushed reading, read in a monotone voice) (percentage)	Speaking time Detailed AI feedback/advice - Pace (words/min) (number and chart) - Body language (eye contact, clear view, distance) - Repetitive language - Filler words - Pitch - Inclusiveness - Pronunciation Numerical data - Delivery (pace, filler words, pitch, mispronunciation) - Content (non-inclusive language, repetitive language) - Audience engagement (lost eye contact, too close or too far from camera, obstructed view)
AI Feedback Notes	Pronunciation feedback more detailed Feedback more quantifiable	More detailed feedback in most areas other than pronunciation Feedback more qualitative

A large part of what I teach are presentation skills. The semester ends with a group presentation. But in addition to the final group presentation, I also want students to practice making presentations and giving them throughout the semester. However, there is not enough class time to have everyone give multiple presentations throughout the semester, so I have the students submit videos of themselves giving their presentations. Before Speaker Progress, I would have students record themselves giving their presentation and attach the video to the assignment. The issue was that students often had videos that exceeded file size limits and could not upload them. Speaker Progress is an ideal answer to this problem.

Speaker Progress is quite different from Reading Progress (Table 1). In Speaker Progress, the content is determined by the student, so each student can work with different content. The AI feedback provided is much more qualitative, although there are a few quantitative values. Also, a huge benefit to Speaker Progress is that students can see the AI feedback before submitting an assignment. This means that students can consider the feedback and rerecord their presentation to improve it and get a higher score. Another major difference is that the AI also gives some feedback on content and "audience engagement". Results from a good recording might look something like Figure 3.

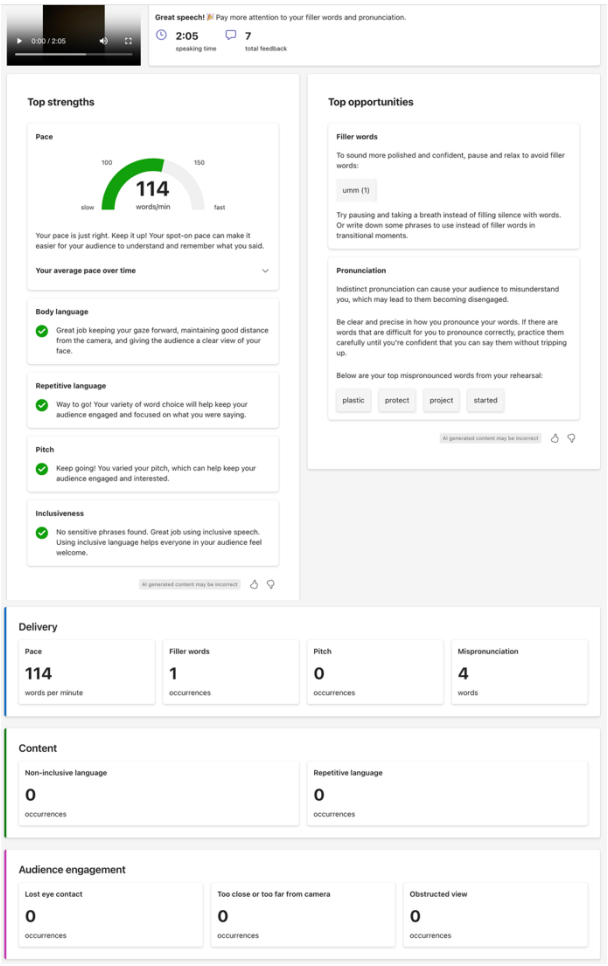


Figure 3. Speaker Progress AI feedback

Teachers can easily watch the student's Speaker Progress video within the assignment, open their own rubric in a panel on the right side of the screen, and give a score to the student. So, Speaker Progress eliminates students' issues with video file sizes, gives them immediate AI feedback, and makes it easy for teachers to assess.

There is one more way that I use Speaker Progress. It is not as the main assignment, but as a way to confirm comprehension. An added benefit is that it also gives students more speaking practice. In English Communication, students must generate their own content – written reports, presentation scripts, and presentation slides. As first year students in my class, they are taught certain rules about using AI, which includes machine translation and ChatGPT. Students are encouraged to use AI to help them produce better reports and scripts. However, there are rules:

1. Students need to understand the meaning of the report/script they are submitting.
2. Students need to be able to say all the words in their report/script.

Students cannot just automatically submit an English translation of their report written in Japanese. They must look at the English and confirm that it is correct. If the generated English is too difficult, meaning the student cannot understand the sentences due to vocabulary and grammar, they are taught to go back and rewrite their report using shorter Japanese sentences. Then they should translate the report again, and check that English. In the future as engineers, they will use AI to assist them in writing reports and essays. The danger is in assuming that AI is always correct. Machine translation is improving year by year, so that the language produced is becoming more and more natural. However, it still makes mistakes which can often produce the opposite meaning of what is intended. Teachers I know have started using software to try and "catch" students using AI, but I want students to use the AI to help them write simple sentences that they themselves understand. I want them to not only learn English but also gain skills that will help them in the future. So, I was searching for a way to verify with reasonable accuracy whether or not they actually understood their content and had confirmed the meaning of the English words and sentences they had submitted. With about 200 first years and 200 second years reports to check, it needed to be something relatively easy to confirm. I also work with the students on pronunciation and presentation skills and have noticed that there is generally a correlation between comprehension and the ability to read something out loud.

So, during the second semester of 2024, I attached a Speaker Progress Learning Accelerator and added the requirement that students read their reports out loud. Because I was checking the reports for about 200 students in a limited period of time, I was not able to listen to all their recordings in their entirety. I briefly looked at the Speaker Progress AI feedback for all the reports. But I only fully listened to the recordings for students whose reports seemed to be a bit beyond their normal level of English. If their reading of the report was mostly smooth and only had a few mispronounced words, I assumed that they had spent some time with the English in the report they had submitted and mostly understood the content. On the other hand, if their reading of the report was very broken and had a high number of mispronounced words, I assumed that they did not understand the report they had submitted and messaged the students.

Results and Discussion

My idea that poor pronunciation in the readings of the reports turned out to be correct. When I messaged the students with poor pronunciation in their recordings, all of them immediately confessed to not fully understanding the English in the papers they had submitted. At this point, I gave the students a chance to edit their papers and submit something that they could understand, along with a new recording. While my assumption about poor pronunciation indicating poor comprehension was correct, at this time I do not have confirmation that good pronunciation really does indicate good comprehension.

Another interesting observation had to do with the pace of the recordings. Students who had read their reports and pronounced most words correctly had a pace around 115 words per minute. But students who admitted to not understanding the content had a pace around 100 words per minute. So, using Speaker Progress to look at pronunciation and pace helped identify students who had incorrectly used AI.

However, there are also some issues with Speaker Progress. One major issue is feedback accuracy. Because Speaker Progress does not work from a script, like Reading Progress, it sometimes makes mistakes analyzing students' content. About 200 students recorded themselves reading their final SDG reports. Recording lengths were anywhere from 1 minute to 5 minutes. Approximately 1 out of 20 recordings were flagged for 1 occurrence of non-inclusive language. In the "Top opportunities" section which provides more qualitative feedback, the inappropriate word would be written as "b*****" or "f***". However, when I went back and carefully analyzed the recording, I could find no instance of the offensive word. Furthermore, I could not even identify any potentially mispronounced words that AI may have mistaken for the inappropriate word. So, without a script to work from, the AI feedback regarding pronunciation has reduced accuracy.

Speaker Progress also does not accurately report on audience engagement. Poor eye contact is often not flagged by the AI unless it is extremely egregious. Based on my experience, I also recognize that this is an area where the original PowerPoint Rehearse with Coach was a bit weak. So accurately recognizing eye contact, or a lack thereof, is something that the AI in Teams is not able to do well yet.

Conclusions

Existing research regarding reading pace is related to extensive reading. However, this research focuses on reading pace related to comprehension of the text students have read. This research is focused more on how reading pace is related to and affects comprehension. However, I could not find research discussing the reverse – statistical data showing how students' comprehension of a text affects their pace when reading aloud. Quantitative

research needs to be done to get a better grasp of the correlation between reading aloud pace and accuracy related to comprehension when the text is self-generated. A better understanding of this correlation would help teachers identify misuse of AI more easily.

In conclusion, Speaker Progress is a very useful, if imperfect, tool. It is important for both teachers and students to keep in mind that it is not fully accurate. However, if used with discernment, it can help students improve presentations before submitting them or giving them in front of an audience. It can also provide students with more opportunities to practice speaking outside of class. For teachers, it can provide a starting point for presentation feedback for presentation recordings, while helping identify cases of improper usage of AI in report content. Again, keeping in mind that current AI limitations do plague Speaker Progress, it is still a helpful step up in education technology.

References

Getting started with Speaker Progress for educators—Microsoft Support. (n.d.). Retrieved May 1, 2025, from https://support.microsoft.com/en-us/topic/getting-started-with-speaker-progress-for-educators-8ed1e5cd-cd78-4f15-bdb5-8a1e22c3cb19

Hasegawa, Y. (2016). Does Reading Aloud Contribute to EFL Reading Fluency Among Learners with Higher/Lower Phonological Awareness? *Bull. Joetsu Univ. Educ.*, *36(1)*. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://juen.repo.nii.ac.jp/record/7215/files/kiyo36_1-15.pdf&ved=2ahUKEwjF5e7Rw6aNAxVzhKgCHeiYMwMQFnoECBQQAQ&usg=AOvVaw2m496g7orjYWqu00nw9Ruc

MURAO, R., ISAJI, T., TANEMURA, S., SHIRONO, H., YAMANAKA, J., ISHIKAWA, J., & NORO, T. (2018). *Does Reading-Aloud Training Facilitate the Improvement of English Stress-Timed Rhythm? A Comparison Between Repeating and Parallel Reading* (No. 0). The Japan Society of English Language Education. https://doi.org/10.20581/arele.29.0_289

Sari, N. G. (2012). *THE CORRELATION BETWEEN STUDENTS' READING ALOUD ACTIVITY AND THEIR ABILITY IN PRONUNCIATION ACCURACY AT MTS BAHRUL ULUM AL ISLAMY KAMPAR REGENCY*. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://repository.uin-suska.ac.id/9386/1/2012_2012129.pdf&ved=2ahUKEwiNyuOCxKaNAxViaPUHHV4FNroQFnoECBcQAQ&usg=AOvVaw31hQi5dXwuLlBdji96mL-K

ETHICAL DILEMMAS IN FIRST-YEAR ARCHITECTURE EDUCATION: THE JOURNEY TOWARDS A SUSTAINABILITY MINDSET

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The inculcation of sustainability principles into architecture education a sustainability mindset amongst architecture students is increasing in urgency. Despite the potential of integrating elements of the United Nations Sustainable Development Goals (UNSDGs) into the curricula, and the growing recognition of sustainability as a professional obligation, architecture education continues to prioritise aesthetics over critical sustainability-related content. This study explores first-year architecture students' perceptions of ethical dilemmas related to sustainability and their readiness for ethical advocacy following learning tasks on sustainable architecture at Singapore Polytechnic. Transformative learning pedagogies, including reflective practices, were employed to deepen students' understanding of sustainability challenges, fostering critical thinking, self-awareness, and the ability to navigate complex, real-world ethical dilemmas in design. With a sustainability mindset conceptualised as a latent construct, this study aimed to initiate the development of students' intrapersonal skills through self-reflection, which provides insights into their evolving mindset and future potential for sustainability advocacy. Two research questions were conceived to guide the study: RQ1 examined how students distinguished ethical dilemmas in sustainability, while RQ2 assessed their preparedness for ethical advocacy after the learning task. Students were invited to participate, while their responses were collected anonymously through an online portal. Thematic analysis revealed two main themes for each research question. For RQ1, 'Deeper Understandings' were identified, with 'Critical Perspectives on Sustainability', reflecting scepticism about sustainability efforts, and 'Shared Responsibility and Balance', emphasising collaboration among architects, users, and clients. For RQ2, 'Ethical Advocacy Preparation' includes 'Disillusionment with Sustainability and Ethical Dilemmas', echoing the internal conflicts students face, and 'Prioritising Adaptive Reuse and Practical Solutions', stressing the importance of adaptive reuse in sustainable design. The findings suggest that reflective exercises enhance students' awareness of sustainability issues and prepare them for the complexities of architectural practice. The study lies in its potential to influence both pedagogy and practice by demonstrating how transformative learning approaches can foster ethical awareness and advocacy among future architects. By addressing gaps in sustainability education, this study offers a framework for cultivating future professionals who are not only adept at identifying ethical dilemmas but are also equipped to champion sustainable solutions.

Keywords: *Architecture Education, Sustainability Mindset, Transformative Learning, Reflective Practices, Ethical Advocacy*

Introduction

Despite the growing importance of the United Nations Sustainable Development Goals (UNSDGs) in architecture education (Akgün et al., 2023), especially UNSDG No.13 (Climate Action), efforts to incorporate SDGs into the architecture curriculum and pedagogy remain limited and sporadically examined (Burton & Salama, 2023). However, architecture education's obsession with building aesthetics (Till, 2009) has reduced the rightful focus on the 'critical content' – the holistic understating of the building's inner workings and spatial, operational, maintenance and energy consumption considerations. A sustainability mindset—comprising values, knowledge, and attributes that guide individuals toward environmentally responsible decision-making (Rimanoczy, 2020) is essential for fostering innovative and sustainable design solutions. However, the integration of sustainability principles into architectural curricula remains underexplored (Burton & Salama, 2023). Transformative learning pedagogies can bridge this gap by prompting students to critically analyse their beliefs and viewpoints, thus fostering a more profound comprehension of sustainability issues (Mezirow, 2000). Activities designed to enhance knowledge and skill sets, along with the development of sustainability-oriented attitudes, can be evaluated through self-reflective exercises that utilise intrapersonal skills as a means to achieve these goals. This study aims to explore the effectiveness of transformative and

reflective learning activities designed to cultivate a sustainability mindset among first-year architecture students at Singapore Polytechnic. As students engage with ethical dilemmas and develop critical skills essential for advocating sustainable practices in their future professional roles, their reflections will provide us with a glimpse of their development of sustainability mindset for their future advocacies.

Sustainability Mindsets in Architecture Education

A sustainability mindset, encompassing values, knowledge, and attributes that guide individuals to address challenges and make decisions aligned with sustainability principles (Rimanoczy, 2020), is becoming crucial for fostering environmentally responsible choices. Cultivating this mindset can encourage alternative perspectives (Rieh et al., 2017), enabling students to develop innovative and sustainable design solutions.

Buildings are significant contributors to global environmental concerns, responsible for up to 19% of greenhouse gas emissions (Mohkam et al., 2022) and between 30% and 45% of worldwide energy consumption (Zamorano, 2022). While advancements in technology have enhanced the energy efficiency of mechanical heating and cooling systems, architects with a sustainability mindset would arguably first consider incorporating passive design strategies further reduce buildings' environmental impact.

Building Mindsets through Transformative Pedagogies

Transformative Learning is an approach that facilitates learners to critically examine their current perspectives and beliefs, and transform them into new ways of understanding with alternative perspective of framing issues and/towards problem solving (Mezirow, 2000). Mezirow's theory posits that learners experience' *disorienting dilemmas*' as critical incidents that prompt reflection and re-evaluation of one's beliefs. As Sinclair et al. (2022) implied, architecture education faces challenges of not having a curriculum that encourages questioning and critical analysis of the built environment. Consequently, students miss opportunities for personal and societal transformation through their education. With an excessive focus on the 'design studio', with the pervasive disconnection from contemporary societal demands, limited experiential learning opportunities have resulted in the lack of transformative learning opportunities.

Reflective Practices as Intrapersonal Skills Guiding Attributes for Sustainability Mindset

Intrapersonal skills are often defined as being associated with metacognition, conscientiousness, self-direction (Hilton & Pellegrino, 2012), change management, transforming beliefs, character and life purpose (Mahmudah, 2016). Intrapersonal capacities are crucial for change agents to navigate the challenges of sustainability work (Ayers et al., 2023; Jaakkola et al., 2022) and theoretically support the implementation of other competencies and as potential moderators (Ayers et al., 2023). Ayers et al. (2023) in their work to understand 'Intrapersonal competence' in the context of developing sustainability mindset, have identified (amongst others) to be able to *regulate and manage the self* (Reflective Practice) as an important trait.

Engaging in reflective practice promotes self-regulation by enabling learners to critically assess their performance and make informed adjustments to their future efforts (Balbay, 2021). Reflections deepen learners' understanding and cultivate a preparedness for self-regulated learning, highlighting its critical contribution to building competencies and enriching personal insights into learning experiences (Patel, 2023). Similarly, Sargeant et al. (2008) asserted the importance of reflections as a bridging elements of integrating/synthesising feedback with actionable change in learning practices in facilitating the abilities of learners to synthesise assessment feedback and apply it constructively to their future efforts. Henceforth, this study will capitalise learning activities that scaffold the knowledge, skill of sustainability and through self-reflections, to potentially solidify learners' attitudes (mindset).

Transformative Learning Activities

Moving away from the main design studio, two activities were conceived to scaffold students' knowledge and skills and self-reflection at the end of the activities. For Activity 1, students were tasked with revising an apartment's floor plan, while Activity 2 focused on organising students into groups for debate. Activity 1's background predicates on architectural practices' frequent encounters with client pressures, often resulting in design compromises.

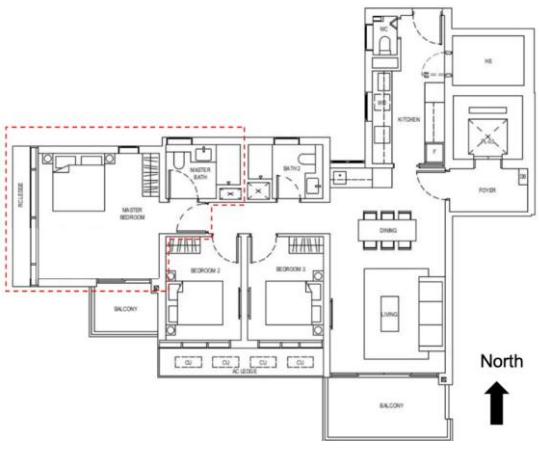


Figure 1: Activity 1's challenge of editing the floor plan

Activity 1 simulated a real-world situation in which a client insisted on positioning the master bedroom to face the western landscape (with the harsh setting sun) as a key-selling feature. While offering a scenic view of the surroundings (with reference from Figure 1), it exposes the master's bedroom to the harsh western sunlight,

escalating energy usage due to increased air conditioning needs. Learners were required to identify and sketch over their solutions in meeting the client's demand for an unobstructed western view by proposing spatial adjustments to mitigate cooling demands through reconfigurations. Figure 2 illustrates the process of which students explore and discuss potential solutions amongst themselves.



Figure 2: Students testing out the different options by over layering and a discussion on their solutions.

Activity 2 extends a similar dilemma in the form of a debate-based learning approach. Such teaching strategies have been reported to boost student engagement, critical thinking, perspective-taking, empathy, and advocacy skills (Mabrey et al., 2021). By navigating through a framework of dilemmas—which demand definitive solutions—to one that embraces paradoxes and coexisting tensions, debates foster transformative learning (Kark et al., 2016). Such exercises theoretically equip students to become active participants in society, preparing them for future civic engagement (Thomas, 2011) and shaping value systems and mindsets through interactive educational experiences (McInnes, 2013). Figure 2 depicts the learning environment of which the debates is carried out. After the session, the tutor then carried out a debrief explaining possible means on meandering the situations.



Figure 3: Students debating in the design studio with an ethical dilemma as the backdrop.

Research Methodology

Hence, the research questions (RQs) guiding this study were **RQ1**: How do first-year architecture students distinguish ethical dilemmas related to sustainability? **RQ2**: How do first-year architecture students perceive their readiness for ethical advocacy in professional settings after participating in a tutorial discoursing sustainability development? First-year architecture students at Singapore Polytechnic were invited to deposit their reflections via an online portal with these reflective questions. To answer **RQ1**, students will reflect upon, '*How has the tutorial on sustainability architecture and energy enhanced your understanding of ethical dilemmas and conflicts in the context of sustainable architecture*?' and aligned to **RQ2**, '*How has the tutorial prepared you for ethical advocacy in professional settings?*' after the lecture and the second learning activity.

The survey, conducted across five studios with 20-21 students each, yielded 130 anonymous responses using Microsoft Forms. Approved by Singapore Polytechnic's IRB (Protocol No. 202407-01). The data analysis process was carried out with Atlas.ti, a qualitative data analysis software, to manage and organise the dataset systematically. The analysis followed an iterative approach grounded with thematic analysis (Braun & Clarke, 2006). Initially, 'Intentional AI Coding' was applied to identify preliminary codes that were concept-specific and reflective of the research questions. These

codes were refined iteratively to ensure relevance and clarity, with the software assisting in highlighting recurring words, phrases, and ideas. Subsequently, the identified codes were manually grouped and regrouped into broader themes by examining patterns, trends, and interconnections within the data and in alignment with the RQs. Each identified theme was critically reviewed to confirm its coherence, distinctiveness, and alignment with the research objectives. Students' direct quotes from survey responses were incorporated to substantiate each theme and provide authentic voices to the analysis.

Results and Discussion

Two main themes were identified for each RQ. For RQ1: *Deeper Understandings*, themes of **Critical Perspectives on Sustainability** and **Shared Responsibility and Balance** were identified. Similarly, for RQ2: *Ethical Advocacy Preparation,* **Disillusionment with Sustainability and Ethical Dilemmas** and **Prioritising Adaptive Reuse and Practical Solutions** were identified.

Under RQ1's Deeper understanding, the first theme of *Critical Perspectives on Sustainability* reflects scepticism about the authenticity of sustainability efforts and emphasises the need for genuine responsibility in addressing environmental concerns. One student remarked: "*(the activities) has made me question that anything done under the name of 'sustainability' is actually be done with the concern of the climate crisis or just under the name of money*". Even as first-year student, this reflection suggests an 'awakening' moment might have been experienced. In the world of architecture education, exemplars are often celebrated for students to implicitly adapt and appropriate (mostly) aesthetic features and exemplar features from these projects into their own work (Goldschmidt, 1998). Perceptions of sustainability were also, unconsciously ingrained into young minds.

Another student echoed: "*Sustainability is not what it seems where it actually benefits the environment a lot, at the same time we should still be responsible when designing, taking into consideration on how it will actually benefit the climate and energy efficiency*". One of the architect's role and responsibility is not only to safeguard the interest of the client, the notion of advising clients of the design's overall impact on the environment will be increasingly paramount. While sustainability is increasingly recognised as important, architects' prioritisation of both aesthetics and cost over environmental considerations when selecting building materials remains pervasive (Conroy et al., 2019). Such reflections were interpreted as positive first steps in instilling sustainability mindsets of their own.

The second theme of *Shared Responsibility and Balance* extended the above discoursed notions whereby students understood shared responsibility between architects, users, and clients, highlighting the importance of collaboration and finding a balance in sustainable practices. As one student reflected, "*Sustainability is not in the form of greenery but in fact in the form of the responsibility of the users"*, two important ideas surfaced: a break away from perception that a green-covered (green walls, vertical plantings) immediately equates being sustainable building and, the role of the end-users of the building will be as important as the architect/client involved in the design process.

It is important that, especially in larger projects, that clients are not necessarily the end-users of the building. Students' awareness that architecture design can extend beyond the field's obsession with aesthetics is critical to inculcate at an early stage. Even though the responsibilities of end-users are critical, Xie et al. (2020) highlighted that green building occupants demonstrated more frequent pro-environmental behaviours compared to those in non-green buildings, further stressing the importance of energy-conscious designs. As echoed by a participant: "*It can be difficult to find the right balance of the clients and architects wants. In order to find balance both sides have to win in terms of the benefits"*, further extends the critical role of an architect. This delicate balancing act requires effective communication, compromise, and a deep understanding of the project's goals and constraints. The debate exercise (Activity 2) was a platform to navigate through difficult sustainability dilemmas of which, the reflective activity could potentially help to crystalise mindsets and value systems.

To answer RQ2: Ethical Advocacy Preparation, the first theme, Disillusionment with Sustainability and Ethical Dilemmas focuses on the internal conflict and confusion students face when idealistic notions of sustainability and ethics clash with the practical complexities of architectural practice. One student reflected: "*I have realised how much I believed the overly glorified idea of "sustainable" buildings and ideas… Knowing that, I'm not sure what I want to accomplish as a future architect now. Everything seems to contradict each other"*. Although such sentiments may seem negative, such unsettling moments may be pivotal in their inculcation of sustainability mindset, thus impacting their future agencies. As Mezirow's (2000) transformative learning theory posits that learners experience 'disorienting dilemmas' as critical incidents that prompt reflection and re-evaluation of one's beliefs, students' the interrogation of the 'accepted' narrative, context, and implications of specific situations to develop skills that are essential for driving and examining sustainability initiatives (Corcoran et al., 2004).

While another student reflected: "*(the activities had) prepared me by showing me how the most ethical way isn't always the* ***easiest way*** *to do thing.* This realisation highlights the complexity of ethical decision-making in real-world scenarios. This underscores the importance of considering multiple perspectives and potential consequences when faced with moral dilemmas. Sustainability mindset will remain as a passive internalised trait unless actively perused and operationalised. One significant aspect of navigating conflict is the necessity for reflective practice in understanding different perspectives. As Griggs et al. (2015) had argued, being engaged in reflective practice fosters a deeper understanding of the dynamics at play in

conflicts and prepares individuals to handle them effectively in the future.

Prioritising Adaptive Reuse and Practical Solutions is the second identified theme for RQ2. This theme focuses on the importance of adaptive reuse, minimal intervention, and considering a building's long-term impact on the environment. As one student remarked: "…*that the first question we should ask as an architect is do we need to demolish the building or can we just break a wall or add a (another) block (Additions or Alternations to existing buildings)*". As clients and developers (and sometimes architecture critics) sought for the spectacle and fresh dynamic forms previously not explored, ideas of retrofitting and conserving existing buildings should be explored. This will, in turn lead to the reduction of construction waste and carbon footprint. Echoing the previous themes of possible friction between clients and architecture regarding sustainability design decisions, students might had come to terms of the difficult road ahead. However, what is critical is that, when students (as future practitioners) prior knowledge and advocacy will prepare them for effective negotiation.

Finally, notions of responsibility reflect the necessity of providing an overview of the different stakeholders, factors and engagements in supporting the development of sustainability agencies. As one student reflected: *"(to) consider about the necessity and responsibilities of the building you are designing which will contribute to climate for some time"*. These holistic overall echoed notions of systems thinking as such holistic understanding to architectural education prepares students for the practical realities of the profession and encourages them to become advocates for environmentally responsible design practices.

Conclusions

This study highlights the essential importance of a sustainability mindset in architecture education, particularly in the early, formative stages of students' academic journey. The findings suggests that first-year architecture students, through focused and well-designed learning activities, can meaningfully construct their ability to identify and navigate ethical dilemmas while developing essential competencies to advocate for sustainable practices. By employing reflective exercises (in supporting intrapersonal skills critical for the inculcation of sustainability mindset and transformative teaching approaches, this research illustrates how students' awareness of sustainability issues can be profoundly deepened.

The thematic analysis revealed that reflective practices not only encourage introspection but also promote active, critical engagement with sustainability challenges, enabling students to explore innovative solutions that balance aesthetic, functional, and ethical dimensions. Furthermore, the study highlights the potential of transformative pedagogies to cultivate a sense of shared responsibility among future architects, empowering them to collaborate effectively with various stakeholders.

Given the urgency of global sustainability challenges, this study reinforces the necessity of embedding sustainability principles into architectural education. Further studies should explore pedagogical strategies towards the integration of sustainability concepts across curricula, examining how theoretical knowledge can be combined with experiential learning opportunities to better prepare students for the real-world complexities of professional practice. This study advances the discussion on transforming architectural education to better reflect global priorities for environmental sustainability and ethical accountability.

References

Akgün, Y., Erkarslan, Ö. E., & Neşeliler, P. (2023). A Guide for a Guide: Using UIA publications for an SDG-focused Studio. *International Journal of Architectural Research Archnet-Ijar*, *17*(3), 443-458. https://doi.org/10.1108/arch-11-2022-0245

Ayers, J. B., Missimer, M., & Bryant, J. (2023). Intrapersonal Capacities for Sustainability: A Change Agent Perspective on the 'Inner Dimension' of Sustainability Work. *Sustainability Science*, *18*(3), 1181-1197. https://doi.org/10.1007/s11625-022-01288-8

Balbay, S. (2021). A Specific Implementation of Reflective Journals in Self-Regulating Academic Presentation Skills. *International E-Journal of Educational Studies*, *5*(9), 12-24. https://doi.org/10.31458/iejes.761278

Braun, V., & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*. https://doi.org/10.1191/1478088706qp063oa

Burton, L. O., & Salama, A. M. (2023). Sustainable Development Goals and the Future of Architectural Education – Cultivating SDGs-centred Architectural Pedagogies. *International Journal of Architectural Research Archnet-Ijar*. https://doi.org/10.1108/arch-08-2023-0201

Conroy, K., Riggio, M., & Knowles, C. (2019). Untitled. *Bioproducts Business*, *4*(9). https://doi.org/10.22382/bpb-2019-009

Corcoran, P. B., Walker, K., & Wals, A. E. J. (2004). Case Studies, Make-your-case Studies, and Case Stories: A Critique of Case-study Methodology in Sustainability in Higher Education. *Environmental Education Research*, *10*(1), 7-21. https://doi.org/10.1080/1350462032000173670

Goldschmidt, G. (1998). Creative architectural design: reference versus precedence. *Journal of Architectural and Planning Research*, 258-270.

Griggs, V., Holden, R., Rae, J., & Lawless, A. (2015). Professional Learning in Human Resource

Management: Problematising the Teaching of Reflective Practice. *Studies in Continuing Education*, *37*(2), 202-217. https://doi.org/10.1080/0158037x.2015.1028528

Hilton, M. L., & Pellegrino, J. W. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Academies Press.

Jaakkola, N., Karvinen, M., Hakio, K., Wolff, L.-A., Mattelmäki, T., & Friman, M. (2022). Becoming Self-Aware—How Do Self-Awareness and Transformative Learning Fit in the Sustainability Competency Discourse? [Review]. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.855583

Kark, R., Preser, R., & Zion-Waldoks, T. (2016). From a Politics of Dilemmas to a Politics of Paradoxes. *Organizational Behavior Teaching Review*. https://doi.org/10.1177/1052562916634375

Mabrey, P. E., Boston-Hill, K. E., Stelljes, D., & Boersma, J. (2021). Debate for Civic Learning: A Model for Renewing Higher Education's Civic Mission. *Journal of the Scholarship of Teaching and Learning*, *21*(4), 100-110.

Mahmudah, L. (2016). Improving the hard skills and soft skills of MADRASAH teachers for dealing ASEAN economic community (AEC). *Addin*, *10*(2), 341-364.

McInnes, D. (2013). The performance of academic identity as pedagogical model and guide in/through lecture discourse. *Teaching in Higher Education*, *18*(1), 53-64.

Mezirow, J. (2000). Learning to think like an adult. *Learning as transformation: Critical perspectives on a theory in progress*, 3-33.

Mohkam, M., Mohammadi, S. M. H., Arababadia, R., & Javaran, E. J. (2022). Impacts of Phase Change Materials on Performance of Operational Peak Load Shifting Strategies in a Sample Building in Hot-arid Climate. *Environmental Progress & Sustainable Energy*, *42*(1). https://doi.org/10.1002/ep.13961

Patel, S. (2023). Role of Reflection in Education and Practice in Anaesthesia: Purpose, Process, Pitfalls and Promotion. *International Medical Education*, *2*(4), 262-275. https://doi.org/10.3390/ime2040025

Rieh, S. Y., Lee, B. Y., Oh, J. G., Schuetze, T., Álvarez, S. P., Lee, K., & Park, J. (2017). Integration of Sustainability Into Architectural Education at Accredited Korean Universities. *Sustainability*, *9*(7), 1121. https://doi.org/10.3390/su9071121

Rimanoczy, I. (2020). What Is a Sustainability Mindset? , 9-24. https://doi.org/10.4324/9781003095637-1

Sargeant, J., Mann, K., Vleuten, C. v. d., & Metsemakers, J. (2008). Reflection: A Link Between Receiving and Using Assessment Feedback. *Advances in health sciences education*, *14*(3), 399-410. https://doi.org/10.1007/s10459-008-9124-4

Sinclair, B. R., Furlan, R., Al-Mohannadi, A. S., & Esmaeili, N. (2022). Design, Build, Occupy, Adapt: Critical Considerations of Architectural Education in an Ethos of Upheaval. https://doi.org/10.4995/vibrarch2022.2022.15223

Thomas, A. (2011). Towards a transformative digital literacies pedagogy. *Nordic Journal of Digital Literacy*, *6*(1-2), 89-101.

Till, J. (2009). *Architecture depends* (Vol. 55). MIT press.

Xie, X., Qin, S., Gou, Z., & Yi, M. (2020). Can Green Building Promote Pro-Environmental Behaviours? The Psychological Model and Design Strategy. *Sustainability*, *12*(18), 7714. https://www.mdpi.com/2071-1050/12/18/7714

Zamorano, M. (2022). Special Issue: Recent Advances in Energy Efficiency of Buildings. *Applied Sciences*, *12*(13), 6669. https://doi.org/10.3390/app12136669

ENTREPRENEURSHIP EDUCATION THROUGH INDUSTRY-ACADEMIA COLLABORATION AT GUNMA KOSEN AND ITS EFFECTIVENESS, Part 2

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One of the unique features of entrepreneurship education at Gunma-KOSEN is that "Introduction to Entrepreneurship" as a basic education course, has been made a required curriculum subject for first-year students. The decision to teach this type of content to first-year students was accompanied by concerns that it might be too early for them in terms of age, but the decision was made in consideration of the fact that the more accustomed students at KOSEN become to being in a group, the less likely they are to act spontaneously out of concern for their surroundings.
This course, which began in FY2024, consists of content that includes the social background of the need for startups, the importance of entrepreneurship, the socio-economic and financial structure, and the importance of intellectual property. The essence of educational goal of this course is for students to understand the elements necessary for starting a new business or project, such as the ability to think outside the box, conceptualization, imagination, and management skills, while learning how to think about finding and solving problems and how to proceed with projects. In this report, we will summarize the effectiveness of this course based on the evaluations and comments that students were asked to write throughout the 15 lectures of this course.
Through the entrepreneurship education we have conducted since FY2023 and by helping students participate in various contests such as DCON (Deep Learning Contest) or business contest, we have realized that students at our school are capable of coming up with ideas when given a problem, but due to their lack of experience, they are not very good at incorporating the process of solving a problem into a feasible project and implementing it. They are also poor at spontaneously taking an interest in their surroundings and identifying problems to be solved.To help overcome these weaknesses, as our first attempt, we held an "On-campus idea contest for solving social issues" from the end of FY2024 to April of 2025. For this purpose, we have obtained cooperation from 16 organizations (city hall, newspapers, banks, and companies), centering on the Gun-Rei Techno Gathering, an industry-academia collaboration support group. Fifty-three students, mostly first-year to third-year students, have participated in the contest. In this presentation, we plan to summarize the results of the contest and the educational effects of the contest.

Keywords: *Entrepreneurship education, "Introduction to Entrepreneurship", for the first-year students, "On-campus idea contest for solving social issues"*

Introduction

The Ministry of Economy, Japan (2022) announced its policy to make startups that solve social problems the mainstay of economic growth and formulated the "Startup Development Five-Year Plan". Included in this plan is the strengthening of entrepreneurship education at technical colleges. The Ministry of Education, Culture, Sports, Science and Technology, Japan (2022) planned the "Project to Develop Facilities and Environment for Start-Up Education at KOSEN" in the supplementary budget for FY2022. Our school was selected for this project and started the "Gunma-KOSEN Type Entrepreneurship Education through Industry-Academia Collaboration" in FY2023.

According to a web report by "Corporation Penmark," an independent survey of approximately 130,000 high school students found that 13.9 % of freshmen expressed interest in starting their own business, and 55.3 % of the respondents indicated that they aspire to establish a startup targeting an emerging market, rather than pursuing a small business such as freelancing or becoming an influencer.

The report also includes results from a survey of approximately 230,000 college students, revealing that 12.4 % of them expressed a desire to start their own business. Interestingly, the percentage of high school students wishing to become entrepreneurs exceeded that of college students.

Based on these findings, early entrepreneurship education at the high school level is considered highly valuable. However, our school was not founded specifically to teach entrepreneurship, meaning that while some students show interest in this field, others do not necessarily do so. Additionally, determining whether an individual is suited for entrepreneurship depends on various personal factors, making it unrealistic for the school to set a goal requiring all graduates to start their own businesses or establish a system that exclusively supports those who do.

For this reason, our school defines entrepreneurship as the ability to proactively shape one's own life. Our goal is to cultivate students' ability to take on challenges, develop creative solutions to social issues using ideas and imagination, and collaborate effectively with others to launch new businesses and projects.

In September and December 2023, two entrepreneurship education workshops (Realize Studio and Trial Factory) were established and began operation. These workshops are open to all students and graduates of the school, as well as members of the Gun-Rei Techno Gathering, the school's industry-academia collaboration support group. They were designed as spaces where participants could refine ideas based on their awareness of social and technical issues and work toward their realization.

At our school, technical support staff, rather than teaching faculty, take the lead in managing these workshops. In addition to their role in educational activities such as project-based learning (PBL) classes and graduation research, the workshops are increasingly utilized by students on a voluntary basis to prototype their own ideas. Details of their operation were described in the previous report.

This paper summarizes the outcomes achieved thus far through the "Introduction to Entrepreneurship" course for first-year students, as well as the educational impact of an on-campus idea contest held throughout the academic year, from February 14 to April 23, 2025.

Outline of the "Introduction to Entrepreneurship"

According to a survey conducted by the Ministry of Economy, Trade and Industry (METI) from May 13 to June 12, 2020, of 1,459 start-up companies established within the past five years, 133 companies responded to the question: "Why do entrepreneurs believe there are not enough start-ups in Japan?" The results showed that 37.6 % of respondents attributed this to a fear of failure, 19.5 % to a lack of entrepreneurs in their immediate environment, and 15.0 % to schooling.

To address these issues, the "Introduction to Entrepreneurship" course was introduced in fiscal year 2024 as a compulsory half-year course for first-year students, providing foundational education in the lower grades. In this course, two faculty members and 12 part-time lecturers from companies took turns teaching classes.

The objective of this course is to equip students with the ability to identify and solve problems, understand how to manage a project, and develop essential entrepreneurial skills, including creativity, imagination, and business management, so that they can consider entrepreneurship as a viable career option after graduation.

The syllabus for this course lists the following 10 objectives.

a) To be able to understand the significance of entrepreneurship and its importance.
b) To be able to think about the meaning of working and learning.
c) To be able to understand the position and responsibilities of corporate activities in society.
d) To be able to understand how work is carried out and the division of roles in a company, and what is important in corporate activities.
e) To be able to understand product development strategies and how to proceed with projects in a company.
f) To be able to understand the importance of the ability to judge issues from a broad perspective and solve them proactively.
g) To be able to understand how to utilize intellectual property rights and their importance in corporate activities.
h) To be able to understand the factors necessary for starting a business.
i) To be able to explain the social significance and responsibility of various industries, occupations, and companies.
j) To be able to think about the roles required of engineers in light of their impact on society, the environment, and people.

The first session of the course serves as an introduction, covering the fundamentals of entrepreneurship, the significance of work, and the purpose of learning. The course consists of a series of 15 weekly lectures, one of which is a regular exam.

From the second session onward, guest lecturers will include experienced entrepreneurs, corporate project leaders, company executives, and professionals who have contributed to society using their specialized knowledge. Drawing from their experiences, they will provide insights on the following topics:

(A) Working in a company - understanding corporate structures and professional roles.
(B) Intellectual property rights - protection, management, and strategic use.

(C) Relationships with financial institutions - their social significance and impact on business.
(D) Collaboration with local governments - the role of public institutions in entrepreneurship.
(E) Case studies of solving social issues through imagination and entrepreneurship.
(F) Product development strategies - successes and failures in corporate innovation.
(G) Entrepreneurship from technical colleges - opportunities and challenges for students.

The course evaluation was designed to allow students to pass without the burden of excessive assignments or additional study outside of class, provided they attended regularly. To achieve this, 30 % of the grading was based on cumulative quiz from each session, while the remaining 70 % was assessed through a mark-sheet system featuring questions similar to those on the quizzes.

As a result, in the 2024 academic year, all students who took the course passed the exam without needing to retake it.

Consideration of the timing of this course

The structure of the course was established through a pre-course consisting of six lectures offered to interested students in the 2023 fiscal year. Following this, “Introduction to Entrepreneurship” became a compulsory course for first-year students in the second semester of their first year in 2024. This timing was chosen to allow for a preparatory period and to ensure that students had already acclimated to the academic environment of the technical college, making the course more effective.

In the 2025 fiscal year, the course was moved to the first semester of first-year students due to the renovation of campus buildings, which limited the availability of large classrooms to the first semester. As a result, the first class of this course was held on the very first day of classes for first-year students.

In both 2024 and 2025, the first lecture in the series was titled "What is Entrepreneurship? On Working and Learning" and covered the meaning of work, career planning, and life after graduation.

There were initial concerns that discussing topics such as work, money, and even the broader implications of life beyond graduation, including perspectives on one’s entire lifetime, might be too early for newly enrolled students. However, when the lecture was delivered, all students engaged seriously, demonstrating genuine interest in the subject matter.

A survey was conducted after the first lecture in the current academic year, with 207 first-year students responding. In addition to questions about the significance of work and success in life, students were asked whether they understood the concept of entrepreneurship after attending the lecture. To this question, 91 % (188 students) answered that they understood it fairly well, while 9 % (19 students) indicated that they did not understand it well. We believe this demonstrates that we are effectively introducing students to our school's entrepreneurship goals, a topic many are encountering for the first time.

Additionally, 200 responses were collected for the open-ended question, "Please write your impressions of the class", which was not a required part of the survey. This unexpectedly high response rate indicated strong engagement, and the students’ feedback clearly reflected that they had internalized the lecture's content and expressed their thoughts in their own words.

From the responses to that survey, here are several. All of these are considered evidence that the timing of the class is not too early and that students are taking it seriously as their own.

"I often hesitate to take action due to various risks, but I realized that without taking action, success is impossible. I need to change my perspective on failure. Failing does not mean the end of everything, so from now on, I want to actively challenge myself and value cooperation with my peers."

"When heard about life after graduation, I initially couldn't imagine much. However, as I listened, I learned a bit about how to establish a vision for the future, which was very insightful."

"I used to think that work was just about earning money, but I never considered it as a source of fulfillment. This was a new discovery for me. Success means realizing one's dreams, and I want to achieve even small successes during my time at KOSEN to work toward my dreams."

"This was my first entrepreneurship class, and it provided a great opportunity to reflect on my future and further education. I would like to discuss my dreams with my family."

"I realized that I am close to becoming a working adult, which made my future feel more tangible. I want to keep thinking about my future, even in the next class."

"I understood the importance of going beyond my comfort zone and developing the ability to take action. Until now, my attitude was based on 'things will somehow work out' without a solid foundation. But now, I want to take action to make 'things will work out' based on actual reasoning."

"Through this class, I had to deeply consider my future path after graduation. I reflected on the reasons for working, what working means, and how I will work. I was able to gain a clearer understanding of my future dreams. I also realized that self-analysis is something I lack, so I want to further explore my strengths and who I am through my experiences at KOSEN."

"I had never thought much about living proactively, but this class helped me understand what jobs I might pursue, what skills I need, and why working is important."

"I learned not only about life after entering society but also about things I can start working on now, like thinking critically. Understanding how I can improve my current life will help me in both school and at home. I want to develop a mindset of setting clear goals and challenging myself without fearing failure."

"I was deeply moved to learn that my school supports not only my current student life but also my future. I will approach my time at KOSEN with a strong sense of

purpose and proactiveness. I appreciate the support I've received and will strive to meet expectations."

"This was my first time hearing about entrepreneurship, and I realized how essential it is in life. Having this mindset makes a huge difference. I also learned that it's okay to rely on others when I can't do things alone, which was reassuring. I was surprised to learn that KOSEN has workshops dedicated to skill development, and I would love to use them."

"The phrase 'It's okay to fail' resonated deeply with me, as I was afraid of failure. This class made me want to actively engage in various challenges without fear."

"Taking this class at the age of 15, when we are still developing our perspectives on work, earning money, and our future, was valuable. During my five years at Gunma KOSEN, I want to reflect more deeply on my future while growing as a person."

Based on these responses, we can conclude that introducing entrepreneurship education in the first semester of first-year students (age 15) at a technical college is not too early for them. However, this may be influenced by the fact that these students voluntarily chose to enroll in a technical college, which is a specialized educational track in Japan. Therefore, it remains uncertain whether this approach would be equally feasible for students in a standard high school setting.

Lean Canvas hands-on workshop, at the final session of the course held after the regular exam

At our school, the final session of the 15-week semester-long course takes place after regular examinations. During the final week of the "Introduction to Entrepreneurship" course in the 2024 fiscal year, a practical workshop on Lean Canvas, a method for structuring ideas into projects, was conducted as a culminating activity to reinforce the concepts covered in previous lectures.

For this workshop, more than 200 first-year students gathered in the gymnasium and were divided into 25 groups, averaging about eight students per group. To encourage interaction among students who had never met before, the groups were formed by mixing students across different classes and departments. A Lean Canvas framework was printed on A0-sized paper, and all team members contributed their ideas by writing on sticky notes and attaching them to the framework to complete their project plan. The social issues each group addressed were randomly assigned in advance.

At the start of the session, students were introduced to real-world applications of Lean Canvas in startup operations. They then engaged in group discussions to collaboratively develop business plans using the framework. Finally, representatives from five groups presented their projects in front of the entire assembly.

Despite having only about 30 minutes to construct their business plans, many groups successfully completed approximately over 80 % of their Lean Canvas framework and developed project concepts worthy of presentation. Faculty members observed that the speed of project planning progressed more efficiently in groups where students spontaneously stepped up to speak and take on leadership roles. In an era when many students are hesitant to voice their opinions in public or fear making mistakes, one significant outcome of this course series was that many students demonstrated the confidence to speak boldly—even in groups where they were meeting their peers for the first time.

The educational impact of this course

The 1,944 responses collected from the final questionnaire, an optional survey, were categorized based on the 12 lecture sessions conducted during the Introduction to Entrepreneurship course in the 2024 fiscal year, excluding the initial introductory session and the final workshop. Figure 1 illustrates the distribution of responses across various thematic groups, expressed as percentages.

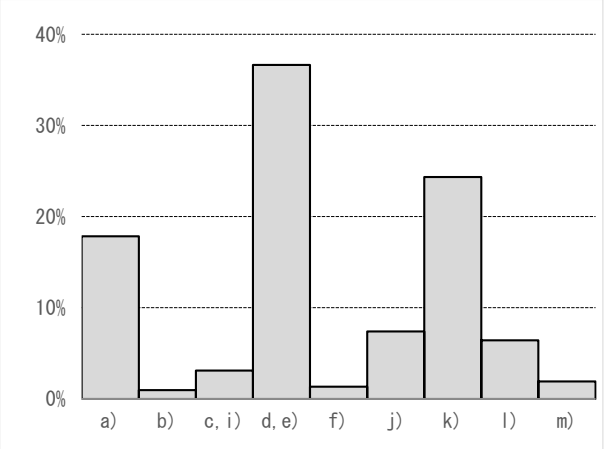


Figure 1. Percentage of which group the subject of the written comments belongs to. These thematic groups align with the syllabus achievement objectives previously outlined in this report and are classified as follows: a) the significance and importance of entrepreneurship, b) the significance and importance of working and learning, c,i) the position and responsibility of business activities in society, d,e) the way work and projects are carried out, f) the ability to judge things from a broad perspective and to solve problems independently, j) the roles they are expected to play, and k) gained the knowledge and the benefits by the course, l) impressed and enjoyed, and m) others.

The topics g) the use and importance of intellectual property rights and h) the essential elements for starting a business were not categorized among the written comments but were taken into account when selecting instructors, corresponding to (B) and (G) in the syllabus, respectively. Additionally, the significance of work and learning is thoroughly covered in the first introductory class, which is not reflected in this graph.

While this graph only illustrates the subject areas mentioned in students' impressions, it suggests that the coursework meaningfully contributes to the attainment objectives outlined in the syllabus. Notably, many comments highlighted a) the significance and importance

of entrepreneurship as well as d, e) the execution of work and projects. Furthermore, 30.7% of students expressed that k) the course was informative and enriching, while l) it was inspiring and enjoyable, indicating that students found substantial value in the subject.

Conversely, only 1.3 % of students commented on f) the ability to assess situations from a broad perspective and solve problems independently. This may be attributed to the fact that such skills cannot be fully developed through lectures alone and require continuous practice and experience.

While there are inherent biases when analyzing specific classes and subjects individually, when viewed as a whole, the course effectively addresses the achievement objectives set forth in the syllabus.

Outline of the "On-campus idea contest for solving social issues"

Through lectures on entrepreneurial subjects in the 2023 and 2024 fiscal years and the call for contest participation, faculty members observed that while students at our school can generate ideas to address problems, their lack of experience hinders their ability to transform these ideas into viable projects and manage their execution effectively. Additionally, they struggle to spontaneously engage with their surroundings and identify problems in need of solutions.

To address these challenges, enhance students' ability to collaborate on projects, and foster proactive decision-making in shaping their futures, we organized an on-campus idea contest focused on solving social issues. The contest was co-sponsored by Gunma National College of Technology and Gun-Rei Techno Gathering, an organization supporting industry-academia-government collaboration. A total of 20 organizations, including city halls, newspapers, banks, and companies, primarily members of Gun-Rei Techno Gathering, participated as mentors and judges.

On February 14, marking the end of the 2024 academic year, 53 students ranging from freshmen to juniors launched the program. They were divided into nine groups, each working over a span of 2.5 months to identify and address social issues. Each student group was assigned a corporate mentor who engaged with them one to two times per week, either online or in person.

Faculty members have ample opportunities to engage with business professionals through joint research, but students have historically had limited interactions with industry figures - mostly through internships, company information sessions, and similar activities. This contest provided a groundbreaking opportunity for students to work alongside corporate mentors on an equal footing over two and a half months, shifting the focus from job-hunting and recruitment to real-world project collaboration. From the companies' perspective, the contest was a welcome initiative, offering them direct engagement with students without the filter of faculty oversight.

The final judging took place on April 23, 2025, during which students and their mentors presented their projects and showcased their prototypes.

The team that won the Grand Prize disregarded the business aspect of profitability, something only students have the freedom to do, and instead focused on solving the problem of portable toilets during disasters. Their project involved disseminating information on how individuals could create portable toilets themselves, earning them an award from the school's principal.

The Excellence Award went to a team that proposed and attempted to implement an algorithm for scanning documents that cannot be processed using a flatbed scanner due to their shape or sensitivity to strong light. Their method utilized video capture technology, and they received an award from the president of Gun-Rei Techno Gathering.

All nine student teams approached social issues from unique perspectives, working to develop solutions. As a result, each team received recognition, either from the judges' companies or through special awards.

The educational impact of this on-campus contest

A questionnaire was administered to students who participated in the contest, with 32 responses collected. These responses were used to evaluate the educational impact of the contest.

Firstly, to assess their efforts, students were asked to rate their experiences on a five-point scale (with 5 being the highest) across eight questions. Below are the questions along with the percentage breakdown of responses:

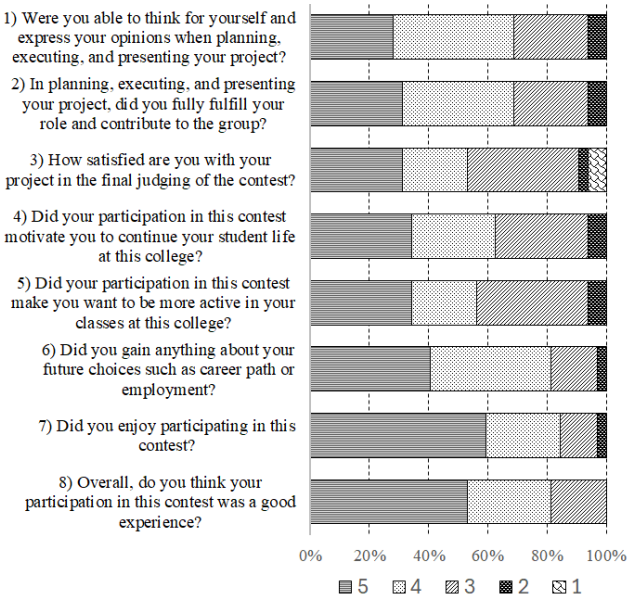


Figure 2. Numerical evaluations from students who participated in the contest. Each item was rated on a 5-point scale (5 = Excellent/High, 1 = Poor/Low).

In summary, less than 10 % of students (3 out of 32) selected 1 or 2 across all survey questions, while 5 or 4 were chosen by the majority of respondents for every question. This suggests that, overall, students rated the contest highly.

Questions 7) and 8) received the highest number of 5 ratings, followed by question 6), which focused on

students' perspectives on their future. This indicates that one of the contest's core objectives, helping students envision their futures, was successfully achieved. Meanwhile, the relatively lower satisfaction regarding project completion in question 3) was not due to a lack of effort but rather the limited timeframe of two and a half months, which restricted students' ability to fully develop their projects despite their enthusiasm.

In the second question, students were also asked to select the abilities they felt they had developed through participation in the contest. The numbers in parentheses represent how many students selected each option.

More than half of the respondents (**16 or more**) reported developing the following abilities:

- Originality and broad perspective – Identifying social issues and finding solutions (18)
- Analytical skills – Investigating problems and seeking solutions (18)
- Action skills – Acting proactively and executing projects (18)
- Objectivity – Evaluating projects from different perspectives (18)
- Membership – Collaborating effectively with peers to carry out projects (17)
- Planning ability – Incorporating solutions into concrete project plans (16)

These results suggest that the contest had a significant impact, encouraging students to think critically, challenge themselves, and engage with their projects meaningfully. The mentorship students received at key stages further contributed to this sense of fulfillment.

While this is based on self-evaluation by students, their efforts were also recognized by mentors, faculty members, and corporate judges who participated in the final judgement. In particular, the mentors who guided the groups throughout the project expressed admiration for students' creativity, initiative, organizational skills, and presentation abilities, especially considering their young ages 15 to 18.

Conversely, fewer than one-third of students selected the following abilities (fewer than 10 responses):

- Information organization skills – Structuring and presenting completed projects (8)
- Presentation skills – Effectively communicating ideas to an audience (5)
- Risk management skills – Anticipating and addressing risks proactively (5)

While these abilities are essential to entrepreneurship, participating in the contest alone was not enough for students to fully develop them. It is expected that these skills will be cultivated further through project-based learning (PBL) courses in higher grades.

Conclusions

The "Introduction to Entrepreneurship" course for first-year students successfully conveyed the significance of entrepreneurship. Additionally, through insights shared by working professionals as instructors, students gained valuable perspectives on how to approach their future careers and projects. These experiences encouraged students to deeply reflect on their own paths and aspirations. Student evaluations of the course included numerous comments expressing its value and enjoyment, indicating a strong demand for this content.

Furthermore, students who participated in the on-campus contest, which ran from the end of the previous academic year to the current year, worked collaboratively in groups for two and a half months under the mentorship of industry professionals. This allowed them to gain essential experience in project execution. As a result, students not only felt their own growth but also received recognition from those around them. The contest provided a rare opportunity for students to engage in long-term, direct communication with professionals without the filter of faculty supervision, broadening their perspectives.

Building on these experiences, it is hoped that students will actively participate in external contests such as DCON and the KOSEN Entrepreneur Summit. Through such engagement, they can further develop their independence and initiative. Ultimately, fostering a proactive mindset in students will not only enrich their school life and personal growth but also positively impact their academic achievements.

Acknowledgements

The establishment of the Entrepreneurship Education Workshop was supported by the "Project to develop facilities and environment for start-up education at KOSEN" (MEXT) in the supplementary budget for FY2022.

The aforementioned on-campus idea contest was successfully conducted with the full cooperation of the co-organizing Gun-Rei Techno Gathering. We received support from a total of 20 companies, financial institutions, and the city hall, with members from these organizations serving as mentors and judges. We sincerely appreciate their contributions.

References

Corporation Penmark (2023), *Survey of Employment Attitudes of High School Students*, Retrieved from https://corp.penmark.jp/news/20230818

Ministry of Economy, Japan (2022, 2022), Trade and Industry, *Startup development 5-year plan,* p7, Retrieved from https://www.cas.go.jp/jp/seisaku/atarashii_sihonsyugi/pdf/sdfyplan2022.pdf
The Situation for Startups in Japan, Retrieved from https://www.meti.go.jp/shingikai/sankoshin/shin_kijiku/pdf/004_03_00.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan (2022), Technical College Startup *Educational Environment Improvement Project*, Retrieved from https://www.mext.go.jp/content/20220110-mxt_senmon01-000026909_1.pdf

INVESTIGATION OF THE EFFECTIVENESS OF 3D CAPTURE AND VR AS LEARNING MATERIALS FOR BEGINNERS OF CIVIL ENGINEERING STRUCTURES

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A Virtual Reality (VR) educational material has been developed for beginners in civil engineering. The VR content consist of civil engineering structures captured in three dimensions using 3D Gaussian splatting. This educational material has three main objectives. First, users can become familiar with the names of structures in their environment by using familiar civil engineering structures as learning content, Second, learners can examine structures in more detail, through multi-perspective observation enabled by 3D capture technology. Third, the material allows learners to experience state-of-the-art technologies by incorporating VR and 3D Gaussian splatting. The target structures for this material are located on the campus of National Institute of Technology, Gunma College. A total of 16 civil engineering structures are captured in 3D and integrated into the VR-based learning system. In addition, the learners are able to view the names of these structures within the VR environment before starting the VR observation. To evaluate the effectiveness of this educational material, a survey is conducted with 28 students from National Institute of Technology, Gunma College. The survey assess the usefulness of using 3D models, the effectiveness of VR, and the benefits of focusing on the environment. Participants responded using a four-point Likert scale: "strongly agree", "somewhat agree", "neutral" and "somewhat disagree". The results showed that over 92.9% of students responded positively ('strongly agree' or 'somewhat agree') to all questions. In addition, participants were shown images of six civil engineering structures that they had observed in VR and were asked to categorize them into one of three options: "Can name the structure", "Probably can name the structure", or "Cannot name the structure". The cumulative response rate for "can name the structure" and "probably can name the structure" was over 85.7% for all structures. Open-ended responses included positive feedback such as "I was surprised by the number of civil engineering structures around me" and "VR helped me understand concepts that are difficult to understand in lectures in a more engaging way". However, a notable negative comment was the issue of motion sickness when experiencing VR. These findings suggest that a VR-based educational material using 3D Gaussian splatting can enhance civil engineering education by making structures more familiar and engaging to learners.

Keywords: *civil structure, learning material, digital twin, VR, 3D gaussian splatting*

Introduction

Civil engineering structures form the backbone of our daily lives. From commuting routes to the surroundings of schools and workplaces, various civil structures are present in our immediate environment. For instance, the National Institute of Technology, Gunma Collage (NITGC), where the authors are affiliated, contains numerous civil engineering structures, including those shown in Photo 1 and listed in Table 1. In this study, the definition of "civil engineering structure" follows the



Photo 1. Rivers and bridges on the NITGC campus

Table 1. Example of civil engineering structures on the NITGC (Nilim, 2025)

Concrete bridge	Asphalt pavement	River dike
Box culvert	Sluice gate	Fall barrier
L-shaped retaining wall	Masonry retaining wall	Concrete block retaining wall
Gravity retaining wall	Inclined retaining wall	Curb stone
Channel works	Grit chamber	Guard fence
U-shaped gutter	L-shaped gutter	Catch basin
Lighting pole foundation	Precast foundation block	Guard fence foundation

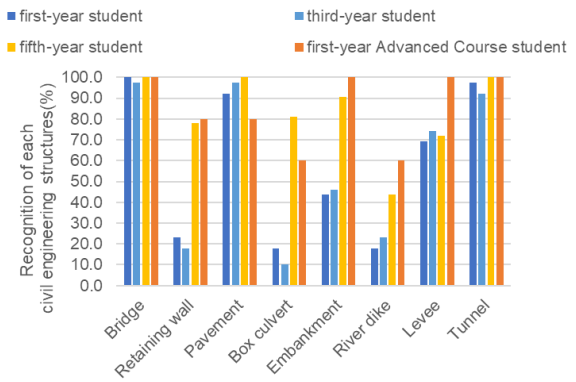


Figure 1. Results of survey on recognition of each civil structure (Watanabe & Takamizawa, 2025)

classification provided in the 2025 revised Construction Work Classification Tree issued by the National Institute for Land and Infrastructure Management (Nilim, 2025).

However, a survey conducted by Watanabe and Takamizawa (2025) targeting students in the Department of Environmental and Advanced Engineering at NITGC revealed that, especially among first- and third-year students, the recognition rate of specific civil engineering structures such as retaining walls, box culverts, and revetments were relatively low (10.0% to 24.0%) as shown in Figure 1. This suggests that such limited awareness is likely not unique to NITGC.

Professionals in civil engineering often notice structures during their travels and contemplate questions such as "Why is it located here?", "Why does it have this shape or structure?", and "What causes its deterioration?". Such reflection contributes to knowledge acquisition through direct observation of real-world structures. For beginners in civil engineering, recognizing various structures is the first critical step to gaining similar insights. While deeper understanding requires specialized knowledge, identifying and acknowledging the existence of these structures is a foundational learning step. Therefore, we emphasize the need for learning materials that help beginners learn the names and functions of civil engineering structures.

In addition, advancements in techniques like SfM-MVS analysis and laser scanning have made it easier to generate 3D point cloud and mesh data, accelerating the application of digital twins in civil engineering. Current studies utilize these technologies for modelling existing structures (Nakamizo and Nishio, 2022), infrastructure management (Otsuki, et al., 2022), and disaster recovery (Watanabe, et al., 2023). Moreover, the use of VR technology to present 3D data in immersive environments is gaining traction in disaster and safety education (Magara, 2019). Given the rapid evolution of digital tools, today's civil engineering students will soon be in positions requiring proficiency in such technologies. Early exposure is therefore essential.

Based on the above, we argue that civil engineering beginners should be provided opportunities to learn using digital twin and VR technologies. However, such learning materials remain scarce. To address this, our study aimed to (1) develop easy-to-understand instructional materials featuring civil engineering structures and (2) offer early exposure to digital twin and VR technologies. We created such materials and had students interact with them to collect feedback on their effectiveness.

Development Method of Learning Materials

This study developed instructional materials targeting structures on the NITGC campus. Table 1 lists the selected structures. As the intended users were NITGC students, we prioritized familiar, accessible structures. However, this method can be implemented elsewhere.

Figure 2 outlines the development process. We first listed relevant structures based on the 2024 Construction Work Classification Tree. The scanning application was scaniverse by Niantic, which supports both "Splat mode"

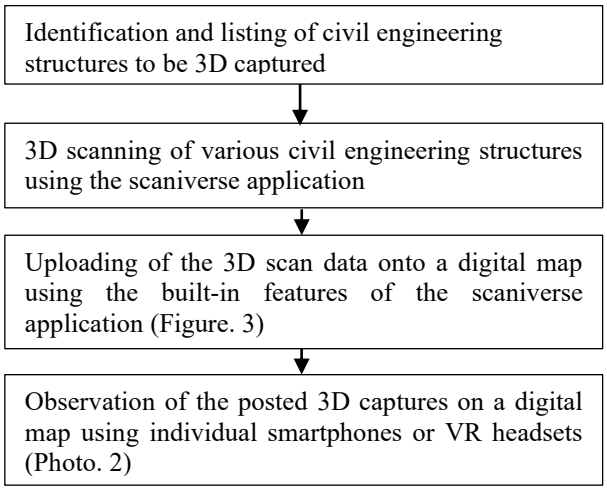


Figure 2. Flow of how to create learning materials

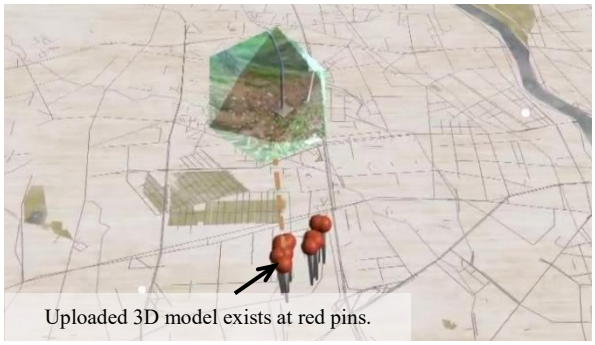


Figure 3. View of the arrangement of the 3D capture in the VR space

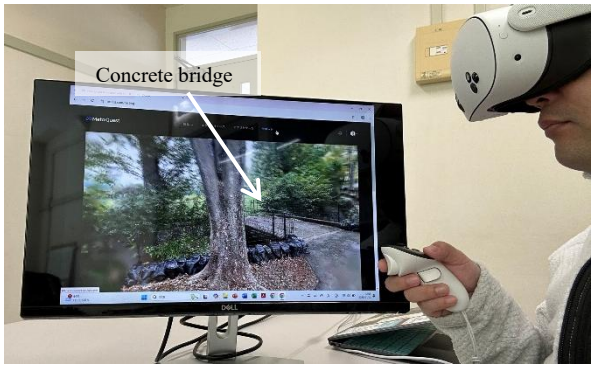


Photo 2. Observe uploaded 3D captures with VR

(using 3D Gaussian Splatting) and "Mesh mode" (combining LiDAR sensors and SfM-MVS). Splat-mode data can be uploaded to a digital map within the app, enabling users to view 3D data and location information on their smartphones.

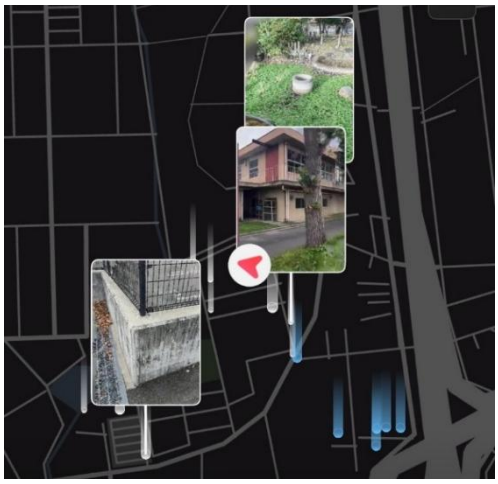
These uploaded 3D captures serve as digital twins, marked on a digital map with pins (Figure. 3). Clicking a pin displays the structure's name and entering the VR environment via the Meta Quest 3S headset allows immersive observation (Photo. 2).

Learning Materials for Beginners

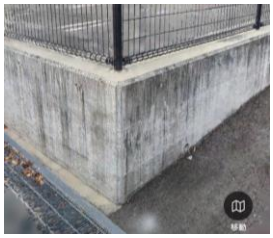
An example of the NITGC campus structure map and 3D captures is shown in Figure 4. We selected 16 structures from areas that are accessible and safe. Four student volunteers participated in the creation of these models, though any smartphone user can contribute. By scanning and uploading structures, students can learn scanning techniques and develop deeper interest in existing data.

Evaluation of Learning materials

We conducted a survey with 28 NITGC students (15 first years, 6 second years, and 7 third years) who used the Meta Quest 3S headset to observe 3D captures via Scaniverse. They evaluated the usefulness of 3D captures, VR technology, and familiar environments using a four-point Likert scale. Additionally, they were shown photos of the observed structures and asked to identify their names from three options: "can name", "probably can name", and "cannot name". A free-response section was also included; 18 students provided feedback. The survey explicitly stated the purpose and content of the study, as well as the privacy policy. Consent to participate in the study was considered to have been obtained upon submission of the completed questionnaire.



(a) Map of civil engineering structures on the NITGC



(b) 3D capture of gravity retaining wall



(c) 3D capture of concrete bridge

Figure 4. Learning materials for beginners of civil engineering structures

Figures 5 to 7 present the survey results, and Figure 8 shows comprehension levels. Table 2 summarizes free-text responses. For 3D capture usefulness, 89.3% answered "strongly agree" and 10.7% "agree", with a total of 100% positive feedback. Positive comments from free comments included the ability to observe structures from various angles. Some noted quality differences among models, suggesting further investigation into factors affecting model clarity (e.g., smartphone specs, scanning speed). For VR usefulness, 82.1% chose "strongly agree" and 14.3% "agree", though 3.6% responded "neutral". Some negative feedback mentioned 3D motion sickness and difficulty wearing the headset. However, many appreciated the engaging, memorable experience VR provided. Regarding the use of familiar environments as a target area, 75.0% responded "strongly agree" and 17.9% "agree". One student suggested expanding beyond the campus to unfamiliar structures. Conversely, others found the experience eye-opening, realizing the abundance of civil structures in their daily surroundings. The Free-text feedback indicate that incorporating emerging technologies such as 3D scanning and virtual reality into the learning process enhances the memorability of the educational experience.

Comprehension of structure names exceeded 85.7% for all cases when combining "can name" and "probably can name" responses. Notably, these students had not formally studied the names of these structures in class, indicating the educational value of the materials.

Conclusions

We develop VR-based instructional materials to teach civil engineering beginners about structural names and forms using real structures on the NITGC campus. The materials enable multi-angle observation through 3D scanning and immersive learning through VR. Surveys with 28 students reveale 100% positive responses for the usefulness of 3D captures, 96.4% for VR, and 92.9% for using familiar environments. Free-text feedback highlights the advantages of multi-perspective observation, immersive engagement, and newfound awareness of nearby structures. Some drawbacks included model quality inconsistency and 3D motion sickness. Comprehension surveys showed over 80% recognition rates for all structure names, confirming the material's educational effectiveness. The process of co-developing the materials with students also suggested potential applications in structure inspection and diagnosis. These materials demonstrate that civil structures in any location can be digitized and viewed in VR. By familiarizing novices with 3D scanning and VR,

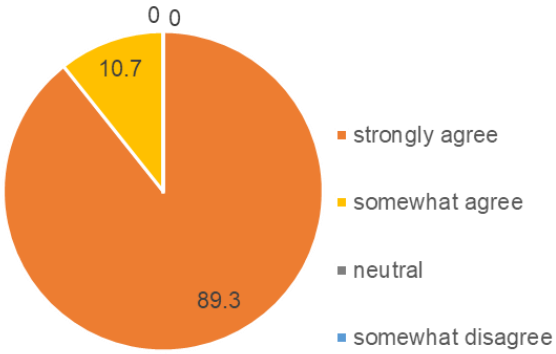


Figure 5. Usefulness of using 3D captures

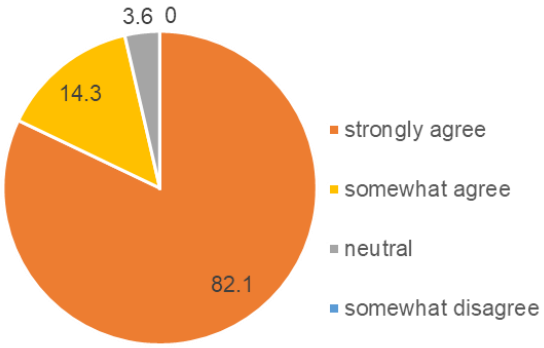


Figure 6. Usefulness of using the familiar environment as a target

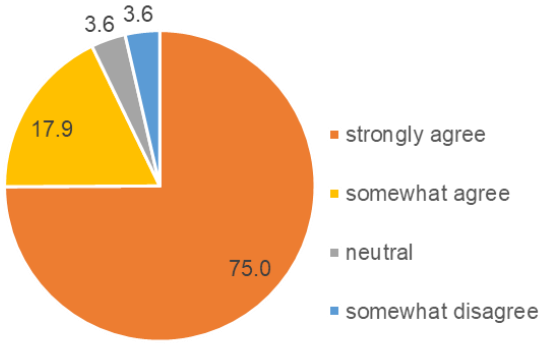


Figure 7. Usefulness of familiar environments

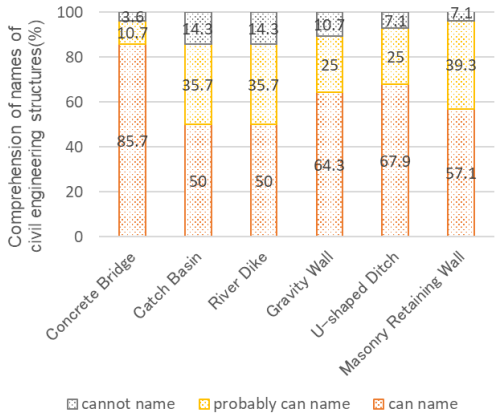


Figure 8. Recognition of each civil structure

Table 2. Free comment responses

No.	Free comment responses
1	I felt that 3D captures, which can be observed from various angles, can be used in various ways compared to photographs.
2	Some structures had blurred images or only a portion of the image was clearly visible, so I thought it was necessary to scan carefully.
3	I thought it was very easy to understand when I experienced it after learning in the classroom because I felt as if I was actually there. On the other hand, I thought it was an issue that some people get drunk and that it takes a little time to put on the goggles.
4	I had seen people using VR in game situations and thought it looked interesting, so I was very happy to be able to actually use it.
5	I was surprised that it was easier than I thought to observe my own model in VR.
6	I was amazed at how easily I could VR and experience the world around me. It was my first time wearing goggles and it was immersive.
7	It was very good to be able to see civil engineering structures from various perspectives that we cannot see in our daily lives, such as from inside a water catchment basin or from the sky. I also felt that it could be used effectively as a learning material, as it tickled the students' interest because they could learn while moving their bodies, unlike sitting down and looking at the material.
8	I was surprised that the scenery was projected more clearly than I had imagined. I thought it was an advantage to be able to see the local scenery without having to go there.
9	Using VR and 3D captures was fresh and interesting. I think it is good to show places inside the school, but I think it will deepen my understanding of the target structure if I can see places that are not often seen.
10	I thought it was good to be able to observe structures from various perspectives by using 3D captures. I was also a little surprised to realize that there are so many civil engineering structures in our everyday environment. I would like to look for them myself.

the program aims to further advance the use of the technology in civil engineering.

In this study, we utilize the 3D scanning and map-based uploading functions of an existing application, Scaniverse. Furthermore, we developed an educational

material that integrates this application with a VR service. The primary focus of this material is to help students learn the names and shapes of civil engineering structures. Initially, the names of the structures are introduced through classroom instruction, with the functions of each structure being explained theoretically. However, we consider it more effective for students to deepen their understanding of these functions by viewing the 3D models in VR. Future improvements will aim to provide a more integrated learning experience combining both theoretical and VR-based instruction.

The services used in this study assume the public sharing of 3D models. For this project, a location-specific map focused exclusively on civil engineering structures However, when similar mapping and scanning activities are conducted for other purposes, there is a risk that all uploaded models may be displayed simultaneously on the same map. This could hinder users from efficiently locating the specific information they seek. Additionally, depending on the scanned object or location, some data may be unsuitable for public release due to privacy or security concerns. These issues suggest that, from a quality assurance standpoint, there will be cases where a closed-access version of the material is necessary.

Moreover, regarding the free responses in the questionnaire that addressed the quality of the 3D models, it is necessary to analyze the factors that influence model quality to ensure a minimum standard is met. Although this study is based on responses from 28 participants, future work will involve the accumulation and analysis of more data to obtain a more robust evaluation of the material.

Finally, although this study focused on beginner-level students in civil engineering at National Institute of Technology, Gunma College and utilized familiar, nearby structures as educational content, the free-response section of the survey highlighted that one of the advantages of digital materials is enabling observation of distant structures that are not easily accessible. While the current material was developed using a relatively simple method focusing on local civil infrastructure, we plan to expand its application to preserve and convey disaster-related information—such as damage caused by earthquakes or heavy rainfall—for future generations.

Acknowledgements

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References

Magara, T. (2019). Applications and Initiatives of VR/AR in the Construction Industry, *Journal of JCMA*, Vol. 71, No. 4, pp.62-66. (in Japanese)

Nilim, (2025), National Institute for Land and Infrastructure Management, Construction Type System Tree. Retrieved May 12, 2025, from https://www.nilim.go.jp/lab/pbg/theme/theme2/sekisan/tree/tree.htm

Nakamizo, T., Nishio, M. (2022). Finite Element Modelling with shell element from 3D point clouds of thin walled steel structural members, *Intelligence, Informatics and Infrastructure*, Vol. 3, No. J2, pp.786-794. (in Japanese)

Niantic scaniverse, Into The Scaniverse. Retrieved May 10, 2025, from https://scaniverse.com/quest

Meta. Retrieved May 10, 2025, from https://www.meta.com/jp/quest/quest-3s/

Otsuki, S., Imai, R., Tsukada, Y., Umehara, Y., Tanaka, S., Hirano, N. (2022). Research for utilizing product model using point cloud data in the maintenance of social infrastructure, *Intelligence, Informatics and Infrastructure*, Vol. 3, No. J2, pp.945-953. (in Japanese)

Watanabe, Y., Inoue, K., Ikeda, T., Kobayashi, M., Yokoyama, W. (2023). Investigation of the application of smartphone surveying for rapid shape determination of post-disaster slopes and design of countermeasure works, *Intelligence, Informatics and Infrastructure*, Vol. 4, No. 2, pp.73-83. (in Japanese)

Watanabe, Y., Takamizawa, T. (2025). Proposal for New Learning Materials Based on Questionnaire Survey on the Recognition of Civil Engineering Structures. *THE GUNMA-KOSEN REVIEW*, No.43, pp.39-44. (in Japanese)

BLENDED LEARNING OF AC CIRCUITS FOR TRANSFER STUDENTS FROM THAI-KOSEN TO JAPANESE KOSEN

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This article reports on a blended learning of AC circuits. The course is designed for the selected second-year Thai-KOSEN students who are directly transferred to the third year of Japanese-KOSEN by bypassing an extra education. On the way, the students face two barriers in the transfer: one is the Japanese language, and the other is the curriculum gaps.
For example, if a student belongs to the Mechatronics engineering department in KOSEN-KMITL or the Automation engineering department in KOSEN-KMUTT, where AC circuit is not taught in the second year, is transferred to one of the Electrical departments in a Japanese KOSEN, where the first course of AC circuits is taught in the second year, the student starts from the second course of AC circuits in Japan. The first course of AC circuits, including phasors, impedances expressed by complex numbers, and circuit analysis, is not only the vital foundation for the succeeding courses of AC circuits but also a challenging course for students to learn by themselves. The extra 'AC circuit' course is one of the courses that fills in the curriculum gaps. It started in the 2023 Academic Year (AY) with nine one-hour face-to-face lessons for KOSEN-KMITL students and remote lessons for KOSEN-KMUTT students. As the students' timetable is fully packed with regular courses, the extra course was set in the evening after the regular lessons during the three months from December to February. It became a lecture on basic concepts and analysis techniques of AC circuits because of the limited time. The students did not have time to explore the circuits during the lessons.
In 2024 AY, we changed the teaching style to blended learning, combining on-demand lecture videos with face-to-face exercises for KOSEN-KMITL students. Nine-hour lectures are divided by topics into 40 video clips and served through MS Teams with the teaching materials and exercise sheets, which are provided two weeks before the face-to-face exercise sessions. The students are expected to watch the videos before the exercise sessions and are ready to tackle the exercise questions immediately at the start of the exercise sessions.
The blended learning worked well for the course, possibly because the students were highly motivated to learn the subject and well-informed about the necessity from those who had transferred to Japanese KOSEN in previous years.

Keywords: *blended learning, AC circuits, transferring students, curriculum gap*

Introduction

The National Institute of Technology (NIT) set up a program to accept the top 17% of Thai KOSEN students directly into the third year of Japanese KOSENs after completing their second year in a Thai KOSEN. The program aimed to unite KOSENs in the two countries into a single system and encourage young Thai students to work internationally.

The transfer students face two hurdles to overcome when learning in Japanese KOSENs. The first obvious hurdle is the language used in teaching. Almost all Japanese educational institutions use Japanese as the teaching language, and KOSENs are no exception. Because of the language barrier, international students usually take one year of intensive language courses in Tokyo before starting their KOSEN studies. However, the transfer program from Thai KOSENs does not include those intensive language courses. Instead, the students from Thai KOSENs must learn the Japanese language in and out of their regular language lessons during the two years in Thailand. Although they also receive additional language lessons before they are transferred to Japan, the engineering terminologies and typical expressions used in engineering subjects are out of reach in the regular language lessons.

The second hurdle is the curriculum gaps between the Thai KOSEN and the host KOSEN in Japan. Serious gaps exist in programming language C and AC circuits courses for some transfer students. For example, second-year students of the Mechatronics Engineering department (ME) at KOSEN-KMITL in Thailand learn DC circuit analysis in their second year, but AC circuits in the third year (KOSEN-KMITL, 2025a). On the other hand, some host KOSENs in Japan teach the first course of AC circuits during their second year (NIT, 2025). As the transferred ME students do not stay in the third year in

Thailand or the second year in Japan, they miss the opportunity to take the first AC circuits course by transferring from Thailand to Japan.

The first course of AC circuits, as is Electromagnetism, is recognized as a challenging course in Electrical Engineering. The difficulty comes from using a mathematical expression called a phasor, which is expressed by a complex number or a rotating vector in the complex plane, to represent an AC wave such as an electric voltage or a current. The relation between an AC voltage and current is also expressed by a complex number called an impedance. Because of these representations, we can use the analytical methods used in DC circuit analysis, and AC circuit analysis becomes simpler. However, novice learners sometimes have difficulty understanding the relationship between a sinusoidal wave and a phasor and take time to use the representation confidently.

As the first course on AC circuits is not an easy subject for students to learn by themselves, NIT prepared an extra course on AC circuits for transfer students. The additional course is designed as nine weekly lessons of one hour each after the regular lessons in Thai KOSENs. The ME students are to learn AC circuits in the additional course in parallel with DC circuit analysis in their regular course. The jam-packed timetable of the regular courses and occasional school events in Thai KOSENs restricts the total lesson time and place of the additional course in the school timetable.

Another factor to consider is the necessity of exercises in learning AC Circuits as retrieval practices. Karpicke and Blunt (2011) found that retrieval practice is a powerful way to promote meaningful learning of complex concepts commonly found in science education. They showed that retrieval practice produced more long-term learning than elaborative studying, such as concept mapping. Their result contradicted the students' prediction that elaborative concept mapping would produce better long-term learning than retrieval practice. They suggested a possible theory to explain the advantage of retrieval: During retrieval, subjects use retrieval cues to reconstruct what happened in a particular place at a particular time. Roediger III and Butler (2011) also reviewed research that contradicted the traditional view by demonstrating that retrieval practice was a powerful mnemonic enhancer, often producing large gains in long-term retention relative to repeated studying. Oakley and Schewe (2021) explain the effectiveness of retrieval practices from a neuroscience perspective and recommend using repeated retrieval more broadly in teaching practice. They claim, 'At the heart of active learning lies something called "retrieval practice." In other words, you want to see if you can pull information from your own memory, or work with it in your mind, rather than simply looking at the material. The more you retrieve the material, and the broader the set of contexts you *retrieve* the materials in, the stronger and more broadly connected the neural links become. Oddly enough, the best way to put information into your long-term memory is to try to *retrieve* it from your own long-time memory instead of just looking at the answer.'

The authors also believe that building the foundation of circuit analysis is hopeless without exercises or the practices to conduct a series of analytical processes that allow students to compose their ideas, make a mathematical model, calculate mathematically, and confirm the appropriateness of the mathematical answer for the engineering problem. Yoshioka, Nishizawa, and Tsukamoto (2001) reported the necessity and the effectiveness of individualized mathematics exercises on KOSEN students' performance. The exercises also improved the students' performance in the following engineering subjects and reduced the number of drop-out students (Nishizawa, Yoshioka, Tsukamoto, and Ozeki, 2003). However, as the time constraints did not allow the extra course to increase the lesson time for incorporating exercises in the face-to-face lessons, we considered employing blended learning for the course to have face-to-face exercises in the limited face-to-face lessons.

Blended learning has evolved significantly, driven by technological advancements and global pedagogical shifts (Ashraf et al., 2021). Initially emerging to overcome the drawbacks of pure online instruction by combining the strengths of face-to-face and online settings, blended learning aimed to enhance learning engagement and provide flexible learning experiences beyond simple online content repositories. Lalima and Dangwal (2017) discussed the concept of blended learning, its main features, and its implementation prerequisites. Means, Toyama, Murphy, and Baki (2013) found the performance advantage of blended learning over traditional face-to-face instruction through their meta-analysis of 45 studies. Tayebinik and Puteh (2009) reviewed the benefits of blended learning, including increased communication, engagement through face-to-face communication, a sense of community, collaborative tasks, adequate feedback, active participation, providing help, and a fun and practical manner of teaching and learning, other than improved academic performance. They concluded that blended learning is more favorable than pure e-learning and offers advantages for learners with a sense of community. Kaur (2013) points out the advantage of blended learning as switching from passive to active learning. The focus of the classroom shifts from a presentational format to one of active learning. This involves putting learners in situations that compel them to read, speak, listen, and think. Oliver and Trigwell (2005) evaluate the benefit of blended learning as the shifts in the emphasis from teacher to learner, from content to experience, and from naively conceptualized technologies to pedagogy.

We employed blended learning in the 2024 AY as a modification to the course of the 2023 AY. By moving lectures from face-to-face lessons to on-demand videos, we could use the face-to-face lesson time for paper-based exercises and interactive discussions on the solutions. A possible concern of blended course design was whether we could rely on the students' learning from the on-demand videos before the face-to-face sessions, as the face-to-face sessions did not work without the students' prior work. However, we were optimistic because the target students of this course knew the necessity of the course and were highly motivated to learn AC circuits.

Materials and Methods or Pedagogy

Face-to-face lectures in the 2023 AY

The extra course in the 2023 AY consisted of nine face-to-face lectures on AC circuits, starting with the waveform of AC voltages and currents, phasor representations of the waves and impedances using complex numbers, and circuit analyses using phasors and impedances (Table 1).

Table 1 Contents of the extra course

Week	Contents
1	Radian, sine and cosine waves
2	AC voltage, inductive and capacitive circuits
3	Calculation of complex numbers
4	Phasors with complex numbers
5	Impedance and admittance
6	Series and parallel AC circuits
7	AC circuit analysis methods
8	AC power
9	Resonant circuits

As the extra course covered more extensive content than the 15 100-minute lessons in the regular course in KOSEN-KMITL, its 60-minute lectures must be packed with denser knowledge than the regular lessons. The course included radian and sinusoidal waves in week 1 and calculating complex numbers in week 3, because the contents were not taught as profoundly as the method to be used in AC circuit analysis in the regular mathematics courses. Other prior knowledge, such as algebra, trigonometric functions, and calculus, is covered well in regular classes.

Teaching materials (PowerPoint files) were also packed with Japanese and English explanations, as learning Japanese terminologies and expressions used in the Engineering context was one of the course's purposes. On the other hand, the lectures were conducted in English to facilitate an easier understanding of the new concepts and ideas.

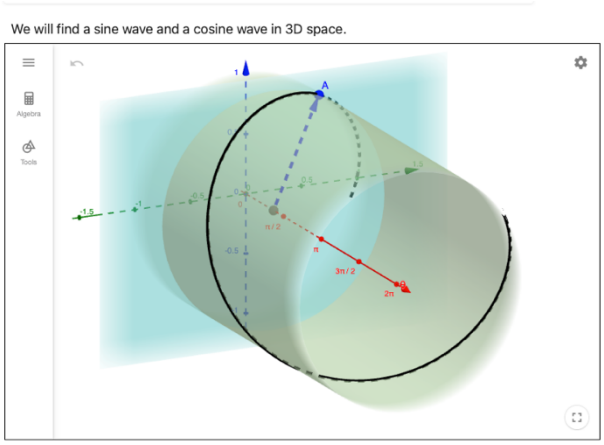
Table 2 Video clips and interactive GeoGebra contents

Week	Video clips	GeoGebra contents
1	6	6
2	3	3
3	4	1
4	4	3
5	4	0
6	5	0
7	5	0
8	5	1
9	4	0

Six ME and nine Computer Engineering (CE) students joined the course. They were expected to tackle the exercises after the lessons by themselves. The materials were all new to the ME students, but for the CE students overlapped with ones as they simultaneously learn AC circuits in their regular course. The lectures were recorded, edited into several short video clips, and uploaded to the server for the students to review the contents after the lessons (Table 2).

The teaching materials included interactive GeoGebra content (Figs. 1 and 2) to visualize mathematical models. GeoGebra (2025) is a free mathematics software tool widely used to create visual, interactive content. Kllogjeri (2017) argues that visualization is expected to teach the students the 'feel' (teach them how to have an eye or sense how to get from 'here' to 'there'). The learning strategy assisted by the mathematics software tool allowed students to better understand abstract content with symbolic expressions through computer visualization with interactive and dynamic graphical representation. Individual work with the content helped low-performing students catch up with their classmates (Werachai & Nishizawa, 2024).

Visualization is especially effective in introductions. For example, a helix in three-dimensional (3D) space can visualize the relation between a sinusoidal wave, which is the shadow of the helix to the x(red)-z(blue) vertical plain in Fig. 1, and a circle, which is the shadow to the other y(green)-z(blue) vertical plain. The animation of a moving point on the helix is a convincing demonstration of the relationship. Leaners confirm the relationship by rotating the helix in the 3D space in this content and observing that the same helix looks like a sine wave, a cosine wave, or a circle when they look at it from different viewpoints. Students' understanding of the relationship is important because it explains why we can use phasors as the representatives of AC waves.

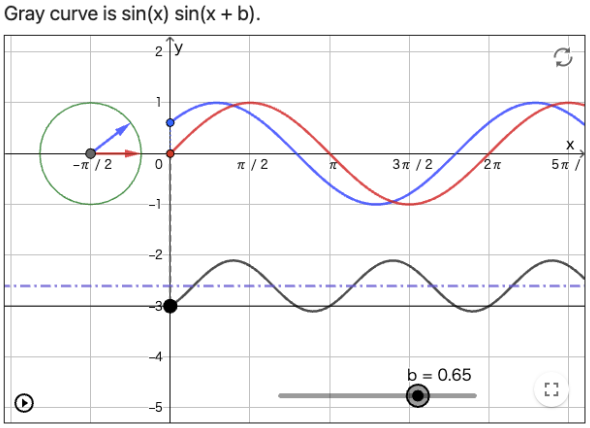


(https://www.geogebra.org/m/z5nr7rnq)

Fig. 1 An interactive GeoGebra content for showing the connection between a phasor and a sinusoidal wave

Fig. 2 is another example that visualizes the relationship between the phase difference of a voltage $v(t)$ and a current $i(t)$, with the power $p(t) = v(t) \cdot i(t)$, which is the multiplication of the two functions. When the amplitudes of the voltage and the current are the same, the amplitude of the power wave stays the same. However, the average power, the central horizontal line of the power wave, changes with the phase difference of the voltage and the current, expressed by the parameter b in Fig. 2. Learners can confirm the relation by shifting the value of phase difference b using the slider in the content. Learning from this content before the face-to-

face lesson is especially valuable because the complex power uses the fact that the average and amplitude of active power, where the contributed voltage and current are in phase, are always the same. Students can ask questions better after learning the relation before the face-to-face lesson.



(https://www.geogebra.org/m/t2y5qrgr)
Fig. 2 An interactive GeoGebra content for showing the change of AC power as a wave

Blended course in 2024 AY

The course consisted of the students' prior learning from the on-demand video lectures on AC circuits (Fig. 3) and interactive GeoGebra content (Figs. 1 and 2), combined with nine face-to-face exercises in the 2024 AY. Nine-hour lectures were divided into 40 video clips shown in Table 2. It is a typical structure of Flipped Classrooms (Delozier & Rhodes, 2017), and its primary purpose is to use every face-to-face lesson for the students' activities in the exercises and discussion.

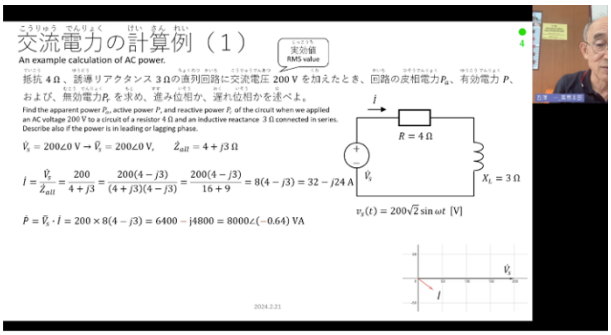


Fig. 3 A snapshot of a lecture video for week eight

The lecture videos recorded in the previous year and teaching materials, including interactive GeoGebra content, were placed on the servers and used as the students' independent learning two weeks before the face-to-face exercises. The students access the online content from their notebook PCs or tablets through the Wi-Fi in the students' dormitories at any time, including weekends. Although visualization, helped by the GeoGebra content, is a powerful method for understanding mathematical models, the time to utilize it comfortably varies from student to student. In that sense, the interactive content might be better used in independent learning than in time-restricted face-to-face lessons. The students tackled the paper-based exercises (Fig. 4), compared their solutions with the example solutions, and discussed their appropriateness with each other in the face-to-face sessions. The exercises were the main activities used in the EE department's regular AC circuits courses in KOSEN-KMITL (KOSEN-KMITL, 2025b). However, the language used in the exercise papers was different. When the exercise papers for transfer students were uploaded to the server with the other learning content, they contained only Japanese sentences. However, additional English texts were added at the face-to-face sessions. The instructor tried to use Japanese as much as possible in the face-to-face sessions to enhance the students' learning of Japanese terminologies and expressions in the 2024 AY. After the exercise sessions, the students were asked to submit their solutions to the file server.

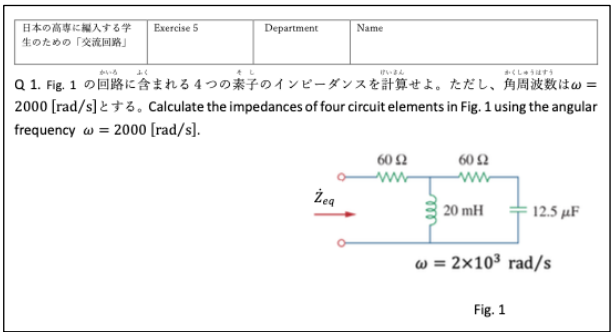


Fig. 4 An example of the exercise sheets

Six ME students were the regular students expected to join the face-to-face exercise sessions, as they did not learn AC circuits in regular courses. Eight Electrical & Electronics (EE) and eight CE students were invited to tackle the exercise problems in the face-to-face sessions. However, for EE and CE students, the extra course was an elective activity, as they were learning AC circuits in their regular classes.

Results and Discussion

Face-to-face lectures in the 2023 AY

All six ME students joined the course, but only three of the nine CE students attended it regularly. The other CE students did not come to the lessons, possibly because the content overlapped with their regular course on AC circuits. The necessity of the course must be reconsidered for the CE students.

According to the questionnaire conducted in August 2024 after the students had transferred to Japanese KOSENs and spent the first semester there, all the students who had regularly attended the course agreed that 'the course was beneficial for the classes in Japan' and 'the class is necessary for juniors who will be transferred to Japan.' However, almost half (44%) of all the transferred students declared they had been too busy to take extra courses before the transfer. It explains why some of the CE students did not join the course.

We could not effectively use interactive GeoGebra content during the lecture because of the limited lesson

time. Although the teacher demonstrated the content to introduce new ideas quickly, the students had little time to manipulate it during the lessons. The content was meant to be used by students to confirm the relationship by manipulating the objects themselves, and its impact in the quick demonstration must be weaker.

Overall, we felt the necessity to redesign the course in the next year: who should join it, how to conduct the course, and how to use the restricted time of the face-to-face lessons.

Blended course in the 2024 AY

The redesigned course adopted blended learning, which combined the students' prior individual learning from the on-demand video lectures and interactive GeoGebra content with the following face-to-face exercise sessions. According to the record on the video server, the ME students viewed all video clips for the first four weeks, but the ratio dropped to less than half in the last three weeks (Table 3). We had no means to check how the students used GeoGebra content.

Table 3 Video views

Week	Views
1	100%
2	100%
3	100%
4	100%
5	67%
6	94%
7	17%
8	48%
9	44%

The instructor recognized that the students had little difficulty tackling the exercise problems until week six, the questions they asked hit the mark, and their discussions in the face-to-face sessions were valuable. The students were well prepared to join the face-to-face exercise sessions, and we could presume that the video clips and the other learning content helped them. On the other hand, they seemed to have some difficulties in the latter three weeks.

We should consider reducing the content of the last three weeks, which cover some technical analyses of AC circuits, AC power, and resonant phenomena (Table 1). These contents may be a little advanced for the first course of AC circuits, and the students' workload for the concurrent regular lessons is also increasing as the final examination of the second semester approaches in late February.

The ME students attended 93% of the face-to-face sessions and submitted 98% of the exercise papers after the sessions (Table 4). The CE students did not join the exercise sessions, but four out of eight submitted solutions to the problems. Their diverse attendance may be deeply affected by their learning of AC circuits in the regular courses and the vague sense of necessity, whether the knowledge of AC circuits is necessary for their further study in Japan. The EE students selected topics to join the exercise sessions, and five out of eight students submitted the exercise papers. They used this course strategically to compensate for the knowledge they learned in the regular course.

Table 4 Attendance at the face-to-face sessions and submission of exercise papers

Department (N of students)	Attendance to the face-to-face sessions	Submission of exercise papers
ME (6)	93%	98%
CE (8)	0%	60%
EE (8)	40%	69%

After the course but before the transfer, five out of six ME students answered the questionnaire. They said they preferred the face-to-face exercise sessions to the face-to-face lectures they did not receive. The support from the students may come from the student-centered activity during the face-to-face lessons (McLaughlin et al., 2014).

By adopting blended learning, we could include exercises in the face-to-face sessions of the extra course on AC circuits for transfer students. The submitted exercise papers showed that the ME students understood the basics of AC circuit analysis at the same level as the EE and CE students, who learned AC circuits in their regular courses. Blended learning also reduced the preparation efforts of the faculty because they could recycle the lecture videos recorded and edited in the former year, and other inherited teaching material.

On the other hand, we could not know whether the interactive GeoGebra content, which is uploaded to the server for the students' prior learning before the face-to-face exercise sessions, helped the ME students learn effectively in this study.

We also need to confirm if the blended course helped the transferred students to learn well in Japanese KOSENs by tracking their learning histories after the transfer.

Conclusions

Blended learning was used to redesign an extra course on AC circuits for transfer students from Thai-KOSEN to Japanese KOSENs in the 2024 AY. The course in the prior year could not include exercises, which were an essential part of learning AC circuits deeply, because of the time constraint. The blended learning method allowed the course to combine on-demand video lectures and individual prior work of the students with face-to-face exercise sessions. The blended course worked well for the students who needed to learn the first course of AC circuits analysis, which might become a serious curriculum gap at the transfer. In the questionnaire, the students also evaluated exercises higher than lectures as face-to-face learning activities. Although we still need to adjust the content for the extra course, it will continue to support transfer students from Thai-KOSEN to Japanese KOSENs. The highly motivated students supported the success of the course.

References

Ashraf, M. A., Yang, M., Zhang, Y., Denden, M., Tlili, A., Liu, J., Huang, R., & Burgos, D. (2021). A Systematic Review of Systematic Reviews on Blended Learning: Trends, Gaps and Future Directions. *Psychology research and behavior management*, *14*, 1525–1541. https://doi.org/10.2147/PRBM.S331741.

Delozier, S. J., & Rhodes, M. G. (2017). Flipped Classrooms: A Review of Key Ideas and Recommendations for Practice. *Educational Psychology Review*, 29. 141-151.

GeoGebra (2025). Accessed from https://www.geogebra.org

Karpicke, J. D., & Blunt, J. R. (2011). Blended learning Retrieval Practice Produces More Learning than Elaborative Studying with Concept Mapping. *Science*, 331(6018), 772–775. DOI: 10.1126/science.1199327.

Kaur, M. (2013). Blended learning – its challenges and future. *3rd World Conference on Learning, Teaching and Educational Leadership*.

Kllogjeri, P. (2017). *GeoGebra in Teaching and Learning Mathematics in Secondary Schools*, LAP LAMBERT Academic Publishing, p.60.

KOSEN-KMITL (2025a). Curriculum of the Mechatronics Engineering program. Retrieved from http://www.kosen.kmitl.ac.th/en/curriculums/diploma-of-engineering-in-mechatronics-engineering-en

KOSEN-KMITL (2025b). Syllabus of '03005090 Electrical Circuit 2', Electrical and Electronics Department. Retrieved from https://drive.google.com/drive/folders/1XTfT7rSdEm2zPZDkVUNo19B19fW-C3Yj

Lalima, & Dangwal K. L. (2017). Blended Learning: An Innovative Approach. *Universal Journal of Educational Research*, 5(1), 129-136.

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., & Mumper, R. J. (2014). The flipped classroom: a course redesign to foster learning and engagement in a health professions school. Academic Medicine, 89, 236–243.

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record*, 115(3) 1–47.

Nishizawa, H., Yoshioka, T., Tsukamoto, T., & Ozeki, O. (2003). Education of Fundamental Mathematics with Individualized Exercises. *KOSEN Kyouiku* (in Japanese), 24, 211-216.

NIT (2025). Syllabus of 'Electric Circuit IIA', NIT Akashi College, Electrical and Computer Engineering. Retrieved from https://syllabus.kosen-k.go.jp/Pages/PublicSyllabus?school_id=27&department_id=12&subject_code=7226&year=2024&lang=en

Oakley, B., & Schewe, O. (2021). *Learn Like a Pro, Science-Based Tools to Become Better at Anything,* 27.

Oliver, M., & Trigwell, K. (2005). Can 'Blended Learning' Be Redeemed? E-Learning, 2(1), 17-26.

Roger III, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, 15(1), 20-27.

Tayebinik, M., & Puteh, M. (2012). Blended Learning or E-learning? *International Magazine on Advances in Computer Science and Telecommunications* (IMACST), 3(1), 103-110.

Werachai, P., & Nishizawa, H. (2024). Impact on Student Learning Outcomes in Mathematics Using GeoGebra. *Proc. of the 29th Asian Technology Conference in Mathematics.* Retrieved from https://atcm.mathandtech.org/EP2024/regular/22164.pdf

Yoshioka, T., Nishizawa, H., & Tsukamoto, T. (2001). Method and Effectiveness of an Individualized Exercise of Fundamental Mathematics. *Community College Journal of Research and Practice*, 25, 373–378.

LEVERAGING 360VR TECHNOLOGY FOR SELF-DIRECTED AND COLLABORATIVE LEARNING: A CASE STUDY ON TECHNOLOGY-ENHANCED ENVIRONMENTAL TRAIL REHEARSALS

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Singapore's Active, Beautiful & Clean (ABC) Waters concept reflects the nation's vision of maximising the use of its waterbodies by seamlessly integrating them into the urban landscape and daily life. This approach promotes public awareness and fosters a sense of stewardship towards water resources and the environment. The *ABC Waters Management* module in the Diploma in Environmental & Water Technology (EWT) introduces students to the ABC Waters concept and allows them to contribute to this national initiative through a real-world service-learning (S-L) project. Specifically, students plan and conduct an ABC learning trail to educate the community about Singapore's ABC Waters programme. Using 360VR technology, a 3D Site Visit platform (3DSV) was developed in January 2024. 3DSV supports both self-directed learning (SDL) and collaborative learning (CL). The platform supports students' preparation through immersive virtual site visits and rehearsals, either individually or in groups. The initial 3DSV interactive features included links to videos and animations demonstrating ABC design features in wet and dry weather flow conditions, and virtual cue cards highlighting key features at each station. The 3DSV platform was further enhanced with self-check station quizzes in the October 2024 Semester. This paper highlights the design of 3DSV, reviews its impact on learning and discusses the insights and considerations when exploring innovative approaches to technology-enhanced learning. To prepare the students for planning and conducting the ABC learning trail, they were briefed about the project requirements, required to participate in a physical familiarisation site visit led by the lecturer and introduced to 3DSV. After conducting the learning trail, the students completed an online survey on their user experiences and feedback on 3DSV. Sixty-eight second-year EWT students responded to the survey over three semesters between October 2023 and February 2025. Most students reported using 3DSV to prepare for the learning trail and found it useful and easy to navigate. They appreciated the virtual access it provided to the physical site, considering it an engaging and viable alternative for facilitation preparation. However, they noted that virtual visits did not replace the need for physical on-site rehearsals. The newly added station quizzes helped students check their knowledge, recall key points, and collaborate effectively within 3DSV. These findings highlight the value of immersive IT tools in promoting self-directed and collaborative learning.

Keywords: *self-directed learning, collaborative learning, 3D virtual sites, 360VR technology, immersive IT tools*

Introduction

Singapore's water policies have evolved from focusing on basic necessities to enhancing liveability. Singapore's National Water Agency (PUB) launched the Active, Beautiful and Clean (ABC) Waters Programme in 2006 to transform waterways and reservoirs from drainage infrastructure for flood management into recreational spaces. PUB aims to harness the full potential of Singapore's waterbodies and foster a sense of stewardship towards water and the environment (Ministry of National Development, 2017). The ABC Waters Programme also supports the nation's stormwater management strategy, climate change adaptation and biodiversity (PUB, 2024).

ABC Waters Management is a second-year module in the Diploma in Environmental & Water Technology (EWT) at Ngee Ann Polytechnic. It introduces students to the ABC Waters concept through a real-world service-learning (S-L) experience. S-L combines community engagement with academic learning, using reflection to deepen understanding of concepts. (Bringle & Clayton, 2012). S-L is a signature pedagogy adopted at Ngee Ann Polytechnic.

As part of the S-L project, students plan and conduct an ABC learning trail to educate the community about Singapore's ABC Waters Programme, the Singapore

Water Story, and environmental issues such as climate change.

Prior to the October 2023 semester, students were briefed on-site and encouraged to revisit the site to familiarise themselves with the site and rehearse. It was observed that time and weather constraints made this difficult. This resulted in students being unfamiliar with the site, and difficulties in managing large groups of visitors, especially when alternative routes were required. Hence, there was a need to turn to technology to improve accessibility to the site and learning trail.

Immersive technology has been widely used in education to provide real-world simulations, access to limited resources and facilitate self-paced and collaborative learning through immersive and interactive learning experiences (Kavanagh et al., 2017). This technology has the potential to enhance learner engagement and motivation through realistic and authentic learning scenarios, and to support personalised self-paced learning whether individually or with peers (Eiris & Gheisari, 2022; Leininger-Frézal & Sprenger, 2022; Suh et al., 2023; Rosendahl & Wagner, 2024; Chaudhari et al., 2025). These reports highlighted the potential for application of 360VR technology to develop a 3D Site Visit platform (3DSV) to support students' preparation for the ABC learning trail through immersive virtual site visits and rehearsals.

This paper details the features of 3DSV, reviews the impact on students' learning, and discusses insights and considerations when exploring the adoption of immersive technology to enhance learning.

Materials and Methods

The 3D Site Visit platform (3DSV) was developed in the October 2023 semester using 360VR technology to support site familiarisation. A Matterport Pro 3 Lidar camera was used to develop the 3DSV platform for the Sungei Ulu Pandan ABC site in western Singapore, spanning 800m along the south bank and 1.4km along the north bank of the concrete-lined river. Besides the route along both banks, a total of six stations (labelled A to F) featuring the ABC treatment elements were included (Figure 1). 3DSV was rendered using Software as a Service (SaaS) from Matterport.



Figure 1: Dollhouse view of the ABC Site and the six stations at Sungei Ulu Pandan.

Interactive 3DSV Features. The following learning features can be accessed by students either independently or collaboratively with their team members.

1. **The videos (Figure 2) and animations (Figure 3)** were designed to deepen students' understanding of the ABC design features in operation in both wet and dry weather flow conditions.

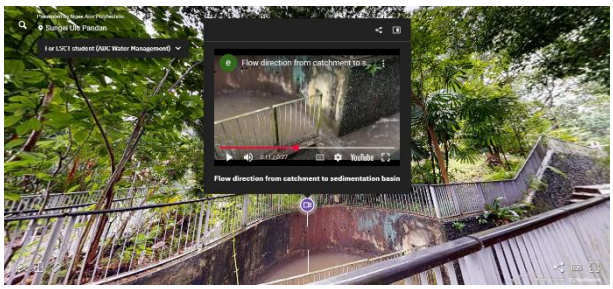


Figure 2: Video embedded at Station B to illustrate the mode of operation in wet weather flow.

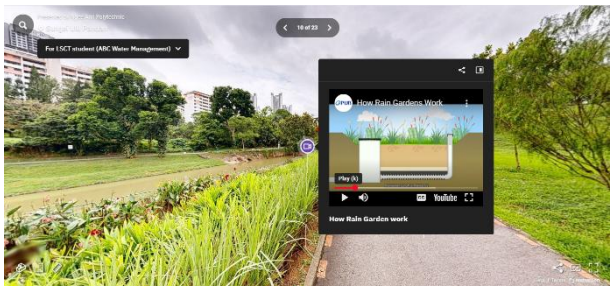


Figure 3: Animation embedded at Station E to illustrate how rain gardens work.

2. The **virtual cue cards** (Figure 4) highlighting the key features at each station aimed to emphasise and reinforce important information to enhance the accuracy and quality of students' delivery of the learning trail to educate the community about Singapore's ABC Waters programme.

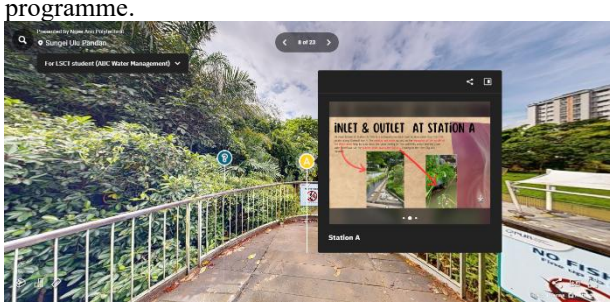


Figure 4: Virtual cue card embedded at Station A

3. The **self-check station quizzes (Figure 5)** were added as an additional feature to the 3DSV platform in the October 2024 semester. These quizzes with automated feedback were embedded using links to the Brightspace Learning Management System. These allowed the students to check their understanding through repeated attempts. The lecturer is able to monitor student performance and provide feedback using Brightspace quiz statistics to address issues with concepts.

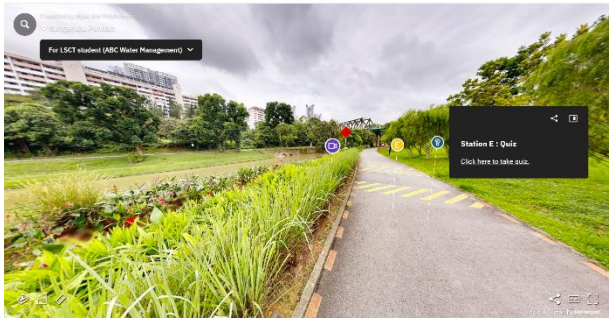


Figure 5: Embedded link to quiz at Station E

Preparation for the ABC Learning Trail. Towards mid-semester, the lecturer briefed the students on the project requirements, conducted a field trip to familiarise them with the site, the route, and the features at each station. The students were strongly encouraged to revisit the site closer to the learning trail event to review the ABC features, stations, script, routing, and delivery flow.

Students were introduced to the 3DSV platform with instructions on how to use it, and what their groups should anticipate and prepare for, on the ground. Students are given the option to choose to use 3DSV while preparing for the learning trail.

Post-Event Survey. After conducting the learning trail, students were required to present their project preparation, implementation, and reflections to the lecturer and service-learning partners. The students completed a Google Forms survey to share their 3DSV user experiences and its impact on their learning. The survey comprised four items with Likert-scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) and four open-ended questions. They were also invited to share their feedback on 3DSV. A total of sixty-eight second-year EWT students responded to the survey over three semesters between October 2023 and February 2025.

Results and Discussion

Of the 68 respondents, 92.6% reported that their groups used 3DSV to prepare for the learning trail. Amongst these users, 98.4% found it useful. The high utilisation might have been boosted by active guidance on using 3DSV to gain student buy-in. Furthermore, allowing the students to propose their own on-site deployment plans might have encouraged site exploration using 3DSV to help their organisation of the learning trail.

User Experience. Most respondents found 3DSV easy to navigate, engaging, and providing easy virtual access to the physical site. Figure 6 shows favorable average ratings above 4 for these indicators of user experience.

These findings supported the application value of immersive technology in providing engaging learning experiences and encouraging repeated visits with easy access to the learning trail site (Kavanagh et al., 2017; Leininger-Frézal & Sprenger, 2022). A (student) respondent shared that *"It was useful as it **helped us to prep better** before the actual day itself and we **don't have to take the time out to physically visit the site to practice**."*

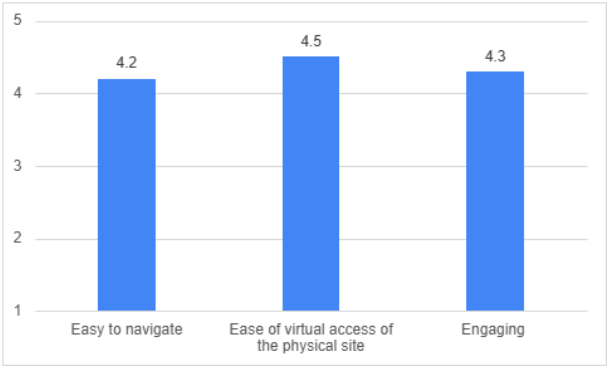


Figure 6: Mean Ratings on User Experience (n=63)

User Impact. Most respondents indicated that 3DSV helped them prepare for the implementation of the learning trail. Figure 7 shows favorable average ratings above 4 for these indicators of user impact.

This positive response appears to be attributed to three key features of 3DSV: 1) allowing visualisation of the physical site, 2) allowing multiple visits to familiarise themselves with the physical site, and 3) helping preparation for the implementation of the activity. Chaudhari et al. (2025) highlight the potential of immersive technologies in enhancing realism and engagement through spatial visualisation and supporting different learners.

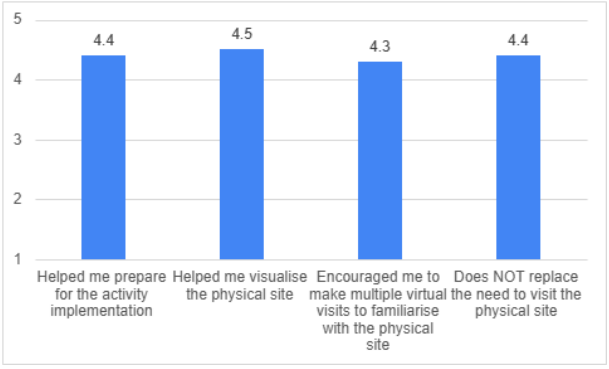


Figure 7: Mean Ratings on User Impact (n=63).

A respondent shared that *"The Matterport site **allowed us to better visualise and familiarise ourselves** with the site as we've only been there once with our tutor. With the Matterport site, we were able to **better prepare ourselves for the actual day event** so as to ensure a smooth sailing experience for both the (visiting) students and us during the introduction of the different sites."*

Another respondent highlighted its overall usefulness while noting its limitation, *"The Matterport site **provided***

us with an accurate view of the site and it helped us prepare better *when it comes to presenting at the stations and it* ***allowed us to visualise the path that we are taking*** *and it is also* ***easy to use and the quality is as if it was right in front of me*** *so it could have been a great alternative for rehearsal and I would feel like there won't be much of a difference but obviously* ***there are certain areas where it is harder to see in the virtual site compared to the physical site*** *but* ***overall*** *the Matterport site was* ***very accurate and reliable****."*

While most of the respondents found 3DSV useful, most also felt that it does not replace a physical visit (mean rating of 4.4 (Figure 7)). This observation aligns with Leininger-Frézal & Sprenger (2022), whose students too, observed that real field trips have more significant advantages. Suh et al. (2023) made similar observations in the context of clinical practice.

A respondent who revisited the physical site for rehearsal shared that "*Despite using the virtual map to go through the different stations online,* ***there were still some parts that we needed to clarify for ourselves physically at the site as the virtual map has limitations*** *to the angle or extent of exploration we can view online".* Another respondent shared that *"Yes, our group did a rehearsal at the physical site due to the lack of visitation to the site by ourselves* (with our lecturer) *so we weren't really familiar with the environment and so we needed to come down and gather information on the site and path that we are taking and I'm glad that we did* ***because we were able to find the exact location of our site and station and other interesting points which we were able to present to the participants with full confidence*** *as we did a trial run during the recce and rehearsal at the physical site."* Yet another respondent shared that *"Some of my groupmates and I went down to Sungei Ulu Pandan again sometime in January to recce the place by ourselves, taking note of how the features work during a heavy downpour. It was interesting to note how the features operate differently with different weather conditions. We saw how it was during Dry Weather Flow (DWF) on the 3 Dec when we visited the site as a class, and we witnessed how it was during Wet Weather Flow (WWF) in mid-Jan when we visited the site on our own. We also went there early on the actual day as a whole group to rehearse and familiarise ourselves with the route again."*

Majority of the findings underscore the value of 3DSV in enhancing preparation to facilitate the learning trail. Clearly, 3DSV provided realistic representation of the site and allowed repeated visits (Rosendahl & Wagner, 2023). However, despite its benefits, 3DSV may not fully replicate the experiences of being at the physical site. A respondent suggested *"[…] Add in sounds! Make the experience more 3D/4D. Have a variation of events. For example, how the water looks like when it rains. How the vegetated swale actually works etc.".* Furthermore, the resourcing (e.g., cost, time, manpower) required limits timely updates to reflect changes at the site. For example, a student highlighted that *"It can be updated from time to time since any things may have changed since doing up the Matterport."*

Self-Directed and Collaborative Learning. The 3DSV features, including videos and animations, virtual cue cards and self-check station quizzes allowed self-directed (independent) and collaborative learning.

Station quizzes were added in the October 2024 Semester. 96.6% of the students (n=30) used the station quizzes to check their knowledge. 100% of these students reported that they used the station quizzes to help them remember the key points to be shared. 90% of the respondents collaborated while using the station quizzes as they prepared for the learning trail event.

Students' reflections and qualitative survey comments indicated that they used 3DSV to prepare and rehearse for the ABC learning trail individually (SDL) and/or with their team members (CL). The qualitative comments highlighted that 3DSV could support collaborative learning. A student shared that *"We had an online practice before the service-learning project.* ***Since our schedule clashes, we use the Matterport site to have a quick run through of our parts (using MS Teams to share screen)*** *as well as using the* ***interactive quiz to enhance our knowledge before the service-learning project day****."*

Just like all educational technologies, the effectiveness of 3DSV depends on its ability to realistically simulate diverse varied real-world experiences and its capacity for timely updates that reflect the evolving contexts. Student feedback highlighted opportunities to enhance the current 3DSV by incorporating dynamic weather simulations and strengthening realism with visual and auditory elements, potentially via AR integration. Furthermore, there is potential to include AI-driven interaction to enable conversations along the learning trail to support practice in simulated real-world context..

Conclusions

The high utilisation, favorable user experiences and impact on learning supported 3DSV as a viable alternative that supports the students' preparation for the ABC learning trail. Most students found 3DSV useful and easy to navigate. They appreciated the easy virtual access to the physical site and found it engaging and useful. The newly added station quizzes also helped students check their knowledge and recall key points effectively within 3DSV. While 3DSV allowed for independent self-paced learning, the qualitative comments emphasised its value in enabling collaborative learning.

Clearly, 3DSV is an important resource for those students who could not revisit the physical site for rehearsal due to time or weather constraints. However, most students, including those who relied on 3DSV for preparation, acknowledged that 3DSV does not replace the need to visit the physical site. They recognised the importance of on-site rehearsal to prepare themselves for aspects of the learning trail that might not be fully captured in the virtual environment, as well as any changes at the site.

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References

Bringle, R. G., & Clayton, P. H. (2012). Civic education through service learning: What, how, and why? In L. McIlriath, A. Lyons, & R. Munck (Eds.). *Higher education and civic engagement: Comparative perspectives* (pp. 101-124). Palgrave Macmillan.

Chaudhari, V. M., Ponnuswamy, S., Muqeem, M., & R., P. (2025). Augmented reality (AR) and virtual reality (VR) in education: Assessing the impact on educational systems, content delivery, and student engagement. *International Journal of Research Publication and Reviews, 6*(6), 1776–1786. https://www.ijrpr.com/archive.php?volume=6&issue=6

Eiris, R., & Gheisari, M. (2022). iVisit-Collaborate: Online Multiuser Virtual Site Visits Using 360-Degree Panoramas and Virtual Humans. *Proceedings of the 37th International Symposium on Automation and Robotics in Construction (ISARC). International Association for Automation and Robotics in Construction (IAARC)*. https://www.iaarc.org/publications/fulltext/037_ISARC%202022_Paper_27.pdf

Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of virtual reality in education. *Themes in Science and Technology Education*, *10*(2), 85–119. https://files.eric.ed.gov/fulltext/EJ1165633.pdf

Leininger-Frézal, C., & Sprenger, S. (2022). Virtual field trips in binational collaborative teacher training: Opportunities and challenges in the context of education for sustainable development. *Sustainability, 14(19), Article 12933.* https://doi.org/10.3390/su141912933 (mdpi.com)

Ministry of National Development (MND): Centre for Liveable Cities, Singapore. (2017). Urban Systems Studies: The Active, Beautiful, Clean Waters Programme: Water as an Environmental Asset (1st ed.). https://isomer-user-content.by.gov.sg/50/7a481fd0-e545-417e-a14b-e414efee6694/rb172978-mnd-abc-water.pdf

PUB, Singapore's National Water Agency. (2024). ABC Waters Design Guidelines (5th ed.). https://www.pub.gov.sg/Professionals/Working-on-ABC-Waterways/ABC-Waters-Design-Guidelines

Rosendahl, P. & Wagner, I. (2024). 360° videos in education: A systematic literature review on application areas and future potentials. *Education and Information Technologies*, *29*, 1319 – 1355. https://doi.org/10.1007/s10639-022-11549-9

Suh, I., McKinney, T., & Siu, K.-C. (2023). Current perspective of metaverse application in medical education, research and patient care. *Virtual Worlds, 2*(2), 115–128. https://doi.org/10.3390/virtualworlds2020007 (mdpi.com)

FOSTERING SELF-DIRECTED LEARNING: INSIGHTS FROM INDUSTRY NOW CURRICULUM

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The Education 4.0 taxonomy in the World Economic Forum 2023 report emphasized areas, such as problem-based and collaborative learning, and lifelong and student-driven learning, to guide educators on the evolving needs of the future workforce. At Singapore Polytechnic (SP), Industry Now Curriculum (INC) is a Project-Based Learning (PjBL) curriculum that trains School of Computing (SoC) students to be industry-ready software developers prepared to work and learn at the same time to stay relevant in the industry. This study investigates how INC students engage in self-directed learning (SDL) and how the self-directedness for INC and non-INC students differs. The study found that INC students are significantly higher in Intrinsic Motivation and Metacognitive Self-Regulation & Self-Monitoring compared to non-INC students in the pre-study. The INC students who submit their Learning Journals more frequently tend to have a greater increase in their Metacognitive Self-Regulation & Self-Monitoring skill.

Keywords: *self-directed learning, project-based learning, self-management, self-monitoring, self-regulation, motivation*

Introduction

The Industry Now Curriculum (INC) adopts a "learn by doing" pedagogy to allow students to achieve learning outcomes by doing industry real world project instead of traditional classroom instruction. INC environment emulates a real software development company project structure with continuous operation beyond an academic semester for students to manage projects and learn on an ongoing basis. Moreover, INC encourages students to set personal learning objectives, track their own progress and evaluate how well these objectives were met, encouraging greater responsibility for their own learning.

This research aims to study how INC students engage in self-directed learning (SDL) in various dimensions and how the self-directedness for INC and non-INC students differs in various dimensions. The findings of this study will inform future designs and implementation of SDL developmental activities for students and contribute to improving the active learning experience of project-based learning environments. The following are the research questions:

RQ1: How do INC students engage in self-directed learning?

RQ2: How does the self-directedness for INC and non-INC students differ?

Literature Review

Project-Based Learning

Project-Based Learning (PjBL) is a student-centered, inquiry-based pedagogical approach that engages students in comprehensive projects, often addressing real-world problems. It aims to cultivate concepts, principles, and practical applications. The process typically involves posing essential questions, designing a project plan, scheduling, monitoring progress, assessing outcomes, and evaluating the learning experience. PjBL fosters active learning, critical thinking, problem-solving, communication, and collaboration through hands-on activities, making it effective for developing crucial 21st-century skills necessary for the job market. It provides practical experience, deeper understanding, and increased motivation by connecting learning to real-life situations and industry needs (Agustina et al., 2022; AlAli, 2024; Asnur et al., 2025; Bahrehvar & Moshirpour, 2022; Masnec et al., 2024; Morrison et al., 2021; Saad, 2022).

Määttä et al (2017) proposed a project-based learning environment called the FIRMA that distinguishes itself from common PjBL by emulating a real software company structure and deeply integrating industry collaboration. The FIRMA operates year-round, not adhering to traditional academic year schedules, which reflects the continuous nature of a real business and requires students to manage projects and learn on an ongoing basis. Students set personal learning objectives, track their working hours, and evaluate how well these objectives were met, encouraging greater responsibility for their own learning. Students can complete a significant portion of their degree within the FIRMA, integrating their project work directly into their curriculum for credits and grades. INC was adapted from this FIRMA approach.

Self-Directed Learning

Garrison (1997) proposed a comprehensive model of Self-Directed Learning (SDL) that includes three overlapping dimensions: Self-Management, Self-Monitoring, Motivation.

At SP, the SDL model expands on these dimensions needed for a self-directed learner. The following are five sub-dimensions in this model:

1. Self-Efficacy for Learning & Performance
   Self-efficacy for learning and performance is a belief in one's capability to succeed in a specific task (Morris, 2019; Pintrich & De Groot, 1990; Bandura, 1982).
2. Growth Mindset
   Growth Mindset, specifically the belief that intelligence and personality are malleable and can change, is identified as a dimension for SDL (Brandt, 2020; Dweck, 2006).
3. Intrinsic Motivation
   Intrinsic motivation, as a dimension of SDL, refers to developing and sustaining motivation for learning (Ryan & Deci, 2020; Brandt, 2020; Garrison, 1997; Pintrich & De Groot, 1990).
4. Help Seeking
   Help seeking is a resource management strategy in learning (Pintrich & De Groot, 1990). Collaboration is intricately related to self-directed learning, and learners develop SDL skills as they engage with others (Brandt, 2020; Gibbons, 2002).
5. Metacognitive Self-Regulation & Self-Monitoring
   There are three general processes in metacognitive self-regulatory activities: planning, monitoring, and regulating (Brandt, 2020; Pintrich, 2004). Planning (e.g., goal setting, task analysis) helps activate prior knowledge. Monitoring (e.g., tracking attention, self-testing) helps understanding and integration with prior knowledge. Regulating involves fine-tuning and adjusting cognitive activities to improve performance by checking and correcting behavior. Self-monitoring involves being aware of the current state of knowledge, searching for information, exploring concepts, confirming knowledge, and assessing outcomes (Zhu & Bonk, 2019; Garrison, 1997).

Robinson & Persky (2020) reported that assessing SDL skills can be challenging because many domains are affective in nature (e.g., problem-solving, collaboration, self-awareness) especially in a PjBL setting, such as INC. Nevertheless, this study will address this gap by investigating how the SDL skills are developed in INC students and compare with non-INC students.

Methodology

INC Pathway Student Recruitment

The recruitment and selection process for students entering the INC pathway is a multi-stage process designed to identify individuals with the necessary technical aptitude, problem-solving skills, and personal attributes to thrive in an industry-focused learning environment. Here's a breakdown of the recruitment and selection process:

Briefing and Initial Registration

The process begins with a briefing for all Year 1 students during Semester 2. This briefing provides an overview of the Project INC pathway, explaining the benefits of the programme such as building relevant portfolio through working on real-life industry projects. Following the briefing, students register their interest through an online Microsoft Form with some of the following information:

- Their passion for Computer Science domain, including descriptions of any favorite work.
- Their thoughts on the characteristics/attributes of a reliable independent learner.
- Their passion for teaching and sharing, and the reasons why.
- A list of their current Co-Curricular Activities (CCAs) or clubs (inside or outside of SP), including their role and capacity.

Gathering Inputs Before Interview

Before the interview stage, additional information is gathered to provide a holistic view of the student's suitability for the INC pathway. This includes:

- Mid-Semester Test results from a Year 1 core module. This module is specifically chosen as a significant reference to assess if a student's learning disposition aligns with that of an INC student, indicating qualities such as being an self-directed learner and good time management. Historically, students who performed well in that Year 1 module have generally been observed to perform well in the INC pathway.
- Feedback from Personal Tutors of the registered students. Tutors provide insights into the student's attitude and character and whether the student is a potential matured team leader.

Interview Process

Students who have registered and provided the necessary input are scheduled for an interview. The interview is conducted by a panel of INC Lecturers who take turns asking questions across specific categories. A score is assigned to each student in the following categories: Technical Skills, Problem-Solving Abilities, Collaboration and Teamwork, Adaptability and Learning Agility, Interest and Passion for Coding, Future Aspirations and Career Goals, Communication Skills.

Scoring and Final Selection

After all interviews are completed, the scores given by the interviewers for each student are consolidated and ranked. The final selection of students for the INC pathway is based on the ranking of their scores.

Continuous Integration and Continuous Delivery (CICD) module

The CICD module is designed as a capstone module to provide them with the opportunity to consolidate prior learning and learn concepts of the industry practice of Continuous Integration and Continuous Delivery

(CI/CD) to develop an application within a team. Throughout the module, students actively develop and operate an application in groups. They manage code repositories, set up automated build pipelines, perform continuous testing, and deploy changes to production environments. By experiencing the entire CI/CD workflow, students acquire practical skills and a deep understanding of how to streamline software delivery and enhance collaboration within a development team. The learning outcomes for the module are the same for INC and non-INC students.

Non-INC Pathway

The non-INC participants include 9 classes of 204 students working on a module project. All lesson materials are released and delivered via the Learning Management System (LMS) weekly, and students are expected to go through and learn the materials before the two onsite practical classes. During practical classes, there would be instructor teaching and learning activities that allow students to collaboratively learn, discuss, and explore on the new lessons and challenges faced. Throughout the semester, students would work on the module project which the student has autonomy to choose the theme and the scope to work on.

INC pathway

The INC participants include 2 classes of 28 students working on a real-world project with an external client. The INC students can consult their tutor throughout the semester for advice whenever necessary. There is no instructor-led teaching during class. Students discover much of what they learn through the prescribed e-learning content in the LMS and through the process of applying their knowledge in the client project. The students do not have autonomy to choose the project theme and scope as the project belongs to the external client. The INC students are expected to record and submit their self-management and self-monitoring every 2 weeks through Learning Journals in the LMS. The information recorded in the Learning Journal are:

- Planning – Targeted Learning Outcomes, Learning Resources & Strategies and Evidence of Accomplishments
- Monitoring and Review – Progress, Problems / Challenges, Plans Ahead

SDL Survey and Focus Group Discussion

An SDL survey, adapted from Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & De Groot, 1990; Roth et al, 2016) was conducted using Microsoft Forms on week 2-3 (pre) and week 17-18 (post) to measure the self-directedness of the INC and non-INC students taking CICD module in the following sub-dimensions:

- Self-Efficacy for Learning & Performance (SE)
- Growth Mindset (GM)
- Intrinsic Motivation (IM)
- Help Seeking (HS)
- Metacognitive Self-Regulation & Self-Monitoring (MRM)

Focus group discussion was conducted with separate sessions of 8 INC students and 8 non-INC students to collect qualitative inputs to add insights to the survey data. Academic performance and LMS data were also used to study the effects of the strategy.

Results

Table 1 shows the number of non-INC and INC students who participated in the pre- and post-study SDL survey.

Table 1
The number of students who completed the pre- and post-study survey

Group	Pre/Post	Number of Students
Non-INC	Pre	145
	Post	133
INC	Pre	26
	Post	27

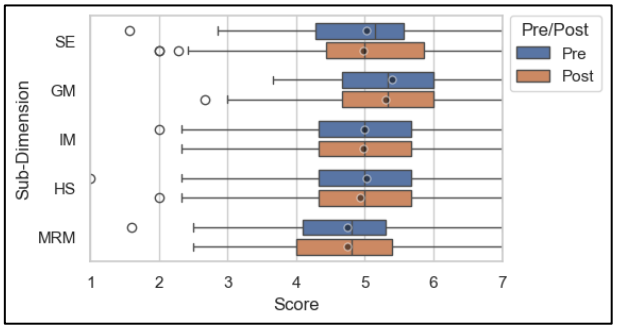


Figure 1. Non-INC students' pre- and post- survey boxplots

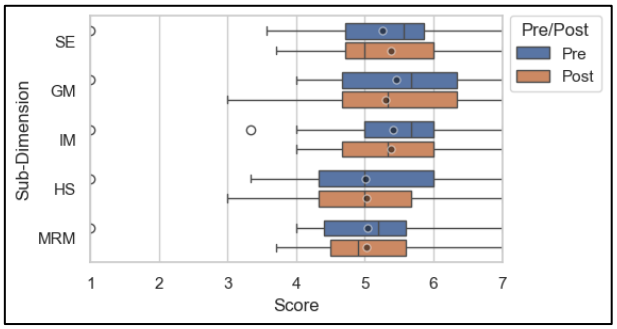


Figure 2. INC students' pre- and post- survey boxplots

A Wilcoxon Signed Rank test was conducted to compare the pre- and post-study survey data for both non-INC (Figure 1) and INC students (Figure 2). There is no significant difference ($p > 0.05$) for each SDL sub-dimension between the pre- and post-study score for both non-INC and INC students.

A Mann-Whitney U test was conducted for pre-study SDL survey score for each sub-dimension between non-INC and INC students (Table 2). There is significant differences ($p<0.05$) between Intrinsic Motivation ($U=834$, $p=0.016$) and Metacognitive Self-Regulation & Self-Monitoring ($U=900$, $p=0.048$) sub-dimensions. Figure 3 shows the boxplots comparing the pre-study

scores for non-INC and INC students. INC students are generally rated higher in median in all SDL sub-dimensions for the pre-study SDL survey compared to non-INC students, except Help-Seeking, with significant difference in Intrinsic Motivation and Metacognitive Self-Regulation & Self-Monitoring.

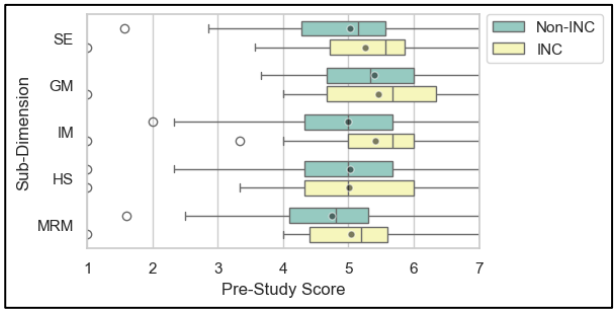


Figure 3. Pre-study survey boxplots for non-INC and INC students

Table 2
Mann-Whitney U test for pre-study survey score between non-INC and INC students

Sub-dimension	N (non-INC)	N (INC)	U	p
Self-Efficacy for Learning & Performance	97	25	962	.112
Growth Mindset	97	25	1072	.372
Intrinsic Motivation	97	25	834	**.016***
Help Seeking	97	25	1171	.791
Metacognitive Self-Regulation & Self-Monitoring	97	25	900	**.048***

As INC students are expected to submit Learning Journals in the LMS, the number of submissions in the dropbox was collated for each student. A Spearman's rank-order correlation revealed a weak to moderate, positive, and statistically significant association between the INC LMS dropbox count and the difference between pre- and post-study SDL score for Metacognitive Self-Regulation & Self-Monitoring, rs(23)=0.397, p=0.05 (Table 3).

Table 3
Correlation between INC LMS dropbox count and the difference between pre- and post-study SDL score, N=25

Sub-dimension	Spearman rs	p
Self-Efficacy for Learning & Performance	.069	.744
Growth Mindset	.187	.371
Intrinsic Motivation	-.163	.437
Help Seeking	.127	.544
Metacognitive Self-Regulation & Self-Monitoring	.397	**.050***

As the Learning Journals are assessed in Assignment 4, a Pearson correlation (Table 4) revealed a moderate, positive, and statistically significant association between Assignment 4 grades and the difference between pre- and post-study SDL score for Metacognitive Self-Regulation & Self-Monitoring, r(23)=0.406, p=0.044.

Table 4
Correlation between Assignment 4 grades and the difference between pre- and post-study SDL score, N=25

Sub-dimension	Pearson r	p
Self-Efficacy for Learning & Performance	.164	.433
Growth Mindset	.219	.292
Intrinsic Motivation	-.089	.671
Help Seeking	.224	.282
Metacognitive Self-Regulation & Self-Monitoring	.406	**.044***

Discussion

RQ1: How do INC students engage in self-directed learning?

Table 3 shows a weak to moderate, positive, and statistically significant association between the INC LMS dropbox count and the difference between pre- and post-study SDL score for Metacognitive Self-Regulation & Self-Monitoring, rs(23)=0.397, p=0.05. The students who submit their Learning Journals more frequently tends to have a greater increase in their Metacognitive Self-Regulation & Self-Monitoring skill. This also positively and moderately correlated with better grades in Assignment 4 (Table 4). The Learning Journal require the students to set their learning goals, define the self-evaluation criteria, plan activities, monitor progress, list challenges faced, and review plans (Gibbons, 2002). With more practice in writing and submitting the Learning Journal, it will improve Metacognitive Self-Regulation & Self-Monitoring skill.

In the focus group discussion, INC students acknowledged the Learning Journal's value in helping them reflect on their learning journey, track progress, and identify areas for improvement (Gibbons, 2002). One student commented, "I just, like, put down what I have done for that week… it makes me realise that, oh, this week I didn't complete as much."

However, there is no significant difference ($p > 0.05$) for each SDL sub-dimension between the pre- and post-study score for INC students in this study. Interestingly, there is a decrease in the median score of all SDL sub-dimensions, except Help-Seeking, between pre- and post-study for INC students, though it is not statistically significant (Figure 2).

Many INC students expressed confusion about what to write in the Learning Journal. They were unsure whether to focus on technical content, personal reflections, or challenges faced. The lack of clarity in column headings and expectations led to inconsistent entries. INC Students also found that daily entries are impractical, citing difficulty recalling specific activities and a lack of motivation to write regularly. Several

students also mentioned using AI tools like ChatGPT to draft or expand their journal entries. A recurring theme was that students often completed journals out of obligation rather than intrinsic motivation. Deadlines were the primary driver, and some admitted to backfilling entries just before submission. The above sentiments may have resulted in a mixed perceived value of the Learning Journal in the students' own learning process. Määttä et al (2017) also reported about challenges faced by students when using a learning diary each month and replaced it by letting students defining the learning objectives at the beginning of the project and evaluating how well they were met at the project's completion. However, from the earlier results, the reduction of the Metacognitive Self-Regulation & Self-Monitoring activities may not help the students to develop it.

The tutors shared that it took a few rounds of tutor feedback to the students before the students are clearer on what to write in the Learning Journal and the good practices, despite the students being briefed and given examples in the template. The tutors also shared that it was time-consuming to go through all the submitted journals and challenging to give timely feedback for each journal. This may have resulted in the students' lower motivation of submitting the Learning Journal too.

INC students shared that their engagement in SDL is strongly influenced by personal interest. When topics resonate, they are more likely to invest time in research and experimentation (Ryan & Deci, 2020; Morris, 2019). One commented, "If the topic is something I don't find interesting… I don't think I will try to search more about it." Conversely, lack of interest leads to minimal effort. Another commented, "Whether I put in extra effort depends on whether I'm interested in that module." The lack of student autonomy or choice in the INC students' project may have reduced their Intrinsic Motivation and affected their engagement in SDL in general, which may explain the drop in median rating in Figure 2.

RQ2: How does the self-directedness for INC and non-INC students differ?

From Table 2 and Figure 3, INC students are generally rated higher in median in all SDL sub-dimensions for the pre-study SDL survey compared to non-INC students, except Help-Seeking, with significant difference in Intrinsic Motivation ($U=834$, $p=0.016$) and Metacognitive Self-Regulation & Self-Monitoring ($U=900$, $p=0.048$). As described earlier for the INC recruitment process, the INC students took the active steps to describe areas related to SDL in their application such as their passion, their thoughts on the characteristics/attributes of a reliable independent learner and their passion for teaching and sharing. Moreover, they are being interviewed and assessed with SDL-related criteria such as Collaboration and Teamwork, Adaptability and Learning Agility, and Interest and Passion for Coding. Hence, it is not surprising that there is a higher pre-study SDL rating of INC students, especially Intrinsic Motivation and Metacognitive Self-Regulation & Self-Monitoring.

From the focus group discussion, both INC and non-INC students are motivated by grades and deadlines, but INC students mentioned that their motivation is also tied to personal interest and growth. Ryan and Deci (2020) suggest that traditional grades often undermine students' intrinsic motivation. Resourcefulness is mentioned as a crucial SDL attribute for INC students in contrast to non-INC students as the students research beyond provided materials which can be due to the needs of real-world projects (Brandt, 2020; Knowles, 1975). Both non-INC and INC Students shared that SDL is most effective when working on projects. They learn by doing, iterating, and solving problems, often discovering gaps in their knowledge through hands-on experience. One non-INC student commented, "Only when I'm doing my project… then I go back to read.". Similarly, one INC student commented on such learning gap in a real-world project, "We skipped the design step… changing the database was very painful."

The tutors gave the feedback that time management is the recurring theme for both INC and non-INC groups influencing the students' success (Pintrich & De Groot, 1990). Students who planned tasks weekly and maintained individual to-do lists were more likely to meet project deliverables. Conversely, those who procrastinated or underestimated task complexity tended to fall behind. The bi-weekly submission of the Learning Journal provides INC tutors with an indication of how well the INC students are growing in their Metacognitive Self-Regulation & Self-Monitoring skill (Table 3).

Limitations

A limitation of this study is the relatively small sample size of INC students, which may restrict the generalizability of our findings. It might be possible that some changes might have occurred but were not statistically significant due to the limited sample size. Moreover, the SDL skills of the students may be affected by other factors, such as concurrent modules or personal life.

Future Studies

Future research could include more batches of students to expand the sample size of INC students. The Learning Journal could be improved by providing better guiding questions and example statements to reduce the confusion the students faced when using it and encourage more frequent use to develop the Metacognitive Self-Regulation & Self-Monitoring skill. Generative AI technology can be explored to enhance the use of the Learning Journals by the students and to provide timely feedback by tutors. Future studies can also explore various Intrinsic Motivation strategies to help INC students be motivated to learn (Ryan and Deci, 2020) and research how Help-Seeking skill can be developed.

Conclusions

Our findings do not indicate significant differences for each SDL sub-dimension between the pre- and post-study score for INC students. However, the INC students

who submit their Learning Journals more frequently tend to have a greater increase in their Metacognitive Self-Regulation & Self-Monitoring skill. There is a mixed perceived value of the Learning Journal in the students' own learning process and the lack of Intrinsic Motivation may have affected the desired development of the Metacognitive Self-Regulation & Self-Monitoring skill for the INC students. Hence, the Learning Journal can be improved for more intuitive use to help students build SDL skill.

INC students are generally rated higher in all SDL sub-dimensions for the pre-study SDL survey compared to non-INC students, except Help-Seeking, with significant difference in Intrinsic Motivation and Metacognitive Self-Regulation & Self-Monitoring. The recruitment process may have selected those students with higher SDL skills to enter the INC pathway. Both groups are motivated by grades and deadlines and agreed that project work helps them develop SDL skills. However, the INC students reported that they are also motivated by personal interest and growth. Time management is a key factor observed by tutors of both groups for academic success and the Learning Journal provided a regular structure for INC students to plan, monitor and review their learning and for tutors to track their progress.

References

Agustina, W., Degeng, I. N. S., Praherdhiono, H., & Lestari, S. R. (2022). The effect of blended project-based learning for enhancing student's scientific literacy skills: An experimental study in University. *Pegem Journal of Education and Instruction*, 13(1), 223-233.

AlAli, R. (2024). Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning. *Geo Journal of Tourism and Geosites*, 53(2), 421-430.

Asnur, L., Jalinus, N., Faridah, A., Irfan, D., Mubai, A., & Utami, F. (2025). Empowering Project-Based Learning Model With Video Blog. *TEM Journal*, 14(1).

Bahrehvar, M., & Moshirpour, M. (2022). Full-stack development and soft skills: An agile-based learning framework. *Proceedings of the Canadian Engineering Education Association (CEEA)*.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American psychologist*, 37(2), 122.

Brandt, W. C. (2020). Measuring Student Success Skills: A Review of the Literature on Self-Directed Learning. 21st Century Success Skills. National Center for the Improvement of Educational Assessment.

Dweck, C. S. (2006). *Mindset: The new psychology of success.* Random house.

Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult education quarterly*, 48(1), 18-33.

Gibbons, M. (2002). *The self-directed learning handbook: Challenging adolescent students to excel*. John Wiley & Sons.

Knowles, M. S. (1975). *Self-directed learning: A guide for learners and teachers*.

Määttä, S., Roslöf, J., & Säisä, M. (2017). Development of the learning process in a project-based learning environment. In *Proceedings of the 13th International CDIO Conference* (pp. 270-278).

Masnec, L., Stapić, Z., & Benkus, M. (2024). Bridging Academia and Industry: A Collaborative Approach to Software Development Education. In *35th International Scientific Conference CECIIS 2024* (pp. 433-440). Varaždin: University of Zagreb, Faculty of Organization and Informatics.

Morris, T. H. (2019). Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education*, 65(4), 633-653.

Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2021). Teachers' role in students' learning at a project-based STEM high school: Implications for teacher education. *International Journal of Science and Mathematics Education*, 19, 1103-1123.

Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational psychology review*, 16, 385-407.

Pintrich, P.R. & De Groot, E.V. (1990) Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82(1), 33-40.

Robinson, J. D., & Persky, A. M. (2020). Developing self-directed learners. *American journal of pharmaceutical education*, 84(3), 847512.

Roth, A., Ogrin, S., Schmitz, B. (2016) Assessing self-regulated learning in higher education: a systematic literature review of self-report instruments. *Educational Assessment, Evaluation and Accountability*, 28, 225–250.

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary educational psychology*, 61, 101860.

Saad, A. (2022). The effectiveness of project based learning with computational thinking techniques in a software engineering project course. *Journal of Contemporary Issues and Thought*, 12(1), 65-79.

Zhu, M., & Bonk, C. J. (2019). Designing MOOCs to facilitate participant self-monitoring for self-directed learning. *Online Learning*, 23(4), 106-134.

MEASUREMENT OF STUDENTS' DEVELOPMENTAL OUTCOMES FOR SERVICE-LEARNING INCORPORATED INTO THE CURRICULUM OF AN ENGINEERING DESIGN MODULE

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Abstract

This study investigates the developmental impact of mandatory service-learning within Republic Polytechnic's (RP) Engineering Design module. Employing a quantitative approach, the research utilizes a modified Service-Learning Outcomes Measurement Scale (S-LOMS) to assess changes in engineering students across four categories: Knowledge application, Personal and professional skills, Civic orientation and engagement, and Self-awareness. Results indicate significant positive impacts ($p < .001$) on overall student development. While most domains demonstrated improvement, relationship and team skills, and critical thinking showed limited change. Further analysis revealed that team skills, specifically, contributed to the lack of significant improvement in the relationship and team skills domain. Notably, the study also explores the implications of contextualizing the S-LOMS questions within the specific service-learning framework of the module. The findings suggest that integrating face-to-face service-learning within the Engineering Design curriculum effectively enhances students' developmental outcomes, warranting further investigation into the nuanced application of the S-LOMS in this context.

Keywords: *S-LOMS, Service-learning, engineering, students' engagement*

Introduction

Service-learning in Singapore, RP and the School of Engineering (SEG)

In 2000, Singapore's Ministry of Education (MOE) introduced service-learning elements into the curriculum, which later evolved into the Values in Action (VIA) program. VIA aims to cultivate socially responsible individuals by emphasizing civic responsibility, social cohesion, and personal development. This program, implemented in primary and secondary schools, utilizes community service and reflection to shape students into responsible citizens. Recognizing the positive outcomes, several tertiary institutions in Singapore have adopted service-learning initiatives.

RP adopts a collaborative approach involving lecturers and students from diverse diploma programs to conceive and execute Service-Learning projects, under the auspices of the Office of Student and Graduate Affairs (OSG). This strategy empowers students to apply their academic competencies and knowledge to address community needs. As part of their Year 1 Life Skills module, all RP students partake in an Introduction to Service-Learning workshop. Following this, they have the opportunity to participate in organised projects or initiate service-learning projects independently. Importantly, these endeavours are not linked to specific courses nor credit requirements, and no formal academic evaluation is attached to them. Instead, students engage in reflective discussions and maintain journals to enrich their individual learning journeys.

The Engineering Design (ED) module in RP's School of Engineering (SEG) takes on service-learning with a more structured approach by providing SEG students with distinctive opportunities to interact with beneficiaries. These interactions consist of offering instruction in mobile app usage, on-site visits to technologically advanced companies, and ability to conduct user interviews to understand enhancement necessary for the beneficiaries' daily lives. Over the course of a week, this service-learning segment lays the groundwork for the ideation phase of students' engineering projects and inspires the development of prototypes within the ED module. Collaborating closely with five voluntary welfare organisations, the students complete these projects in teams. This program offers a distinctive platform for first year SEG students to innovate ideas and develop prototypes addressing societal needs and real-life problems, fostering meaningful service-learning experiences through direct interaction with the beneficiaries, which are the elderly. In total, students spend ten weeks creating and refining prototypes after understanding users' requirements. Eventually, the beneficiaries are then invited to test these prototypes and provide feedback.

The incorporation of service-learning into a module has been exceptionally well-received by all stakeholders involved as it provides an authentic experience with key outcomes such as: creating a solution to a real-world problem, ideation of potential solutions through design-thinking methodologies, community engagements, social responsibility and promoting skills development of the students.

The success of this initiative is evident in the accolades received: the MOE Innergy Award (Silver) in 2019, PAYM Service-Learning Champions Project Accolade (Silver) in 2019, and the RP Curriculum Innovation Award in 2019.

The Service-Learning Outcomes Measurement Scale (S-LOMS)

The Hong Kong Polytechnic University, in collaboration with Lingnan University, Hong Kong Baptist University, and The Education University of Hong Kong, initiated a joint project titled 'Cross-institutional Capacity Building for Service-Learning in

Hong Kong Higher Education Institutions' (Ngai et al., 2019). This collaborative effort aims to advance service-learning as a transformative pedagogy across institutions. Within this project, investigators from Lingnan University, supported by peers from collaborating universities, developed the Service-Learning Outcomes Measurement Scale (Snell & Lau, 2020).

The S-LOMS is used by students in Hong Kong to evaluate their developmental outcomes arising from their engagement in service-learning. These outcomes encompass 11 learning domains categorised under knowledge application, personal and professional skills, civic orientation and engagement, and self-awareness. In service-learning courses, students acquire soft skills, attitudes, and personal attributes that may not be clearly reflected in their academic performance. Through assessing self-perceived changes before and after participating in service-learning, the S-LOMS captures these developmental impacts (Lau and Snell, 2021).

Two studies have validated the Service-Learning Outcomes Measurement Scale (S-LOMS), with one specifically comparing scores from samples in Hong Kong and Singapore, notably Republic Polytechnic (Lau and Snell, 2020). As Lau and Snell considered that S-LOMS could be a feasible instrument for measuring the developmental outcomes of service-learning in Asian jurisdictions beyond Hong Kong, they have included Singapore in one of their studies. In this study, the students in RP volunteered to participate in service-learning outside their scheduled class time, whereas Hong Kong students were required to contribute to service-learning to fulfil university requirements. RP had collected the data from this group of students using S-LOMS and contributed the data to this study to validate the S-LOMS. Interestingly, the research revealed consistently higher perceived pre-test and post-test results for service-learning amongst Hong Kong students compared to Singaporean students. While this difference may partly stem from the diverse backgrounds of the respondents, it is also suggested that variations in the design of service-learning programs undertaken by students in each region contribute to this divergence.

Research indicates that students derive greater benefits from systematically designed service-learning programs that align with course content, grading requirements, and service criteria (Astin et al., 2000; Mabry, 1998). Several studies recommend that educational institutions with similar service-learning arrangements contemplate integrating these programs into regular academic courses or modules (Hanover Research, 2014; Jenkins & Sheehey, 2012; Snell & Lau, 2020), which SEG has accomplished.

Methodology

This study addresses the following research question: What are the developmental changes in engineering students arising from mandatory service-learning taking place as part of the 'Engineering Design' module?

We employed a quantitative research design to analyse the impact of service learning on the developmental changes of engineering students. We measured the students' self-perceived developmental outcomes using an online survey, slightly modifying the wording of items in the S-LOMS survey to specifically contextualize them for the service learning incorporated into a module, rather than using general service-learning statements (refer to Appendix A for a complete list of the original S-LOMS survey and the modified statements).

An online survey was used to measure 56 items, on a 10-point Likert scale, (1= strongly disagree to 10= strongly agree), administered at two points, namely, the inception of the service-learning project in Week 2 and at the end of the semester around Week 12. The items from S-LOMS cover 11 domains and 15 sub-domains, which are grouped into four major categories as illustrated in Figure 1. First year engineering students enrolled in the 'Engineering Design' module were invited to voluntarily complete the S-LOMS survey before as well as after their service-learning projects. Figure 2 depicts the list of events with the service-learning projects as the intervention.

Figure 1:

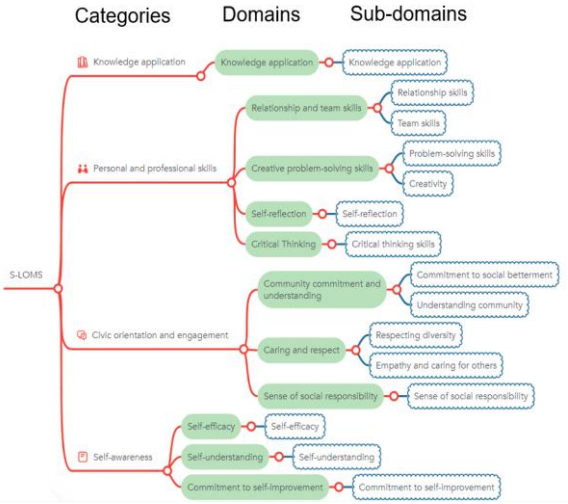
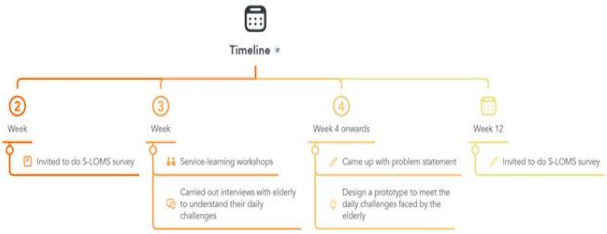


Figure 2:



Quantitative Methods

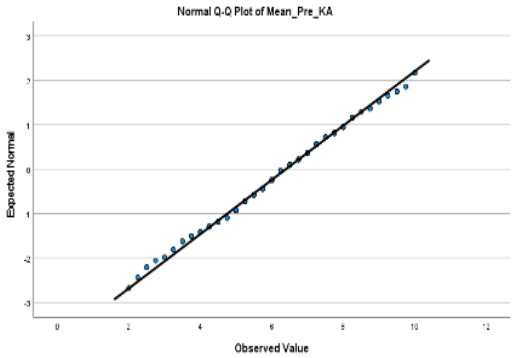
By utilising the S-LOMS (Lau and Snell, 2021) survey, this research project aims to investigate if there are any significant developmental changes in first-year engineering students arising from service-learning taking place as part of their mandatory contribution.

A total of 397 students participated in the pre-survey and post-survey, forming the sample for the cohort (800 students) who participated in the face-to-face service-learning projects.

When determining if there is a significant difference between the means of two paired measurements, like pre- and post-test scores, paired t-tests are typically employed. Hence, 15 paired sample t-tests were employed for this group of 397 engineering students using the pre-test and post-test scores to determine whether there were significant developmental changes arising from service-learning across the 11 domains and 4 major categories. This allows us to assess if the students have achieved the desired learning outcomes of the students under Introduction, paragraph 4 of this research paper.

The assumption of normal distribution was established with the use of Q-Q plots in Figure 3, and this sets the precedence to conduct the paired t-tests. Normality has been satisfied for all paired t-tests. An example of the normal Q-Q plot for the mean under knowledge application before survey is shown in Figure 3, where the observed values match closely to the expected normal.

Figure 3:



Results and Discussion

Four paired samples t-tests, comparing the pre- and post- survey data across the four categories of knowledge application, personal and professional skills, civic orientation and engagement, and self-awareness were conducted, and results showed significant improvement in the developmental changes for all four categories. The results are summarised in Table 1.

Table 1: Paired Sample t-tests Results across Four Categories

	Group	*N*	Mean	*SD*	*t*	Degrees of freedom	*p*
Knowledge application	Pre	397	6.39	1.64	-9.89	396	< .001
	Post	397	7.25	1.35			
Personal and professional skills	Pre	397	6.85	1.47	-5.10	396	< .001
	Post	397	7.21	1.27			
Civic orientation and engagement	Pre	397	6.65	1.56	-12.36	396	< .001
	Post	397	7.56	1.20			
Self-awareness	Pre	397	6.76	1.54	-7.11	396	< .001
	Post	397	7.29	1.28			

Thereafter, we delved into the 11 domains that are within the four categories, results are in Table 2. Two domains, namely relationship and team skills, and critical thinking, did not exhibit significant improvements. The domain of self-understanding demonstrated significant enhancement with $p<.01$, while the remaining eight domains displayed significant improvement ($p<.001$).

Table 2: Paired Sample t-tests Results across 11 Domains

	Group	N	Mean	SD	t	Degrees of freedom	p
Knowledge application	Pre	397	6.39	1.64	-9.89	396	< .001
	Post	397	7.25	1.35			
Relationship and team skills	Pre	397	7.08	1.49	-1.29	396	0.197
	Post	397	7.18	1.38			
Creative Problem-solving skills	Pre	397	6.54	1.62	-8.69	396	< .001
	Post	397	7.21	1.32			
Self-reflection	Pre	397	6.75	1.60	-5.35	396	< .001
	Post	397	7.18	1.42			
Critical thinking	Pre	397	7.19	1.61	-1.39	396	0.166
	Post	397	7.31	1.28			
Community commitment and understanding	Pre	397	6.51	1.61	-9.41	396	< .001
	Post	397	7.23	1.26			
Caring and respect	Pre	397	6.89	1.57	-13.27	396	< .001
	Post	397	7.94	1.31			
Sense of social responsibility	Pre	397	6.48	1.75	-11.77	396	< .001
	Post	397	7.50	1.40			
Self-efficacy	Pre	397	6.35	1.70	-11.40	396	< .001
	Post	397	7.33	1.38			
Self-understanding	Pre	397	7.14	1.60	-2.51	396	0.013
	Post	397	7.35	1.32			
Commitment to self-improvement	Pre	397	6.79	1.70	-4.15	396	< .001
	Post	397	7.16	1.52			

For domain on relationship and team skills, further t-tests were conducted on the sub-domains namely relationship and team skills. Further analysis, documented in Table 3, to separately examine relationship skills and team skills revealed that within the domain, relationship skills has shown a significant improvement with $p<.01$, and team skills is the factor that has not shown significant improvement arising from the service-learning. This indicates that students have shown improvement in all sub-domains except for critical thinking and team skills.

Table 3: Paired Sample t-tests Results across Two Sub-domains

	Group	N	Mean	SD	t	Degrees of freedom	p
Relationship skills	Pre	397	6.88	1.54	-2.91	396	0.004
	Post	397	7.14	1.55			
Team skills	Pre	397	7.27	1.58	0.644	396	0.52
	Post	397	7.22	1.38			

Conclusions

From the quantitative results outlined above, we conclude that integrating service-learning into the academic curriculum of the Engineering Design module whilst conducted face-to-face yields positive and significant impacts on students' developmental outcomes across the four main categories of Knowledge application, Personal and professional skills, Civic orientation, and engagement, as well as Self-awareness ($p <.001$). Further analysis in relationship and team skills in Table 3 has shown that students have shown improvement in all sub-domains except for critical thinking and team skills. The sub-domain of critical thinking showed improved mean scores for the post-survey ($M=7.31$, $SD=1.28$) compared to the pre-survey ($M=7.19$, $SD=1.61$), however, the difference was not significant, $t(396)= -1.39$, $p=0.166$. Based on studies, improvement in critical thinking takes place when students are able to assess reality critically and endure perplexity (Dewey, 1933; Freire, 1993). When students are culturally competent, specifically the ability for intergenerational interactions, they can make insightful decisions under different situations through analysis and interpretations (Goldberg & Coufal, 2009). Positioned at this stage whereby students were still in the process of attempting to build their cultural competence, this might be possibly one of the contributing factors as to why significant differences in the sub-domain of critical thinking did not emerge.

However, we should note that pre-existing attributes not presented as part of this research paper may have affected the post-test results due to the high collaborative nature of the students being in the same class, reflecting the students' existing proficiency in teamwork.

It is important to contrast the results of the S-LOMS study done previously in RP together with Hong Kong students (Lau & Snell, 2021) where a comparison of RP students pre-test and post-test scores across the 11 domains took place. In this case, there were eight domains that showed significant improvements in mean scores, whereas domains of caring and respect, sense of social responsibility, and commitment to self-improvement had $p>.05$ for RP students. One possible reason attributing to the different impacts on the students' development across the 11 domains could be due to the nature of the curated activities during the service-learning project.

Moreover, we hypothesise that the variable of team skills which did not show significant differences in our study when compared to the past S-LOMS of Lau & Snell's (2021) study might be largely due to the fact that students were already working in smaller teams before this project, in comparison to S-LOMS of Lau & Snell's (2021), where students are coming together for the first time, from various classes for a one-off service-learning engagement.

Challenges and Limitations

In this research, there were certain limitations that occurred, it is clear that there were non-significant improvements in key domains due to pre-existing attributes that cannot be accounted for during the duration of the project. This is highlighted in earlier text on the proficiency of the team's skills, resulting in non-significant changes. There are also methodological limitations whereby S-LOMS modifications were adjusted in the context of our survey that may affect compatibility that may require further validation to ensure reliability. Similarly, challenges were faced during data collection, especially due to the incomplete details in the survey collected. Additionally, RP's collaborative classroom approach seen in problem-based learning may have skewed team skill results as students are working in prior groups before the service-learning project.

Acknowledgements

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References

Astin, A. W., Vogelgesang, L. J., Ikeda, E. K., & Yee, J. A. (2000). *How service learning affects students*. University of California, Los Angeles, Higher Education Research Institute.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

Chang, C., & Yap, M. S. (2017). Service-learning: Appreciating the community as co-educator. In T. Y. Leong & H. M. Cheah (Eds.), *The heart of learning* (pp. 171–182). Singapore University of Social Sciences.

Choo, J., Tan, Y. K., Ong, F., Tiong, S. S., Nair, S., Ong, J., & Chan, A. (2019). What works in service-learning? Achieving civic outcomes, academic connection, career preparation, and personal growth in students at Ngee Ann Polytechnic. *Michigan Journal of Community Service Learning*, *25*(2), 95–132. https://doi.org/10.3998/mjcsloa.3239521.0025.208

Goldberg, L. R., & Coufal, K. L. (2009). Reflections On Service-Learning, Critical Thinking, And Cultural Competence. *Journal of College Teaching & Learning* (TLC), 6(6).

Hanover Research. (2014). *Best practices for scaling service-learning*. Hanover Research.

Jenkins, A., & Sheehey, P. (2012). A checklist for implementing service-learning in higher education. *Journal of Community Engagement and Scholarship*, *4*(2). http://jces.ua.edu/a-checklist-for-implementing-service-learning-in-higher-education/

Lau, K. H., & Snell, R. S. (2020, November). A Tale of Two Cities in Service-Learning: Cross-Cultural Comparison Between Hong Kong and Singapore of Student Developmental Outcomes After Service-Learning Experience and Validation of S-LOMS. In *The 3rd Conference for Higher Education Research-Hong Kong 2020: Innovations of Higher Education Amid the Pandemic: Institutional Management, Teaching, and Research Perspectives*.

Lau, K. H., & Snell, R. S. (2021). Validation of S-LOMS and comparison between Hong Kong and Singapore of student developmental outcomes after service-learning experience. *Michigan Journal of Community Service Learning*, *27*(2).

Ma, C. (2018a, March 19). *Community engagement and service-learning in Asia* [Paper presentation]. Brown Bag Series at Providence University, Providence: Rhode Island, USA.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd edition). Sage Publications, Inc.

Ministry of Education (MOE) of Singapore. (2020). *Values in*

action. https://www.moe.gov.sg/programmes/values-in-action

Neuman, W. L. (2003). *Social research methods: Qualitative and quantitative approaches*. Boston: Allyn and Bacon.

Ngai, G., Shek, D. T. L., Yue, K., Xu, H. X., & Snell, R. S. (2019, January 1). *Cross-institutional capacity building for service-learning in Hong Kong higher education institutions*. Repository.eduhk.hk. https://repository.eduhk.hk/en/publications/cross-institutional-capacity-building-for-service-learning-in-hon

Snell, R. S., & Lau, K. H. (2020). The development of a service-learning outcomes measurement scale (S-LOMS). *Metropolitan Universities*, *31*(1), 44-77.

Appendix 1

Edited S-LOMS questions:

Category: Knowledge Application

1 I know how to transfer knowledge from the design-thinking process to a service-learning project.
2 I can make connections between theory (service-learning concepts) and practice in a service-learning project.
3 I am able to apply/integrate classroom knowledge (providing design solutions) to deal with complex issues faced by the elderly.
4 I know how to apply what I learned to solve real-life problems faced by the elderly.

Category: Personal and Professional Skills

5 I am good at building relationships between the elderly.
6 I can easily establish effective relationships with the elderly.
7 I can build long-term relationships with the elderly.
8 I am good at keeping in touch with the elderly.
9 I have the necessary skills for making groups function effectively in a service-learning project.
10 I am good at resolving conflicts in a service-learning project.
11 I am confident in leading others toward common goals in a service-learning project.
12 I participate effectively in group discussions and activities in a service-learning project.
13 I am able to solve challenging real-life (service-learning) problems.
14 I feel confident in dealing with a problem related to service-learning.
15 I often modify my strategies to solve a problem related to service-learning when the situation changes.
16 I feel confident in identifying the core of a problem related to service-learning.
17 I am not afraid of trying new things in a service-learning project.
18 I am able to generate original ideas in a service-learning project.
19 I am able to look at an issue from a fresh perspective in a service-learning project.
20 When necessary, I can think of alternatives in a service-learning project.
21 I always think how I can improve myself in a service-learning project.
22 I will evaluate myself after completing a task in a service-learning project.
23 I consider circumstances when reflecting on how well I have performed in a service-learning project.
24 I reflect on myself regularly in a service-learning project.
25 I can analyze an issue comprehensively in a service-learning project.
26 I often look at complex issues from different angles in a service-learning project.
27 I can understand others' viewpoints when we are making decisions together in the service-learning project.

Category: Civic Orientation and Engagement

28 I think about how I can serve the elderly after graduating.
29 I will play my part to reduce social problems for the elderly.
30 I always actively discuss possible improvements for the elderly.
31 I will contribute my abilities to make a better place for the elderly.
32 I can identify challenges in the elderly community.
33 I can investigate the challenges faced by the elderly in need.
34 I can identify issues that are important for a disadvantaged elderly community.
35 I can identify useful resources of an elderly community.
36 I can respect the elderly whose background is different from mine.
37 I am willing to try to understand the elderlies whose backgrounds are different from mine.
38 I respect the needs of the elderly from different backgrounds.
39 I appreciate the ideas of the elderly from different backgrounds.
40 I observe the elderlies' feelings and emotions.
41 I consider the elderlies' points of view.
42 I care about the elderly.
43 I believe that taking care of the elderly, who are in need, is everyone's responsibility.
44 I feel obligated to help the elderly who are less fortunate than me.
45 I believe that everybody should be encouraged to participate in civic affairs.

Category: Self-awareness

46 Most things I do, I do well.
47 I have many good qualities when dealing with the elderly.
48 I am satisfied with my achievement in dealing with the elderly so far.
49 I am positive about myself in a service-learning project.
50 I have a clear picture of what I am like as a person when dealing with the elderly.
51 I know my strengths and weaknesses when dealing with the elderly.
52 I have a clear understanding of my own values and principles when dealing with the elderly.
53 I know what I need in my life.
54 I am always motivated to learn more about service-learning.
55 I always keep my service-learning knowledge and skills up-to-date.
56 I look out for new service-learning skills or knowledge to acquire.

Implementation of Regional Co-Creation Education: Fostering Innovative Talent and Advancing ICT Education through Government-academic Collaboration

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In an increasingly advanced information society, there is a growing demand for educational models that foster fundamental professional competencies—such as problem-solving and collaboration—particularly in regional contexts. This study examines the educational effectiveness of the Electrical Technology Innovation Practicum, a regional co-creation initiative in which students engage in project-based learning through virtual company activities. Since 2018, the practicum has enabled students to develop STEAM-related skills while addressing both hypothetical and real-world regional challenges. From 2021, the program also tackled the shortage of ICT educators by providing outreach programming lessons in local schools. Questionnaire surveys of participating students and pupils indicate progressive skill development and enhanced motivation, especially among upper-year students. The findings suggest that virtual company-based PBL is a promising model for cultivating core competencies and contributing to regional education reform.

Keywords: *Electrical Technology Innovation, Science and Engineering Talent Education, Regional Co-Creation, Programming*

Introduction

In recent years, the importance of collaboration and partnership between educational institutions and local communities has been increasingly emphasized, with a growing demand for the development of open education systems that foster regional connections and mutual support. Furthermore, the COVID-19 pandemic exposed the vulnerabilities of Japan's centralized social structure, in which intellectual, human, and material resources are heavily concentrated in urban areas. To survive in the "With/Post-COVID" era, a shift toward a more sustainable and resilient social structure is essential. In this context, regional decentralization and the development of innovation ecosystems that empower local communities to autonomously solve their own problems have become critically important (Ministry of Education, Culture, Sports, Science and Technology [MEXT] website).

Against this backdrop, educational approaches aimed at nurturing human resources capable of addressing regional challenges and contributing to the future of society—such as Project-Based Learning (PBL) and virtual company-based pedagogies—are gaining attention. For example, Thorsteinsson (1997) demonstrated the effectiveness of a virtual company model designed for educational purposes, showing that students were able to practically acquire teamwork and management skills. Similarly, Tuhkala et al. (2021) illustrated how a manufacturing simulation game can foster collaborative creativity and digital learning, while Goeser et al. (2018) reported that virtual environments and VR-based engineering education contribute to learning outcomes and the development of hands-on skills. These previous studies have mainly focused on internal learner development, such as creativity, technical understanding, and teamwork.

However, cases in which virtual company education is applied to solving regional issues or supporting local ICT education remain limited both in Japan and internationally. While the effects of digital and virtual educational environments on student learning have been explored, how these models can be utilized for regional collaboration and problem-solving has not been sufficiently examined. In this regard, the Electrical Technology Innovation Practicum, which has been implemented at Anan National College of Technology since 2018, stands out as a pioneering initiative. By leveraging the virtual company model, the program has established a sustainable framework for industry-government-academia collaboration (Komatsu, 2019; Kozai, 2020).

This study builds upon these previous efforts and re-evaluates the educational significance of the practicum from the perspectives of regional co-creation and the development of STEAM competencies. Rather than focusing solely on students' acquisition of skills, we aim to highlight broader educational impacts, including ripple effects on the local community, and to explore how the virtual company model can contribute to the development of a sustainable regional education model.

The purpose of this study is to answer the following two research questions:

1. Does a practical education program using virtual companies enhance students' basic professional skills (competencies), such as problem identification, problem-solving ability, and collaboration?

2. Does regional collaboration through virtual company activities contribute to improving the quality of programming (ICT) education in the local community?

To address these questions, this study analyzes student questionnaire results from the Electrical Technology Innovation Practicum, along with case examples of programming education support activities conducted at local elementary and junior high schools.

Materials and Methods or Pedagogy

This study aims to introduce and evaluate a practical initiative that seeks to enhance regional problem-solving capacity and foster the development of future STEAM professionals through a regional co-creation education model, realized through collaboration between educational institutions and local communities. At the center of this initiative is the Electrical Technology Innovation Practicum, implemented by the Department of Creative Engineering at Anan National College of Technology.

In this practicum, students operate virtual companies as a means to cultivate an entrepreneurial mindset and essential professional competencies. These virtual companies, centered around electrical technology, explore a wide range of technical fields—including power systems, electronic circuits, robotics, AI, IoT, and entertainment. Within a hypothetical social context, students examine how these advanced technologies can be applied to real-world business scenarios. The ultimate goal is to nurture individuals capable of leading emerging industries and contributing to regional revitalization.

This practicum also places project-based learning (PBL) at its core and emphasizes collaboration with local companies and municipalities. Students engage directly with regional issues and are encouraged to analyze problems independently and propose solutions through group discussions.

The program aims to establish a sustainable educational model that integrates entrepreneurship education, PBL, and early-stage STEAM education, thereby contributing to both the cultivation of innovation-oriented human resources and the advancement of regional communities.

This report seeks to clarify whether the core competencies required in STEAM education—such as creativity, collaboration, and problem-solving—are effectively developed through student-driven experimental and practical activities. The main focus is on the Electrical Technology Innovation Practicum conducted by the Department of Creative Engineering, in which students organize virtual companies and work in teams to design and execute projects related to electrical engineering. These projects incorporate advanced technologies such as AI, IoT, and robotics in hands-on, project-based learning environments.

To understand how students recognize and demonstrate these competencies, a post-practicum questionnaire was conducted to assess their self-perceived growth and acquisition of skills.

Among the various activities conducted during the practicum, this report highlights outreach programming lessons delivered at local elementary and junior high schools as an initiative aimed at returning educational outcomes to the community. In these lessons, students utilized teaching materials they developed themselves, supporting the early development of STEAM talent while promoting ICT and programming education in the region. After the lessons, a follow-up questionnaire was administered to participating students to evaluate changes in their interest in programming education.

Through these integrated efforts, this report examines how student-led learning contributes to the development of key competencies and how these skills are applied in ways that are socially meaningful and impactful.

Overview of the Electrical Technology Innovation Practicum

The Electrical Technology Innovation Practicum is a long-term educational program conducted over three academic years (2nd to 4th year) as one of the themes in the Electrical and Electronic Engineering Laboratory at the Department of Creative Engineering, Anan National College of Technology. The practicum is held biweekly and includes 8–10 themes annually.

In this practicum, students establish and manage virtual companies, taking the lead in year-long, project-based learning activities. The process begins with student leaders recruiting members and forming teams. Each team creates an annual activity plan and presents it through posters and oral pitches to acquire virtual currency (ANET), used to simulate corporate funding for materials and salaries—enhancing the realism of company operations.

The teams then proceed with projects aimed at internal events such as open campuses for junior high school students and the school festival Sōasai, while some prepare for external competitions like the KOSEN GCON (Girls × SDGs × Technology Contest).

Midway through the academic year, teams present their progress in a midterm presentation session, receiving objective feedback from faculty. During Sōasai, they also engage in outreach by showcasing their work to local residents and visitors. At the end of the year, final presentations are conducted, and students reflect on their growth by maintaining continuous activity reports.

Through this structured process, students systematically cultivate key STEAM-related competencies, including creativity, planning, collaboration, and execution. The practicum serves as a practical educational model, promoting both regional co-creation and real-world problem-solving skills through a virtual company framework.

Initiatives for Solving Real-World Challenges

This section introduces a programming education support initiative carried out by one of the mock companies, targeting elementary and junior high schools in Anan City. The students involved took this opportunity to apply the project management and presentation skills they had developed through the practicum in a real educational setting. This case demonstrates that the Electrical Technology Innovation Practicum has played a central role not only as an on-campus educational program but also in improving the quality of ICT education in the local community.

Since 2021, Anan National College of Technology has continuously implemented programming education support activities for local elementary and junior high schools. A distinctive feature of this initiative is that students take the lead in developing teaching materials and delivering lessons, applying their specialized knowledge and technical skills to contribute to regional education. From 2021 to 2023, students conducted interviews with elementary school teachers to identify classroom needs, particularly the importance of experiential learning and alignment with textbooks. Based on these insights, they developed programming materials tailored to upper elementary and junior high school students. After conducting lessons for around 30 pupils, they revised the materials based on feedback. Additionally, students reported their progress directly to the Mayor of Anan City and organized public programming events at local shopping malls—demonstrating both outreach and community engagement.

In 2024, the focus shifted to addressing the lack of standardized programming materials in junior high schools. Leveraging the skills acquired through the Electrical Technology Innovation Practicum, students developed and promoted unified teaching materials. Specifically, they created practical lessons using microcontrollers to control 8×8 LED panels, and conducted multiple sessions across junior high schools to support standardization efforts. Teacher training seminars were also held, with over 50 elementary and junior high school teachers participating. These workshops provided practical, classroom-ready teaching materials and offered guidance on implementation in actual lessons.

Furthermore, in collaboration with the Anan City Youth Invention Club, a local science education organization, students led hands-on programming workshops for approximately 30 elementary and junior high school students. Participants, ranging from 4th graders to 2nd-year junior high students, engaged in activities such as controlling electric fans and using water level sensors. Outreach programming classes in 2024 also introduced foundational IoT concepts. Using single-chip microcontrollers, students taught lessons involving LED control and environmental sensing (e.g., temperature and humidity), enabling participants to experience emerging technologies firsthand.

Through these efforts, student-led initiatives have significantly contributed to the promotion of programming education in the region and the early development of STEAM talent. The activities demonstrate how practical, project-based engagement by students can foster both personal growth and meaningful social impact.

Results and Discussion

Student survey

To evaluate whether the practical education program based on virtual companies contributed to the improvement of students' fundamental professional skills—such as problem-finding ability, problem-solving ability, and collaboration—we conducted a questionnaire targeting students who participated in the Electrical Technology Innovation Practicum.

Specifically, students were asked to respond to items related to the following eight competencies.:

1. Problem-Solving Skills (Fig. 1, 2)
   - Q1 : When faced with a new problem, are you able to analyze the situation and come up with a solution?
   - Q2 : Do you have confidence in staying calm and finding solutions even in difficult situations?

2. Critical Thinking (Fig. 3, 4)
   - Q3 : When judging whether information is correct, do you consider other perspectives and evidence?
   - Q4 : Are you able to think deeply about the background and reasoning behind things, not just surface-level information?

3. Management Skills (Fig. 5, 6)
   - Q5 : When working in a group, can you facilitate smooth progress while integrating others' opinions?
   - Q6 : Are you able to plan efficiently by prioritizing within limited time and resources?

4. Creativity (Fig. 7, 8)
   - Q7 : Can you generate new ideas by combining existing concepts and ways of thinking?
   - Q8 : Do you enjoy thinking from different perspectives and coming up with original ideas?

5. Implementation Skills (Fig. 9, 10)
   - Q9 : Are you able to take action to bring your ideas into concrete form?
   - Q10 : Do you believe that it is important not only to make plans but also to actually try things out?

6. Self-Inquiry (Fig. 11, 12)
   - Q11 : Do you reflect on how your own way of thinking and values were formed?

Q12 : Do you try to objectively reflect on and understand your emotions and behavioral tendencies?

7. Self-Acceptance (Fig. 13, 14)
   Q13 : Do you accept yourself as you are, including both your strengths and weaknesses?
   Q14 : Are you able to acknowledge failures and shortcomings positively, without denying them?

8. Self-Regulation (Fig. 15, 16)
   Q15 : Do you adjust your actions and learning methods in a planned manner to achieve your goals?
   Q16 : When your motivation drops, do you think about how to recover it and take action?

The questionnaire focused on competencies required in STEAM education.

The survey items are listed below, and the response options were: “Yes,” “Probably yes,” “Probably no,” and “No.”

The number of valid responses was as follows:

2nd-year students: 29
3rd-year students: 25
4th-year students: 29
5th-year students: 25

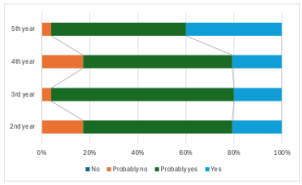


Fig. 1 The response results for Q1.

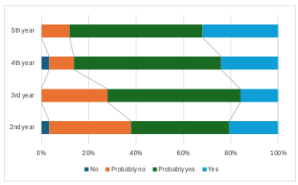


Fig. 2 The response results for Q2.

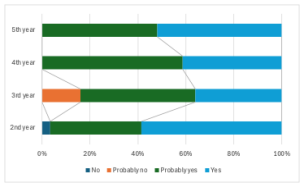


Fig. 3 The response results for Q3.

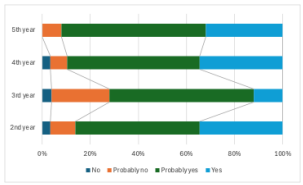


Fig. 4 The response results for Q4.

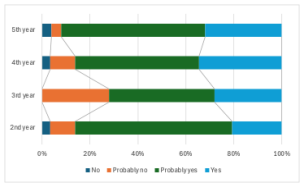


Fig. 5 The response results for Q5.

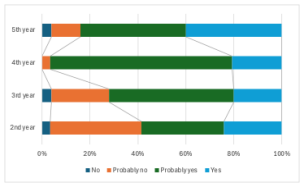


Fig. 6 The response results for Q6.

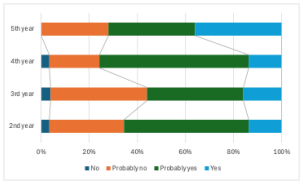


Fig. 7 The response results for Q7.

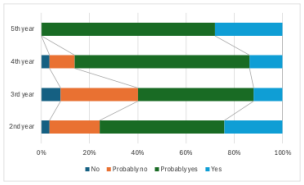


Fig. 8 The response results for Q8.

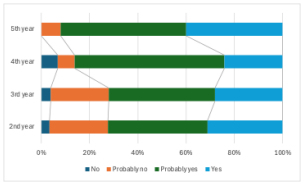


Fig. 9 The response results for Q9.

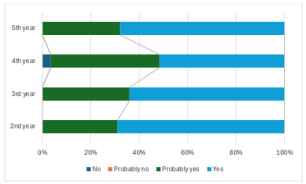


Fig. 10 The response results for Q10.

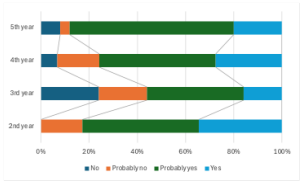


Fig. 11 The response results for Q11.

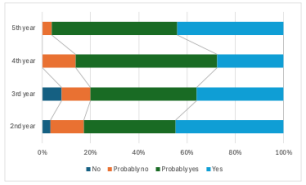


Fig. 12 The response results for Q12.

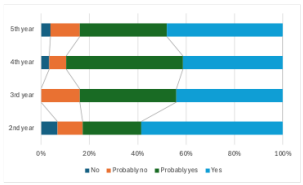


Fig. 13 The response results for Q13.

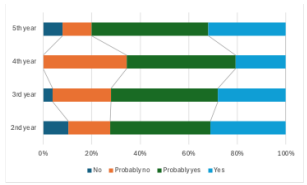


Fig. 14 The response results for Q14.

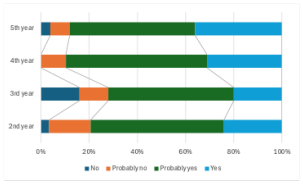


Fig. 15 The response results for Q15.

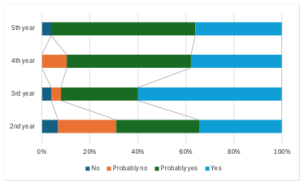


Fig. 16 The response results for Q16.

Trends by Question

The analysis of survey responses revealed several notable trends across academic years. Many questions demonstrated a positive correlation between grade level and the proportion of affirmative responses. For example, in Q1 （When faced with a new problem, are you able to analyze the situation and come up with a solution?） and Q2 (Do you have confidence in staying calm and finding solutions even in difficult situations?), 5-year students reported significantly higher rates of positive responses. This suggests that hands-on experience gained through practicum and virtual enterprise activities contributed to the enhancement of students’ self-efficacy in problem-solving.

Similarly, questions related to management competencies—such as Q5 (When working in a group, can you facilitate smooth progress while integrating others’ opinions?) and Q6 (Are you able to plan

efficiently by prioritizing within limited time and resources?)—showed increasing affirmative responses among upper-grade students. These results imply that as students assume more complex roles within the virtual enterprise structure, their management and coordination skills are further developed.

With regard to creativity, Q7 and 8, which assessed students' abilities to generate novel ideas and to enjoy thinking from alternative perspectives, also demonstrated upward trends with academic advancement. These findings support the idea that creativity is fostered through the iterative and open-ended nature of virtual enterprise and project-based learning.

Conversely, items related to self-reflection—such as Q11 (Do you reflect on how your own way of thinking and values were formed?) and Q12 (Do you try to objectively reflect on and understand your emotions and behavioral tendencies?)—showed more varied responses across years, indicating that these attributes may be influenced more strongly by individual characteristics than by academic progression alone.

An analysis of the skills developed through the practicum, categorized by competency area, revealed the following trends:

First, in terms of problem-solving skills, students improved their ability to identify and resolve issues through hands-on experience with real-world challenges in the virtual company activities. Positive responses increased with academic year, indicating the practical effectiveness of the program in enhancing these abilities.

Second, regarding critical thinking skills, students across all academic years consistently demonstrated a strong awareness of the importance of evaluating information accuracy and considering multiple perspectives. This suggests that a foundational level of information literacy has already been cultivated.

Third, management skills showed remarkable improvement particularly in the 4th and 5th years. Through experiences in project management and leadership within the virtual company setting, students strengthened their capacity to prioritize tasks and coordinate within teams.

Fourth, in the area of creativity, opportunities for free thinking and prototyping nurtured students' originality. Especially among senior students, there was a noticeable increase in both idea generation and the willingness to take action, suggesting the practicum effectively supports the development of creative thinking.

Fifth, with regard to implementation skills, all year levels showed a strong emphasis on moving from planning to testing and refinement. In the 5th year, a higher level of execution ability was observed, indicating that repeated practice contributed to improved capability in realizing ideas.

Sixth, for self-inquiry and self-acceptance, individual variation was significant, and clear trends by academic year were limited. Deepening self-understanding and reflection will likely depend on continued use of reflective reports and dialogic support in the future.

Lastly, in self-regulation, there was progressive maturity observed in students' planning and adjustment of learning strategies as they advanced in academic years. Notably, 5th-year students demonstrated greater self-awareness in behavior management and improved their ability to evaluate the feasibility of their actions.

These results suggest that the practicum—particularly the virtual company-based activities—serves as an effective educational method for fostering multidimensional competencies in engineering education.

Questionnaire Survey for Students Who Participated in the Outreach Programming Lessons

To examine whether the virtual company activities contribute to improving the quality of ICT education and fostering a sense of community engagement, a survey was conducted with students who participated in outreach programming classes for elementary and junior high schools.

The survey used a 5-point scale and collected 266 valid responses.

- Did you have an interest in programming before attending the class?
- After attending the class, did you become more interested in programming?
- Do you want to continue learning programming in the future?

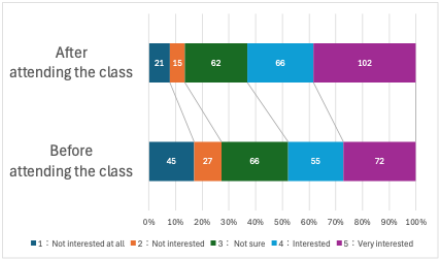


Fig. 17 Changes in Students' Awareness of Programming After the Lesson

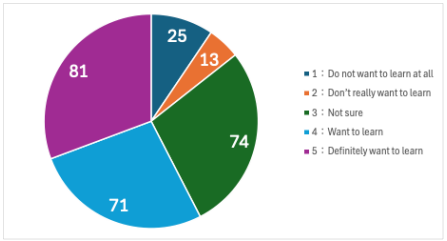


Fig.18 Motivation to Learn Programming

Based on the above results, it became clear that the proportion of students who answered "interested" before the lesson increased after the lesson, and more students reported feeling "very interested." Furthermore, a high percentage of students indicated that they "want to continue learning programming," showing a clear increase in their motivation to learn.

From the perspective of addressing regional issues through virtual company activities, students took the initiative in developing teaching materials, conducting lessons, and providing teacher training. In doing so, they played a role in supplementing on-site challenges such as a shortage of materials and a lack of skilled ICT teachers. In collaboration with Anan City, the initiative also

produced ripple effects throughout the region, such as reporting to the mayor and holding public events at commercial facilities.

The management skills, teamwork, and presentation abilities cultivated through the practicum and virtual company activities were applied to real-world educational support efforts, demonstrating a virtuous cycle between student growth and regional contribution. This initiative thus served not just as an on-campus project, but as a practical program that made a tangible impact on community education.

It is evident that virtual company activities are not only effective in fostering students' professional competencies but also contribute significantly to improving the quality of ICT education and expanding the base of programming education in the region. Moving forward, further collaboration with more schools and local governments is expected to lead to the development of a sustainable educational support model.

Future Improvements and Educational Strategies

Regarding Self-Inquiry and Self-Acceptance, the survey revealed no clear upward trend across academic years, with significant individual variation. Since these skills are essential for autonomous professional growth, it is necessary to incorporate mechanisms into the educational design that foster deeper self-understanding. This can include the regular use of reflection sheets, portfolio assessments, and individual interviews.

The virtual company activities represent an exemplary model of practice-based education connected to real-world contexts. In particular, among fifth-year students, the full cycle of problem identification, resolution, execution, and reflection was shown to have a positive effect on skill development. Moving forward, collaboration with multiple regional stakeholders and industrial partners, along with the introduction of interdisciplinary practicum themes, will aim to cultivate a broader range of skills and enhance students' adaptability to society.

Conclusions

This study examined how the Electrical Technology Innovation Practicum and virtual company activities contributed to both student skill development and practical solutions to regional challenges. Through the practicum, students progressively cultivated a wide range of competencies—including problem-solving, creativity, management, collaboration, and implementation skills. Notably, upper-year students showed a marked increase in confidence and ability to take action, indicating the effectiveness of the hands-on learning approach.

In the virtual company activities, students took initiative in developing teaching materials, conducting outreach classes, and providing teacher training. These efforts directly addressed real-world issues in regional ICT education, such as the shortage of instructional materials and qualified educators. Moreover, collaboration with the local government (e.g., Anan City) led to wider community impact, including official reports to the mayor and public events held in commercial venues, demonstrating the ripple effects of student-led initiatives.

These findings indicate that the program functioned not merely as an educational project but as a practical model of engineering education that simultaneously fosters student growth and addresses social issues. Moving forward, further expansion of partnerships with schools and municipalities, along with the establishment of a continuous support system, will be key to developing a sustainable, community-integrated educational model.

References

Ministry of Education, Culture, Sports, Science and Technology (MEXT) Website, *Support Program for the Formation of Co-Creation Hubs* (*Regional Co-Creation Field*). https://www.mext.go.jp/content/20210119-mxt_sanchi01-000012164_2.pdf

Thorsteinsson, U. (1997). A Virtual Company for Educational Purpose. In *Proceedings of the Thirty-Second International Matador Conference*, 221‑226.

Tuhkala, M. et al. (2021). Virtual Enterprise Simulation Game as an Environment for Collaborative Creativity and Learning, In *Proceedings of the International Conference on Engineering Education for Sustainable Development* (*EESD*), 126‑133.

Goeser, P. T. et al. (2018). VIEW: A Virtual Interactive Web-based Learning Environment for Engineering. *Advances in Engineering Education*, 6 (3), 1–29.

Merlin ' s Playground (2024). The usage of virtual reality in engineering education. *Virtual Education Review*, 8 (1), 10‑15.

Komatsu, M., & Matsumoto, T. (2019). Constriction of Innovation Practice on Electrical Technology for Working Persons. *IEEJ Transactions on Fundamentals and Materials*, 139 (11), 492-497.

Kozai, T. et al. (2020). Practice of training next-generation laser engineers through innovation practice on Electrical Technology. *Fundamentals and Materials Society Frontiers in Education*, 25-28.

LEARNER'S PERCEPTION OF ARTICULATE RISE IN ASYNCHRONOUS ONLINE LEARNING (AOL) FOR PHARMACOTHERAPY

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Abstract

Flipped classroom, widely adopted in education, commences with asynchronous online learning (AOL), followed by in-session workshops to further reinforce learner-centric pedagogies. Effective AOL requires meaningful, memorable, and motivational content to encourage self-directed learning. Traditional didactic pre-recorded lectures often lack interactivity and immediate feedback, hindering active learning and knowledge retention. Articulate Rise, an educational technology (EdTech) platform, addresses these issues by incorporating multimedia elements and interactive activities, to enhance the learning experiences. This mixed-method study explores whether Articulate Rise is an effective EdTech tool for improving the learning experiences for pharmacotherapy learners.

Year 2 Diploma in Pharmaceutical Science learners from the School of Applied Science, Nanyang Polytechnic, participated in learning experience surveys before and after participating instructor-designed pharmacotherapy AOLs via Articulate Rise. The effectiveness of the design was quantitatively measured with a survey referencing the 3M (Meaningful, Motivational, Memorable) quality dimensions, on a 5-point Likert scale. Differences between the results of the two surveys and the reliability of the findings were assessed at a significance of $p = 0.05$. Learners' perceptions of the strengths, challenges, and areas for improvement in AOL were gathered and thematically analysed to gather qualitative insights into the effectiveness of Articulate Rise – adopted as an EdTech Tool - in improving pharmacotherapy learning experiences.

81 (93.1% response rate) and 74 (85.1% response rate) learners participated in the pre- and post-surveys, respectively. No significant differences were found in the composite measures of the 3Ms between the two groups. Good internal consistency between the components and each of the 3Ms was established, confirming the survey's reliability in assessing the AOL's effectiveness. Learners also found that the AOL lessons flow clearly, are flexible for self-paced learning, and the embedded activities enhance interactivity and understanding. Sub-analysis revealed a significant reduction in 'attention' in Articulate Rise ($M = 3.71$, $SD = 1.07$, $p = 0.043$] as opposed to viewing pre-recorded lectures ($M = 4.07$, $SD = 0.75$, $p = 0.043$). Also, issues in the learning packages, such as reliance on audio features without adequate visual explanation, and navigation difficulties, were notable challenges among learners.

Articulate Rise may potentially enhance the learning experience of pharmacotherapy learners in AOL. However, it requires intentional enhancements to audio-visual explanations and user-friendliness to retain learners' engagement and attention and maximise its potential in AOL. Ongoing iterative improvements may potentially maximise the effectiveness of Articulate Rise in AOL within and beyond pharmacy education.

Keywords: *Articulate Rise, Asynchronous Learning, EdTech, Pharmacotherapy, Pharmacy Education*

Introduction

Pharmacy education has undergone a paradigm shift, transitioning from lecture-based methods to an active-learning, learner-centric approach (Husband, Todd & Fulton, 2014). A proliferating and popular approach, Cui et al., (2023) defined flipped classroom as "a method that instructors expose pre-work to learners outside of class, and then use class time to arrange harder work to assimilate knowledge". By incorporating educational technologies (EdTech) in asynchronous online learning (AOL) with solving case studies during face-to-face tutorials, the flipped classroom approach is linked to improve academic outcomes, including higher course grades, enhanced examination scores, and better pre- and post-test performance (Cui et al., 2023; Chen et al.; 2018; Hew et al., 2018). Despite the growing emphasis on digital learning tools, limited research has been conducted on the effectiveness of Articulate Rise in AOL environments, particularly in pharmacy education. This study aims to evaluate learner's experience associated with Articulate Rise in AOL segment of the flipped learning approach in a pharmacotherapy module.

Literature Review

Challenges in AOL

In AOL, Cui et al. (2023) highlighted that traditional instructional model, such as pre-recorded lectures, are often passive, lengthy and lacks engagement. This likely attributed to a limited capacity of the working memory and the lack of active processing to internalise the information, which are criteria listed in theories of the Cognitive Theory of Multimedia Learning (Mayer, 2014; Mayer, 2019). Efforts to reduce extraneous processing, manage essential processing and foster generative processing are necessary to meet the goal of instructional design for an AOL (Mayer, 2018).

Educational Technology Solutions

Articulate Rise is an EdTech platform that incorporates multimedia elements and interactive activities to enhance AOL experiences (Articulate, n.d.). The block-based system supports multimedia integration, bite-sized content creation and hands-on interactive activities to facilitate information retention and comprehension (Articulate, n.d.). These LMS-compatible learning packages can be imported into different LMS for seamless, user-friendly access of interactive content for the learners. This avoids the need to toggle between browsers or browser windows (Articulate, n.d.). The design principles of Articulate Rise correspond with the Cognitive Theory of Multimedia Learning, which emphasizes how instructional design should align with cognitive information processing (Mayer, 2019). While similar EdTech tools have shown promise in pharmacy education - such as Articulate Storyboard 360's successful implementation in scaffolded inverse blended learning (SIBL) that led to enhanced student performance (Ang, 2020) - research specifically examining the effectiveness of Articulate Rise 360 remains limited.

Research Questions

Given the growing emphasis on digital learning tools, the intuitiveness of Articulate Rise 360's web-based development that offers a modern learning experience, this study aims to evaluate learner's experience associated with Articulate Rise in AOL segment of the flipped learning approach in a pharmacotherapy module from two angles:

1) How does Articulate Rise 360 enhance the learner's perception in AOL, as compared to conventional, pre-recorded lectures (CPL)?
2) What features of Articulate Rise 360 learning package encourage or limit self-directed learning in AOL, compared to CPL?

Methods

In this exploratory, prospective, mixed-method study, 87 second-year learners enrolled in the Diploma in Pharmaceutical Science program at Nanyang Polytechnic (NYP), Singapore, participated in the study. These learners were conveniently sampled, based on the enrolment into "*Anti-Infectives & Medication Therapy in ENT and Musculoskeletal Disorders*" (MTEMD) module. MTEMD is a 5-credit module comprising 75 hours of instruction over 15 weeks. The first fourteen weeks consist of curriculum lessons, while the final week is designated as an examination week. During Weeks 1 to 7, learners interacted with traditional, pre-recorded AOL materials available on the D2L BrightSpace learning management system (LMS). In Weeks 8 to 16, learners transitioned to an AOL learning package designed with Articulate Rise 360; Articulate Rise 360 was selected for the study as it is one of the key educational technology tools subscribed to by Nanyang Polytechnic. Each week, learners were provided with an Articulate Rise 360 learning package accompanied by lecture notes to facilitate their lesson preparation for the face-to-face in-class workshops.

The "*3M Quality Dimensions for Engaging Learning*" questionnaire (Nanyang Polytechnic, 2022) presented in iSATE 2024 with the topic of "*Learning Experience Design (LXD) for Learner Engagement"*, measured on a 5-points Likert scale, was used to ascertain the learner's perception of the AOL approach (**Figure 1**). Briefly, the 3M Quality Dimensions described "meaningful", "motivation" and "memorable" as the three key outcomes of engaged learning, to develop the ability and passion for self-directed learning. These outcomes are supported by eight quality dimensions, each playing a crucial consideration in attaining the 3M outcomes of engaged learning. The questionnaires were issued at Week 8 (pre-survey) and 16 (post-survey) to examine the learner's perception at baseline and after undergoing AOL via Articulate Rise, respectively. Qualitative data was collected in Week 16, to solicit strengths, limitations and the area of improvements of the learning package.

Quantitatively, Mann-Whitney U-Test was performed, using Stats Kingdom (Stats Kingdom, n.d.), to test for differences in the 3M outcomes and the eight quality dimensions between the Pre- and Post-Survey to discern for any difference in learner's engagement between pre-recorded lectures and Articulate Rise 360 learning packages. All statistical tests were performed as a two-tailed test, with a statistical significance of $p = 0.05$. The qualitative feedback solicited at Week 16 were analysed and thematically classified by two contributors. The responses were grouped into common categories based on their content. The themes were cross reviewed by the contributors. Any disagreements in classification were discussed and resolved them before finalizing the data to ensure consistency and accuracy in the analysis.

Results and Discussion

Of the 87 learners, 81 (93.1% response rate) completed the pre-survey, while 74 (85.1% response rate) participated in the post-survey. The study found that the interactive Articulate Rise learning package is as equally effective in supporting their learning experiences in pharmacotherapy as the traditional, pre-recorded lectures.

3M Domains	3M Quality Dimensions		Definitions of 3M Quality Dimensions
1. Meaningful *Incorporate real-life contexts that facilitate active, constructive, intentional & collaborative engagement, by integrating cognitive (thinking), affective (feeling), and psychomotor (doing) domains, to develop competency & purposeful learning.* [1, 2, 9]	1.1	**Application**	The ability to use learned material in new and real-life situations. This may include the application of rules, methods, concepts, principles, laws, and theories. [3]
	1.2	**Problem-Solving**	The synthesis of learning and application in new and different situations to propose solutions and consider alternatives to a problem.[4]
	1.3	**Collaboration**	The learning that occurs when two or more students learn together through dialogue and social interaction, considering each other's perspectives and experiences to solve problems and develop a shared understanding of meanings. [5,6]
2. Motivational *Motivational lesson design clarifies the flow of the lesson and incorporates scaffolding and activities that encourage learners to participate and engage in learning.* [10, 12]	2.1	**Attention**	The behavioural process in capturing and sustaining learners' interest while stimulating curiosity towards learning.
	2.2	**Autonomy**	The sense of empowerment, providing our learners achievable choices and endorsement in a task. [15]
	2.3	**Confidence**	The sense of mastery over a task or domain when learners believe that their success is a direct result of the progressive effort they put in.
3. Memorable *Learners can appreciate and connect their learning with the outcomes and the curriculum.*	3.1	**Appreciation**	The understanding of the purpose and importance of lesson outcomes as learners go through the learning process. [16]
	3.2	**Connection**	The engagement of learners emotively & cognitively.[16, 20, 21, 22]

Figure 1: The 3M Quality Dimensions for Engaging Learning indicates Meaningful, Motivational and Memorable as the key outcomes of learning experience design. Each key outcome is supported by two to three quality dimensions, serving as a criterion of consideration in learning experience design (Nanyang Polytechnic, 2022).

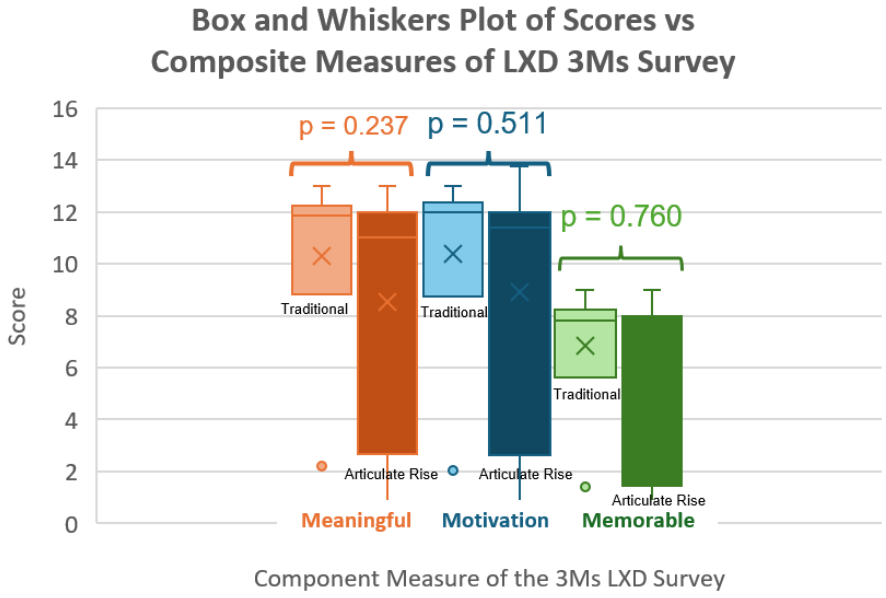


Figure 2: Comparison of learner perceptions across different AOL methods (Traditional, Pre-recorded, and Articulate Rise). The analysis indicates no statistically significant differences in Memorability, Meaningfulness, and Motivation among these learning modalities.

Statistical analyses revealed slight numerical variations and no statistically significant differences in perceived meaningfulness, motivation, and memorability between the two AOL delivery methods (**Figure 2**). Both methods offer instructors asynchronous tools that can be selected based on context, instructional objectives, and available resources, without compromising learner engagement.

Reliability testing, conducted using Cronbach's alpha test, indicated that the "3M Quality Dimensions for Engaging Learning" questionnaire effectively measured learners' experiences. The analysis demonstrated an acceptable level of internal consistency for the memorability dimension ($p = 0.730$), while both motivation ($p = 0.865$) and meaningfulness ($p = 0.876$) exhibited good internal consistency. These findings confirm the robustness and reliability of the questionnaire in assessing the key aspects of learning engagement within the study.

In the component analysis in each of the 3Ms, there were no statistically significant differences in all the quality dimensions, except for "*attention*" (**Table 1**). Notably, learners found in harder to retain attention in Articulate Rise ($M = 3.71$, $SD = 1.07$, $p = 0.043$) than traditional, pre-recorded approaches ($M = 4.07$, $SD = 0.75$, $p = 0.043$).

Table 1: Component analysis of the *3M Quality Dimensions for Engaging Learning*, evaluating the eight quality dimensions under "*Memorable*", "*Meaningful*", and "*Motivation*" across the two AOL methods (Traditional, Pre-recorded, versus Articulate Rise).

Sub-Domain	Pre-Survey [Median (IQR)] (n = 81)	Post-Survey [Median (IQR)] (n = 74)	p-value (p = 0.05)
Meaningfulness			
Application	4 ± 0.75	3.97 ± 0.90	0.959
Problem-Solving	4.04 ± 0.75	3.88 ± 0.95	0.309
Collaboration	3.91 ± 0.98	3.58 ± 1.11	0.059
Motivational			
Attention	4.07 ± 0.74	3.71 ± 1.09	**0.043***
Autonomy	4.14 ± 0.76	4.11 ± 0.93	0.864
Confidence	3.95 ± 0.78	4 ± 0.93	0.434
Memorable			
Appreciation	4.12 ± 0.74	4.15 ± 0.74	0.697
Autonomy	3.78 ± 0.89	3.81 ± 0.89	0.877

* *statistical significance ($p < 0.05$)*

Qualitative analysis revealed that this is plausibly attributable to the lengthiness of content, the improper user experience and/or the insufficient of explanation of contents. Learners shared that:

"The notes used to accompany the articulate rise is also too wordy, making it hard to find information."

"Lesser in-depth explanation so sometimes can be a bit confusing."

"Not much aside from the fact that if I leave (the Articulate Rise Learning package) halfway (into the lessons), I'll have to redo the content from the start".

Conversely, learners also highlighted that the Articulate Rise learning packages offered flexibility in completing their knowledge acquisition process, enhanced the interactivity between the learning content and the learners, and an improved flow and organisation of learning contents when Articulate Rise is adopted. This offers learners to take control of their learning, allowing them to review materials and adjust their pace based on their individual progress.

"Due to my short attention span, long lectures do cause me to blur out halfway, this results in me not being able to understand most of what the lecturers are talking about. However, with this new AOL, I can engage in interactive activities where I am constantly challenged, and it has given me the motivation to learn and grasp the concepts presented. This method of learning is really suited to my learning needs."

"The Articulate Rise helped to break down each topic into multiple chapters and you can view each of the chapters without having to scroll through to find them. Additionally, Articulate Rise makes things less wordy and more visual, so it is better for me."

Among the key strengths, the enhanced interactivity and the flexibility for self-paced learning align with findings from existing literature (Ang, 2020; Shin et al., 2019). In Ang's (2020) attempt in adopting Articulate Storyline 360 – an interactive learning package – for Diploma in Pharmaceutical Science students, 89% of learners highlighted that the AOL was interactive, engaging and offered flexibility to control their own learning pace. This underscores that interactivity and self-paced learning are highly valued by learners, reinforcing the idea that an effectively designed, flexible and engaging AOLs can enhance the learning experiences.

Macroscopically, the benefits and limitations solicited by learners who participated in the survey returned an ambivalent response, with a balanced mix of advantages and limitations of the Articulate Rise 360 learning package. This might be attributed to the varied learner's characteristics across the cohort of learners. For instance, the perennial concept of "Learning Styles Theory", illustrated in the "VARK model", suggests that individuals learn best when instruction matches their preferred mode of learning — visual, auditory, read and write or kinaesthetic (Fleming, 1995).

Traditional and pre-recorded lectures offer direct auditory and visual explanations to learners (Romanelli et al., 2009), whereas Articulate Rise 360 learning packages requires hands-on navigation and read-write engagement. The spectrum of learning style preferences varied the interest in the modality of AOL, likely contributing to the finding of this study. It is plausible that the community of learners exhibited a mixed preference for both CPL and Articulate Rise 360,

reflecting the diverse ways in which individuals engage with and respond to different instructional approaches.

Hence, deliberate efforts are needed to better accommodate learners' needs by enhancing the integration of audiovisual content while maintaining interactivity. Learners suggested that:

"Maybe try to add everything into the rise as sometime the recorder videos inside have info not mentioned in rise and then get very confused where the info is or where am I know in the lectures."

To accomplish this, educators must continuously refine and enhance content and features through iterative improvements, ensuring a more effective learning experience at the community level.

This study has several limitations. Firstly, this study was designed as an explorative study. Its generalisability is restricted, as the study design compares between different weeks of learning content, which may affect the efficacy of the results. Moreover, the findings are based on a specific learner group. Furthermore, this study focuses on the learners' perception in theoretical learning. The actual impact of AOL on enhancing the attainment of the learning outcome of face-to-face tutorials in a blended learning pedagogy. Lastly, it does not assess long-term knowledge retention or real-world application. However, these findings still provide insights into learner engagement and motivation. While practical applications were not included, the study establishes a foundation for evaluating theoretical learning in digital environments.

Future research should consider broadening participant diversity, integrate practical learning methods such as simulations or case-based exercises, and include follow-up assessments to measure long-term retention and real-world application of knowledge. Future study could also compare AOLs with the same content to understand the differences in perceptions between two modes of AOL. These steps will enhance the understanding of AOL's impact on both theoretical and applied learning, ensuring a more comprehensive evaluation of its effectiveness in blended learning environments.

Conclusions

Articulate Rise, with its improved interactivity and self-paced structure, presents a viable alternative to the traditional pre-recorded lectures used in the flipped classroom approach. However, to maximise its effectiveness, careful attention must be given to maintaining learner engagement. Thoughtfully curated content, clear explanations, and an intuitively designed user interface can significantly enhance the learning experience. Further research is needed to explore its impact on other subjects, knowledge acquisition and skills training.

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I extend my gratitude to the School of Applied Science, Nanyang Polytechnic, for its support in the development and integration of Articulate Rise into the module.

References

Ang, J. W. J. (2020). Scaffolded inverse blended learning: An approach to teach an online general chemistry course. Journal of Chemical Education, 97(9), 2839–2844.

Articulate. (n.d.). Rise 360. Articulate. https://www.articulate.com/360/rise/

Chen, K. S., Monrouxe, L., Lu, Y. H., Jenq, C. C., Chang, Y. J., Chang, Y. C., & Chai, P. Y. (2018). Academic outcomes of flipped classroom learning: A meta-analysis. Medical Education, 52(9), 910–924.

Cui, H., Xie, X., Wang, B., & Zhao, Y. (2023). Effectiveness of flipped classroom in pharmacy education: A meta-analysis. BMC Medical Education, 23(1), 881.

Fleming, N. D. (1995). I'm different; not dumb: Modes of presentation (VARK) in the tertiary classroom. In A. Zelmer (Ed.), Research and development in higher education: Proceedings of the 1995 annual conference of the Higher Education and Research Development Society of Australasia (HERDSA) (Vol. 18, pp. 308–313). HERDSA.

Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves learner learning in health professions education: A meta-analysis. BMC Medical Education, 18(1), 38.

Husband, A. K., Todd, A., & Fulton, J. (2014). Integrating science and practice in pharmacy curricula. American Journal of Pharmaceutical Education, 78(3), Article 63.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (2nd ed., pp. 43–71). Cambridge University Press.

Mayer, R. E. (2019). Thirty years of research on online learning. Applied Cognitive Psychology, 32(5), 615–622.

Nanyang Polytechnic. (2022). 3M Quality Dimensions for Engaging Learning. https://staff.nyp.edu.sg

Romanelli, F., Bird, E., & Ryan, M. (2009). Learning styles: A review of theory, application, and best practices. American Journal of Pharmaceutical Education, 73(1), 9.

Shin, J., Gruenberg, K., & Brock, T. (2019). A novel online platform promotes asynchronous class preparation

and thought transparency. Currents in Pharmacy Teaching & Learning, 11(10), 1069–1076.

Stats Kingdom. (n.d.). Statistics calculator and tools. Stats Kingdom. https://www.statskingdom.com/

INVESTIGATING THE EFFECTIVENESS OF SIMULATION-BASED TRAINING ON SOCIAL WORK STUDENTS IN FIELDWORK PLACEMENT

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This study aims to explore the effectiveness of simulation-based case conferences, developed in partnership with the Ministry of Social and Family Development (MSF), on the competency of students in handling real-life internship-based case conferences. This research will examine whether simulation-based training can effectively prepare students for the challenges they will encounter during their internships, and how this preparation influences their confidence, decision-making skills, and overall performance in actual case conference settings. Three validated survey tools; Simulation Effectiveness Tool, Self-Efficacy in Clinical Skills Scale and Social Work Skills Inventory, were contextualized with consideration towards the attainable key competencies in the Nanyang Polytechnic's (NYP) Social Work simulation framework to develop a pre and post training survey for the learners. The participants for this research are Year 3 students from the Diploma in Social Work in NYP. Learners' perceptions of the training were also gathered and thematically analysed to gather qualitative insights into the effectiveness of simulation-based training on field work placements. The results of the pre- and post-survey indicate a significant positive impact of simulation-based training on students' preparedness for managing real-life case conferences. These findings affirm the effectiveness of simulation-based training in bridging the gap between theoretical learning and real-world practice in social work education. This research also highlights the value of simulation-based learning as a powerful tool for enhancing practical skills in social work students. The partnership with the Ministry of Social and Family Development (MSF) underscores the benefits of collaboration with external agencies, which bring real-world relevance and depth to training scenarios.

Keywords: *Social work, Simulation based training, Placement*

Introduction

In social work education, bridging the gap between theoretical knowledge and practical application is a persistent challenge. Simulation-based training has emerged as a promising pedagogical approach to enhance students' preparedness for real-world scenarios. (Lateef, 2010) This study investigates the effectiveness of simulation-based case conferences, developed in collaboration with the Ministry of Social and Family Development (MSF), in equipping students with the competencies required for managing real-life case conferences during their internships. Specifically, the research examines the impact of such training on students' confidence, decision-making skills, and overall performance in actual case conference settings. Simulation-based learning offers students the opportunity to practice their skills in a realistic, yet risk-free setting. Feedback and inputs from fellow classmates and facilitators also contribute to the students' learning. At the end of the session, students were able to learn about stakeholder management and experience how to navigate various barriers to achieve a collective goal.

To prepare social work students for their fieldwork placement, Nanyang Polytechnic's School of Health and Social Sciences, partnered with the Ministry of Social and Family Development (MSF) to pilot a simulation-based case conference in November 2023. After the pilot training program, research was designed to investigate the effectiveness of the training. The research was conducted between June 2024 and February 2025. The objective of the research was mainly to investigate the effectiveness of this training. The 2 main research questions were –

1. How does simulation-based training impact the competency levels of social work students during their field work placements?
2. What are the perceptions of the students on the simulation-based training?

Literature Review

What is Simulation?

Simulation is an "exemplar method" in teaching holistic competence; and has a long history of wide use in medicine, nursing and other healthcare professions. (Lateef, 2010) During the simulation-based case conference, each student was tasked to portray a certain stakeholder role. Based on the assigned role, the students were given different information, and they had to engage in discussion, with the aim to collaborate and come to a consensus on follow up plans based on the issues identified in the case study. This gave students opportunities to practice their engagement, empathy, case conceptualisation and micro skills. Students will then be asked to reflect on their learning and have feedback given via the instructor and other fellow students.

Importance of simulation-based learning

Simulation-based learning has gained traction in social work education as an effective means to develop practical skills in a controlled environment. Studies have demonstrated that simulations can significantly enhance students' self-efficacy and clinical competencies. For instance, a systematic review by Kourgiantakis et al. (2019) highlighted the positive outcomes of simulation-based education in social work, noting improvements in students' confidence and skill acquisition.

The use of standardized clients, portrayed by trained actors, has been identified as a common simulation method that provides consistent and realistic practice scenarios (Bogo, Rawlings, Katz, & Logie, 2014). Such simulations allow students to engage in authentic client interactions, thereby enhancing their readiness for field placements. Additionally, virtual reality and computer-based simulations have been explored as innovative tools to further enrich social work training (Washburn et al., 2016).

Furthermore, simulation-based training has been linked to increased self-efficacy among social work students. A study by Badger and MacNeil (2002) found that students who participated in simulated client interactions reported greater confidence in their direct practice skills. These findings suggest that simulation exercises can effectively prepare students for the complexities of real-world social work practice.

Competence

NYP's Diploma in Social Work aims to develop professionals who can function competently as Social Work Associates in the social service sector. Kourgiantakis (2019) outlined a model of Holistic Competence as comprising procedural and meta-competence. Procedural competence consists of skills such as developing a collaborative relationship, conducting an assessment, and utilizing diverse intervention frameworks. Meta- competence refers to "the ability to be introspective about one's cognitive and affective states" and includes processes such as self-regulation, reflection and awareness. The figure below outlines NYP's Social Work Simulation Framework.

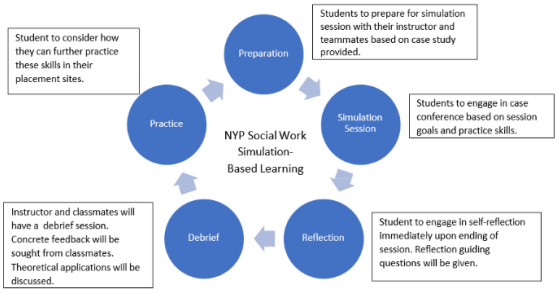


Fig 1 NYP's Social Work Simulation Framework

Materials and Methods

Participants

Participants comprised Year 3 students enrolled in NYP's Diploma in Social Work program. There were 43 students who were enrolled in the program and who completed the survey. Inclusion criteria required the learners to have completed 2 years of the NYP's Diploma in Social work program and the training program organised in collaboration with MSF. Ethical approval was obtained from the polytechnic's institutional review board, and informed consent was secured from all the participants. There was no control group in this study, as all students were required to undergo the simulation-based training to ensure fairness and uniformity in the educational experience.

Measures

This study employed a mixed-methods approach to assess the effectiveness of simulation-based case conferences through the simulation-based training. The survey instrument comprised of 16 items which were adapted from three validated simulation tools and aligned with the key competencies outlined in Nanyang Polytechnic's (NYP) Social Work simulation framework. The alignment identified four main domain areas to be measured, namely the student's self-perception on the following,

1. Confidence and self efficacy
2. Skill acquisition and competence
3. Self awareness and mental resilience
4. Interpersonal and collaboration skills

The three validated survey tools were namely –

1. Simulation Effectiveness Tool (SET): Measures students' perceptions of the simulation's realism and educational value.
2. Self-Efficacy in Clinical Skills Scale (SECSS): Assesses students' confidence in their clinical abilities.

3. Social Work Skills Inventory (SWSI): Evaluates proficiency in essential social work skills.

Research design and procedure

Pre- and post-training surveys were administered to quantitatively measure changes in the four identified domain areas stated above. The participants rated their level of agreement on a five-point Likert scale, which ranged from one (strongly disagree) to five (strongly agree). Five response categories were used because, although research indicates that as the number of response categories increases, so do reliability and validity, such small differences within a large number of response categories may not reflect actual differences in the construct being measured. Additionally, learners' perceptions of the training were also gathered and thematically analysed to gather qualitative insights into the effectiveness of simulation-based training on field work placements.

The pre-survey was conducted before the training. The post-survey and the qualitative feedback were conducted after the training and after the students completed their field work placement.

Intervention

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The intervention involved Year 3 Students enrolled in the Diploma in Social Work Programme. MSF briefed the students on the cases they would be simulating. This would be followed by role allocation and preparation for the simulated case conference. After the simulation, the students would have a reflective practice session, and a group debrief. This simulation would involve several cases and it would be conducted 1-2 months before the students fieldwork placement.

Results and Discussion

Data Analysis

Before conducting paired t-tests to compare pre- and post-test scores, data normality was assessed using the Shapiro-Wilk test. If normality assumptions were violated, non-parametric alternatives such as the Wilcoxon signed-rank test were applied. Effect sizes were calculated to determine the magnitude of observed changes. Participants completed the pre-survey prior to the simulation-based training and the post-survey immediately after the training. Data were analysed using paired t-tests to determine the significance of changes in survey scores. Analysis of the pre- and post-survey data revealed a significant positive impact of the simulation-based training on students' preparedness for real-life case conferences.

Qualitative feedback was collected through open-ended questions administered via the same online survey platform, allowing participants to elaborate on their perceptions of the resources and their applicability to teaching practices. This method was chosen for its flexibility and capacity to gather in-depth insights from diverse participants asynchronously. For the qualitative data, a grounded theory approach was used for thematic analysis. Data from open-ended survey responses and participant reflections were systematically coded. Initial open coding identified recurring patterns, followed by axial coding to establish relationships among themes. Selective coding refined overarching themes while addressing any contradictions in participant responses. To enhance reliability, two independent researchers reviewed the coding framework, and discrepancies were resolved through discussion.

Results

Students demonstrated notable improvements in key competencies, including:

1. Analyzing Case Information: Enhanced ability to critically assess and interpret client data.
2. Facilitating Stakeholder Collaboration: Improved skills in coordinating with various parties involved in case management.
3. Formulating Actionable Plans: Greater proficiency in developing effective intervention strategies.

The table below presents the quantitative findings displaying the mean pre- and post- survey scores. Significant improvements were observed in all domains ($p < 0.05$), indicating the positive impact of the training.

Table 1 Quantitative results

Domains	Pre survey Mean (SD)	Post survey Mean (SD)	Mean Difference
Confidence and self efficacy	3.2 (0.6)	4.3 (0.5)	+1.1
Skill acquisition and competence	3.4 (0.7)	4.4 (0.4)	+1.0
Self awareness and mental resilience	3.1 (0.8)	4.0 (0.6)	+0.9
Interpersonal and collaboration skills	3.3 (0.6)	4.2 (0.5)	+0.9

Post-training results reflected a marked improvement in student outcomes across key domains, with the mean score for confidence and self-efficacy rising from 3.2 (SD = 0.6) to 4.3 (SD = 0.5). This substantial increase highlights the positive impact of the simulation-based training in boosting students' confidence and readiness to handle real-life case discussions.

Qualitative feedback underscored the practical relevance of the simulations. Students highlighted that the realistic scenarios and guided debriefing sessions deepened their understanding of the complexities

inherent in case conferences. These findings align with existing literature emphasizing the value of simulation-based learning in enhancing social work education (Kourgiantakis et al., 2019).

Table 1 Quanlitative results

Theme	**Key Insights**	**Example of Feedback**
Confidence and Familiarity with Case Conference	Many Students expressed an increased sense of confidence	"It gives me an idea of what to expect in a real case conference" "knowing what to expect in case conference, and preparing ways to structure information when questioned of certain aspects"
Application of Facilitation and Organisational Skills	Students reported a better grasp of facilitation techniques	"Facilitating skills are important" "Prep work is essential"
Understanding of Interagency Collaboration	A recurring theme was students' enhanced understanding of the collaborative nature of case conferences	"This workshop helps me better understand the purpose and roles of the different agencies" "I would listen to the different viewpoints of the different stakeholders"
Professionalism	Several respondents acknowledged the importance of professionalism	"I need to be prepared and professional" "Different workers have different ways of dealing with a certain situation, and it is inevitable to meet people who may be difficult to work with. By exposing myself to these types of people, I can better expect what is coming for me and be prepared to face them with professionalism"
		.
Enhanced readiness for real world practice	Students appreciated the transferability of the simulation experience.	"It is a good idea to pre empt us with a simulation" "In my upcoming fieldwork placement, having this understanding will be beneficial as I would know which agency can support my client in the best way."
Critical thinking and Prioritization of client needs	Students reported gaining insights into how to weigh various perspectives	"I would listen to different viewpoints and prioritise based on safety" "Understanding how to prioritise client's needs, which agency should focus in which aspect"

Discussion

The study's findings affirm the effectiveness of simulation-based training in bridging the gap between theoretical learning and practical application in social work education. By providing students with realistic, practice-based experiences, such training enhances their confidence and competence in stakeholder management and supporting with real-life case conferences. The collaboration with the Ministry of Social and Family Development (MSF) exemplifies the benefits of partnering with external agencies to enrich educational initiatives.

Insights from the experience in empowering students to navigate social work complexity points to its effectiveness in the competency development of students and the importance and significance of partnering, co-creating, co-teaching, and co-mentoring of students that must be a key aspect of any curriculum. As educators prepare students for the transition from the classroom to the professional world, these varied forms of partnership will serve an important role in nurturing the appropriate attitude and aptitude, which will go far in building both the personal and professional identities of our students.

The qualitative responses from students revealed that simulation-based case conference training significantly enhanced their preparedness for fieldwork.

Students reported increased confidence in participating and facilitating discussions, with many noting a clearer understanding of how real-life case conferences are conducted. The training also deepened their awareness of interagency collaboration, enabling them to better appreciate the distinct yet complementary roles of various stakeholders. Furthermore, students highlighted the importance of facilitation skills, preparation, and maintaining professionalism in complex team settings. These insights suggest that beyond technical skill acquisition, simulation-based learning fosters critical thinking, adaptability, and collaborative attitudes essential for effective social work practice. This aligns with prior research emphasizing the value of realistic, practice-oriented training in building both competence and confidence in future practitioners (Kourgiantakis et al., 2019).

Limitations

Several limitations should be noted. First, the study relied on self-reported qualitative feedback, which may be influenced by students' subjective perceptions and a desire to provide socially desirable responses. The absence of a control group also limits the ability to make causal claims about the effectiveness of simulation-based training compared to other learning approaches.

In addition, the findings are based on a small sample size from a single institution, which may affect the generalizability of the results to other social work programs or settings. Finally, long-term impacts on actual field performance were not assessed, leaving questions about how well the skills and insights gained from the simulation transfer to real-world practice.

Recommendations

Given the positive outcomes observed, it is recommended that social work curricula incorporate simulation-based learning as a core component to enhance practical skills development. Future collaborations with external agencies should be pursued to ensure training scenarios remain relevant and reflective of current practice realities. Additionally, further research could explore the long-term impact of simulation-based training on graduates' performance in the field.

Acknowledgements

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References

Badger, L. W., & MacNeil, G. (2002). Standardized clients in the classroom: A novel instructional technique for social work educators. Research on Social Work Practice, 12(3), 364-374.

Bogo, M., Rawlings, M., Katz, E., & Logie, C. (2014). Using simulation in assessment and teaching: OSCE adapted for social work. Council on Social Work Education.

Kourgiantakis, T., Sewell, K. M., & Bogo, M. (2019). The integration of simulated practice in social work field education: A scoping review. Research on Social Work Practice, 29(8), 876-889.

Washburn, M., Bordnick, P., & Rizzo, A. S. (2016). A pilot feasibility study of virtual patient simulation to enhance social work students' brief mental health assessment skills. Social Work in Health Care, 55(9), 675-693.

Lateef, F. (2010). Simulation-based learning: Just like the real thing. *Journal of Emergencies, Trauma, and Shock*, 3(4), 348–352. https://doi.org/10.4103/0974-2700.70743

ENHANCEMENT OF SEAFARER TRAINING WITH VISUALIZATION OF SHIP MOORING CONDITIONS

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This study focuses on improving maritime education through mooring training using a line tension visualization system and a small vessel. Improper mooring can lead to Snapback, a dangerous phenomenon caused by excessive rope tension, where a broken rope recoils and can injure crew members. Since mooring line tension fluctuates due to weather and sea conditions, continuous monitoring is essential to ensure stability and safety. Traditional mooring training relies on large mooring equipment, which presents safety risks and limits the frequency of hands-on practice. To overcome these challenges, this study introduces a training system that enables students to observe mooring tension in real time. Using six mooring lines equipped with tension sensors, the system allows students to visually assess load distribution during mooring operations. Comparative experiments were conducted to analyze different mooring methods and their effects on load distribution. On April 26, 2024, 21 navigation students participated in six experimental sessions, each lasting 10 minutes. Data was collected at a resolution of 10 points per second, providing a detailed view of mooring tension dynamics. The results indicate that improper mooring leads to excessive load concentration on a single line, increasing the risk of breakage. A post-training survey revealed that over 80% of students demonstrated an understanding of mooring principles, confirming the effectiveness of the training materials. However, some students struggled to interpret tension graphs, as they did not clearly indicate the corresponding forces acting on each mooring line. Future improvements will focus on enhancing the visualization of mooring forces, making data interpretation more intuitive.

Keywords: *Seafarer training, Teaching material, Monitoring moored a ship, Quantification of mooring line tension*

Introduction

When a rope breaks during the mooring of a ship, it causes a phenomenon known as Snapback. Snapback is a dangerous problem because a broken rope rebounds and can cause a serious injury if it strikes a person. According to the Japan Transport Safety Board (2012), approximately 33% of onboard work-related fatalities and injuries occurred during mooring or anchoring operations. Therefore, crews must maintain the mooring lines and properly moor ships to prevent excessive tension on the ropes. Failure to moor a ship properly can result in the continued tension of a single mooring rope, which can lead to the breakage of the mooring rope. The tension on a ship's mooring lines will vary over time and place due to ship movements caused by changes in weather and sea conditions, so the crew must constantly monitor the condition of the lines. The knowledge and ability to properly moor a ship is an important skill for seafarers.

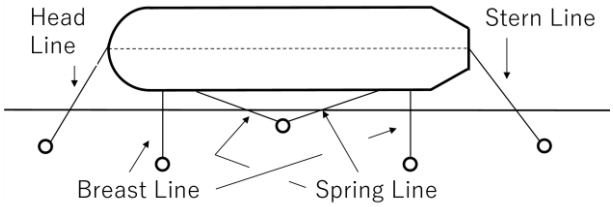


Figure 1. General mooring of a ship at the quay. And the name of each mooring lines.

Seafarers' education institutions now teach students to moor large ships using the mooring equipment installed on training vessels. However, the operation of such large equipment is hazardous, and there are limitations on the number of training sessions and the time available. These concerns have been highlighted in safety guidelines issued by the Ministry of Land, Infrastructure, Transport and Tourism (n.d.), which emphasize the importance of proper training and risk management during onboard engineering operations. This makes it difficult for each student to learn repeatedly over time. In this study, we developed a mooring training material using a mooring line tension visualization device and the small ship “HAMAKAZE” of the Yuge College of Maritime Technology in order to enhance the education of seafarers. The purpose is for students to visualize the condition of mooring ropes, to understand the use of each mooring rope, and to learn the correct mooring method. Figure 1 shows a general mooring arrangement of a ship at the quay, which serves as a basis for understanding the roles of each mooring line. Unlike large equipments, this teaching material uses a small ship and small equipments,

which allows students to train as many times as they wish. The educational potential of this teaching material is also being investigated through demonstrations in classrooms on land, since the mooring line tension data recorded in this experiment can be reviewed with the students at a later date, in the classroom.

Materials and Methods

The basic purpose of mooring is to secure a vessel to a quay, buoy, or anchor, making it less susceptible to the influence of wind and tidal currents (IMO, 2024). This involves the following three key elements. Mechanical Stability: Properly arranging mooring lines (ropes or wires) to prevent the vessel from moving. Load Distribution: Evenly distributing the tension in the mooring lines to avoid excessive strain on any single line. Friction and Wear: The material and environmental conditions of mooring lines affect their wear, necessitating regular inspections and replacements. The objective of this study is to create effective instructional materials that help students in the Department of Maritime Technology practically understand the mechanical stability and load distribution of mooring. In developing the instructional materials, simulations were incorporated and combined with hands-on training to create a learning environment where students' understanding could be assessed. As part of this initiative, a system was introduced using an easy-to-operate small vessel to measure the tension in mooring lines. This allows students to learn about load distribution and mechanical stability in mooring operations from both theoretical and practical perspectives. For the tension measurement environment using a small vessel, a system was designed to incorporate tension sensors for real-time data acquisition. Additionally, comparative experiments on different mooring methods were conducted to analyze the effects of load distribution.

For the mooring training, the college's small vessel HAMAKAZE (Figure2, Length: 14.9 m, Displacement: 16 tons) will be used. The training will take place at the school's floating pier.



Figure 2. The college's small vessel HAMAKAZE.

Tension load cells are attached to six mooring lines connecting the vessel to the quay to measure changes in tension during mooring (Figure 3). The collected data is transmitted to a computer via a data acquisition system, where the tension variations are displayed in real time. A tension load cell (LTM-1KN, NIPPON TOKUSHU SOKKI Co., Ltd.), an amplifier (NTS-1280, NIPPON TOKUSHU SOKKI Co., Ltd.), and a data acquisition system with an A/D converter (NR-X100, TH-08, KEYENCE) were used. NR-XH1 (KEYENCE) was used as the data acquisition and display software.

During the experimental training, real-time graphing of the measurement results from tension sensors will allow students to intuitively understand changes in the load distribution of mooring lines. Additionally, comparative experiments on different mooring methods will help them learn the role of each mooring line. The experiment was conducted six times, varying the number of mooring lines and the distance between the quay and the vessel. Table 1 shows the experimental conditions. The experimental training was conducted on April 26, 2024, with 21 students from the Maritime Department's Navigation Course. Each experiment lasted 10 minutes, during which data was collected. The temporal resolution of the data was 10 points per second. Therefore, the data was averaged every second to create the analysis dataset.



Figure 3. A tension load cell (LTM-1KN) attached to a mooring line.

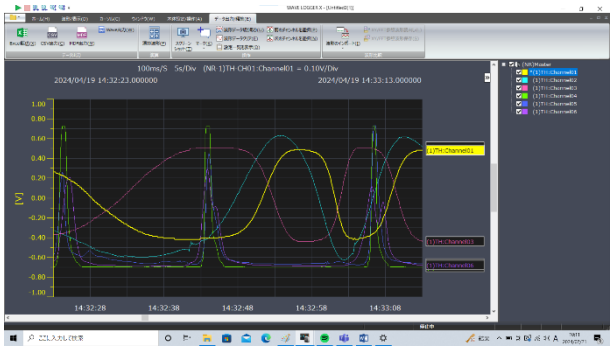


Figure 4. The appearance of the computer screen during mooring line tension measurement (NR-XH1).

Table 1. The experimental training conditions.

Experiment No.	Distance Between Quay and Vessel	Number of Lines	Remarks
1	1m	6	All Lines
2	1m	2	HeadLine, SternLine
3	1m	2	Fore and Aft BreastLine
4	1m	4	HeadLine, SternLine, Fore and Aft BreastLine
5	0m	4	HeadLine, SternLine, Fore and Aft BreastLine
6	0m	6	All Lines

Results and Discussion

At the beginning of the experimental training, students are taught the general theory of mooring, including the roles of each mooring line (IMO, 2024). Figure 5 illustrates the movement directions of a moored vessel and the corresponding mooring lines. The mooring lines that counteract the force attempting to move the vessel forward (Direction A) are Fore Spring Line (a1) and Stern Line (a2). Next, the mooring lines that counteract the force attempting to move the vessel backward (Direction B) are Headline (b1) and Aft Spring Line (b2). These four mooring lines should ideally be positioned at a small angle relative to the quay. Finally, the mooring lines that counteract the force attempting to move the vessel sideways (Direction C) are Fore Breast Line (C1) and Aft Breast Line (C2). These two mooring lines should ideally be positioned at an angle close to 90 degrees relative to the quay.

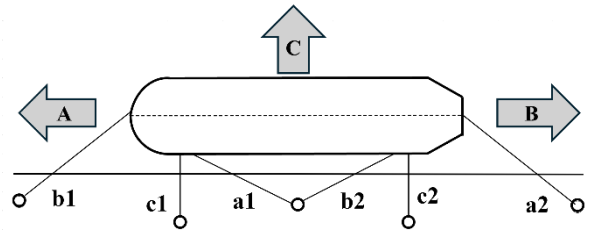


Figure 5. The movement directions of a moored vessel and the corresponding mooring lines.

Initially, in the experimental training, the measurement results from the tension sensors are visualized in real time through graphs, allowing students to intuitively understand changes in the load distribution of mooring lines. Figure 6 shows the time series of mooring lines in Experiment 1. At that time, the weather conditions included wind blowing diagonally from the left rear of the stern at a speed of 3.1 m/s. To counteract the forward-moving force of the vessel caused by the wind from the stern, the load is continuously applied mainly to the stern line and aft spring line, ensuring appropriate load distribution. Next, between 3 and 6 minutes, the vessel experienced hull motion due to waves generated by another ship. This resulted in an even distribution of load across all mooring lines, followed by a gradual reduction in load. From this, it can be inferred that the tension was dispersed among the other mooring lines, effectively stabilizing the vessel at an early stage. Since the aft spring line is the only mooring line counteracting the lateral forces acting on the vessel, a potential countermeasure would be to loosen the aft spring line and redistribute the load onto the two breast lines.

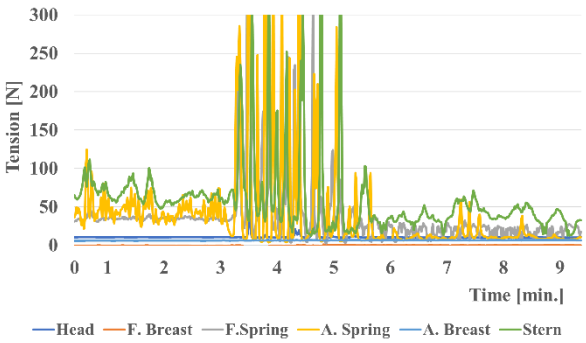


Figure 6. Time series of mooring line tension in experiment 1.

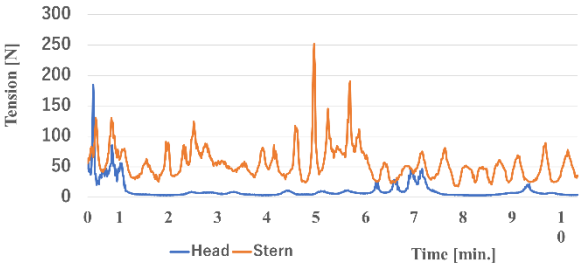


Figure 7. Time series of mooring line tension in experiment 2.

Next, four experiments were conducted to help students understand the role of each mooring line by varying the number of mooring lines. Figure 7 shows the time series of mooring line tension under the condition where only the headline and stern line were used (Experiment 2). In Figure 6, it is necessary to counteract the external force acting on the vessel using two mooring lines, but the load is concentrated only on the stern line. If excessive force continues to be applied to a single mooring line, there is a risk of it breaking. Experiment 3 yielded the same results (no figure available). Therefore, it is clear that two mooring lines are insufficient for maintaining stability.

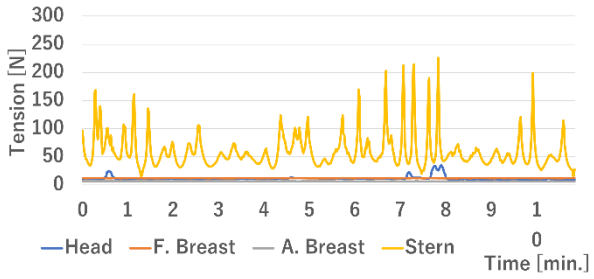


Figure 8. Time series of mooring line tension in experiment 4.

In Experiment 4 (Figure 8), four mooring lines were used; the headline, fore breast line, aft breast line, and stern line. Throughout the experiment, the tension remained on the stern line, making it impossible to distribute the load. The wind was blowing from the stern direction, and since only the stern line was available to counteract this external force, the load was concentrated on a single mooring line. If excessive force continues to be applied to a single mooring line, there is a risk of it breaking. Therefore, it is clear that four mooring lines were insufficient to maintain stability.

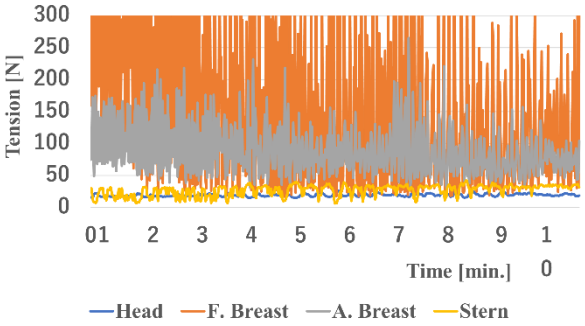


Figure 9. Time series of mooring line tension in experiment 5.

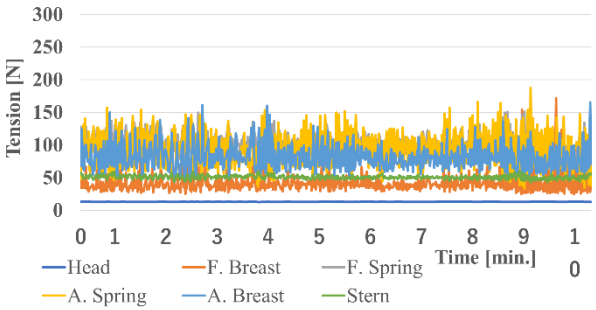


Figure 10. Time series of mooring line tension in experiment 6.

In Experiments 5 and 6 (Figures 9 and 10), measurements were conducted with the distance between the vessel and the quay set to 0m. This mooring method prioritizes cargo operations by ensuring that the vessel remains stationary. As a result, it was confirmed that strong and continuous loads were applied to two specific mooring lines. When using this method, the risk of mooring line breakage must be considered. Therefore, in addition to the six existing mooring lines, increasing the number of mooring lines would be an appropriate measure for secure mooring.

A survey was conducted with 21 students from the Maritime Department's Navigation Course who participated in the experimental training. Table 2 lists the survey questions. Additionally, Table 3 presents the response options for the survey.

Figures 11 shows the survey results. It was found that over 80% of students demonstrated understanding for each question item. Therefore, the objective of the training materials has been achieved. However, in Question 1, four students had difficulty understanding how to interpret the displayed graphs on the computer. The main issue appears to be that the graph showing the tension of six mooring lines does not clearly indicate which mooring line corresponds to which force. Therefore, as shown in Figure 5, it was determined that adjustments should be made to display each mooring line in relation to the movement of the moored vessel, improving clarity and comprehension.

Table 2. Survey questions.

Question Number	Survey Questions
Q1	Was the diagram displayed on the screen easy to understand?
Q2	Did you understand how to use the experimental equipment?
Q3	Did you understand the handling of mooring equipment and mooring lines?
Q4	Did you understand the role of each mooring line?
Q5	Did you understand the required number of mooring lines?
Q6	Did you understand the appropriate arrangement of mooring lines?
Q7	Did you understand the appropriate distance between the vessel and the quay?
Q8	Did you understand the effects of wind and tidal currents on mooring lines?

Table 3. Survey response options.

Response Number	Description
0	Did not understand
1	Understood
2	Can explain to others
3	Can explain to others and apply the knowledge

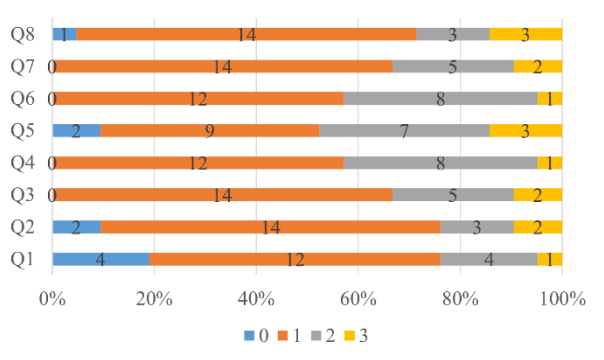


Figure 11. Survey responses for Q1–Q8.

Conclusions

Students conducted an experimental training in which they safely arranged mooring lines using a small vessel and measured and displayed their tension in real time.The survey question results indicate that over 80% of students demonstrated a clear understanding of the concepts covered, confirming the effectiveness of the instructional materials. However, some students encountered difficulties in interpreting the displayed graphs and identifying specific mooring lines, suggesting a need for improved visual representation. Based on these findings, adjustments will be made to enhance clarity, ensuring better comprehension in future training sessions. We would like to consider ways for students to reproduce and analyze the collected data in the future.

Acknowledgements

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References

Japan Transport Safety Board. (2012). JTSB Digest No. 3: Analysis of marine accidents involving injuries during ship operations. Ministry of Land, Infrastructure, Transport and Tourism. Retrieved from https://jtsb.mlit.go.jp/bunseki-kankoubutu/jtsbdigests/jtsbdigests_No3/No3_pdf/jtsbdi-03_all.pdf

Ministry of Land, Infrastructure, Transport and Tourism. (n.d.). Safety management manual for each type of engineering work onboard ships. Retrieved from https://www.mlit.go.jp/common/000114450.pdf

IMO. (2024). Revised Guidance on Shipboard Towing and Mooring Equipment (MSC.1/Circ.1175/Rev.1). International Maritime Organization.

SYSTEMATIC SCAFFOLDING AND FACILITATION IN ENGINEERING EDUCATION: A DATA-DRIVEN, PEER-MENTORED FRAMEWORK FOR TRANSFORMATIVE LEARNING

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In contemporary classroom settings, where the students come from diverse educational backgrounds and possess varying learning abilities, the pace at which they grasp concepts differs significantly. Freshmen entering polytechnic institutions face considerable challenges in understanding the first year engineering courses, necessitating systematic scaffolding both within and outside the classroom. Recognizing this need, the Learning Support Programme (LSP) has been implemented in Temasek Polytechnic, School of Engineering (TP-ENG), for eight common engineering subjects, benefiting approximately 1000 students per semester.

The LSP is a structured and meticulously planned approach conducted outside regular timetabled hours. It aims to support students who struggle with conceptual understanding, thereby enhancing their performance in assessments and ensuring they keep pace with their peers. Dedicated facilitators, often the subject leaders, adopt a systematic method to ensure students grasp and apply engineering concepts effectively. The inclusion of senior students as peer mentors within the LSP framework fosters an interactive and collaborative learning environment. This peer-to-peer interaction enables mentees to gain clarity and confidence through engaging discussions and shared experiences.

Students' performance in the continual assessments provides feedback to the class tutors on their students learning and highlights areas where students are struggling. Automated workflow systems, utilizing Microsoft tools, issue timely email invitations to students identified as at-risk, ensuring proactive engagement. Furthermore, the LSP maintains records of attendance and participation, employing dashboard analytics to visualize student progress allowing for timely interventions and support.

As major assessments approach, the programme intensifies its support through focused tutor-based LSP sessions. These sessions offer tailored guidance on fundamental concepts, problem-solving strategies, significantly boosting students' confidence and preparedness for exams. Comparative performance tracking of invited students participating in the LSP against their non-participating peers consistently highlights the programme's effectiveness in improving academic outcomes and motivating students to participate in the LSP.

This initiative underscores the importance of structured, outside classroom support in bridging learning gaps and fostering a culture of continuous improvement. By leveraging pedagogical innovation, the LSP not only addresses immediate academic challenges but also contributes to long-term student retention and success in engineering education.

Keywords: *Learning Support Programme, Peer Mentoring, Data-Driven Interventions, Microsoft Power tools, data visualization.*

Introduction

Polytechnic education in Singapore is the vital component of post-secondary education that offers practical and career-oriented training. Education statistics digest (2021) reports that around 48 percent of students from post-secondary education are enrolling into polytechnic, of which around 4800 students enroll in engineering courses. Engineering diploma aims to prepare students for immediate employment or further studies, equipping them with applied knowledge, technical skills, and problem-solving abilities that align with industry demands. Transitioning from secondary school to polytechnic can be challenging for many first-year students as polytechnic education emphasizes self-directed learning, group projects, and critical thinking. This shift from a more structured and teacher-directed secondary school environment can be disorienting for students. Lim et al., (2008) highlighted that students accustomed to didactic methods may struggle with the open-ended, application-focused nature of polytechnic learning. Inadequate foundational knowledge in core subjects such as mathematics and physics also hampers their ability to grasp advanced engineering concepts. Hence the transition to polytechnic education requires students to adopt effective learning strategies.

A study by Zhang et al. (2024) involving 450 first-year engineering students found that students who improved their learning strategies demonstrated better academic performance. Apart from technical knowledge, students need to develop soft skills like the ability to communicate and work well in teams and managing workloads. Addressing these learning difficulties requires a multifaceted approach, combining curriculum adjustments, development of learning strategies, and institutional programs aimed at supporting students' academic and personal growth.

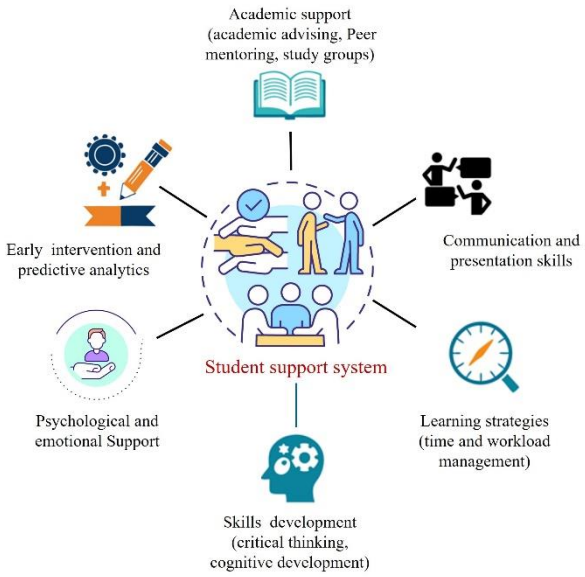


Figure 1: Student support system.

Support systems (Figure 1) that could help first-year students cope with the initial challenges include: (a) Access to knowledgeable academic advisors who can help students navigate their academic journey and address any challenges they encounter. (Robbins et al., 2012). (b) Offering one-to-one tutoring services where students can receive additional help with challenging subjects or concepts to improve learning outcomes (Dixson, 2010). (c) Pairing students with seniors who as their mentors, can provide guidance, support, and valuable insights into the engineering field (Kovacs et al., 2016). (d) Development of a predictive analytics model in early detection of students falling behind and provide targeted intervention (Low et al., 2024). (e) On-campus mental health support for stress, anxiety, low self-confidence, or academic pressure. (f) Conducting learning skills workshops in time management, note-taking, exam strategies, and critical thinking. (g) Providing training in technical report writing, reading technical lab manuals, and improving communication skills. Student support systems discussed in (e) to (g) apply to all the polytechnic students and hence those systems need to be implemented at the institution level. Strategies in (a) to (d) are more specific to individual disciplines and are suitable to be implemented at the school or subject levels. In this paper, we are sharing the subject level scaffolding and support offered to the first-year students in coping with the learning difficulties.

Pedagogy

The 3-tier Response to Intervention (RTI) model was formulated by Fuchs et al., (2008) as an educational framework aimed at early identification and support for students with learning and behavior needs (Figure 2). Tier 1 support is provided to all the students and is differentiated enough to meet all students needs and learning styles. Students who appear below grade level on academic screening assessments will often qualify for tier 2 intervention, which typically involves evidence-based interventions focused on specific content or skills, and some instruction in a small-group setting. Students who continue to perform below grade level on benchmark assessments and show little to no response to the tier 2 interventions, may then be found eligible for tier 3 intervention, which consists of either small-group, or in some cases one-to-one, instruction. Students who are enrolled in diploma courses in TP-ENG are from various academic backgrounds with different learning styles and abilities. Hence, apart from tier 1 support, students also need systemic scaffolding and support that is offered at tier 2 and tier 3 levels.

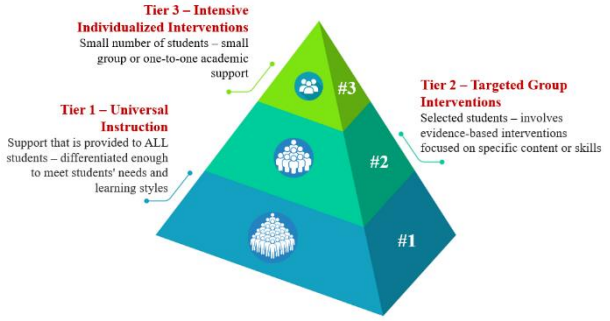


Figure 2: RTI tiered model.

Methodology

The pace at which polytechnic engineering diploma students understand the concepts during the classroom lessons varies among individuals. Some students may need more time and structured support during and after the classroom lessons. To assist students who require additional time and guidance to understand the concepts, the Learning Support Programme (LSP) was introduced in TP-ENG for first-year students. This programme covers eight core subjects and supports approximately one thousand students each semester. LSP sessions are scheduled outside of the timetabled lesson hours and are conducted by a couple of faculty members per subject who are also the subject leaders. LSP sessions are conducted via two approaches. Approach 1: Students who need help with the concepts are encouraged to attend the LSP sessions and clarify their misconceptions or seek help in better understanding of the concepts. Approach 2: Based on tier 2 of the RTI tiered model, selected students are invited to attend the weekly LSP sessions. Those students failing post-lesson quizzes are identified and email invitations are sent to them to attend the LSP sessions.

During the LSP sessions, the faculty member follows a structured lesson plan where the focus is on ensuring that the students get the concept correct and are also able to apply the concept to problem-based scenarios. Weekly LSP sessions provide the targeted small-group interventions to those students who are at risk and have not made adequate academic progress. As students are in small-group setup, they tend to be more open to discussions and seek clarifications from the faculty members. Small-group instructions or additional support with strategies focusing on specific skill gaps foster learning and in turn better academic performances. Timely short-term support and intervention help students comprehend the concepts more thoroughly, encouraging them to continue learning subsequent topics with ease. The effectiveness of LSP sessions stems from their data-driven approach and targeted support for selected students in need.

Apart from classroom-based learning, students in TP-ENG also attend hands-on practical classes where they relate the practical observations with the fundamental concepts learnt in the classroom. Weekly LSP sessions are also structured to support students who have difficulties with hands-on skills. During the LSP sessions, apart from getting support in conceptual understanding, students can also seek help with practical experiments.

Data-driven Targeted Group Intervention

Core engineering modules are offered to close to one thousand first-year students spread over forty plus tutorial classes with around twenty-five students in each tutorial class. Given the large cohort size, to save time and improve productivity, selection of students for the LSP sessions is automated using Microsoft tools like Microsoft forms and power automate applications. Figure 3 shows the selection process of students for the LSP sessions. Apart from selecting students for LSP sessions based on their post-lesson quiz performance, tutors can also identify students who may need more time and guidance in understanding the concepts. Students with special educational needs also benefit from the support provided to them during these sessions.

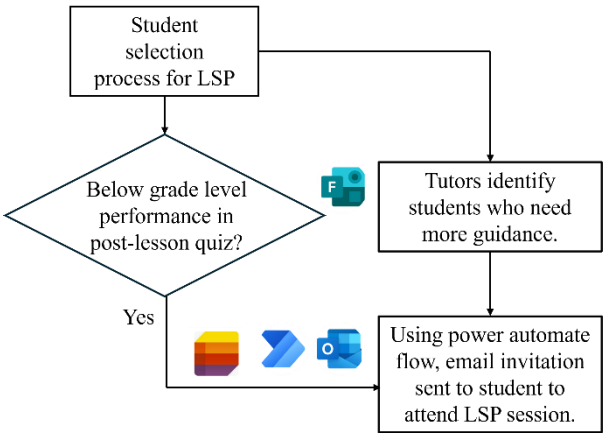


Figure 3: Student selection process for LSP.

Dashboard visualizations of students' post-lesson quiz performance are created using the Microsoft power BI app. Figure 4a and 4b shows the screenshot of dashboard visualization for Engineering Mathematics 1 and Circuit Analysis subjects, respectively. Selecting their tutorial class from the drop-down menu allows subject tutors to see their class's performance. Dashboard also shows the status of email invitations sent to underperforming students to attend LSP sessions (Figure 4a). Apart from showing the students' performance in the quiz, the dashboard also shows the overall confidence level of the students in understanding the concepts discussed during the lessons (Figure 4b). This provides tutors with feedback on student learning and highlights the concepts that require further explanation.

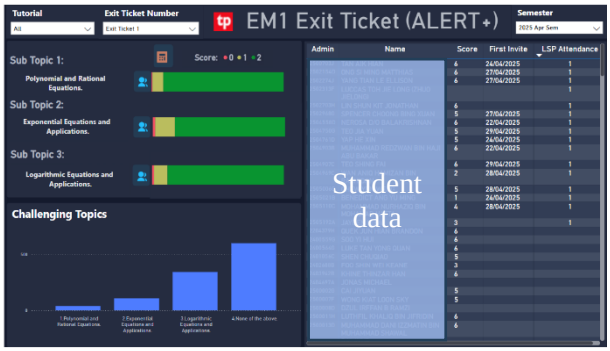


Figure 4a: Screenshot of the dashboard visualization of the post-lesson quiz analysis for Engineering Mathematics 1 (EM1).

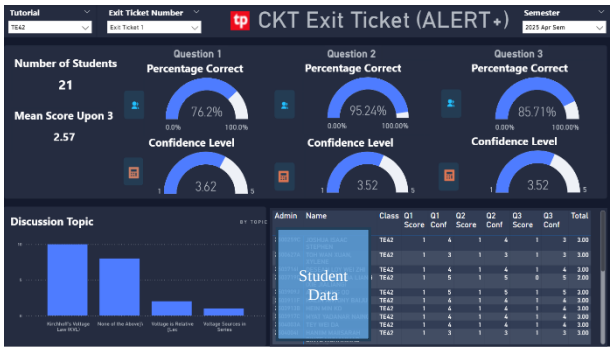


Figure 4b: Screenshot of the dashboard visualization of the post-lesson quiz analysis for Circuit Analysis (CKT).

During the LSP session, students scan a QR code to access a Microsoft form for recording their attendance. Microsoft power BI app retrieves the attendance data from Microsoft form to generate dashboard visualizations of students' attendance (Figure 5). Subject tutors retrieve student attendance data from the dashboard by selecting the academic year, semester, subject, tutorial class, and the date of the LSP session. With the data, which is also downloadable, tutors can closely monitor the student's learning progression and check on those who were invited for LSP sessions but failed to attend the LSP sessions.

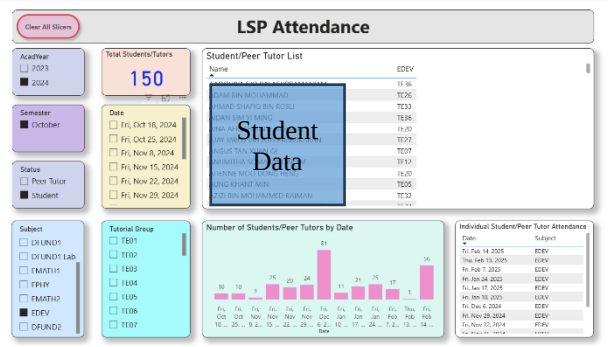


Figure 5: Dashboard for LSP attendance.

Peer Tutoring Programme

Under the Peer Tutoring Programme (PTP), senior students with high academic achievements are recruited as peer tutors. Peer tutors take on a mentoring role to assist students attending LSP sessions, either in small groups or individually. Structured lesson plan for the LSP sessions is shared with the peer tutors. They are also given training, so they are well prepared to guide the students during the LSP sessions. During the LSP sessions, at times, students may be intimidated to ask faculty members questions on fundamental concepts. However, students feel comfortable with the mentors and are open to discussing their learning difficulties and seeking advice from peer mentors. Apart from subject level guidance, peer mentors also share with students their academic coping strategies and provide them career guidance. The bond between the mentor and students at times, continues even beyond the LSP sessions. The inclusion of peer mentors into the LSP framework results in a collaborative learning environment.

Faculty members need to dedicate additional time to help students with special educational needs meet academic requirements. In such cases, a dedicated peer tutor is appointed to mentor and guide the student. This frees up the time of the faculty member who then can guide more students during the LSP sessions. Peer tutors are rewarded with co-curricular activities points for their contribution as peer mentors. To qualify for the points, peer tutors are expected to commit to certain number of mentoring hours per semester. Peer tutors' attendance is captured using the same QR code system that the students use to report their attendance for the LSP sessions. Peer mentor attendance data can be monitored using the LSP attendance dashboard as shown in Figure 5.

Enhanced LSP

In recent years, polytechnic is seeing an increase in number of freshmen with technical background coming from vocational schools. They possess strong practical skills but lack a solid foundation in Mathematics and Science. They have knowledge gaps in these subjects compared to students enrolled in polytechnic from mainstream secondary schools. Given the sizeable number of vocational school students, the weekly LSP sessions cannot accommodate everyone due to limited availability. Hence enhanced LSP system has been implemented that provides guidance within the timetabled hours unlike the weekly LSP sessions that are happening outside the timetabled hours. Ten tutorial classes were formed with students coming from vocational schools and the lesson plan was structured to cater to their learning needs. Apart from the integrated LSP within the timetabled hours, these students may also choose to attend the weekly LSP sessions offered to the rest of the cohort.

Tutor-based LSP

A week prior to major assessments, the weekly LSP sessions see a surge in attendance, with more students coming for support or to clarify their doubts. The faculty members along with the peer mentors are not able to handle the huge turnout. Hence, close to major assessments, the weekly LSP session is replaced with tutor-based LSP and is conducted by the tutorial class tutor for their own students who need more guidance on the concepts. Tutor-based LSP is made compulsory for students who are identified to be at-risk of failing the upcoming assessment. Tutors are also free to recommend students based on their assessment. During the tutor-based LSP, tutors provide guidance on fundamentals concepts; discuss problem-solving strategies which helps in instilling self-confidence in students to face the major assessments. Tutor-based LSP is conduced twice in a semester; one before the midterm assessment and another one before the end of the semester assessment. Subject leader: (a) prepares the lesson plan for the tutor-based LSP and makes it available for all tutors. (b) standardises the time slot for the respective subject. (c) makes venue arrangements for the tutor-based LSP. Attendance for the tutor-based LSP is captured using the same QR code as for the weekly LSP sessions.

Results and Discussion

Students attending LSP have benefited from the structured support provided to them outside of the timetabled hours which is evident from the subject satisfaction surveys done at the end of the semester. Students feedback that the additional support has helped them gain better understanding and reinforcement of the concepts and are able to do well in the assessments. Figure 6a presents the survey results on weekly LSP sessions for Digital Fundamentals 1 (DFUND1). 503 students participated in this survey conducted by the DFUND1 subject team.

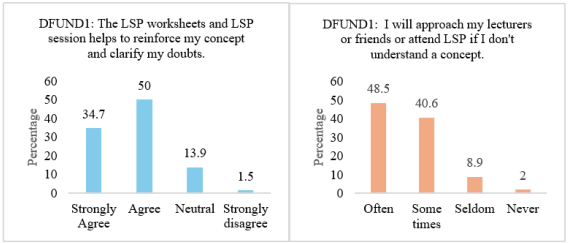
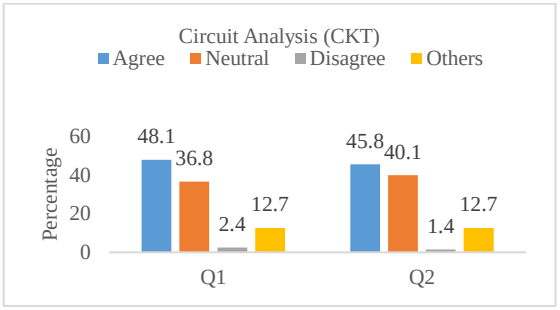


Figure 6a. Survey results (DFUND1).

Around 85% of survey participants either strongly agree or agree that the LSP sessions are helpful and when needed would seek help from the weekly LSP sessions. Figure 6b shows the survey results conducted by the Circuit Analysis (CKT) subject team on the effectiveness of the enhanced LSP. 212 out of 250 freshmen enrolled into enhanced LSP participated in the survey. Close to 85% agree that the enhanced LSP sessions help them in understanding the concepts better and are willing to attend LSP to seek help in their academics.



Q1: When I need help, I attend CKT LSP sessions, and they are helpful.
Q2: LSP questions discussed during the tutorial session helps me in understanding the concepts better.

Figure 6b. Survey results (CKT).

The effectiveness of the tutor-based LSP was evaluated by analyzing the subject-wise performance of students who were invited to participate. Students who were invited and attended the LSP sessions had a higher pass percentage than those who were invited but did not participate. Tracking of similar data for all the eight subjects over few semesters has also shown similar enhanced performance in the major assessments with almost 50% decline in the failure grade for those who attended the tutor-based LSP.

Like the performance analysis for tutor-based LSP, a study was done to check the effectiveness of the enhanced LSP. Data shows that the percentage of passes in all subjects for the students under enhanced LSP has improved. Apart from passing, their average scores have also improved consistently over the past few semesters.

Conclusions

Since the implementation of LSP in 2010 at TP-ENG, studies have shown that there has been significant enhancement to the academic performance of those freshmen struggling with core engineering subjects. By systematically identifying at-risk students through data-driven methods, the LSP provides targeted support outside regular class hours, ensuring these students receive the necessary guidance to grasp complex concepts. Enhanced LSP provides the much-needed support to the first-year students from vocational schools. Additional teaching resources are allocated for this implementation as enhanced LSP is integrated into the timetabled hours. The integration of peer mentoring within the LSP framework fosters a collaborative and supportive learning environment, where senior students guide their juniors, making the learning process more interactive and less intimidating. Automated administrative processes, utilizing Microsoft tools, streamline the selection and invitation of students, ensuring timely and proactive engagement. The programme's success is evidenced by improved academic outcomes and positive student feedback, highlighting its role in addressing immediate learning challenges. The LSP's structured approach, combined with innovative pedagogical methods, not only supports students academically but also helps them develop essential skills for their future careers. As the programme continues to evolve, it remains a vital component of Temasek Polytechnic's commitment to providing comprehensive support to its engineering students, ensuring they are well-equipped to meet the demands of their academic and professional journeys.

References

Dixson, M. D. (2010). Creating effective student engagement in online courses: What do students find engaging? Journal of the Scholarship of Teaching and Learning, 10(2), 1-13.

Fuchs, D., Fuchs, L., & Vaughn, S. (2008). *Response to intervention: A framework for reading educators*. International Reading Association.

Kovacs, P. D., Ridenour, C. S., & Berry, L. (2016). Impact of formal mentoring on career advancement of polytechnic university employees. Mentoring & Tutoring: Partnership in Learning, 24(4), 305-322.

Lim, L., Tan, C., & Gopinathan, S. (2008). *Education reform in Singapore: Towards greater creativity and innovation?* NIRA Review.

Low B., Cha C., & Teoh C. (2021) Using Predictive Analytics to Identify First-year Engineering Students at Risk of Failing Engineering Physics ISSN: 2435-5240 The Southeast Asian Conference on Education 2021: Official Conference Proceedings (pp. 1-11) https://doi.org/10.22492/issn.2435-5240.2021.1

Ministry of Education (2021). *Education Statistics Digest 2021*. Retrieved from https://www.moe.gov.sg/-/media/files/about-us/education-statistics-digest-2021.ashx?la=en&hash=9E7EFD9B8088817C207F8AE797037AAA2A49F167

Robbins, R. M., Stommel, M., & Kuska, H. A. (2012). The impact of academic advising on student engagement and student success: Implications for student affairs professionals and community colleges. Community College Journal of Research and Practice, 36(10), 747-769.

Zhang, S., Shi, Q., Garza, T., Li, C. (2024). Exploring first-year engineering students' learning strategies and academic performance. Education and Lifelong Development Research, 1(2), 58-71. https://doi.org/10.46690/elder.2024.02.02

Effectiveness of Disaster Education for Elementary and Junior High School Students Incorporating Programming Education and Active Learning

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This study implemented the lesson on creating an evacuation game. It could be learned active learning, digital education and disaster education at once. Creating an evacuation game allows participants to decide for themselves how to evacuate in the event of an actual disaster. This means that they will be able to make better decisions in the event of a natural disaster. On the lesson, the aims of this study were to clarify the level of understanding, identify problems and propose ways to deal with them. The targeted grades were from 5th grade elementary school to junior high school. The period of implementation covered the three-year period 2022-2024. The lesson was conducted in two stages: the first stage, which implemented basic programming content, and the second stage, which used all aspects of disaster prevention, active learning and programming. The purpose of implementing of the first stage was to learn how to use the Scratch as the programming software used in the second stage. The first stage was implemented four times, two plus two in the second and third year. The second stage was implemented 8 times, 3+3+2 from the first to third year. National Institute of Technology (KOSEN), Wakayama College was chosen as the place to learn about disaster management using active learning, and Scratch was used for programming. The duration of the lesson was 60 or 180 minutes (including breaks). Results of the questionnaire after the lesson showed that the majority of participants answered that the lesson was easy to understand. However, some of the elementary school children answered that it was difficult. In this case, it would be desirable to mobilize personnel to assist and to be able to accommodate participants who do not fully understand the content. Many participants stated that the duration of the lesson was long. This was not resolved by incorporating different teaching methods and content, such as active learning and disaster management education. There are no particular problems with the content of the lesson, however the duration of the courses needs to be shortened.

Keywords: *disaster, active learning, program, elementary school, junior high school*

Introduction

In order to improve the effectiveness of education, it is nowadays necessary to provide not only one-way classes, but also classes in which students think and learn for themselves. In other words, there is a growing demand for classes that incorporate active learning in education. Recently information subjects have become compulsory in elementary and junior high schools in Japan. This is because of the need to acquire information literacy and programming skills. The impact of the COVID-19 epidemic has led to remote teaching not only in Japan but also in many other countries. This remote teaching can be good or bad depending on the device and internet environment, and this environment is prone to individual differences. Requiring paid applications in addition to the device resulted in many students slowing or stopping learning.

On disaster prevention, earthquakes have occurred in various parts of Japan, for example the Great Hanshin Earthquake in 1995 and the Great East Japan Earthquake in 2011. Recently, there have been concerns about a huge earthquake in the Nankai Trough, which could be bigger than the Great East Japan Earthquake. Cabinet Office and Japan Meteorological Agency of Japanese government officially announced for “giant earthquake warning” on 8 August 2024. Natural disasters are a universal phenomenon, occurring not only in Japan but also in the rest of the world. We need to be prepared for such earthquakes and one of the measures is disaster education. Disaster prevention education includes disaster prevention card game, disaster prevention games, and methods to help evacuate oneself by listening to storytellers about the situation in the event of a disaster. Other methods of disaster preparedness are discussed through local disaster management events such as an evacuation drills and community discussions in a local area. Many of the participants are often only representatives of a local area such as group leaders, town council leaders, etc. Therefore, disaster education may not reach the entire local population including students and pupils.

Delivery classes and Specialized courses to elementary and junior high school students will be important for the early identification of science and engineering personnel. The sophistication of those

lessons is always necessary to discover even more efficiently. In conducting such lessons, the content of the lessons must be understandable to elementary and junior high school students, and their comprehension must be verified.

What is the purpose

This study aims to examine the feasibility of combining active learning, digital education and disaster education with lessons for elementary and junior high school students. In addition, the aim is to use the results of the questionnaire after the lessons has been conducted to suggest ways to improve the lessons. Final goal of the lessons is to create the evacuation game for a natural disaster. Creating this evacuation game will enable people to think for themselves about evacuation routes in the event of a disaster, and they will be able to identify possible hazardous events in advance during evacuation. The game can apply any disaster education learned to individual communities because it is targeted at the area in which the student lives. Therefore, they can expect to improve their own evacuation decision-making when a natural disaster occurs in their area. Furthermore, they can then simulate in advance to work out the best way to evacuate themselves.

This study used the programming software Scratch, which is using in many elementary and junior high school in Japan. （Scratch, Programming language developed by the Media Lab at the Massachusetts Institute of Technology (MIT). , https://scratch.mit.edu/） . This software was chosen because it can be used without an internet connection and has the advantage that it can be shared with others who have an internet connection.

Details of implementation

This lesson was carried out in two stages. In the first stage, it conducted basic programming education classes. Specifically, it was the lesson on the basic use of the scratch. In the second stage, it involved the lesson on creating the evacuation game using the scratch.

The first stage of the class: Four lessons were held between 2023 and 2024 (two each in 2023 and 2024). The composition of participants (man 25people, woman 3people) was mostly elementary school students, as shown in the results by grade of participants in Figure 1.

The lessons were held to teach basic operation of the scratch and programming methods for about one hour. The impetus for this lesson was the confirmation that some elementary and junior high schools were not using the scratch in a lesson. Therefore, this course began to be implemented in 2023.

The second stage of the class: Eight times were held between 2022 and 2024 (3+3+2 times in each year). The composition of participants (man 64 people, woman 10 people) was mostly elementary school students too, as shown in the results by grade of participants in Figure 2.

This lesson was conducted for approximately three hours (including breaks) as two sessions (for two lectures). The location of the lesson was Wakayama

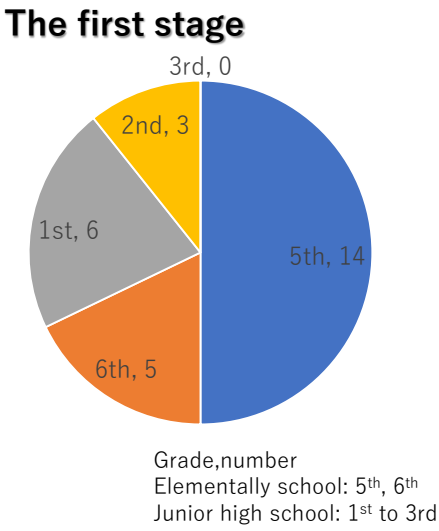


Figure 1 Number of participants on the First

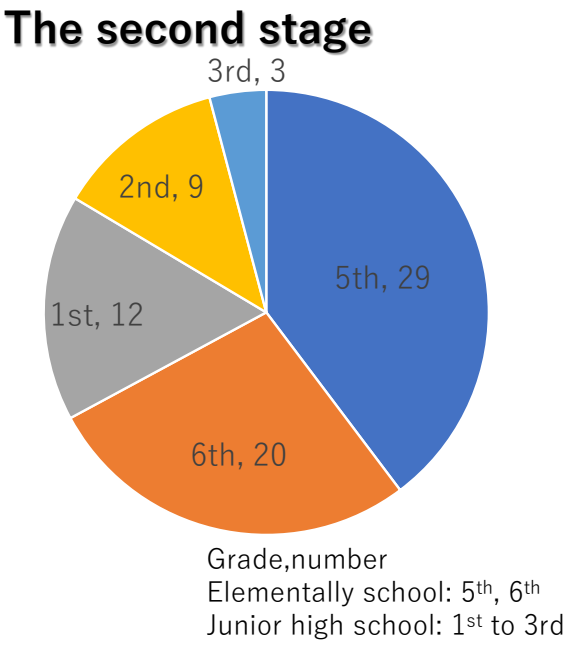


Figure 2 Number of participants on the second



Figure 3 Briefing on disaster prevention

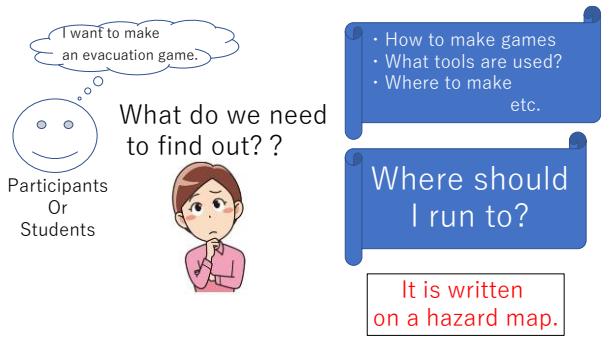


Figure 4 Explanatory material for creating evacuation game

National College of Technology. A tsunami is expected to hit this part of the Wakayama National College of Technology in the event of a huge Nankai Trough earthquake. It is also a suitable location for creating disaster prevention games, as an intensity of 7 is predicted. The lesson flow is described below.

Disaster prevention and programming explained: The following information was provided to participants as shown in Figure 3.

Description of the programming software (Scratch) used to create the evacuation game.

Description of checking for creating the evacuation game as shown in Figure 4. (The aim of combining photography and programming was to create a realistic evacuation game.)

Explanation of how to check hazard maps. (A few elementary and junior high school students had never seen a hazard map before, therefore we explained how to read it.)

Explanation of how to check a route and a dangerous spot when to evacuate. (The participants used a hazard map to identify evacuation routes and dangerous places for elementary and junior high school students before checking an actual site.)

Implementing lessons using active learning: The participants took photographs of the evacuation routes and the hazardous areas where they had just identified by using a tablet capable of taking photographs (Figure 5, Figure 6). (By checking the actual location, the participants were possible to recognize the width of the route and obstacles along the way, which are difficult to notice on hazard maps. In addition, they will be able to imagine what the possible hazards of the assumed hazardous areas were.)

Importing the photos taken by the participants into a computer.

To create the evacuation game by the scratch for programming learning: Photographs of the evacuation routes and the hazardous areas taken were imported into the scratch programmed (Figure 7).

The evacuation game was created in which arrows were used to progress along the evacuation route (Figure 8). (The system allows the selection of the best and the least suitable paths for evacuation routes to provide a gaming experience.)



Figure 5 Active learning outside



Figure 6 Identification of hazardous areas

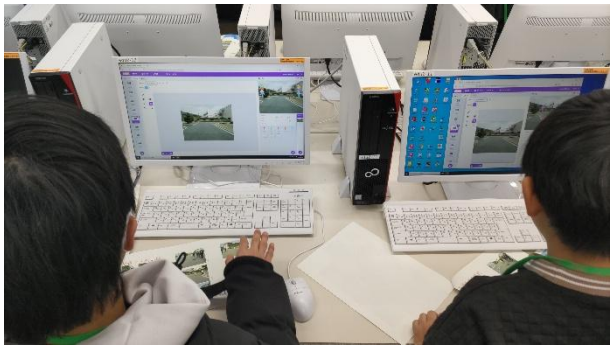


Figure 7 Programming creation (import a photograph)



Figure 8 Selection by arrows on the evacuation game



Figure 9 Showing hazardous area on the evacuation game

It created an evacuation game that also visually identifies hazardous areas (Figure 9). (Figure 8 shows that the direction of travel can be selected. In this case, going left will take to the designated evacuation area, while going right will take to the expected tsunami inundation zone. Therefore, the correct answer was to go left. The game assumes that the choice was made while looking at the hazard map.)

The evacuation game is completed with active learning and programming.

Results and discussions

All questionnaires conducted in this paper were rated on five-grade evaluation (five-grade evaluation : Excellent, Good, Fair, Poor, Very Poor or Unacceptable).

The first stage of the class: Figure 10 shows the results of the questionnaire confirming the grade of understanding of the first stage in the lesson. Many participants answered that they understood the content, so there were no problems with the content. Understandable was defined in this paper as participants who answered Excellent and Good. However, a few participants indicated that they did not understand such as fair or Poor. They were in the fifth grade of elementary school. As a general trend in Japan, programming education starts in the fifth grade. They may not have been familiar with the program of the Scratch.

Figure 11 shows the results of the questionnaire asking about the length of the lesson. Six respondents as equivalent to 20% of the total stated that it was poor or unacceptable. This means that the lesson was a little or very long for the responses. These six included three elementary school students and three junior high school students. It was found that negative responses were not only elementary school children but also junior high school students. In Japanese elementary and junior high schools, the time of a class is generally 45 or 50 minutes per session. This lesson is about one hour. It was found that some participants responded negatively if a lesson was longer than 45 or 50 minutes.

The second stage of the class: Figure 12 shows the results of the questionnaire confirming the grade of

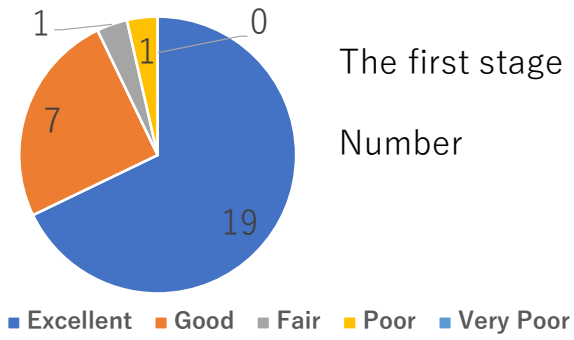


Figure 10 Results on comprehension at the first

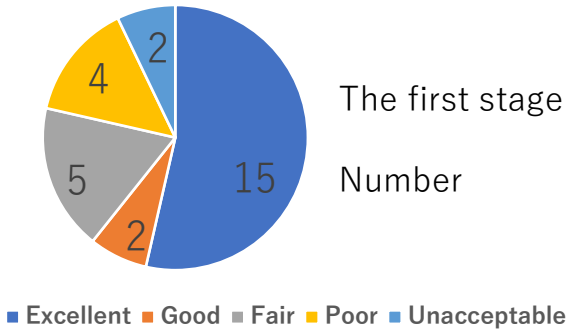


Figure 11 On the length of the lesson time at the first

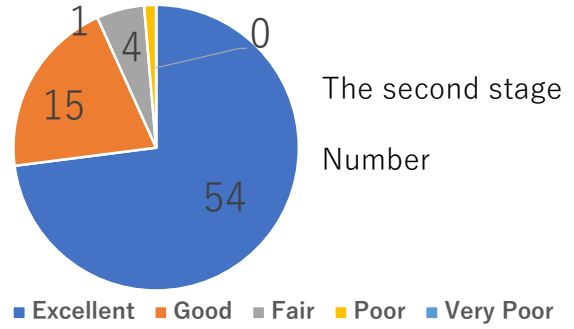


Figure 12 Results on comprehension at the second

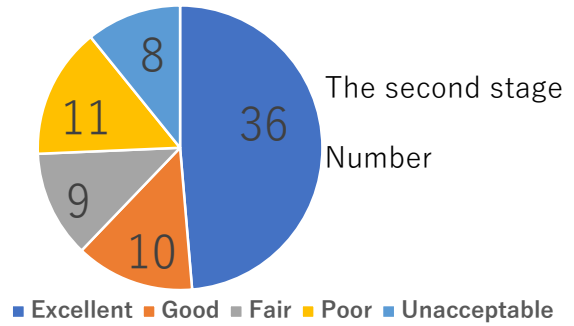


Figure 13 On the length of the lesson time at the second

understanding of the second stage in the lesson. The results show that more than 80% of the participants answered excellent or good. They understood the lesson, which means that most of them found the content of the lesson easy to understand. A small number of participants

indicated that it was difficult to understand such as fair or poor. The content was particularly difficult for some elementary school student. Many participants as elementary and junior high school students indicated that the content was easy to understand, even if it incorporated many contents such as disaster prevention, active learning and programming education. The lessons conducted in this study could be implemented in elementary and junior high schools.

Figure 13 shows the results of the questionnaire on the length of lecture time in the second stage of the lesson. From the results of the survey, 25% of respondents answered poor or unacceptable. It means that the lesson time was long. This result was considered to be due to the length of this lesson, which was three hours long including breaks. The results also show the similar trend in the percentage of response results compared to the results of the first stage of the questionnaire, as shown in Figure 11. The common feature of these two lessons was the implementation of programming. The contents with disaster prevention and active learning were not implemented in the first stage lesson. It was considered that elementary and junior high school students may be made to feel that the lesson time is too long when it is lesson. Some participants in fifth grade of elementary school students and second grade of junior high school students indicated that they did not understand this lesson even if they have received training on how to use the scratch beforehand. The measures to be taken in implementing this lesson, it is important to have someone to assist where necessary after checking students' understanding of the program. Regarding the length of the lesson, many participants stated that it was long. This was not resolved by incorporating different teaching methods and content, such as active learning and disaster management education. It is therefore advisable to conduct lessons that can be conducted in a shorter time of 45-50 minutes.

Conclusions

Education in elementary and junior high schools nowadays requires disaster education, education using active learning and programming education. This study created the lesson in which these can be learnt at the same time, and to clarify the level of understanding and problems in the lesson. The aim in this study is to propose ways to address this problem. The target groups were from 5th grade of elementary school students and third year of junior high school students. These grades were targeted because programming education is provided in schools. The implementation was carried out over three years from 2022 to 2024 for the second stage of the lesson (for the first stage of the lesson, it was 2 years of second year and third year). The lesson was conducted in two stages: the first stage, which implemented basic programming content, and the second stage, which used all aspects of disaster prevention, active learning and programming. The purpose of implementing of the first stage was to learn how to use the Scratch as the programming software used in the second stage. The first stage was implemented four times, two plus two in the second and third year. The second stage was implemented 8 times, 3+3+2 from the first to third year. The results of the questionnaire showed that the majority of participants answered that the lesson was easy to understand, however a few participants gave negative responses. Many of them were elementary school children. Regarding the length of the lesson, many participant including junior high school students answered that the lesson was too long. The daily class time in elementary and junior high school was 45 or 50 minutes and this course was 60 or 180 minutes (with a break in the middle). It can be assumed that the reason for this negative response was the difference in the daily teaching hours. Therefore, the lesson time needs to be shorter. To summaries the issues, there are no problems with the content of the lesson, however the length of the lesson time should be adjusted. This lesson was also difficult for some primary and secondary school students, it would be desirable to mobilize personnel to assist and to be able to accommodate participants who do not fully understand the content.

References

Academic Society Liaison Association Corresponding to the Great East Japan Earthquake. (2014). Global sharing of the findings from the Past Great Earthquake Disasters in Japan, Joint Statement of 30 Academic Societies The activities and initiatives of the 30 academic societies. https://janet-dr.com/070_seimei/141129_seimei_eng.pdf (accessed 2025.05.14).

Australian Council for Computers in Education (ACCE) (2014). Digital Technologies in the Australian Curriculum. http://journal.acce.edu.au/index.php/AEC/article/download/64/pdf (accessed 2025.04.29).

Ayumu Tanaka. (2015). The impacts of natural disasters on plants' growth: Evidence from the Great Hanshin-Awaji (Kobe) earthquake. Regional Science and Urban Economics. 50. 31-41.

Bonwell, Charles C.; Eison, James A. (1991). Active Learning: Creating Excitement in the Classroom. ASHE-ERIC Higher Education Reports. p.121.

Cabinet Office HP. Disaster Management. https://www.bousai.go.jp/kyoiku/panf/report_brochure_etc.html(accessed 2025.05.14).

Computing At School (CAS) (2015a). CAS Computing Progression Pathways KS1 (Y1) to KS3 (Y9) by topic. http://community.computingatschool.org.uk/resources/1692 (accessed 2025.04.29).

Computing At School (CAS) (2015b) CAS Computational Thinking - A Guide for teachers. http://community.computingatschool.org.uk/resources/2324 (accessed 2016.05.29).

Gobo city HP. hazard map. https://www-city-gobo-lg-jp.translate.goog/kurasi/bosai/hazardmap/index.html?_x_tr_sl=ja&_x_tr_tl=en&_x_tr_hl=en(accessed 2025.05.14).

Hay DB. (2007). Using concept maps to measure deep, surface and non-learning outcomes. Studies in Higher Education. 32. pp39‐57.

The Australian Curriculum, Assessment and Reporting Authority (ACARA) (2015a). Technologies. http://www.acara.edu.au/technologies.html (accessed 2025.04.29).

The Australian Curriculum, Assessment and Reporting Authority (ACARA) (2015b). Digital Technologies Foundation to Year 10 scope and sequence. http://v7-5.australiancurriculum.edu.au/australian20curriculum.pdf?Type=0&s=DI&e=ScopeAndSequence (accessed 2025.04.29).

Tottori Prefectural International Exchange Foundation HP. https://www.torisakyu.or.jp/ja/1/y735/a112/a975/(accessed 2025.05.14).

TRANSFORMING LEARNING IN WAFER FABRICATION PROCESS THROUGH SMART LEARNING SPACES

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Abstract

Training a skilled workforce for the semiconductor industry presents significant challenges due to the need for specialized equipment, complex wafer fabrication processes, and cleanroom environment. To address these challenges, Singapore Polytechnic's School of Electrical and Electronic Engineering (SEEE) has transformed the Wafer Fabrication Fundamentals (WFF) module through the integration of Smart Learning Spaces (SLS).

SLS provides a technology rich environment that enables immersive and interactive learning experiences. The tutorial lessons have been redesigned using the TPACK (Technological Pedagogical Content Knowledge) framework to integrate technology tools with teaching methods and subject expertise. Traditional lessons have been transformed into collaborative problem solving sessions where students use smart TVs to discuss and present their ideas, encouraging peer learning and knowledge sharing.

Implementing SLS requires a change in teaching method, with teaching staff playing a key role in facilitating student learning. Training sessions were conducted to equip teaching members with the skills needed to foster collaborative learning within the SLS environment. Blended learning techniques were introduced, allowing students to extend their learning beyond the classroom by observing real time wafer fabrication processes remotely. Advanced audio visual technology, including high resolution cameras and wireless audio systems, enables seamless communication among facilitators and learners, while interactive whiteboards support dynamic learning experiences.

Over a one and a half year implementation period (from 2023 Semester 2 to 2024 Semester 2), approximately one hundred and twenty second year students from the Diploma in Electrical and Electronic Engineering (DEEE) participated in SLS classroom for each semester. Students worked in teams, engaging in depth discussions and shared learning experiences, replicating real world collaborative settings. Peer learning, collaborative problem solving, and instant feedback helped students monitor their progress and enhance their understanding.

A mixed method approach, including focus group discussions and surveys, showed that SLS positively impacts engagement, understanding, and skills development. Students agreed that the learning experience in the SLS was engaging, allowed them to learn collaboratively with group mates, and provided opportunities to share their learning. This led to better knowledge retention, improved learning outcomes, and addressed the foundational training needs for a skilled workforce in the semiconductor industry. The implementation of SLS for the WFF module demonstrates how leveraging on technology and redesigning lessons can effectively motivate and facilitate student learning, with students showing improved understanding of wafer fabrication concepts, stronger peer learning capabilities, and better preparation for industry challenges.

Keywords: *Smart Learning Space, Collaborative, Peer learning, Semiconductor Industry, Wafer Fabrication*

Introduction

The semiconductor industry plays a vital role in powering today's digital world, with rapid growth demanding a workforce that can adapt and readily apply its knowledge. However, preparing such a workforce remains a significant challenge due to the complexity of wafer fabrication and the limitations of traditional teaching methods. Recognizing this gap, Singapore launched a new programme to train its semiconductor talent pool (Subhani, 2024), addressing the need for more industry ready professionals. This initiative is further supported by the government's allocation of S$1 billion for biotech and semiconductor R&D in Budget 2025, highlighting the strategic importance of nurturing skilled talent to sustain the sector's growth (Oh & Yuan, 2025).

In the School of Electrical and Electronic Engineering (SEEE), these challenges are observed in the Wafer Fabrication Fundamentals (WFF) module, a second year course within the Diploma in Electrical and Electronics Engineering (DEEE), where the delivery of hands-on training is constrained by the need for specialized equipment, complex wafer fabrication processes and the requirement for a cleanroom environment. To enhance learning outcomes, SEEE has adopted technology

enabled environments that promote active, collaborative, and blended learning. These Smart Learning Spaces (SLS) integrate digital tools such as learning analytics, seamless access systems, and intelligent technologies to support adaptive and personalized learning. Research by Hwang (2014) emphasized the value of mobile and context-aware learning in enhancing personalization and student motivation, while Koper (2014) outlined the conditions for effective smart learning ecosystems that bridge formal and informal learning through data-driven personalization. Recent research by Koukaras et al. (2025) further emphasizes the transformative role of AI-driven telecommunications in enabling secure, real-time, and personalized educational experiences through smart classroom infrastructure.

The pedagogical foundation for implementing SLS is guided by the Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2006). TPACK integrates technology with pedagogy and content knowledge to create meaningful and contextually relevant learning experiences. Chai et al. (2013) demonstrated its effectiveness in engineering education, particularly in supporting conceptual understanding through digital simulations. Niess (2005) extended the framework to mathematics education, arguing that technology must be deeply embedded within both content and pedagogy. Chai et al. (2010) proposed a developmental pathway for pre-service teachers, emphasizing the need for structured professional development.

Blended learning approaches, which combine traditional face-to-face instruction with online activities, complement the use of SLS. Garrison and Vaughan (2008) advocated for blended learning as a flexible model that supports autonomous learning, while Means et al. (2013) provided empirical evidence that it enhances theoretical understanding through multimedia simulations and remote laboratory experiences.

Collaborative learning strategies are also important to SLS. Prince (2004) reviewed the effectiveness of active learning in promoting cognitive engagement and skill development, and Johnson and Johnson (2009) emphasized the role of cooperative learning in fostering communication, teamwork, and critical thinking where these are skills essential in the semiconductor industry.

The transformation of the WFF module at SEEE exemplifies how these theoretical foundations and pedagogical strategies can be applied to support workforce development in a high tech field. Implemented across three semesters with approximately one hundred and twenty second year students, the collaborative model involved peer learning, and group presentations using digital platforms that mirror real-world industry practices. Preliminary findings from student feedback indicate increased engagement, enjoyment of collaborative experiences, and improved learning outcomes. These results align with broader educational trends, highlighting the positive impact of active and technology-based learning (Laurillard, 2012).

Purpose of Study

This study assesses the impact of Smart Learning Spaces (SLS) on learning effectiveness in wafer fabrication training through a collaborative and blended learning approach. It examines how a technology-enhanced environment bridges the misalignment between classroom learning and practical experience by integrating immersive technologies with active learning strategies. The study also includes a pilot implementation of blended learning conducted for a mass tutorial lesson which aims to evaluate how the integration of online and in-person instruction, facilitated by appropriate educational technology tools, enhances student engagement and comprehension of wafer fabrication concepts.

Research Questions

- To what extent does the SLS, enhanced with educational technology tools, support students' active participation and deep understanding of wafer fabrication concepts?
- How can educational technology tools be designed to foster meaningful peer learning and knowledge sharing during wafer fabrication training across both physical and virtual learning environments?

Materials and Methods or Pedagogy

This study adopted a mixed-methods approach to investigate the impact of Smart Learning Spaces (SLS) on the teaching and learning of wafer fabrication processes. By integrating both quantitative and qualitative techniques, the study ensured a comprehensive understanding of student engagement, instructional effectiveness, and technology integration.

Research Design and Participants

Quantitative data were collected over three consecutive semesters from second year students enrolled in the Wafer Fabrication Fundamentals (WFF) module within the Diploma in Electrical and Electronics Engineering (DEEE). The average participation rate was 73%, enabling consistent monitoring of the SLS implementation and its impact. Additionally, two focus group studies were conducted to gather qualitative insights. The first focused on evaluating the effectiveness of SLS in tutorials environments, while the second explored students' experiences with blended learning, including perceived challenges and suggestions for improvement. Each focus group comprised three to four students per class, selected to ensure diverse representation across different lecturers.

Data Collection and Analysis

Data were gathered through structured surveys using a five-point scale and semi-structured focus group discussions. Surveys assessed students' perceptions of learning effectiveness, engagement, and the integration of educational technology. Each focus group lasted about 90 minutes, was recorded, and then written out for review. A thematic analysis was applied to the qualitative data, with one group focusing on tutorial delivery and the other on blended learning experiences. Quantitative survey results were summarized using bar charts and percentages to complement and triangulate the qualitative findings.

Implementation of Smart Learning Spaces (SLS)

Phase 1: Foundations of SLS Implementation

The first phase of SLS implementation focused on preparing teaching members and fostering collaborative learning. Rather than applying the full Technological Pedagogical Content Knowledge (TPACK) framework, this stage emphasized basic digital readiness and iterative instructional design. Teaching members received basic training on SLS tools before the semester began, including demonstrations of platform features and strategies for facilitating interactive learning. Two meetings per semester were held to share feedback, best practices, and areas for improvement, supporting iterative refinement of teaching methods.

Student activities were designed to promote peer interaction and shared exploration of course content. Structured materials supported content delivery, while group tasks and discussions encouraged engagement. Technology was introduced gradually through collaborative tools embedded in the SLS platform. This phase established a foundation for more integrated and technology-enhanced instruction in subsequent stages.

Phase 2: Real-Time Blended Learning in Semiconductor Education

The second phase introduced a pilot session to explore blended learning through the integration of real-time demonstrations and theoretical instruction. The aim was to enhance student engagement and improve understanding of semiconductor fabrication processes using synchronous, multi-location learning.

The session focused on the vacuum process in wafer fabrication. One class attended the session in person at the SLS classroom, while seven other classes joined remotely from two lecture halls in Singapore Polytechnic. Two laptops were used in the cleanroom, one capturing the technical executive and the other focused on the sputtering vacuum system. To maintain clarity, only one camera feed was displayed at a time. Microsoft Teams facilitated real time interaction, allowing students to observe the process and ask questions directly to both the facilitator and technical executive.

Students received structured content before the session to support contextual understanding. During the real-time demonstration, guided questioning and peer discussions encouraged active participation. Digital tools such as screen sharing, and video streaming supported seamless delivery and collaborative learning.

While the pilot was limited to a single session, it demonstrated the potential of SLS to support engaging and effective instruction across diverse learning environments. The experience also revealed areas for improvement, particularly in the integration of technology to streamline real-time demonstrations and enhance interaction across remote settings. These insights will guide future refinements and support the broader adoption of blended learning strategies.

Results and Discussion

Phase 1: Foundations of SLS Implementation

To evaluate the initial implementation of SLS, a student focus group was conducted in fifth week of Semester 2, 2023 with 17 students across different classes. Feedback was organized into three key themes: learning environment, interaction format, and technology use.

- *Learning Environment*
  Students commended the classroom's layout for supporting visibility and collaboration. One student remarked, *"This is the best tutorial room I've ever been to."* The space encouraged participation and reduced fear of making mistakes.
- *Interaction Format*
  Tutorials involved group discussion and presentations. Students appreciated the recap sessions and felt more engaged than in traditional classrooms. However, the one-hour duration was insufficient for meaningful discussion and sharing.
- *Technology Use*
  Smart TVs were underutilized due to unfamiliarity and limited collaborative features. Students preferred verbal discussions. They also recommended more video content and thought provoking questions to deepen engagement.

Following the focus group, teaching members met during the term break to redesign tutorials, focusing on enhancing engagement through interactive content and critical thinking activities to deepen engagement. These instructional changes were later evaluated through end-of-semester surveys to support continuous improvement of the SLS experience. A cohort wide survey was also conducted at the end of the semester to gather broader feedback on SLS. Responses remained positive across three semesters, with consistently high levels of agreement despite a slight dip in top ratings. This variation may be attributed to the survey overlapping with other ongoing feedback activities.

Student Engagement Analysis

Figure 1 shows strong student engagement across three semesters. Around 90% of students agreed or strongly agreed with engagement related statements. While "strongly agree" responses dipped slightly, "agree" responses rose, showing steady positive feedback. The chart highlights SLS's role in supporting meaningful learning.

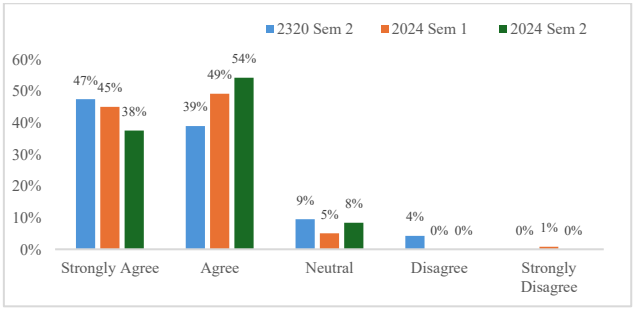


Figure 1: Student responses to the statement- I found the learning experience in the SLS to be engaging.

Student Perceptions of Group Collaboration

Figure 2 shows consistently high student satisfaction with group collaboration in SLS across three semesters. Agreement levels remained strong, with 88% to 97% of students either agreeing or strongly agreeing that SLS enhanced their collaboration skills. "Strongly agree"

responses ranged from 41% to 48%, while "agree" responses stayed between 40% and 50%. These findings underscore SLS's effectiveness in promoting peer interaction and teamwork.

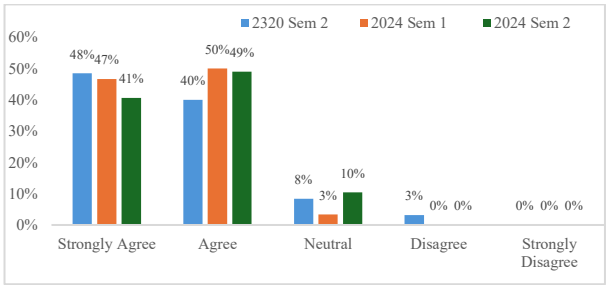


Figure 2: Student responses to the statement - I can learn collaboratively with my groupmates in the SLS

Analysis of Student Presentation Opportunities

Figure 3 shows a clear upward trend in student satisfaction with opportunities to present and share their learning. Satisfaction rose from 77% in 2023 Semester 2 to 96% in 2024 Semester 1, before dipping slightly to 89% in 2024 Semester 2, which may be attributed to a lower participation rate during or teaching staff being unfamiliar with the new setting. The increase aligns with the redesign of tutorial sessions, which likely contributed to greater engagement. These findings suggest that the revised structure effectively enhanced student participation and presentation opportunities.

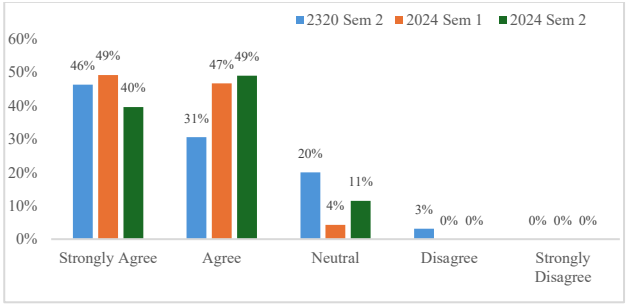


Figure 3: Student responses to the statement - I have opportunities to share or present my learning to my classmates

SLS Technology Use for Semester 2410 and 2420

As mentioned earlier, following the focus group, teaching members met to redesign tutorials with a focus on interactive content and critical thinking to deepen engagement. By the end of 2024 Semester 1, students were consistently using technological tools in the SLS. The smart TV interactive whiteboard was the most utilized feature (81% and 80%), highlighting its role in promoting engagement. PowerPoint remained the primary delivery tool. Other tools, such as internet access and document editing platforms, saw moderate but steady use, reflecting students' willingness to engage with digital resources that support direct instruction. Figure 4 shows the comparative usage across both semesters.

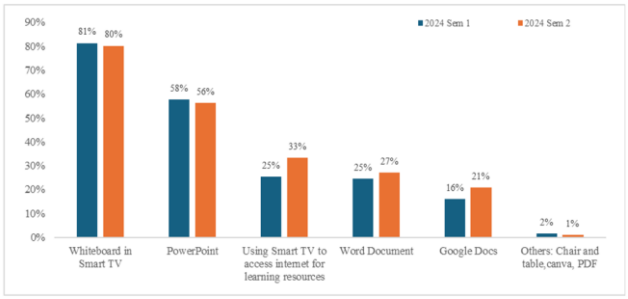


Figure 4: Student responses to the statement - Which of the following have you used in the SLS?

Phase 2: Real-Time Blended Learning in Semiconductor Education

A blended learning approach was implemented for teaching vacuum technology in wafer fabrication, designed to enhance student engagement and bridge theoretical concepts with practical applications. The session involved seven classes across two lecture halls, with an additional class connected through the SLS. The learning experience was coordinated between a facilitator in the SLS environment and a technical executive conducting real-time demonstration the cleanroom, while facilitators in lecture halls connected via Microsoft Teams to ensure synchronous participation.

This integrated approach combined digital and physical learning environments, enabling students to observe and understand practical applications through real-time demonstration. Post-session surveys assessed three aspects: blended learning effectiveness, theory-to-practice application, and lesson engagement. Feedback from this setup is shared in the following section.

Student Feedback on Blended Learning Effectiveness

Feedback gathered from different learning settings revealed distinct patterns in student experience. Students connected through the SLS responded positively, with 74% indicating the lesson was effective and no negative responses recorded. This suggests that the real-time facilitation and interactive features of the digital environment contributed to stronger engagement and clearer understanding.

In comparison, feedback from students in lecture halls was more mixed: 38% found the session effective, 25% were neutral, and 37% disagreed.This contrast may highlight the limitations of conventional setups, which typically rely on basic tools like projectors, speakers, and wired microphones. Figure 5 compares student feedback, showing stronger outcomes in SLS-enabled classrooms and highlighting the need for better tech in lecture halls.

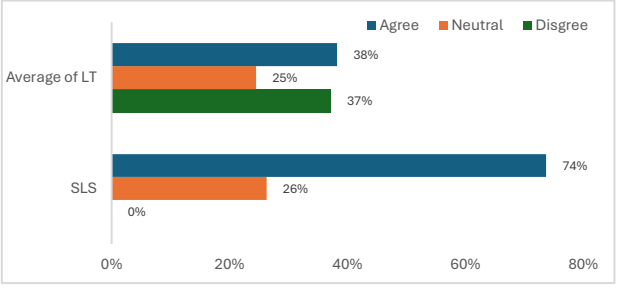


Figure 5: Student responses to the statement - The lesson was effective in helping me understand vacuum processes in wafer fabrication

Student Feedback on Application of Theory to Practice

Students engaged in a blended learning session featuring a real-time vacuum process demonstration through Microsoft Teams. The session, hosted in the SLS environment, was facilitated by a technical executive using two laptops. One laptop captured the technical executive providing the instructional teaching. The other displayed the vacuum system of the sputtering process with a single pinned camera view to maintain clarity.

Student feedback indicated that 74% of those in the SLS environment felt the session enhanced their understanding of both theoretical and practical aspects, compared to 43% of students in traditional lecture halls. Only 5% of SLS participants expressed disagreement, whereas 35% of students in the traditional lecture hall setting did not find the session beneficial. Figure 6 illustrates this contrast in perceived learning effectiveness across the two environments.

These findings suggest that the interactive, guided approach within the SLS environment enhanced student engagement and comprehension. To further optimise the experience in SLS, improvements in camera angles and audio quality during real-time session in the cleanroom could be considered. Meanwhile, the varied responses from lecture hall students point to a need for greater interactivity and instructional support in traditional settings.

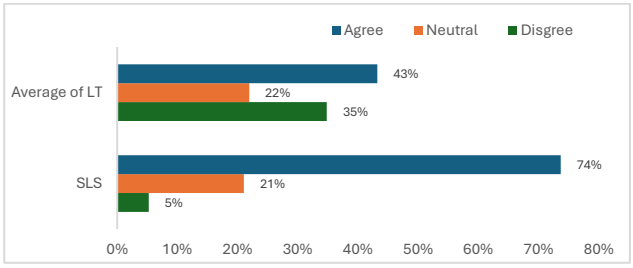


Figure 6: Student responses to the statement - The lesson enhanced my understanding of how theoretical concepts apply to practical vacuum processes.

Student Feedback on Lesson Engagement

As shown in Figure 7, 74% of students in the SLS environment found the lesson engaging, with only 5% expressing disagreement. In contrast, just 35% of students in traditional lecture halls agreed, while 39% disagreed and 27% remained neutral. These findings suggest that the structured and interactive nature of the SLS environment significantly enhanced student engagement. The contrast underscores the need for traditional settings to adopt more interactive strategies and technologies to improve participation and attention.

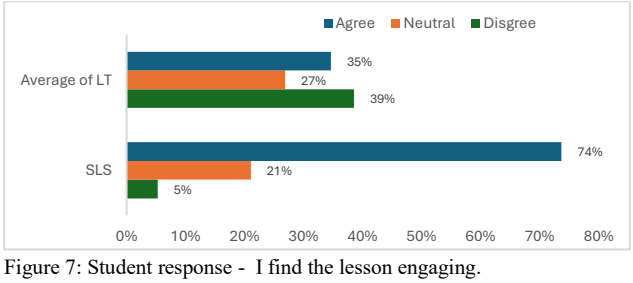


Figure 7: Student response - I find the lesson engaging.

Focus Group Study: Lecture Hall Experience

Student feedback on lesson effectiveness, theory-to-practice application, and engagement revealed clear contrasts between learning environments. Students in the Smart Learning Space (SLS) reported higher satisfaction, with 74% finding the sessions both effective and engaging. In contrast, students in traditional lecture halls expressed lower satisfaction, pointing to limitations in supporting blended learning.

To gain deeper insights into the challenges of traditional settings, a focus group was conducted with lecture hall participants. The discussion revealed a mix of positive observations and constructive suggestions, summarized into five key themes:

- *Demonstration and Practical Understanding*
  Students appreciated the real-time demonstration, especially the ability to zoom in on specific components of the vacuum system, which one stated "really helped us understand how it works."
- *Peer Learning Experience*
  Learning alongside friends was seen as beneficial, with students noting it was "easier to learn when you're with friends" as it encouraged informal discussion and comfort in asking questions.
- *Instructional Delivery*
  The session was overly reliant on slides and lacking interaction, with one student describing it as "just another lecture" with limited engagement.
- *Technology and Infrastructure*
  Technical issues such as poor audio, unstable internet, and slow screen transitions were common, and one participant shared that "the screen froze or the audio cut out," making it difficult to stay focused.
- *Suggestions for Improvement*
  Students recommended smaller group formats to improve interaction and suggested allowing online learners to join from anywhere, saying it would "make it easier to ask questions and stay engaged."

A key recommendation was to conduct future blended sessions in smaller groups to improve interaction and engagement. Students also suggested allowing online learners to join synchronously from any location. Overall, the findings highlight the need to strengthen both technology and teaching approaches in traditional lecture settings to support more effective blended learning.

Conclusion

This study investigated how Smart Learning Spaces (SLS), supported by educational technology, can enhance student participation and understanding in wafer fabrication training. In Phase 1, the Wafer Fabrication Fundamentals module was redesigned to move away from passive lectures and toward more active learning. Students responded positively, reporting higher engagement and greater confidence in sharing ideas. Tools that encouraged inclusive participation and peer teaching played a key role in this improvement.

Phase 2 built on this by introducing a blended learning model that combined real-time demonstrations with digital delivery through the SLS. Students in the

SLS environment reported higher satisfaction with lesson effectiveness, engagement, and the connection between theory and practice, compared to those in traditional lecture halls. These results suggest that the use of interactive tools and structured digital environments can significantly improve learning outcomes.

However, engagement in Phase 2 was slightly lower than in Phase 1, likely due to the challenges of managing both in-person and remote learners simultaneously. Feedback from focus groups from students in the lecture halls pointed to the need for smaller group formats, better audio-visual systems, and more interactive teaching strategies to maintain attention and support knowledge sharing across different settings.

As shown in recent studies, smart learning environments that integrate digital tools, real-time feedback, and flexible delivery methods support students' active participation and promote deeper understanding. This study supports those findings, showing that a well-designed SLS can bridge the gap between theory and practice, and foster collaboration in both physical and virtual classrooms.

Going forward, future research could explore the long-term impact of SLS on student performance and workforce readiness. There is also potential to enhance learning through industry partnerships and emerging technologies such as AI-driven feedback and engagement tracking, which can help tailor instruction to individual needs and improve overall learning experiences.

Acknowledgements

The successful implementation of the SLS was made possible through the dedicated contributions of academic staff Julie Fan, Cassandra Low, Derrick Ting, and Wong Weng Yew, along with the invaluable support of technical executives He Qun, Tang Lian Geck, Nur Akmar Mahat, and Tan Chiao Ning.

References

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society*, *13*(4), 63-73.

Chai, Ching & Koh, Joyce & Tsai, Chin-Chung. (2013). A Review of Technological Pedagogical Content Knowledge. *Educational Technology & Society, 16*(2), 31–51.

Garrison, D. R., & Vaughan, N. D. (2008). *Blended learning in higher education: Framework, principles, and guidelines*. John Wiley & Sons.

Hwang, G. J. (2014). Definition, framework and research issues of smart learning environments - a context-aware ubiquitous learning perspective. *Smart Learning Environments*, *1*(1), 1-14.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, *38*(5), 365–379.

Koper, R. (2014). Conditions for effective smart learning environments. *Smart Learning Environments*, *1*(1), 5.

Koukaras, C., Koukaras, P., Ioannidis, D., & Stavrinides, S. G. (2025). AI-driven telecommunications for smart classrooms: Transforming education through personalized learning and secure networks. Telecom, 6(1), 45–62.

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for learning and technology*. New York, NY: Routledge.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record, 115*(3).

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

Oh, T., & Yuan, Y. J. (2025, February 12). *Singapore's pipeline of local semiconductor talent still years away from meeting demand: Industry watchers*. The Business Times. https://www.businesstimes.com.sg/singapore/economy-policy/singapores-pipeline-local-semicon-talent-still-years-away-meeting-demand-industry-watchers

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231.

Subhani, O. (2024, November 14). *Singapore to launch new training programme to boost semiconductor talent pool: Gan Kim Yong*. The Straits Times. https://www.straitstimes.com/business/singapore-to-launch-new-training-programme-to-boost-semiconductor-talent-pool-gan-kim-yong

ENHANCING HIGHER-ORDER THINKING THROUGH AI CHATBOTS: A MULTI-DOMAIN STUDY

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Artificial intelligence (AI) is increasingly integrated into education, yet its role in fostering higher-order thinking skills remains underexplored (Lu et al., 2024; Putra et al., 2023). As part of educational innovation, AI-assisted learning is being explored to enhance students' cognitive engagement and problem-solving abilities. Generative AI has demonstrated potential in facilitating cognitive engagement, but empirical research on its direct impact on analytical reasoning and critical thinking is limited. While existing studies have examined AI's role in academic writing (Kim et al., 2024) and Socratic questioning (Chukhlomin, 2024), fewer investigations have considered chatbot implementations across multiple cognitive domains. This study addresses this gap by analysing how AI chatbots function as cognitive scaffolding tools to support analytical and critical thinking among students from the School of Engineering at Temasek Polytechnic.

The study examines two AI-assisted learning interventions in the subject Leadership Fundamentals. The first implementation utilises a writing-focused AI chatbot to develop reflective thinking through structured questioning, while the second integrates an AI-powered chatbot to support ethical decision-making. Developed on the Mizou platform, both implementations employ a mixed-methods approach. Pre- and post-surveys with two intervention groups to measure the chatbots' effectiveness were implemented.

The findings indicate a measurable increase in student engagement and confidence in analytical tasks, with students describing chatbots as facilitators of structured thinking rather than passive information sources. These findings align with previous research on AI's role in student interaction (Kim et al., 2024; Wang et al., 2024) and suggest that AI-driven cognitive scaffolding may support higher-order cognitive skills.

These findings point the way for educators to further explore AI-assisted learning models that align with engineering education needs (Alamri & Alharbi, 2023) and examine AI chatbots' role in developing metacognitive and higher-order thinking skills in higher education (Lim & Makany, 2023). This paper provides information for researchers interested in further exploring the impact of AI-generated prompts on student inquiry and decision-making (Koji et al., 2024).

Keywords: *AI-assisted learning, educational innovation, cognitive scaffolding, higher-order thinking, personalised learning, student engagement, alternative assessment*

Introduction

Higher-order thinking skills (HOTS) are essential for students to navigate the increasingly complex challenges of the 21st century workplace and society. These skills, including critical thinking, analytical reasoning, problem-solving, and ethical decision-making, are particularly crucial for engineering students who will face multifaceted technical and ethical dilemmas in their professional careers (Alamri & Alharbi, 2023). Despite this recognised importance, developing these cognitive skills within traditional educational frameworks remains challenging, often due to constraints in providing personalised guidance and constructive feedback at scale.

Recent advances in generative artificial intelligence (AI) have created new possibilities for educational interventions aimed at fostering higher-order thinking. Generative AI systems, particularly AI-powered chatbots, offer potential as cognitive scaffolding tools that can engage students in dialogue, prompt reflection, present multiple perspectives, and guide analytical processes (Wang et al., 2024). These capabilities align with educational theories emphasising the importance of cognitive engagement, dialogic learning, and structured scaffolding in developing complex thinking skills (Chukhlomin, 2024).

While research has begun to explore generative AI applications in education, most studies have focused on narrow domains such as academic writing assistance (Kim et al., 2024) or automated feedback mechanisms. Fewer investigations have examined how chatbots might function across multiple cognitive domains simultaneously, particularly for higher-order thinking

development. Additionally, questions remain about implementation strategies, effectiveness measurement, and best practices for integrating these technologies into existing curricula (Putra et al., 2023).

This study addressed these gaps by investigating the implementation of AI chatbots as cognitive scaffolding tools in two distinct but complementary scenarios within a Leadership Fundamentals course for engineering students at Temasek Polytechnic. The first implementation focused on developing reflective thinking through guided questioning, where the AI acted as a coach to help students articulate and refine their life statements, a process requiring substantial self-awareness. The second implementation targeted the analysis of multiple perspectives in ethical dilemmas, employing AI to help students systematically examine complex scenarios from various stakeholder viewpoints.

By employing a mixed-methods approach to evaluate these implementations, this study aimed to contribute to the growing body of knowledge about effective AI integration in educational contexts, particularly for higher-order thinking development. The Mizou platform, an educational chatbot system powered by generative AI, enabled the creation of pedagogically sound chatbots that scaffolded complex thinking processes while providing a safe environment for students to explore and articulate their thoughts. The study examined how structured AI interactions might enhance students' reflective capacities and ethical reasoning skills which are both crucial for engineering students who will face complex technical and ethical challenges in their professional lives.

Materials and Methods or Pedagogy

This study employed a structured approach to investigate the effectiveness of AI-powered chatbots in enhancing higher-order thinking skills among engineering students. The research framework was designed to assess two specific AI-assisted learning interventions implemented in the Leadership Fundamentals subject at Temasek Polytechnic during the April 2025 semester.

A mixed-methods design was employed to evaluate the effectiveness of the AI chatbot interventions. This approach captured both quantitative measures of skill development and qualitative insights into students' experiences. The research design built upon preliminary observations from an informal pilot conducted in October 2024, which indicated positive student reception to AI-assisted learning activities.

The study included approximately 50 first-year engineering students enrolled in Leadership Fundamentals during the April 2025 semester. The self-leadership focused course was specifically chosen because it emphasises higher-order thinking and reflective skills over content memorisation, making it an ideal context for evaluating cognitive scaffolding interventions. Participants were divided into two intervention groups, with each group experiencing one of the two chatbot applications.

Both interventions utilised the Mizou platform. Mizou was selected for several key advantages: educational focus with features tailored to classroom implementation; privacy and security compliance with educational standards; customisability allowing educators to design chatbots with specific personalities and interaction patterns; analytics capabilities providing insights into student engagement; and accessibility through an intuitive interface that requires no technical expertise from students.

The first chatbot intervention, named "Life Purpose", was designed to develop reflective thinking through structured questioning. It guided students through a metacognitive process to articulate and refine their personal life statements. Key features included sequential prompting that gradually increased in cognitive complexity, guided questions encouraging deeper reflection, personalised feedback based on student responses, and reflection prompts connecting personal values to professional contexts. This intervention aimed to develop students' ability to engage in meaningful self-reflection, a prerequisite for articulating vision for self.

The second chatbot intervention, named "Ethics Explorer", focused on ethical decision-making by facilitating the analysis of multiple perspectives in a complex scenario. Designed as a Discussion Facilitator, this chatbot guided students through a structured ethical reasoning process using an ethical dilemma. It encouraged diverse viewpoints by consistently providing contrasting perspectives and occasionally introducing controversial angles to challenge student thinking. Rather than providing direct answers, it guided decision-making through focused questions.

The Ethics Explorer employed a scenario-based approach where students assumed the role of different stakeholders in an ethical dilemma involving technology misuse (specifically, a deepfake video scenario with significant consequences for multiple parties). Throughout the process, students were prompted to identify stakeholder concerns, propose potential actions, justify decisions with logical reasoning, prepare counterarguments, and consolidate a final position. Guiding questions such as "What are the assumptions behind this choice?" and "How does this decision affect other stakeholders?" stimulated higher-order thinking and helped students navigate the ethical complexity.

This intervention targeted students' ability to recognise and navigate complexity, consider diverse viewpoints, and engage in evidence-based reasoning which are essential components of ethical decision-making. The learning objectives focused on developing higher-order thinking skills, including understanding ethical issues, applying ethical reasoning, evaluating arguments, and developing well-reasoned justifications.

The study measured students' self-reported confidence and abilities in higher-order thinking skills following the chatbot activities to assess the quality and depth of thinking demonstrated.

The study's design was informed by several theoretical perspectives including Scaffolded Learning Theory, Bloom's Revised Taxonomy, and Ethical Reasoning Frameworks. This theoretical grounding ensured that the chatbot interventions were designed not

merely as technological tools but as pedagogically sound approaches to cognitive development.

Results

The results of the study indicated that both AI chatbot interventions had a measurable impact on students' higher-order thinking capabilities, with distinct yet complementary findings across the two implementations. Prior to the interventions, participants reported varied levels of engagement with generative AI technology, with 32% of the Life Purpose chatbot participants and 42% of Ethics Explorer chatbot participants using generative AI technology frequently for academic work. A significant majority (68% and 75% respectively) perceived generative AI to be "fairly useful" or "extremely useful" for schoolwork **[Figure 1].** This pre-existing familiarity with AI technologies likely contributed to students' ability to engage with the chatbot interfaces, as evidenced by the high proportion of participants agreeing that the chatbots were easy to use (88% for Life Purpose chatbot and 81.3% for Ethics Explorer chatbot). This technological fluency allowed students to focus on the cognitive demands of the tasks rather than navigating unfamiliar technology, creating favourable conditions for developing higher-order thinking skills.

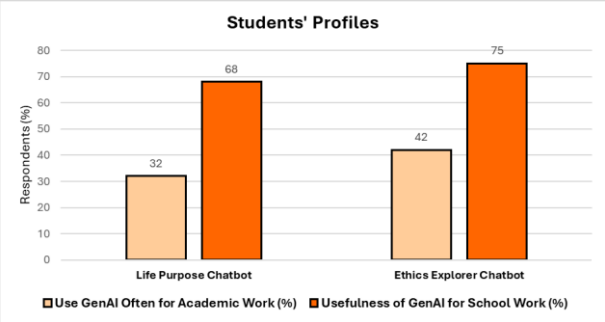


Figure 1: Students' profiles in Temasek Polytechnic

For the Life Purpose chatbot intervention, the pre- and post-intervention comparison revealed substantial improvements in students' self-reported abilities. Participants reporting high confidence (those selecting 'completely confident' or 'very confident') in completing reflective exercises doubled from 36% pre-intervention to 72% post-intervention. Similarly, the percentage of students confident in elaborating on thoughts with examples increased from 44% to 68%, while those able to critically assess their own views rose from 60% to 68%. Perhaps most notably, students confident in expressing thoughts in writing increased from 28% pre-intervention to 64% post-intervention, with 72% reporting they could write an effective Life Purpose Statement with the chatbot's assistance **[Figure 2].**

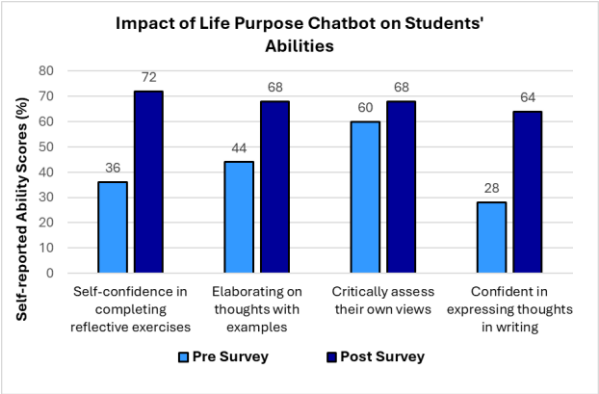


Figure 2: Students showed notable improvement across all self-reported skills

The post-intervention survey for the reflective thinking chatbot showed that 76% of respondents agreed or strongly agreed that "Using the Mizou Bot for this activity helped to enhance my ability to reflect," and 80% agreed that it helped them "structure ideas in writing better." An overwhelming 92% agreed that "The use of GenAI for this activity helped me to quickly formulate my Life Purpose Statement." When identifying cognitive skills applied during the activity, 23% indicated "analysis & reasoning," 18% selected "evaluating different perspectives/justifying a stand," and 19% noted "creating solutions/recommendations." **[Figure 3]**

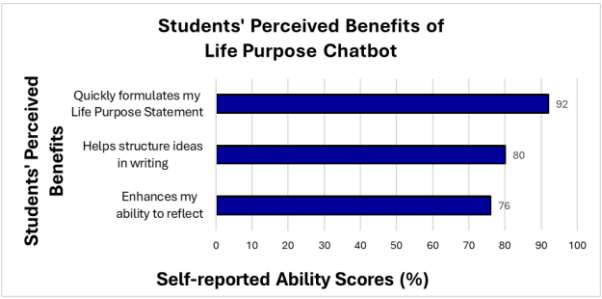


Figure 3: Students' perceived gains in reflection and idea structuring after using the Life Purpose Chatbot

For the Ethics Explorer chatbot intervention, the post-intervention survey revealed that 62.6% of respondents agreed or strongly agreed that "Using the Mizou DebateBot for this activity helped to enhance my higher-order thinking skills." More definitively, 68.8% of participants agreed that the Ethics Explorer chatbot helped them "examine different perspectives", which aligns closely with the intervention's design goal of fostering perspective-taking as a critical component of ethical reasoning. The strongest positive responses were observed regarding the chatbot's ability to scaffold argumentation and critical analysis, with 75.1% of participants agreeing or strongly agreeing that the chatbot helped them "quickly formulate arguments and counter arguments" and "examine bias and assumptions in my arguments." **[Figure 4]**

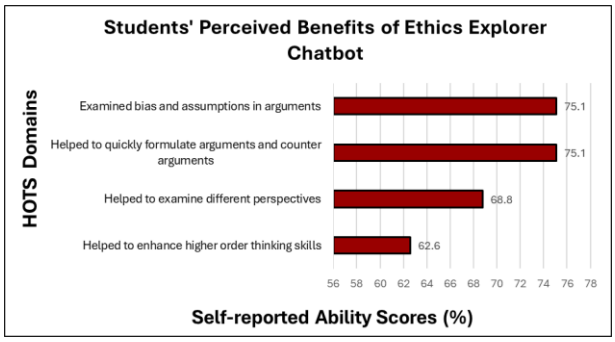


Figure 4: Students' perceived gains in reflection and idea structuring after using the Ethics Explorer Chatbot

When asked to identify the cognitive skills they applied during the activity, 81.3% of participants indicated "analysis & reasoning," and "evaluating different perspectives and/or justifying a stand," while 62.5% noted "creating or formulating solutions/ proposals/ recommendations." These responses correspond to the higher levels of Bloom's Revised Taxonomy which are analysing, evaluating, and creating.

Interestingly, whilst 75% of the Ethics Explorer chatbot participants indicated that the dialogue activity "would not have made a difference" had it been conducted without generative AI, only 24% of the Life Purpose chatbot participants shared this view. This suggests a perceived difference in utility between the two implementations. This disparity indicates that students found the reflective thinking chatbot more instrumental to completing their task than the ethical reasoning chatbot.

The qualitative responses provided deeper insights into how each chatbot facilitated higher-order thinking. For the Life Purpose chatbot, students highlighted how it helped them articulate and structure their thoughts, with comments such as "it helped me craft my life purpose statement and helped me analyse my thoughts" and "it helped me to put my ideas into a proper paragraph which encapsulated all of my points." Students particularly valued how the chatbot synthesised their inputs, with one noting it "compiled and analysed my strengths and passion which is then helped generate what would be a good future career for me." Challenges included responses that were "a bit generic" or "didn't understand me quite well."

For the Ethics Explorer chatbot, students described the chatbot as offering meaningful cognitive scaffolding through statements such as "it kept asking for even more clarification for us to work on our answer" and "it gave me different questions that I can consider." Several students highlighted perspective-taking benefits with comments such as "I was able to examine and analyse various opinions and verify different perspectives on the topic" and "Learning about the other stakeholder's opinions." The development of argumentation skills was evident in feedback like "offered me counterarguments" and "It gave me a different perspective on my statement." Some challenges were also reported, with several students finding the chatbot's responses "vague" or noting that "it didn't give me a straight answer," which aligns with the chatbot's design intention to scaffold thinking rather than provide direct answers. When asked about ethical concepts learned, responses such as "not being biased," "be aware of consequences," and "view from different perspectives" suggested development of ethical reasoning frameworks.

Discussion

The findings align with previous research on AI's role in student interaction and educational inquiry (Kim et al., 2024; Chukhlomin, 2024). The complementary results from the two chatbot implementations demonstrate how structured AI interactions can target specific cognitive domains – reflective thinking and ethical reasoning – while engaging students across multiple levels of Bloom's Revised Taxonomy. The reflective thinking chatbot appeared particularly effective at helping students translate abstract thoughts into coherent written expressions, supporting metacognitive development. Meanwhile, the Ethics Explorer chatbot fostered critical analysis and perspective-taking essential for ethical reasoning.

The apparent difference in perceived necessity between the two chatbots suggests that technological interventions may be more valued by students when they address specific challenges, they find difficult (such as articulating complex personal reflections) compared to tasks they might feel more confident tackling independently (such as ethical discussions). This insight has implications for targeted AI implementation in educational contexts.

These findings collectively contribute to our understanding of how purpose-built AI chatbots can function as cognitive scaffolding tools that engage students in different aspects of higher-order thinking. The results suggest that carefully designed AI-facilitated dialogues can meaningfully contribute to both reflective capacity and analytical reasoning skills essential for professional development.

Conclusion

This investigation explored the potential of AI chatbots as cognitive scaffolding tools in education, with a particular focus on enhancing reflective thinking and ethical reasoning capabilities. Our findings strongly support this application: both the Life Purpose and Ethics Explorer chatbot implementations demonstrated effectiveness in strengthening their respective targeted cognitive domains.

The Life Purpose chatbot was particularly successful, enabling most students to articulate coherent personal reflections, which is a clear indication of the tool's capacity to foster deeper reflective thinking processes. Similarly, the Ethics Explorer chatbot proved valuable for developing ethical reasoning skills by facilitating students' examination of diverse perspectives and construction of well-supported arguments.

Interestingly, we observed a marked difference in how students perceived the necessity of these tools; while

three-quarters of Life Purpose chatbot users considered the AI beneficial to their learning process, only about a quarter of Ethics Explorer chatbot users viewed the chatbot as adding value to their work. This disparity suggests that students found AI assistance more valuable for personal reflection tasks and writing deliverables than for ethical reasoning exercises. This could indicate that articulating and structuring personal reflections presents a greater cognitive challenge for many students, making technological scaffolding particularly beneficial for this domain. Alternatively, it may reflect differences in how these specific chatbots were designed or implemented within their respective learning activities.

Our results contribute meaningful empirical evidence to an emerging area of research on AI-supported higher-order thinking development. Furthermore, by implementing these tools through the Mizou platform, we demonstrated how educators without specialised technical expertise can successfully incorporate AI scaffolding into their teaching practices, addressing our aim of identifying accessible and scalable educational interventions.

While our study was conducted within a specific institutional context, our approach that combines structured design methodology, theoretical grounding, and mixed-methods assessment, offers valuable insights that may inform similar AI-assisted learning initiatives in other educational settings. The experiences and perceptions captured in this exploratory study provide a practical foundation for educators interested in implementing AI chatbots as cognitive scaffolding tools.

Moving forward, we recommend that researchers expand investigation into how AI chatbots can scaffold higher-order thinking skills across additional cognitive domains and disciplinary contexts, evaluate the longitudinal impacts on student learning outcomes, and work to identify evidence-based practices for sustainable integration of these tools into higher education curricula.

Purpose-built AI chatbots, when thoughtfully designed and strategically implemented, represent a promising complement to traditional instructional approaches, supporting students' development of the reflective capacity and ethical reasoning skills that are increasingly essential for success in today's complex professional environments.

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References

Alamri, A., & Alharbi, H. (2023). Adaptive learning using artificial intelligence in e-learning: A systematic review and meta-analysis. Education Sciences, 13(12), 1216. https://doi.org/10.3390/educsci13121216

Chan, K. Y. C., & Hu, W. (2024). Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. International Journal of Educational Technology in Higher Education.

Chukhlomin, V. (2024). Socratic prompts: Engineered dialogue as a tool for AI-enhanced educational inquiry. Latin American Business and Sustainability Review.

Dutta, S., Ranjan, S., Mishra, S., Sharma, V., Hewage, P., & Iwendi, C. (2024, February). Enhancing educational adaptability: A review and analysis of AI-driven adaptive learning platforms. In 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM) (pp. 1–5). IEEE. https://doi.org/10.1109/ICIPTM54933.2024.10563448

Kim, J., Na Li, S., & Detrick, R. (2024). Exploring students' perspectives on generative AI-assisted academic writing. Education and Information Technologies.

Koji, Y., Zefan, S., & Yang, C.-L. (2024). AI as extraherics: Fostering higher-order thinking skills in human-AI interaction. arXiv:2409.09218v2 [cs.HC]. https://arxiv.org/abs/2409.09218

Lu, J., Zheng, R., Gong, Z., & Xu, H. (2024). Supporting teachers' professional development with generative AI: The effects on higher-order thinking and self-efficacy. IEEE Transactions on Learning Technologies.

Putra, F. W., Rangka, I. B., Aminah, S., & Aditama, M. H. (2023). ChatGPT in the higher education environment: Perspectives from the theory of high-order thinking skills. Journal of Public Health.

Lim, S. S., & Makany, T. (2023). Deploying chatbots to build students' critical thinking skills: Leveraging generative AI effectively and purposefully in higher education. In Encyclopedia of Educational Innovation. M. A. Peters & R. Heraud (Eds.). Springer. In press.

Wang, S., Christensen, C., Cui, W., & Tong, R. (2024). Exploring the impact of artificial intelligence in teaching and learning: A systematic review. Research in Science Education. https://doi.org/10.1007/s11165-024-10176-3

Multi-modality AI-enabled Multisensory Learning for Dyslexia Students

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The AI-Sense Adaptive Learning Hub (AIALH) investigates the transformative role of AI in enhancing multisensory learning experiences for students with dyslexia and special educational needs (SEN). By integrating auditory, visual, and kinesthetic modalities, AI-driven platforms can create personalized learning pathways that cater to individual strengths and challenges, making learning more accessible and effective.

The AIALH provides a web-based interface platform which comprises of four keys AI-based training components in assessing and monitoring personal academic records. It further streamlines the learning and teaching processes and fosters personalized learning experiences. In addition, it also makes use of the blockchain technology that allows secure and transparent tracking of learner progress to ensure personalized learning pathways in an adaptable and credible manner.

This multifaceted approach leverages advanced technologies to create an inclusive and effective learning environment for dyslexic students which ultimately enhancing their educational outcomes. Through AIALH, educators can better support diverse learning needs, ensuring that all SEN students can have the opportunity to thrive in their educational journeys.

Keywords: *multisensory learning, dyslexia, special educational needs, multi-modality*

Introduction

Dyslexia is a neurodevelopmental learning disorder that impacts reading and writing abilities, requiring specialized support from trained educators (Hong Kong Specific Learning Difficulties Research Team, 2021). In Hong Kong, the number of dyslexia cases is rising 3% each year while the number of trained teachers is increasing only 0.2% annually. Furthermore, only about 20% of schools provide systematic support for students with special needs. Besides, students with dyslexia encounter significant difficulties in traditional academic environments, therefore, personalized learning strategies and multi-sensory teaching methods could greatly improve their engagement and language skills (Ho & Lam, 2020; Hong Kong Society of Child Neurology and Developmental Paediatrics, 2005; Ortega-Ochoa, et al., 2024).

To address these challenges, an AI-enabled multi-sensory learning and teaching system, namely, AIALH has been developed, initially for primary school students. It focuses on detection and providing personalized, interest-oriented, multi-sensory training activities for learning. The system tracks learning experiences to offer continuous support, aiming to improve students' learning outcomes, personalized learning and confidence as well as relieve the impact of the trained teacher shortage. We hope this system will foster a more inclusive learning environment in Hong Kong, addressing the urgent need for effective support for students with dyslexia.

The system can provide immediate feedback using AI-enabled assessments, and adaptive training that offers similar exercises with varied content until the student demonstrates mastery. Additionally, all assessment results will be stored confidentially on the blockchain, allowing trained teachers to securely access the data when students transfer to other schools. Although the system is initially developed for primary students in Hong Kong, the platform can be extended for secondary and post-secondary levels.

The system utilizes latest AI technologies to gather, process and analysis data. It also presents personalized performance insights to teachers through dashboards, enabling data-driven decision-making. Generative AI provides interest-based training tailored to individual student needs, boosting learning skills and confidence. The system tracks all learning experiences to offer continuous support for long-term learning activities.

Key learning outcomes include enhanced reading and writing skills and academic confidence for students with dyslexia, while also alleviating the workload for trained teachers. The system is a web-based application that requires only accessible devices (e.g., tablets, laptops, or mobile phones) with internet connectivity for schools and students. It utilizes AI for adaptive learning and assessment, as well as data analytics to track student progress.

System Overview and Architecture

In today's educational landscape, integrating technology into learning processes is essential, especially for students facing challenges like dyslexia. The innovative multi-sensory AI learning system is designed to support literacy development across three main components: writing, speaking, and reading skills. The system emphasizes cross-platform accessibility, personalized learning experiences, and engaging methods to foster academic growth.

By adopting a cross-platform design, the system ensures that students can effectively practice both at home and in school. This approach allows direct access to the learning platform, encouraging consistent practice and facilitating easier integration into educators' curricula.

In order to enhance learning interest, the virtual tutor created using Comfy UI AI personalizes matching each student's interests and learning needs. By evaluating students' preferred genres and topics, the AI generates tailored lessons that engage learners and boost their motivation. This individualized approach not only meets academic requirements but also fosters a love for learning.

The system consists of four key training components:

1. The handwriting component focuses on addressing alphabetics mirroring, a common challenge for students with dyslexia. The process begins when students write a paragraph by hand and upload it as an image, then the convolutional neural network (CNN) analyzes the handwriting to detect mirrored alphabetic in a word. The results are sent to the AI for further analysis, which compares the current performance with historical data. Based on this analysis, students receive tailored vocabulary exercises that specifically target their challenges with mirrored characters, thereby reinforcing their handwriting skills.
2. Reading and speaking skills training component is to enhance pronunciation accuracy during reading aloud, the speaking skills training utilizes audio recordings. Students record themselves reading a selected text, which is then converted to written form using Google Text-to-Speech (gTTS) technology. The system compares this transcribed text with the original paragraph to identify any mispronounced words. Feedback is provided immediately, and these mispronounced words are logged for future practice, allowing students to focus on areas that need improvement.
3. Engagement is critical for effective reading skill development. In the reading skills training component, students begin by selecting topics and genres that interest them. The system then presents a related video story along with a virtual tutor. Following the video, questions are generated using gTTS and natural language processing (NLP) techniques. Students' answers are assessed against their past performance, and based on these results, a ChatBot API generates personalized reading exercises. This method not only reinforces comprehension but also keeps students engaged with content that resonates with them.
4. To motivate students and track their progress, the rewarding trainings component is incorporated. Students earn stamps for completing sections of the training with an 85% learning target. All results and analyses are compiled into a dashboard accessible to teachers, allowing for easy evaluation of student performance. Based on this data, students can either advance to more challenging material or receive additional support to reinforce foundational skills.

The Web-based/Mobile platform is designed to provide a comprehensive educational experience for dyslexic learners through a variety of carefully structured functions and features which include:

- “User management” includes registration and login, which handle user authentication and session management.
- “Handwriting assessment” focuses on analyzing handwriting errors (e.g. letter formation, reversals, line adherence, spacing), analyzing handwritten inputs to provide feedback and writing practice based on identified errors.
- The “pronunciation assessment” category evaluates spoken language against stored pronunciation errors, offering corrective feedback through English pronunciation feedback. In terms of Comprehension Assessment, the platform engages students with short article comprehension tests that generate related questions.
- “Question generation” develops deeper analytical questions based on the content of genre-specific video stories. It also creates a virtual tutor tailored to the genre, aimed at boosting interest for students learning.
- “Data visualization” features progress tracking, utilizing visual dashboards to present user performance metrics. This classification effectively organizes the platform's functionalities, enabling targeted enhancements and a streamlined user experience.
- All the assessments will be securely storing on blockchain, and student interactions will be created and maintained in knowledge base.

See Figure 1 for the system architecture.

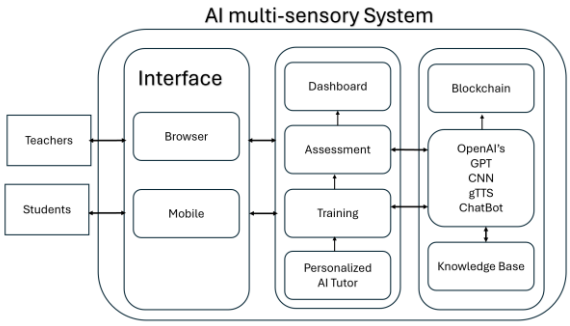


Figure 1: AI multi-sensory System Architecture

Methodology

To develop an effective educational tool for dyslexic learners encompasses several critical phases, each designed to ensure comprehensive support and accurate assessment.

First, data will be collected using the Dyslexia Handwriting Dataset from existing research and exercises completed by dyslexic students. This will be followed by data cleaning to remove unsuitable images, such as those that are blurred.

Next, students' handwriting will be analyzed using CNNs. CNNs are particularly effective for image analysis and can efficiently handle large datasets, thereby enhancing the model's overall performance.

For assessing students' pronunciation, we will fully utilize the Google Speech Recognition API in conjunction with gTTS for text-to-speech feedback. This interactive approach provides an effective method for evaluating and improving students' pronunciation skills.

To enhance reading comprehension, we will leverage the GPT API to generate interactive questions based on reading materials. This feature promotes engagement and fosters a deeper understanding, catering to the unique needs of dyslexic learners.

In the training and evaluation phase, the dataset is split into training set and testing set for periodic training and evaluations.

The assessment data will be presented on a user-friendly dashboard. This dashboard displays results clearly and incorporates visual charts to track student progress, making complex data accessible and actionable for educators. By presenting information in an intuitive manner, we empower educators to make informed decisions tailored to each student's needs.

Finally, all assessments will be securely stored on a blockchain. This decentralized system will be accessible to all special needs schools, allowing teachers to conveniently trace and access students' records. This ensures both the integrity of the data and ease of access for educators.

Overall, these outlines a systematic approach to creating tools that effectively support dyslexic learners, ensuring that each phase contributes to the overall success of the educational intervention.

Use Case

Although AI multi-sensory are initially planned to be prototyped and tested in teaching English for primary school, it also can be adapted for other subjects that use English as the medium of instruction. SEN schools, as well as primary and secondary schools, continually strive to support students with SEN in multi-ethnic communities, where many students come from disadvantaged or vulnerable backgrounds. We will invite these students to assist in testing the features and design of the AI multi-sensory system.

During the prototype development, we will investigate the protocols and processes for preparing teaching materials for knowledge base (KB) creation. Additionally, we will compile a set of frequently asked questions and answers based on a genre-specific story video to serve as benchmarks for upcoming testing and evaluations. An initial set of features and metrics will also be identified and defined to assess interaction patterns.

To test and evaluate the features and designs of the AI multi-sensory system, additional interaction pattern designs will be prototyped and distributed to selected schools that provide training for students with dyslexia. This will include students with varying degrees of dyslexia from different countries, allowing for a comparative analysis of learning outcomes based on interactions within each selected school. We will further analyze user experiences and the effectiveness of the system in supporting students in their English language learning process.

Conclusions

The proposed multi-sensory AI learning system offers a comprehensive approach to literacy education, particularly for students with unique learning challenges. By leveraging technology to create a personalized, engaging, and supportive learning environment, we can empower students to develop essential writing, speaking, and reading skills. This system not only aims to improve academic outcomes but also fosters a lifelong love of learning, making literacy accessible and enjoyable for all students.

In future development, the system will integrate a listening component, further enhancing its effectiveness for dyslexia students. This addition will make the multi-sensory AI learning system even more comprehensive and beneficial for teachers and students.

References

Qiao, H. & Zhao, A., 2023. Artificial intelligence-based language learning: illuminating the impact on speaking skills and self-regulation in Chinese EFL context. Frontiers in Psychology, 02 11, Volume 14, DOI:10.3389/fpsyg.2023.1255594.

Runge, A. et al., 2024. A generative AI-driven interactive listening assessment task. Volume 7, doi:10.3389/frai.2024.1474019.

Ortega-Ochoa, E. et al., 2024. Exploring the utilization and deficiencies of Generative Artificial Intelligence in students' cognitive and emotional needs: a systematic mini-review. Frontiers in Artificial Intelligence, doi: 10.3389/frai.2024.1493566

Mannekote, A. et al., 2024. Large language models for whole-learner support: opportunities and challenges. Frontiers in Artificial Intelligence, Volume 7, doi:10.3389/frai.2024.1460364.

Rosli, M. S. A. B. et al., 2021. Development of CNN Transfer Learning for Dyslexia Handwriting Recognition. 2021 11th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), pp. 194-199, doi: 10.1109/ICCSCE52189.2021.9530971.

Zapata-Rivera, D. et al., 2024. Generative AI in education. Frontiers in Artificial Intelligence, Volume 7, doi: 10.3389/frai.2024.1532896.

Isa, I. S., Rahimi, W. N. S., Ramlan, S. A. & Sulaiman, S. N., 2019. Automated detection of dyslexia symptom based on handwriting image for primary school children. Procedia Computer Science, Volume 163, pp. 440-449.

Ho, F.-c. & Lam, C. S.-c., 2020. Special Education and Integrated Education in Hong Kong, doi:10.1093/acrefore/9780190264093.013.1199.

Hong Kong Society of Child Neurology and Developmental Paediatrics. (2005). Position Paper on Special Learning Disabilities and Dyslexia in Hong Kong. Retrieved from [https://hkcndp.org/cmst/doc/publication/position_paper/SLD/SLD%20Position%20Paper%202005.pdf].

Tarjiah, I., Supena, A., Pujiastuti, S. I. & Mulyawati, Y., 2023. Increasing the reading ability of a student with dyslexia in elementary school: an explanatory case study by using family support, remedial teaching, and multisensory method. Frontiers in Education, Volume 8, doi:10.3389/feduc.2023.1022580.

Sulaiman, S. N., 2021. CNN Comparisons Models on Dyslexia Handwriting Classification, s.l.: Universiti Teknologi MARA.

Seman, N. S. L. et al., 2021. Classification of Handwriting Impairment Using CNN for Potential Dyslexia Symptom. 2021 11th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), pp. 188-193, doi: 10.1109/ICCSCE52189.2021.9530989.

Zhang S, Fan H, Zhang Y. The top-cited Studies on dyslexia Research: A Bibliometric analysis. Front Psychiatry. 2021 Jul 22;12:714627, doi:10.3389/fpsyt.2021.714627.PMID:34366943; PMCID:PMC8339432.

Hong Kong Specific Learning Difficulties Research Team, 2021. Understanding Dyslexia. [Online] Available at: https://hksld.eduhk.hk/understanding%20dyslexia/what%20is%20dyslexia [Accessed 30 06 2025].

EFFECT OF STUDENT MINDSET ON FAILURE TOLERANCE IN LEARNING FROM DELIBERATE FAILURE

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This paper shares the work done in investigating possible effect of growth mindset in influencing students' perception of failure. This is expressed in the form of failure tolerance, which is measured using a validated survey instrument to indicate to extent to which a failure is seen as an opportunity to learn and improve. The study was carried out with a group of Year 2 students taking the module "Marine Engine Room Simulator Training" from the Diploma in Marine Engineering. The students undergone a range of learning tasks over a period of one semester; using computer simulation that mimics tasks they are expected to perform in the real world when they joined the marine industry upon graduation. These learning tasks were designed using the CDIO Framework with "build-in" elements that will purposefully create challenges with potential that students will not achieve the desired performance outcomes, hence the term "learning from deliberate failure". The students had earlier learnt of growth mindset in Year 1 from another module. The hypothesis is that "Growth mindset can positively improve students' failure tolerance". Surveys were administered before and after the learning tasks using the School Failure Tolerance Scale, along with questions related to assess growth mindset. Students were also required to write 2 reflection journals on their learning experiences, which were analyzed for their sentiments. This paper first provides a brief introduction to learning from deliberate failure, and literature reviews on failure tolerance and growth mindset, followed by the methodology known as "design-based research" which is used to design the series of learning tasks with elements of deliberate failure". The paper then provides a summary of an earlier effort on learning from deliberate failure that preceded the work reported on in this paper, to provide the proper context of learning, and outlined the scope of this paper. The current work is then covered in details; including findings from student surveys and reflection journals of their learning experience. This was followed by an exploration of areas of improvement in light of the findings.

Keywords: *Deliberate Failure, Growth Mindset, Failure Tolerance, Design-based Research, CDIO Framework*

Introduction

Learning from deliberate failure – often shortened to learning from failure – is a pedagogy whereby the lecturer purposefully (deliberately) design student learning tasks that will produce outcomes not expected, i.e. a failure. (Cheah, 2023). The rationale for doing so is to engage students in deeper learning through reflection on the learning process, that gradually shapes the students' view to see failures as something not to be avoided during learning. Learning from failure is the dominant approach to training of professionals working in high-risk industries such as power plant (including nuclear), airlines, maritime, and chemical processing. Such industries operate on 'complex systems' (Cook, 1998, 1999, 2020) with the following characteristics: (i) they contain changing mixtures of failures latent within them; (ii) they always run in degraded mode; (iii) changes to the system can introduce new forms of failure; (iv) safety is a characteristics of systems and not of their components; (v) views of 'causes' limit the effectiveness of defenses against future events. In these industries, the consequence of a failure if unmitigated, is often catastrophic. Failure-free operations thus require experience with failure; and timely respond with the proper corrective actions. Training is often done using simulators, where engineers and technicians practiced on handling various failure scenarios.

Failure Tolerance and Growth Mindset

Failure is defined as an outcome that deviates from desired results – a lack of success (Edmondson, 2023). Learning from failure does not happen on its own. Rather, it is a skill that needs to be learned and practiced. Failure tolerance is defined as "a tendency to respond to failure in a relatively constructive manner" (Kim & Clifford, 1988). Studies by Clifford, et al (1988) had shown that failure tolerance is a reliable predictor of responses to failure. Failure tolerance can be measured using the School Failure Tolerance Scale (Clifford, 1988), or SFTS in short. Subjects with high failure tolerance responded more constructively to failure than did subjects with low failure tolerance (Kim & Clifford, 1988).

Growth mindset (GM) is the belief that your abilities, talents, and skills can be developed over time with effort,

learning, and dedication (Sousa, 2023). Dweck (2006) classifies two distinct mindset groups on a continuum: Growth and Fixed. Those inhabiting a fixed mindset tend to believe that skills and abilities are innate. In other words, one is born smart or talented. Individuals with a fixed mindset tend to view failure as permanent, generally choose to pursue easier tasks and are less likely to persist in the face of challenges. Growth mindset individuals, on the other hand, typically see failure as a chance to learn, embrace challenges as a way to experiment and use creative problem-solving. As noted by Dweck (2015): "In a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work – brains and talent are just the starting point. This view creates a love of learning and a resilience that is essential for great accomplishment."

Given the above, it is reasonable to expect that students with growth mindset will be more open-minded with respect to handling failure, i.e. see failure as an opportunity to learn and improve (Mueller & Dweck, 1998). Indeed much of the literature expounded on the need to develop growth mindset in view of its many advantages. Mindset interventions in particular, were found to be very useful in promoting students' growth mindset (Kapasi & Pei, 2022). Shahagun et al (2021) proposed a pedagogy for growth mindset for higher education and showed that students exposed to the growth mindset teaching pedagogy demonstrated improvement in their growth mindset beliefs. However, one area that is not well studied is the relationship of mindset and resilience to failure.

Methodology: Design-based Research

The approach we adopted is termed design-based research (Reeves, 2006). It aims at developing empirically grounded theories through combined study of both the process of learning and the means that support that process (diSessa & Cobb, 2004; Gravemeijer, 1998). Barab & Squire (2004) provided a broad and generic definition that encompasses most variations on the terminology:

"*A series of approaches, with the intent of producing new theories, artefacts, and practices that account that account for and potentially impact learning and teaching in naturalistic settings*".

Anderson & Shattuck (2012) suggested that a quality design-based research is defined by the following:

- Being situated in a real educational context
- Focusing on the design and testing of a significant intervention
- Using mixed methods
- Involving multiple iterations
- Involving a collaborative partnership between researchers and practitioners
- Evolution of design principles
- Practical impact on practice

One of the primary advantages of design-based research is that it requires practitioners and researchers to collaborate in the identification of real teaching and learning problems, the creation of prototype solutions based on existing design principles, and the testing and refinement of both the prototype solutions and the design principles until satisfactory outcomes have been reached by all concerned. Design research is not an activity that an individual researcher can conduct in isolation from practice; its very nature ensures that progress will be made with respect to, at the very least, clarification of the problems facing teachers and learners, and ideally, the creation and adoption of solutions in tandem with the elucidation of robust design models and principles.

Reeves (2006) suggested a 4-stage process as shown in Figure 1. He further noted that the most noteworthy of design-based research is that design researchers do not emphasize isolated variables, even though they did focus on specific objects and processes in specific contexts. Instead, they try to study those as integral and meaningful phenomena. Because of its iterative and consultative nature, design-based research is unlikely to engender researcher-imposed directives on how problems should be approached (Herrington & Reeves, 2011). It addressed one of the criticisms of contemporary education research which Anderson (2005) expressed as "…those types of research that unilaterally descend for testing in a classroom and then disappear with the researcher once the experiment has been concluded". Quite the contrary, design-based research has the capacity to change the ways that researchers and practitioners together investigate and solve significant educational problems in powerful ways. Again, as noted by Anderson (2005): "Design-based research does not seek for universal solutions but rather for deep understanding of innovations and the factors that affect improvement in local contexts".

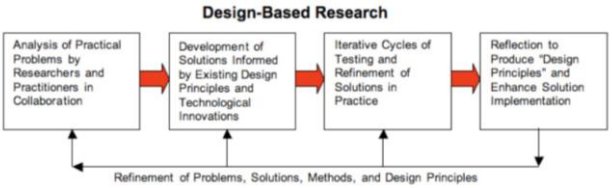


Figure 1. Stages in Design-based Research

Scope for This Paper

The present work is built upon earlier effort by Cheah (2023) who introduced the pedagogy for learning from deliberate failure based on the CDIO Framework. This is followed by a pilot run in Semester 2 of Academic Year 2023/2024 involving Year 2 students from Singapore Polytechnic's (SP) Diploma in Marine Engineering (DMR). The main outcome of DMR is to produce skilled manpower for the marine industry, based on Standards of Training, Certification and Watchkeeping (STCW) Code Table A-III/1 from the International Maritime Organization (IMO, 2010).

The pilot run featured a series of learning tasks lasting a whole semester in the DMR 60-hour core module entitled "Marine Engine Room Simulator Training". Design interventions used include a range of learning tasks using simulator that mimic the preparation of a commercial crude oil tanker to set sail from "cold" condition, to keeping watch at sea and subsequently bring

it back to port (Cheah et al, 2024) . The study divides students into 2 groups: experimental group (44 students) who received various design interventions and control group (33 students) who were guided through the process by the lecturer. Their SFTS were computed based on their responses to pre- and post-test surveys.

In contrary to our expectation, the outcome from the pilot run showed the reverse result: the control group showed an improvement in failure tolerance compared to the experimental group; although statistically the difference is not significant. This can be explained as the control group, having received guidance from the faculty throughout the semester, developed a false sense of confidence, hence reported a higher failure tolerance.

Responses from the reflection journals also proved to be not very useful, as we had used a generic set of questions based on the Gibbs Reflection Cycle (Gibbs, 2013) and students in general responded poorly. That notwithstanding, we gained an important insight that guided the design of current study: that some students remained positive when encountering failures during the various interventions. It then dawned on us that the DMR students had been taught growth mindset in a stakeholder module "Education and Career Guidance 2" (ECG2) within the same semester as "Marine Engine Room Simulator Training". One of the activities in ECG2 requires students to score their own mindset by answering a set of questions adapted from Dweck (2006).

Explanation of Current Work Done

For the current work, which ran for Semester 1, Academic Year 2024/2025, we hypothesized that students with greater growth mindset will be more failure tolerant. Since growth mindset is scored individually for each student, we henceforth conclude that it is necessity to analyze the SFTS scores on an individual basis. We are interested in finding out if high score for GM correlates with high SFTS scores; as well as to continue investigating if the design interventions helped to improve students' failure tolerance.

As required by design-based research, we made some changes for the current study based on learning gained from the pilot run. We also made some changes in the timing when activities with deliberate failure are introduced: namely in the second term, hence freeing up time for students to familiarize with the ship engine and simulator. The learning tasks remained unchanged. Table 1 showed a summary of the students' learning experience for the current study. Table 2 provides brief explanation of each learning task with elements of deliberate failure.

It also worth noting that for current work, because the cohort size of students taking the module "Marine Engine Room Simulator Training" is small – only 41 students in total. This, and the reason of perceived competence mentioned above, led us to decide to do away with the control group.

Table 1. Lesson Plan for Term 1 and Term 2 Activities

Term 1 – Familiarization (NO INTERVENTION INTRODUCED)		
Week	Brief Description of Activity	Key Remarks
1	Cold Ship Start-Up (1) *Familiarization with Engine Room and Power Plant Trainer*	• For all these exercises, no interventions were introduced. • The systems and operational sequences were explained and demonstrated and thereafter the students practiced them, • Instructors step in when students seek help to resolve when they encounter failures.
2	Cold Ship Start-Up (2) *Seawater Cooling Systems Fresh Water Cooling Systems*	
3	Cold Ship Start-Up (3) *Compressed Air System*	
4	Main Power Start-Up *Diesel Generator Start-Up and Paralleling*	
5	Auxiliary System Start-Up *Fuel Oil System Lube Oil System*	
6	Auxiliary Boiler Start-Up *Steam Generation*	
7	Continual Assessment 1 (INDIVIDUAL, 1-hr, 40%): Learning Journal All students submit a report comprising answers to questions posed in each activity for the past 6 weeks. All students are to submit a short reflection report, answering specific 4 questions posed.	
8, 9-11	Mid-semester Test Week – No lesson for this module, followed by 3-week Term Break	
Term 2 – Operation (WITH INTERVENTIONS INTRODUCED)		
Week	Brief Description of Activity	Interventions
12	*Revision of Term 1* Start of Parallel Generator – *after going through the steps in Term 1*	See Table 2
13	Continual Assessment 2 (INDIVIDUAL, 1-hr, 30%): "Cold Ship Start Up to Own Power" Each student is to demonstrate his/her understanding from all earlier lessons.	
14	"One Hour Notice" Preparation to leave port and set sail *Lube Oil Purifier Start up*	See Table 2
15	Repeat of "One Hour Notice" to leave port and set sail	See Table 2
16	Out at Sea: Keeping watch duties and responding to alarms	See Table 2
17	Continual Assessment 3 (INDIVIDUAL, 1-hr, 30%): "One Hour Notice to Departure" and set sail. Each student is to demonstrate his/her understanding from all earlier lessons. Students reflect on their experiences and submit individual reflection journals.	
18	Set Aside for Make-Up Lessons, if needed	
19-20	Semestral Examination (2 weeks) – Not Applicable for this Module	

To avoid survey fatigue among students, we embedded a set of questions related to GM along with the questionnaire for SFTS. Lastly, we also retained the submissions of reflection journals by individual students, but this time we provided them with the following guidance questions to help them focus on key issues to help us with subsequent analysis.

Q.1 What was the "failure" experience?

Briefly describe what went wrong or failed when you carried out the exercise (from starting of main generators to preparing systems for main engine to start) during the Engine simulator lessons.

Q2. What your feelings & thoughts about the experience?

Briefly describe how you feel (e.g. emotion, stress, anger, anxiety or excitement) when you encountered the "failure" situation. In your answer, please discuss if you see benefits from such failure; or how did you manage the feeling that arisen. You may include before, during, and after the encounter.

Q3. What do you think contributed to the situation?

Consider what actions taken by you and/or other people or actions that should have been taken but not done; that have contributed to the situation.

Q4. What did you learn and what could you have done differently?

With references to your answers to Questions 2 and 3 earlier, describe what you learned from this situation, for example, how it changed your view about failure or focus on following the procedures, etc. Also consider if there are skills that you think you need to develop to better handle the situation.

Table 2. Learning Tasks with Deliberate Failure

Example 1: Failure during Main Power Start-Up 2 groups of students will be given Challenge Case A, while another 2 groups will be given Challenge Case B, as explained below. In both cases, students need to analyze and understand the relationship between process variables to make sense of the changes reported in the system dashboard. • Challenge Case A: Sea chest blocked with plastic or other garbage; or strainer plugged with varying degree of dirt. • Challenge Case B: LT Fresh Water Pump with varying degrees of low suction pressure, which could be due to pump wear.
Example 2: Failure during Auxiliary System Start-Up This activity is again to expose students to the relationship between process variables in another important item in the ship's engine. Facilitator will load exercise with any of the following issues causing high compressed air temperature. • Varying degrees of low LT Fresh Water Pump pressure, where potential causes could be air leak on the suction side or pump problem. • Varying degrees of dirty compressor intercoolers, and its impact on system performance in terms of affected process variables (namely temperature and pressure), from which students will infer the "health status of the system.
Example 3: Failure to bring up Parallel Generator For the first activity in Term 2, failure to start the parallel generator mostly stemmed from failure to carry the process in the prescribed manner. What was done differently between the experimental and control groups was that students from the experimental group were asked to reflect on what they did wrong, and why the following the steps mattered. On the other hand, students from the control group were told what went wrong and had the steps explained to them by the Facilitator.
Example 4: Failure to successfully operate the Lube Oil Purifier In the next activity, after successfully started the parallel generator, students will also need to bring into operation the lube oil purifier. Facilitator will take note of how many students still made mistakes in this key step. Facilitator will also demonstrate an example of failure to emphasize that even when all start-up procedures were adhered to correctly. Facilitator will explain the cause and effect to students from the control group, For the experiment group, the cause of the introduced failure will not be made known to students. Students will be asked to provide plausible reasons that can lead to a failure, and potential consequences of each failure. Facilitator can also different failure scenarios for different experimental groups, again to promote peer learning). This will set the context for Continual Assessment 3.

Results and Discussions

The SFTS and GM combined survey was first administered before students embarked on the learning tasks of Table 2 (pre-test) and again after they had completed the learning tasks (post-test). All 41 students responded to the pre-test, but only 31 responded for the post-test. Tables 3 and 4 showed the SFTS and GM scores from the 2 surveys; and correlation analysis to investigate possible relationship between SFTS and GM respectively. All data are based on same number of respondents (N = 31) for consistency in comparison. Student identities were anonymized before analysis.

Table 3. Pre- and Post Test Survey Results

N=31	Pre-Test	Post-Test	p-value
SFTS	3.020	3.017	0.9750
GM	3.068	3.154	0.5410

Table 4. Correlation Analysis (Pre- and Post-Test)

N=31	Pre-Test		Post-Test	
	SFTS	GM	SFTS	GM
SFTS		0.340 p=0.0294		0.293 p=0.1100
GM	0.340 p=0.0294		0.293 p=0.1100	

The results, unfortunately, are inconclusive. Contrary to expectation, failure tolerance after intervention appeared to have decreased instead; albeit only slightly and the change is statistically insignificant. Likewise, the slight increase in growth mindset, while expected, is also statistically insignificant. The observed changes between pre-test and post-test numbers therefore can be attributed to random chance and no conclusion can be drawn. The results when reviewed alongside the reflection (see later) seemed to indicate that the emotional impacts associated with the stress and time-pressure are influencing the SFTS ratings given. Students in general do not respond to the SFTS questions in an objective manner. This is perhaps not too surprising, as experincing failure is not pleasant for most people: failure tends to hurt one's ego and violate one's beliefs and expectations.

Likewise, the relationships between failure tolerance and growth mindset, while showing slight positive correlation, did not lend themselves to definitive explanation: it was statistically significant for the pre-test but not the case for the post-test. The results can be attributed to the small sample size. Only 31 out of 41 responses were used. This is because for the post-test, some students did not complete the survey and/or reflection journal.

Next, we turn to the reflection journal. Here we made use of all respnoses submitted, as we wanted to glean as much as possible on students' learning experiences. For the analysis, we make use of the free version of ChatGPT to help us in performing sentiment analysis. The results are rather comprehensive, and only key findings are summarized here, as shown in Table 5. For more details, including the prompts used, use the LINK here.

Table 5. Pre- and Post Test Survey Results

Phase	Dominant	Focused	Key Features
Before Intervention	Negative (stress, frustration, confusion)	What went wrong?	Feeling of failure dominates
Transition	Mixed (neutral, analytical)	Why did it happen?	Recognizing mistakes and causes
After Intervention	Positive (growth, confidence, motivation)	What did I learn?	Improved problem-solving, teamwork, and confidence

Some of the findings that contributed to Table 5 are now briefly discussed. Firstly and most importantly, we are mindful of the careless use of Generative AI tools in performing such an analysis. We in fact noted cases of student quotes produced by ChatGPT that cannot be found in the source documents (i.e. student responses in the journals). Therefore, we carefully checked the outcomes from ChatGPT in this current study and is satisfied that the findings presented did sufficiently captured the sentiments expressed in the journals. These are now elaborated below.

At the earlier phase of their learning, students express frustration, stress, and confusion as their primary emotions. These negative emotions stem from: (a) Technical issues (e.g. forgetting to open valves, difficulty locating parts), (b) Lack of familiarity with systems (e.g. not knowing required sequences), (c) Communication breakdowns (e.g. unclear instructions, lack of teamwork), and (d) Feeling rushed or overwhelmed (e.g. alarms causing panic, trying to do too much at once).

Through reflections, students analyzed the failure and began to recognize some contributing factors. There is a shift from frustration to understanding the root causes, with a range of mixed of negative and neutral sentiments. Key realizations include: (a) Many failures resulted from rushing and not following proper sequences, (b) Lack of familiarity with the system and its components, and (c) Need for better communication and planning which could have prevented confusion.

From the post-test reflections, we can see evidence of increasing positive sentiments from lessons learnt, as demonstrated in the post-test reflection. Students show a more positive and constructive mindset, focusing on growth and improvement. Common themes include: (a) Failure as a learning opportunity, recognizing that failure helped them improve, (b) Better problem-solving skills arise from systematic thinking and patience, (c) Increased confidence and preparedness, i.e. better equipped to handle similar situations in the future, and (d) Improvement in teamwork and communication: better understanding of clear roles and leadership.

Possible Areas of Improvement

Several areas of improvement had been identified earlier by Cheah et al (2024). Some, such as changes to the timing in introducing learning interventions (in Term 2 only) and used of guidance questions for reflection, had been implemented in this current work. Some other areas of improvement are shared below: some reaffirmed the needs to revise aspects identified in the earlier pilot run but not yet implemented in this current study; others are fresh insights from this current study. Only the latter are discussed here.

Revamp of the DMR Program

This is an on-going effort aimed at the redesign of the DMR program towards an integrated curriculum using the CDIO Framework. Details are provided elsewhere by Cheah et al (2024).Suffice to repeat here is that key feature of the redesign effort is to "spread out" the coverage of basic skills and attitudes needed to support learning in general and learning from failure in particular, in other core modules prior to embarking on the module "Marine Engine Room Simulator Training". This will free up time in this module to facilitate the learning process to engage students in deeper learning from failure.

Redesign of Module "Marine Engine Room Simulator Training" and selected Learning Tasks

The reflection journal results had highlighted some challenging areas for students. An example is that of starting the generator. The revision allocated in Week 12 (see Table 1) may not be sufficient. The module team will review the learning design and time allocation for this segment. Video recording for this task can also be created to allow students to self-practice on their own, after learning the task in Term 1 and before embarking on the assessment in Term 2. Another area worthwhile looking into is to introduce a 'condensed' version of the combined SFTS-GM survey; using a reduced number of questions. We can also explore feasibility on expanding the teaching of growth mindset to include approaches to manage negative emotions in the face of perceived setbacks.

Change in Instructional Approach towards Facilitation

By and large, in order to ensure compliance with IMO requirements, the de facto training approach used is very instruction-directed: Faculty inform students what they need to do each step of the way, leaving very little room for critical thinking, troubleshooting and problem-solving. This is largely the approach taken in Term 1, in order to get students up-to-speed with understanding the simulator system. This can be supplemented with more "probing" questions, using "what if" scenarios to engage students in deeper learning. This can serve as useful approach to design professional development workshops for faculty. The use of prerecorded videos can again be very useful.

Use Student-centred Pedagogy: Collaborative Learning

We can use the CDIO approach to explicitly introduce elements of teamwork and communication into the learning tasks, to help students in managing these non-technical aspects of the process. This can be done using collaborative learning pedagogy whereby there are clear roles for each students and how everyone can contribute to the collective learning. Basic skills in teamworking and communication can be inculcated in other modules beginning from Year 1.

Conclusion

The work presented in this paper yielded the expected positive relationship between growth mindset and failure tolerance, but it is not statistically significant. More useful are the students' responses in the reflection journals, which showed a shift in disposition from the initial frustration with failures which is seen as a setback, to a gradual understanding that failures can serve a useful learning tool. We conclude that the endeavour is still a worthwhile one, as it yielded other valuable insights that can guide subsequent iterations of the learning tasks using deliberate failure using the design-based approach, guided by the CDIO Framework.

References

Anderson, T. & Shattuck, J. (2012). Design-based Research: A Decade of Progress in Education Research? *Educational Researcher*, Vol.41, No.1, pp.16-25

Anderson, T. (2005). Design-based Research and its Application to a Call Centre Innovation in Distance Education, *Canadian Journal of Learning and Technology,* 31(2)

Barab, S. & Squire, K. (2004). Design-based Research: Putting a Stake in the Ground, *Journal of the Learning Sciences*, 13(1), pp.1-14

Cheah, S.M., Tay, D. & Lim, H.L. (2024). Pedagogy for Learning from Failure using CDIO Framework: Marine Engineering Pilot Run, *Proceedings of the 20th International CDIO Conference*, Tunis, Tunisia: Ecole Supérieure Privée d'Ingénierie et de Technologies (ESPRIT)

Cheah, S.M. (2023). Chemical Engineering Education: Pedagogy for Learning from Failure in Process Plant Operations, *Proceedings of the 19th International CDIO Conference*, Trondheim, Norway: Norwegian University of Science & Technology

Clifford, M.M., Kim, A., & McDonald, B.A. (1988). Responses to Failure as Influenced by Task Attribution, Outcome Attribution, and Failure Tolerance, *Journal of Experimental Education*, 57(1), pp.19-37

Clifford, M.M. (1988). Failure Tolerance and Academic Risk-taking and in Ten- to Twelve-year-old Students, *British Journal of Educational Psychology*, Vol.58, pp.15-27

Cook, R.I. (1998, 1999, 2020). How Complex Systems Fail, Revision D (00.04.21), Cognitive Technologies Laboratory, University of Chicago, from https://www.adaptivecapacitylabs.com/HowComplexSystemsFail.pdf

diSessa, A. A. & Cobb, P. (2004). Ontological Innovation and the Role of Theory in Design Experiments, *Journal of the Learning Sciences*, 13(1), pp.77-103

Dweck, C.S. (2015). *Carol Dweck Revisits the 'Growth Mindset'.* Education Week

Dweck, C.S. (2006). *Mindset: The New Psychology of Success*, New York, NY: Random House

Edmondson, A. (2023). *Right Kind of Wrong – The Science of Failing Well,* New York, NY: Atria Books

Gravemeijer, K. (1998). Developmental Research as a Research Method, in *Mathematics Education as a Research Domain: A Search for Identity*; J. Kilpatrick & A. Sierpinska (Eds.), Dordrecht: Kluwer Academic Publishers, pp.277-295

Gibbs, G. (2013). *Learning by Doing. A Guide to Teaching and Learning Methods (Online Edition)*, Oxford Centre for Staff and Learning Development, Oxford Brooks University, Oxford, UK

Herrington, J. & Reeves, T.C. (2011). Using Design Principles to Improve Pedagogical Practice and Promote Student Engagement, *Proceedings of ASCILITE*; Hobart, Tasmania, Australia

IMO (2010), STCW Code Section A-III/1 Chapter III 2010 Res 2), from https://www.edumaritime.net/stcw-code/stcw-iii-1-oicew-dde

Kapasi. A. & Pei, J. (2022). Mindset Theory and School Psychology, *Canadian Journal of School Psychology*, Vol.37(1), pp.57-74

Kim, A. & Clifford, M.M. (1988). Goal Source, Goal Difficulty, and Individual Difference Variables as Predictors of Response to Failure, *British Journal of Educational Psychology*, 58(1), pp.28-43

Mueller, C.M. & Dweck, C.S. (1998). Praise for Intelligence Can Undermine Children's Motivation and Performance, *Journal of Personality and Social Psychology*, 75, pp.33-53

Shahagun, M.A., Moser, R. Shomaker, J. & Fortier, J. (2021). Developing a Growth Mindset Pedagogy for Higher Education and Test its Efficacy, *Social Sciences & Humanities Open*, 4, 100168

Reeves, T. C. (2006). Design Research from a Technology Perspective, in *Educational Design Research*, J. van den Akker, K. Gravemeijer, S. McKenney & N. Nieveen (Eds.), London: Routledge, pp.52-66

Sousa, B.J. (2023). Growth Mindset. In: *Encyclopedia of Heroism Studies*. Allison, S.T., Beggan, J.K. & Goethals, G.R. (eds)., New York, Springer, from https://doi.org/10.1007/978-3-031-17125-3_88-1

IMPACT OF MICROLEARNING-SUPPORTED FLIPPED LABORATORY ON STUDENTS' LEARNING MOTIVATION AND ACHIEVEMENTS IN APPLIED CHEMISTRY

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Abstract

This study investigated the impact of a microlearning-supported flipped laboratory (MSFL) approach on students' learning motivation and achievements in Applied Chemistry. Laboratory experiences are essential in science education, yet traditional setups often present challenges. The flipped laboratory model, enhanced with microlearning, addresses these by enabling pre-class engagement with theoretical concepts and optimising hands-on learning during lab sessions. A mixed-method quasi-experimental design was employed with 60 polytechnic students divided into experimental (n=36) and control (n=24) groups. The experimental group received MSFL instruction for three lab sessions, while the control group received conventional instruction. The intervention utilised Edpuzzle, an interactive video platform that presents essential information in small, manageable chunks with embedded quiz questions to reduce cognitive load and provide immediate feedback. Data were collected through pre- and post-surveys based on the Motivated Strategies for Learning Questionnaire (MSLQ), pre- and post-quizzes, and open-ended questions. Quantitative analysis revealed significantly higher post-quiz scores for the experimental group compared to the control group, indicating improved learning achievement. However, despite consistently higher motivation scores in the experimental group, no significant differences were found in motivation measures between groups. Qualitative analysis of student feedback highlighted benefits such as enhanced preparation, conceptual reinforcement, and self-regulated learning, as well as challenges related to content design and technical issues. Based on these findings, several recommendations emerged for improving MSFL: ensuring alignment between pre-laboratory videos and in-lab procedures, addressing technical issues to enhance engagement, and incorporating additional formative assessments to support motivation and self-regulated learning. This study contributes to science education by providing evidence for the effectiveness of integrating microlearning into flipped laboratory instruction. It highlights both the potential for improved learning outcomes and the complexities of influencing student motivation in laboratory settings, offering valuable insights for educators seeking to enhance student engagement and achievement in science courses.

Keywords: *flipped laboratory, microlearning, motivation, learning achievement, science education*

Introduction

Laboratory experiences play a crucial role in Science education, enhancing student engagement by bridging theoretical knowledge with practical application (Duban et al., 2019; Hofstein & Lunetta, 2003).

Despite their importance, several challenges hinder the effectiveness of laboratory lessons:

1. Varying Student Comprehension: Differences in prior knowledge and cognitive abilities create disparities in understanding, making it challenging for educators to address individual needs effectively. Some students may find the content repetitive and unchallenging, while others may find it novel and overwhelming (Mok, 2012).
2. Cognitive Overload: Extensive laboratory manuals and information-heavy materials can overwhelm students, limiting their ability to focus on core concepts (Johnstone et al., 1994).
3. Limited Personalised Feedback: Large class sizes make it difficult to provide individualised feedback, which is essential for effective learning (Gutiérrez et al., 2011).

To mitigate these challenges, educators have incorporated pre-laboratory activities such as instructional videos, interactive simulations and pre-lab worksheets, which reduce information overload and promote deeper engagement (Johnstone et al., 1994).

The flipped laboratory, an extension of the flipped classroom method, enhances learning by shifting theoretical instruction to pre-lab activities, allowing students to engage in higher-order cognitive processes such as analysis and evaluation (Claesson et al., 2020; Loveys & Riggs, 2018). This method optimises in-lab interactions and promotes a deeper understanding of scientific principles.

Microlearning, which delivers information in small, structured segments, reduces cognitive load and enhances engagement (Kossen & Ooi, 2021; Leong et al., 2020). Edpuzzle, a video application, integrates interactive features and personalised feedback, enabling students to pause, rewind, and track progress, fostering active learning and boosting motivation (Fidan, 2023; Ramasany et al., 2022; Shelby & Fralish, 2021).

As Schnotz et al. (2009) highlight, motivated learners invest more mental effort, leading to improved learning outcomes. Thus, integrating microlearning within flipped laboratory may enhance student motivation, manage cognitive load and improve academic performance. This research, hence, investigates the impact of MSFL on students' learning motivation and achievements in Applied Chemistry.

Literature Review

Pre-lab activities play a crucial role in enhancing students' learning experiences and motivation in laboratory settings. Moozeh et al. (2019) emphasised the benefits of online pre-labs, such as instructional videos, which offer students unlimited access, flexibility, cost-effectiveness, and real-time feedback, leading to improved student preparedness, confidence, sense of autonomy, and experiment efficiency. Similarly, Gregory and Di Trapani (2012) emphasised that well-designed pre-laboratory preparation aids students in understanding and learning. Jolley et al. (2016) introduced visual and critical thinking strategies in pre-lab activities, effectively shifting cognitive learning to the pre-lab phase to reduce cognitive overload at the start of the class. While their study did not show significant improvements in academic performance, the students felt more prepared and motivated for laboratory work. These findings collectively underscore the importance of pre-lab activities in promoting student readiness and motivation for laboratory experiments.

The flipped laboratory approach, an extension of the flipped classroom pedagogy, further enhances pre-lab activities. Claesson et al. (2020) described flipped laboratory as shifting essential knowledge acquisition to pre-lab activities, allowing students to engage in higher-order thinking during lab sessions. This aligns with Bloom's taxonomy, where class time is dedicated to application and analysis rather than passive learning. Mellefont and Fei (2016) found benefits in terms of increased class time for laboratory tasks, flexible preparation opportunities, and access to valuable resources for revision. Moreover, Mshayisa and Basitere (2021) emphasised that well-designed and well-executed flipped laboratory classes can foster independent learning and critical thinking, improving learning outcomes. De La Flor López et al. (2016) further noted that online pre-lab quizzes enhance student readiness for laboratory sessions through real-time formative feedback.

Microlearning principles are increasingly integrated into flipped laboratories to optimise student learning. As defined by Gutierrez et al. (2011), microlearning involves bite-sized instructional units that improve engagement and retention. Nikou and Economides (2018) found that mobile-based microlearning offers just-in-time and flexible learning, catering to individual needs. Fidan (2023) further demonstrated that microlearning-supported flipped classrooms enhance engagement, self-regulation skills, learning performance, and motivation while reducing cognitive overload. Applied to flipped laboratories, microlearning makes content more manageable and appealing, contributing to better student outcomes and satisfaction.

Motivation, explained through Self-Determination Theory (SDT), is a multifaceted concept with distinct categories based on the reasons or goals driving an action. Intrinsic motivation stems from inherent interest while extrinsic motivation is rooted in achieving separable outcomes (Ryan & Deci, 2000). Muir (2021) further delves into the psychological needs integral to SDT, highlighting competence, autonomy, and relatedness as key psychological needs that influence motivation. Abeysekera and Dawson (2014) connect these needs to the flipped classroom, suggesting that fostering active participation and environments satisfying autonomy, competence, and relatedness enhances intrinsic motivation. Supporting this, Sergis et al. (2018) found that students in a Flipped Classroom Model (FCM) reported higher autonomy, competence and relatedness, facilitated by collaborative activities, scaffolding activities as well as peer- and mentor-supported social contexts.

Aims of Study and Research Questions

This study aimed to investigate the effects of MSFL intervention on students' learning motivation and learning achievements. The following research questions were formulated to guide the data analysis:

RQ1: Does using MSFL improve students' learning achievement more than conventional instruction?

RQ2: Does using MSFL improve students' motivation (i.e. intrinsic motivation, extrinsic motivation, self-efficacy and task value) more than conventional instruction?

RQ3: What were the students' learning experiences when adopting MSFL?

Method

This study employed a mixed-method quasi-experimental design implemented across three laboratory lessons.

Convenience sampling was used to recruit participants from the module A391 Materials Processing class in the Polytechnic. A total of 60 students (39 females, 21 males) participated in the study. 18.3% were 17 years old, 45.0% were 18, 26.7% were 19, and 10.0% were 20 years old and above. All participants were informed that participation was voluntary and their responses would be kept confidential. Ethical approval was obtained from the Polytechnic In-House Ethics Review Committee.

The participants were divided into two groups: an experimental group (n=36) and a control group (n=24). The experimental group received the MSFL intervention,

while the control group received conventional laboratory instruction for all three laboratory lessons.

The experimental group completed pre-class activities one week before each of the three lab sessions. These activities involved watching Edpuzzle videos of the lab practical with embedded quiz questions. This was followed by short in-class discussions to address the pre-class activity.

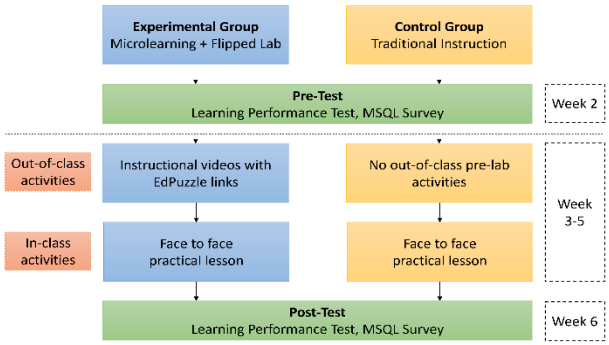


Figure 1. Experimental procedure

Data were collected using online questionnaires (pre-survey and post-survey) and quizzes (pre-quiz and post-quiz). The pre-survey and pre-quiz were administered before the start of the three laboratory sessions to assess students' baseline levels of learning motivation and prior knowledge of the laboratory topics, respectively. The post-survey and post-quiz were administered after the three laboratory sessions to measure any changes in these aspects. Figure 1 shows the experimental procedure. The surveys were based on the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993), which is a validated and reliable instrument for assessing students' motivation. In this study, 17 items with 7-point Likert scale (ranged from 1-"not at all true of me" to 7-"very true of me") from four MSLQ subscales were used:

- intrinsic motivation (3 items, sample item: "In this course, I prefer course material that arouses my curiosity, even if it is difficult to learn"),
- extrinsic motivation (3 items, sample item: "If I can, I want to get better grades in this course than most of the other students"), and
- self-efficacy (5 items, sample item: "I'm confident I can do an excellent job on the assignments and tests in this course").
- task-value (6 items, sample item: "I think I will be able to use what I learn in these practical lessons in other lessons.").

The quizzes consisted of 15 multiple-choice questions designed by the instructor and validated by an expert within Republic Polytechnic (RP) who was not involved in the research team.

The experimental group additionally answered two open-ended questions in the post-survey to provide qualitative feedback on their experiences with the MSFL intervention.

Quantitative data were analysed using IBM SPSS version 24.0. Based on the Shapiro-Wilk normality test, it was found that not all samples from the experimental and control groups followed a Gaussian distribution. Therefore, non-parametric Mann-Whitney U test was used for measuring between-group differences at 0.05 level of significance.

Qualitative responses were analysed thematically by two independent researchers to identify emerging themes and ensure credibility (Braun & Clarke, 2006; Patton, 1999).

Results

Table 1 presents the means and standard deviations for the quiz scores and the four MSLQ subscales (Intrinsic Motivation, Extrinsic Motivation, Self-Efficacy, and Task-Value) for both the control (N=24) and experimental (N=36) groups at pre-test and post-test. In the pre-test, the experimental group showed slightly higher mean scores across all measures compared to the control group. This trend continued in the post-test, with both groups demonstrating improvements in quiz scores and most motivation subscales.

Table 1. Descriptive Statistics

		Pre-Test		Post-Test	
		Control (N=24)	Experimental (N=36)	Control (N=24)	Experimental (N=36)
Learning Achievement	Mean	4.96	5.94	10.79	12.17
	Std. Deviation	1.90	2.01	2.40	2.26
Intrinsic Motivation	Mean	4.49	5.12	4.90	5.13
	Std. Deviation	1.42	1.20	1.36	1.28
Extrinsic Motivation	Mean	5.56	5.78	5.19	5.35
	Std. Deviation	1.45	1.17	1.29	1.35
Self-Efficacy	Mean	4.00	4.51	4.69	4.84
	Std. Deviation	1.21	1.14	1.23	1.26
Task-Value	Mean	4.68	5.13	5.03	5.25
	Std. Deviation	1.25	1.16	1.29	1.22

Table 2 displays the correlations and reliability measures for the post-survey ratings of the four MSLQ subscales. All subscales demonstrated high internal consistency, with Cronbach's alpha values ranging from .86 to .95. Strong positive correlations were observed between all subscales ($r \geq .84$, $p < .01$), indicating a high degree of interrelation among the motivation constructs.

Table 2. Correlations and reliabilities

	M	SD	α	1	2	3	4	5
1. Learning Achievement (LA)	11.62	2.39	-	-				
2. Intrinsic Motivation (IM)	5.04	1.30	.91	.11	-			
3. Extrinsic Motivation (EM)	5.29	1.32	.86	.048	.84**	-		
4. Self-Efficacy (SE)	4.78	1.24	.94	.132	.89**	.85**	-	
5. Task-Value (TV)	5.16	1.24	.95	.158	.93**	.90**	.89**	-

*α denotes Cronbach's alpha; **p<.01*

To ensure the comparability of the experimental and control groups at baseline, Mann-Whitney U tests were conducted on the pre-test scores (see Table 3). The results indicated no significant differences between the groups on any of the measures ($p > .05$ for all comparisons). This suggests that the groups were homogeneous at the start of the intervention, allowing for meaningful comparisons of post-test results.

Table 3. The Mann-Whitney U test results of pre-quiz and pre-survey for the two groups of students

	Mann-Whitney U	Z	p
Learning Achievement	308	-1.892	.058
Intrinsic Motivation	327	-1.591	.112
Extrinsic Motivation	404	-.426	.670
Self-Efficacy	317	-1.739	.082
Task-Value	333	-1.497	.134

Mann-Whitney U tests were also used to compare the post-test scores between the experimental and control groups (see Table 4). The analysis revealed a significant difference in quiz scores (U = 293, Z = -2.116, p = .034), with the experimental group (M = 12.17, SD = 2.26) outperforming the control group (M = 10.79, SD = 2.40). This suggests that the MSFL intervention had a positive effect on students' learning achievements. Regarding motivation, the experimental group showed slightly higher mean scores across all MSLQ subscales compared to the control group. However, these differences were not statistically significant.

Table 4. The Mann-Whitney U test results of post-quiz and post-survey for the two groups of students

	Mann-Whitney U	Z	p
Learning Achievement	293	-2.116	.034
Intrinsic Motivation	377	-.834	.404
Extrinsic Motivation	397	-.533	.594
Self-Efficacy	384	-.718	.473
Task-Value	379	-.794	.427

These results indicate that while the intervention appeared to improve learning achievements, it did not significantly affect students' motivation as measured by the MSLQ subscales, despite the consistently higher motivation scores in the experimental group.

The results from the qualitative data, collected through open-ended questions, are organised into two main categories: benefits and challenges of the MSFL.

The following were some benefits of MSFL as suggested from the thematic analysis:

- Pre-Class Preparation: The most frequently mentioned benefit (40.48%) involved the value of pre-class activities in preparing students for the laboratory sessions. Students appreciated the opportunity to familiarise themselves with the upcoming practical work *("I'd like that I get to familiarise myself with pre-reading activities before my practical lesson"*). This pre-exposure allowed them to develop a foundational understanding and anticipate the learning objectives *("It gives me a heads-up of what to expect for the next few lessons and gives me a gist of what I can learn in future sessions"*).
- Conceptual Reinforcement: Students (33.33%) highlighted the effectiveness of the intervention in solidifying their grasp of laboratory concepts. By watching videos and engaging with the material beforehand, students felt better prepared for the hands-on activities *("It gives a good understanding of the process and procedure of the practical lab lessons"*). Observing the visual demonstrations *("I get to see the actual process which helps me better understand the concepts"*) facilitated a deeper connection between theory and practice.
- Facilitation of Self-Regulated Learning: A smaller portion of students (14.29%) emphasised the intervention's role in promoting self-regulated learning. The embedded quizzes within the pre-class activities (*"It also has short quizzes and videos to watch which could help me gauge my understanding of the next topic I am going to learn"*) were seen as valuable tools for self-assessment. Students also appreciated the opportunity to clarify any uncertainties before the laboratory session ("*Immediate answers so that students can do more research to bring up more questions and understanding of the topic*").
- Engagement and Interaction: While less frequent (11.90%), some students commented on the engaging and interactive nature of the pre-class activities ("*It was fun and very interactive. The questions were easy and doable*"). The immediate feedback provided by the quizzes ("*I like that it can test us on what we learn immediately*") was perceived as a positive aspect.

The following were some challenges of MSFL as suggested from the thematic analysis:

- Content and Delivery Design: Students identified challenges related to the content and delivery design of the pre-class materials (36.00%). Some students expressed a desire for more detailed explanations within the microlearning activity ("*A bit more could be explained…").* Additionally, a few students reported inconsistencies between the video demonstrations and the actual laboratory procedures ("*It was very different from the practical we carry out in the videos shown and some of the values were changed or reduced to a lower one*").
- Technical Factors: Technical issues with the Edpuzzle platform were another point of concern (36.00%). Students mentioned the inability to skip certain sections ("*For Edpuzzle, I'm not allowed to skip*") and technical glitches within the videos ("*Some of the videos were a bit bugged*") as hindrances to their learning experience.
- Time and Effort Considerations: A smaller group of students (28.00%) expressed concerns regarding the time commitment required for the pre-class activities. The mandatory nature of the pre-work ("*We have to do it*") and the perceived length of the activities ("*It can be quite lengthy*") were aspects that some students found challenging.

Discussion

The results of this study provide insights into the effectiveness of an MSFL approach in enhancing students' learning achievements and motivation in an Applied Chemistry module. The discrepancy between improved learning achievement and unchanged

motivation in the MSFL intervention likely stems from technical issues with Edpuzzle, content design challenges, and the mandatory nature of pre-work activities that fostered compliance rather than enthusiasm. While providing cognitive benefits, these factors created friction that counteracted potential motivational gains, suggesting that learning outcomes and student engagement may be influenced by different aspects of educational design. Based on the findings, several recommendations can be made for lesson design and implementation. First, ensuring alignment between pre-laboratory instructional videos and in-lab procedures can improve clarity and student confidence. Second, addressing technical issues, such as allowing students to navigate video content more flexibly, may enhance engagement. Finally, incorporating additional formative assessments, such as open-ended reflections or peer discussions, could further support motivation and self-regulated learning. These considerations provide practical insights for educators seeking to refine flipped laboratory implementations.

Limitations of Study and Future Research

While the intervention demonstrated potential in enhancing achievement scores, several limitations warrant consideration. The study's small sample size and brief intervention period constrain the generalizability of findings and our understanding of long-term effects. Future research should address these limitations by employing larger, more diverse samples across multiple institutions and conducting longitudinal studies to assess sustained impacts. Moreover, incorporating in-depth qualitative methods such as focus groups or semi-structured interviews could yield richer insights into students' experiences and perceptions. To further explore the intervention's efficacy, subsequent studies could investigate its impact on self-regulated learning using validated instruments like the MSLQ self-regulation subscale (Pintrich et al., 1993). Future efforts should also focus on optimising the design and delivery of microlearning components. By addressing these limitations and pursuing these research directions, the field of science education can gain valuable insights to inform the development of more effective, student-centred learning experiences that foster autonomy and deep understanding in laboratory settings.

Conclusion

This study demonstrates the potential of MSFL approaches to significantly enhance student learning achievements in Applied Chemistry, despite no quantitative evidence of improved motivation. Qualitative feedback revealed perceived motivational benefits, including enhanced pre-class preparation, reinforced conceptual understanding, and facilitated self-regulated learning. However, the complex nature of student motivation in laboratory contexts and implementation challenges underscore the need for careful design and ongoing refinement. These findings contribute to the literature on innovative science laboratory education approaches, suggesting that while MSFL can improve learning outcomes, further research is needed to optimise their motivational impact and address implementation issues. Educators and instructional designers should consider incorporating these approaches in laboratory settings while remaining mindful of potential obstacles. Future research should focus on refining these methods, investigating their long-term effects, and developing a more nuanced understanding of their influence on student motivation and learning in science education.

References

Abeysekera, L., & Dawson, P. (2014). Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. Higher Education Research & Development, 34(1), 1-14. https://doi.org/10.1080/07294360.2014.934336

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa.

Claesson, L., Kans, M., Hakansson, L., & Nilsson, K. (2020). STEM Education on equal terms through the flipped laboratory approach. (pp. 46-62). Springer.

De la Flor López, S., Ferrando, F., & Fabregat-Sanjuan, A. (2016). Learning/training video clips: an efficient tool for improving learning outcomes in Mechanical Engineering. International Journal of Educational Technology in Higher Education, 13(6). https://doi.org/10.1186/s41239-016-0011-4

Duban, N., Aydoğdu, B., & Yüksel, A. (2019). Classroom Teachers' Opinions on Science Laboratory Practices. Universal Journal of Educational Research, 7(3), 772-780. https://doi.org/10.13189/ujer.2019.070317

Fidan, M. (2023). The effects of microlearning-supported flipped classroom on pre-service teachers' learning performance, motivation and engagement. Education and Information Technologies, 28, 12687–12714. https://doi.org/10.1007/s10639-023-11639-2

Gregory, S.-J., & Di Trapani, G. (2012). A Blended Learning Approach to Laboratory Preparation. International Journal of Innovation in Science and Mathematics Education, 20(1), 56-70. Retrieved from https://openjournals.library.sydney.edu.au/index.php/CAL/article/download/6650/7296

Gutiérrez Rojas, I., Crespo García, R. M., & Delgado Kloos, C. (2011). Orchestration and Feedback in Lab Sessions: Improvements in Quick Feedback Provision. Towards Ubiquitous Learning. EC-TEL 2011. 6964, pp. 424–429. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-23985-4_33

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. Science Education, 88(1), 28-54. https://doi.org/10.1002/sce.10106

Johnstone, A. H., Sleet, R. J., & Vianna, J. F. (1994). An information processing model of learning: Its application to an undergraduate laboratory course in chemistry. Studies in Higher Education, 19(1), 77-87. https://doi.org/10.1080/03075079412331382163

Jolley, D. F., Wilson, S. R., Kelso, C., O'Brien, G., & Mason, C. E. (2016). Analytical Thinking, Analytical Action: Using Prelab Video Demonstrations and e-Quizzes To Improve Undergraduate Preparedness for Analytical Chemistry Practical Classes. Journal of Chemical Education, 93(11), 1855–1862. https://doi.org/10.1021/acs.jchemed.6b00266

Kossen, C., & Ooi, C. Y. (2021). Trialling micro-learning design to increase engagement in online courses. Asian Association of Open Universities Journal, 16(3), 299-310. https://doi.org/10.1108/AAOUJ-09-2021-0107

Leong, K., Sung, A., Au, D., & Blanchard, C. (2020). A review of the trend of microlearning. Journal of Work-Applied Management, 13(1), 88-102. https://doi.org/10.1108/jwam-10-2020-0044

Loveys, B. R., & Riggs, K. M. (2019). Flipping the laboratory: improving student engagement and learning outcomes in second year science courses. International Journal of Science Education , 41(1), 64-79. https://doi.org/10.1080/09500693.2018.1533663

Mellefont, L., & Fei, J. (2016). Student perceptions of 'flipped' microbiology laboratory classes. International Journal of Innovation in Science and Mathematics Education, 24(1), 24-35. Retrieved from https://openjournals.library.sydney.edu.au/CAL/article/view/8300

Mok, H. N. (2012). Student Usage Patterns and Perceptions for Differentiated Lab Exercises in an Undergraduate Programming Course. IEEE Transactions on Education, 55(2), 213-217. https://doi.org/10.1109/te.2011.2162070

Moozeh, K., Farmer, J., Tihanyi, D., Nadar, T., & Evans, G. J. (2019). A Prelaboratory Framework Toward Integrating Theory and Utility Value with Laboratories: Student Perceptions on Learning and Motivation. Journal of Chemical Education, 96(8), 1548–1557. https://doi.org/10.1021/acs.jchemed.9b00107

Mshayisa, V. V., & Basitere, M. (2021). Flipped laboratory classes: Student performance and perceptions in undergraduate food science and technology. Journal of Food Science Education, 20(4), 208-220. https://doi.org/10.1111/1541-4329.12235

Muir, T. (2021). Self-determination theory and the flipped classroom: a case study of a senior secondary mathematics class. Mathematics Education Research Journal, 33, 569–587. https://doi.org/10.1007/s13394-020-00320-3

Nikou, S. A., & Economides, A. A. (2018). Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high school students. Journal of Computer Assisted Learning, 34(3), 269-278. https://doi.org/10.1111/jcal.12240

Pintrich, P. R., Smith, D. A., Garcia, T., & Mckeachie, W. J. (1993). Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (MSLQ). Educational and Psychological Measurement, 53(3), 801-813. https://doi.org/10.1177/0013164493053003024

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. Health Services Research, 34(5 Pt 2), 1189-1208.

Ramasany, V., Md Noor, N., & Mohd Zaid, N. (2022). Effects of Learning Using EDPUZZLE Interactive Video Application on Students' Interest, Engagement and Achievement in Science Subjects. Innovative Teaching and Learning Journal, 6(2), 59-72. https://doi.org/10.11113/itlj.v6.111

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. Contemporary Educational Psychology, 25(1), 54-67. https://doi.org/10.1006/ceps.1999.1020

Schnotz, W., Fries, S., & Horz, H. (2009). Some Motivational Aspects of Cognitive Load Theory. In S. Wosnitza, A. Karabenick, A. Efklides, & P. Nenninger (Eds.), Contemporary Motivation Research: From Global to Local Perspectives (pp. 86-113). Göttingen: Hogerefe.

Sergis, S., Sampson, D. G., & Pelliccione, L. (2018). Investigating the impact of Flipped Classroom on students' learning experiences: A Self-Determination Theory approach. Computers in Human Behavior, 78, 368-378. https://doi.org/10.1016/j.chb.2017.08.011

Shelby, S. J., & Fralish, Z. D. (2021). Using Edpuzzle to improve student experience and performance in the biochemistry laboratory. Biochemistry and Molecular Biology Education, 49(4), 529-534. https://doi.org/10.1002/bmb.21494

Enhancement of Educational Methods to Improve Understanding of Convolutional Operations through Impulse Response Measurement

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The National Institute of Technology (KOSEN), Gifu College consists of five departments: Mechanical Engineering, Electrical and Computer Engineering, Electrical Control Engineering, Civil Engineering, and Architecture. Fourth-year students in the Department of Electrical and Computer Engineering conduct a signal processing experiment as part of the "Electrical and Computer Engineering Laboratories" course. The purpose of this experiment is to facilitate students' understanding of signal processing by linking mathematical operations with tangible outcomes. However, many students tend to focus solely on the results of the processing without fully grasping the underlying principles. Furthermore, lectures in related fields often emphasize mathematical concepts, offering few opportunities for students to connect theory with real-world physical phenomena.

To address these challenges, this study aimed to improve the educational approach used in the signal processing experiment. To enhance students' comprehension, a demonstration of room acoustic impulse response measurement was incorporated into the course. This initiative was a collaborative effort between faculty members and technical staff from both the Department of Electrical and Computer Engineering and the Department of Architecture. The class followed this sequence: preparatory study (acquisition of foundational knowledge), demonstration of room acoustic impulse response measurement (understanding practical applications), programming exercises (reinforcing mathematical operations), and report writing. The integration of hands-on demonstrations with theoretical instruction was intended to bridge the gap between abstract concepts and real-world applications.

This paper reports on the structure and educational effectiveness of the classes conducted in 2022 and subsequent years. An analysis of students' experimental reports indicated that the quality of submissions improved when the demonstration was included. Additionally, a student questionnaire revealed that the demonstration had a positive impact on students' understanding of and interest in the subject.

Keywords: *experiment, teaching method, mathematical processes and physical phenomena, academic interest of students*

Introduction

With the advancement of digital technologies in sound and acoustics, there is an increasing demand for engineers with specialized knowledge and skills in these areas. In response to this need, we have been conducting a signal processing experiment as part of the course "Electrical and Computer Engineering Laboratories" since 2021. In 2022, we introduced a demonstration involving room acoustic impulse response measurements to enhance the educational experience. This course is offered to fourth-year students (approximately 19 years old) at the National Institute of Technology (KOSEN), Gifu College.

This paper presents an overview and evaluation of the experiment in the following structure: First, the course outline and educational objectives are described. Next, we detail the enhancements made to the teaching methods. We then present the results and discussion for academic years 2022 and 2023. Finally, we report ongoing developments in 2024 and 2025.

Overview of the Course

The "Electrical and Computer Engineering Laboratories" course for fourth-year students is designed to deepen their understanding of both fundamental and applied technologies in electrical, electronic, and computer engineering through hands-on experimental practice. Students are required to submit a report for each experiment after completing the class. In this course, students are divided into ten groups of 4–5 members to conduct practical experiments, with each student responsible for writing their own individual report.

The course covers several experimental themes, one of which is the subject of this study. It consists of one weekly session, totaling 180 minutes, divided into two consecutive 90-minute periods. Each experimental theme is typically completed within a single-week session, although some themes extend across three consecutive weekly sessions. The course emphasizes student-led experimental activities, with multiple faculty members

and technical staff supporting the process by explaining key points, checking experimental results, and conducting oral examinations.

Students conduct experiments based on manuals prepared by instructors. They are expected to read these manuals in advance and develop an understanding of the experimental procedures and objectives before class. At the end of each session, students deepen their understanding through oral examinations conducted by instructors.

After class, students are assigned individual study tasks and required to submit a written report. Each report includes a summary of the principles and theoretical background, a description of the experimental procedures and results, and a discussion of the findings. Through this process, students develop essential skills in the fields of electrical and electronic engineering and computer technology, such as investigation, analysis, research, and problem solving.

Improved Educational Methods

An experimental theme for signal processing was implemented in this course in 2021. In that year, we conducted a Multimedia Signal Processing experiment focused on programming exercises. In this experiment, students used Python to apply filters, perform convolution, and conduct frequency analysis on image and sound data. Since 2022, the experiment has specialized in signal processing in room acoustics, under the title “Acoustic Signal Processing.” In addition to conventional programming exercises, it includes a demonstration of acoustic impulse response measurements conducted in a room. The purpose of incorporating this demonstration was to provide students with an example of how acoustic signals are acquired in practice, thereby helping them understand the real-world application of signal processing.

As Tachibana (2012) notes, an impulse response is the output of a system when an impulse is applied as an input. It can be transformed using the Fourier transform to reveal the transfer characteristics of the system across a range of frequencies. In the context of architectural spaces, the room acts as a system. Therefore, the impulse response measured in a room characterizes the acoustic transmission path between the sound source and listening position at the time of measurement, effectively reflecting the acoustic properties of the room. During impulse response measurement, a test sound, such as an impulse, is emitted from a nondirectional speaker placed in the room, and both the direct and reflected sounds are captured by a microphone (Figure 1).

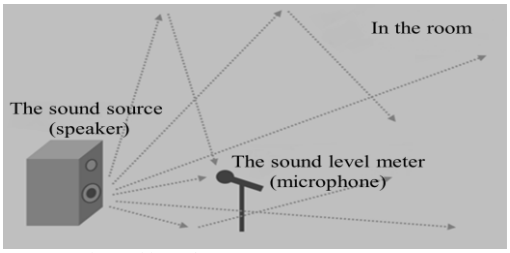


Figure 1. Overview of impulse response measurements

An impulse response demonstration was conducted using the TSP (Time-Stretched Pulse) method. This method was selected because it provides a high signal-to-noise ratio and enables accurate waveform acquisition, even in large spaces.

The TSP signal was generated by the acoustic analysis system DSSF3 real-time analyzer (Yoshimasa Denko), amplified by a YAMAHA XM4180 amplifier, and emitted through a coaxial nondirectional speaker (Listude, Scenery). Direct and reflected sounds were captured using a sound level meter (Ono Sokki, LA-1441). In accordance with International Organization for Standardization (ISO) guidelines ISO3382-1 (2009) and ISO3382-2 (2008), the sound source (speaker) was placed at the center of the room, and the receiving point (sound level meter) was positioned 1.0 meter away from the source. Both the speaker and sound level meter were set at a height of 1.5 meters from the floor, corresponding approximately to the height of a standing human ear.

Before the measurements, students were provided with a verbal explanation of the procedure. They then observed a live demonstration of the measurement, viewed the resulting impulse response waveforms, and listened to the corresponding audio outputs. After the demonstration, the same equipment was used to play and record several anechoic sound sources prepared by each student through the speakers.

The demonstration was conducted in the second gymnasium of NIT, Gifu College. This location was chosen because the large space and limited sound-absorbing surfaces made it easier for students to perceive acoustic reverberations.

In the proposed experimental method, students conducted programming exercises using impulse response data obtained from the measurements. This exercise aimed to help students understand signal processing by linking mathematical operations with tangible results. Specifically, the students performed convolution and frequency analyses using the Fourier transform.

Convolution is a mathematical operation widely used in image and sound processing. It involves two continuous functions, $f(t)$ and $g(t)$, and is defined by the following equation:

$$\int_a^b f(x)g(t-x)dx \qquad (1)$$

In this experiment, the impulse response waveform is denoted as $h(t)$, and the convolution of the impulse response with an arbitrary input waveform $f(t)$ is calculated as follows:

$$h(t) * f(t) = \int_{-\infty}^{\infty} h(x)f(t-x)dx \qquad (2)$$

The resulting waveform represents the original signal $f(t)$ with spatial reverberations of the room acoustics added through convolution with the impulse response.

The Fourier transform is another fundamental technique used in acoustic signal analysis. It decomposes a time-domain signal into its constituent frequency components, enabling visualization of their magnitudes in the form of a spectrogram.

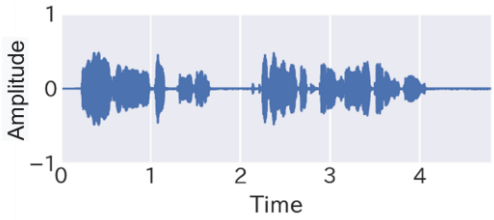
In this programming exercise, students wrote code in Python in the Information Processing Exercise Room at NIT, Gifu College. They used Google Colaboratory (Colab) as the Python environment, either on desktop computers in the lab or on personal laptops. Colab (2019) was selected for this exercise because it runs in a web browser and allows students to write and execute Python programs without setting up a local development environment. Its ease of use and accessibility make it an effective exercise platform.

For this programming task, students were provided with partially completed programs for performing convolution processing and frequency analysis using the Fourier transform. They were required to complete these programs by independently thinking through and writing the missing parts.

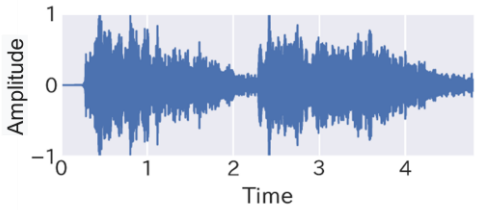
For convolution, students convolved the measured impulse responses with anechoic sound sources prepared in advance. The resulting sound sources, referred to as convolved sources, were anechoic sounds with artificially added reverberations. Students compared sound sources with added reverberations to those with anechoic sources played in the room by visualizing the waveforms and listening to audio playback. Comparisons were made visually by inspecting the waveforms and aurally by listening to the processed sounds.

In the frequency analysis task, students visualized the time variation of the frequency components of impulse responses using spectrograms. They confirmed that sound attenuation varies depending on frequency. Spectrograms were also generated for anechoic sources, convolved sources, and recordings made in a room using anechoic sources. These were compared in terms of frequency content to deepen students' understanding of how room acoustics affect sound.

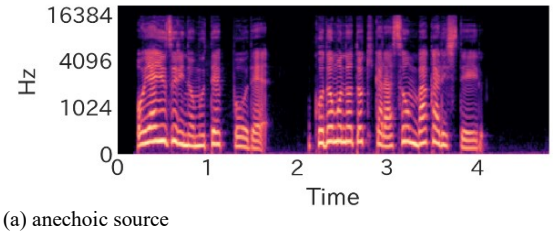
Students implemented Equation (1) in their programs and verified the results using the measured data. The spectrograms of the anechoic and convolved sources are shown in Figures 2, and the corresponding frequency response graphs are presented in Figures 3, respectively.



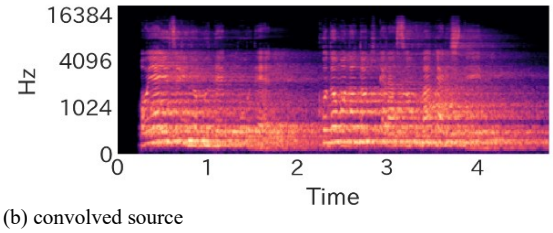
(a) anechoic source



(b) convolved source
Figure 2. Spectrogram of sources



(a) anechoic source



(b) convolved source
Figure 3. Frequency response of sources

The 2022 experiment was conducted as a group-based experimental theme, with students participating in sessions held on June 23, June 30, July 7, July 14, and July 21. Each day, six to eight students (two groups) participated, for a total of 37 students.

On the first day of class (June 23), a measurement demonstration was conducted under the guidance of a faculty member from the Department of Architecture. For subsequent sessions, technical staff from the Department of Electrical and Computer Engineering led the demonstrations.

The second gymnasium and the art room were used as venues for the measurement demonstration in 2022. As mentioned previously, the second gymnasium was selected because of its large space and minimal sound absorption. However, because temperatures in Gifu Prefecture exceeded 30°C from mid-June onward, it was determined that conducting the demonstration in the non-air-conditioned gymnasium posed a risk of heatstroke. Therefore, starting June 30, demonstrations were held in an air-conditioned art room with sufficient space. The experiment conducted in the art room is illustrated in Figure 4.

In 2023, the theme schedule for the “Electrical and Computer Engineering Laboratories” course was revised, and this experiment was conducted as a joint session for all students on May 26. As a result, 41 students participated in the demonstration of the actual measurement, which was held in the second gymnasium. The experiment conducted in the second gymnasium is illustrated in Figure 5.



Figure 4. Demonstration of actual measurement of impulse response in the art room



Figure 5. Demonstration of actual measurement of impulse response in the second gymnasium

Following the demonstration, a lecture on room acoustics was delivered by a faculty member from the Department of Architecture. The lecture covered topics such as an overview of impulse response waveforms, acoustic indices derived from impulse responses, the relationship between resonance and room geometry and volume, and an introduction to the signal-to-noise ratio. Because the experiment was conducted on a single day, all students were able to participate in the measurement demonstration, receive oral explanations, and attend the lecture-style presentation. This enhanced the specialization and cohesion of the course content.

Overview of the Evaluation

To evaluate the educational effectiveness of the proposed experimental method, students' comprehension was assessed based on their report scores. The grading criteria used in this study are presented in Table 1. The evaluation items were divided into four categories: *Formatting, Principles of the Experiment, Procedure and Results of the Experiment, and Discussion*. *Formatting* refers to the overall structure and presentation of the report; *Principles of the Experiment* involve a summary of background knowledge investigated before or after the class; *Procedure and Results* pertain to the experimental process and the data obtained; and *Discussion* reflects the interpretation and analysis of the results.

The scoring criteria shown in Table 1 were applied uniformly across all experimental themes in the course. The same instructors assessed the reports using these criteria in both 2022 and 2023 to ensure consistency in evaluation. Moreover, the instructional approach for writing reports remained unchanged across both years.

In addition, a questionnaire was administered to students to collect self-assessments of their understanding at three stages: before the class, after the class, and after submitting their reports. The questionnaire also included an open-ended section in which students could freely express their opinions on the class and evaluation process.

The questionnaire focused on five topics related to the content and principles of the experiment, aiming to assess students' perceived level of understanding:

a) Digital signal processing
b) Impulse response
c) Convolution operations
d) Frequency analysis using the Fourier transform
e) Mathematical operations and outcomes in digital signal processing

For each topic, students rated their level of understanding on a five-point scale at the time of completing the questionnaire. The scale was based on the achievement levels defined in the Model Core Curriculum (2025) and interpreted as follows:

Table 1. The grading criteria for the reports

	Scores					
	4	3	2	1	0	-1
Formatting					Formatting is consistent	Formatting is inconsistent
Principles of the Experiment			Describe the results of the survey in an easy-to-understand manner	Describe with reference to textbooks and other sources	Rough copy principles written in the procedure manual	No written principles
Procedure and Results of the Experiment	Clearly present with appropriate use of figures and tables	Interpret in own way and summarize in an easy-to-understand manner	Summarize such that others can read and understand	Some points are not clear to others	The procedure and results are lacking and unclear	No description of procedure and results
Discussion	Sufficiently analyze and discuss the results and describe his/her opinion and the content of the investigation in a logical manner	Analyze and discuss the results and logically describe by revisiting theoretical equations or creating new graphs	Analyze the results of the experiment and logically describe his/her opinion	Analyze the results of the experiment and describe in his/her own words	Repeat description of experimental results	No written discussion

1 - Cannot understand basic concepts
2 - Can understand basic concepts
3 - Can understand the content described in the experiment manual
4 - Can explain to others / perform basic processing
5 - Can describe in academic papers / apply in further studies

Results (2022 and 2023)

In 2022, 37 students participated in the class, and in 2023, 41 students participated.

Figure 6 shows the distribution of report scores and the percentage of students for the experimental theme in each year. For reference, the figure also includes results from the 2021 "Multimedia Signal Processing" experiment, which was conducted online due to the COVID-19 pandemic and involved 42 students.

As shown in Figure 6, the number of students who produced higher-scoring reports increased in both 2022 and 2023 compared with 2021. The average report scores were 7.3 in 2021, 8.0 in 2022, and 8.6 in 2023. In 2021, approximately 40% of the students scored 7 points, suggesting a relatively low level of understanding of the experimental content. In contrast, in 2022, most students scored between 7 and 9 points, with 8 points being the most common. In 2023, approximately 40% of the students achieved a perfect score of 10. These results indicate that the average scores in 2023 were higher than in previous years, reflecting a deeper understanding of the experimental content. Students were able to effectively summarize this understanding in their reports. Additionally, the higher scores in 2023 may be attributed to the participation of faculty members from the Department of Architecture in the lecture sessions.

A questionnaire survey was conducted with all students in 2022 and 2023. In 2022, 37 responses were collected before the experiment, 37 after the experiment, and 35 after report submission. In 2023, 41 responses were collected before the experiment, 40 after the experiment, and 36 after report submission.

Figure 7 presents a radar chart illustrating the average response values for each question in the 2022 comprehension questionnaire. The mean values increased gradually from the pre-experiment to the post-report stage, indicating an improvement in students' understanding through both experimental practice and report writing. Notably, item b) *Impulse response* showed the greatest increase, from 1.9 before the experiment to 3.6 after. Similarly, item c) *Convolution operations* increased substantially from 2.0 to 3.5. These results suggest that the hands-on experiment effectively enhanced students' understanding of convolutional processing in room acoustics.

Figure 8 presents a radar chart of the 2023 comprehension questionnaire results, which also demonstrates increased understanding across all question items following the experiment and report writing. The findings in Figures 7 and 8 indicate that the highest level of comprehension was consistently achieved for item b) *Impulse response* in both years.

In the free-response section of the questionnaire, positive comments such as "It was fun" and "It was easy to understand" were noted in both 2022 and 2023. However, in both years, some students also mentioned difficulties in understanding frequency analysis using the Fourier transform.

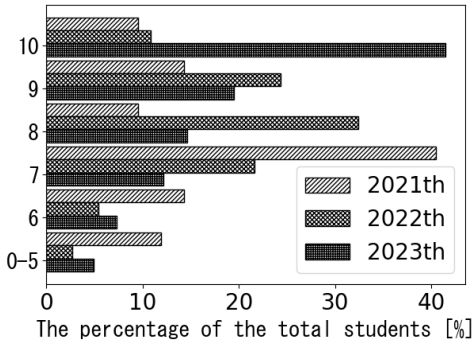


Figure 6. Results of grading of experimental reports

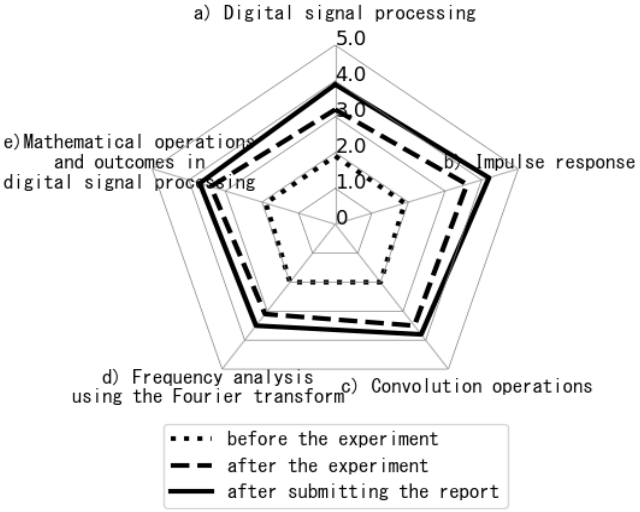


Figure 7. Results of student self-assessment in 2022

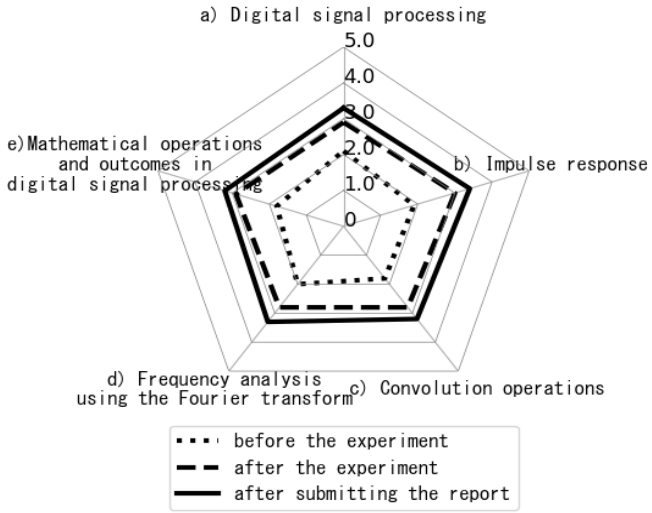


Figure 8. Results of student self-assessment in 2023

Discussion of the Results

The results of the experimental report evaluations indicated that incorporating a demonstration of actual impulse response measurements into the acoustic signal processing experiment significantly enhanced students' understanding of the subject matter. The questionnaire responses also revealed that students perceived an improvement in their comprehension as a result of the experimental practice. Moreover, the demonstration appeared to increase students' interest in specialized knowledge and techniques. In addition, during the lecture delivered by a faculty member from the Department of Architecture, students received a review of the demonstration along with an explanation of the characteristics of indoor acoustics. This lecture is considered to have helped students recognize acoustics as a more familiar and tangible phenomenon, thereby deepening their understanding of the underlying principles.

This positive effect is likely attributable to the use of a familiar topic, room acoustics, and the inclusion of real-world demonstrations, which helped students visualize the phenomena more concretely. Although signal processing is widely used in daily life, students rarely have opportunities to study it in an experiential context. In this experiment, students recorded the sound of an anechoic source they had prepared as it reverberated within the room and then simulated the same acoustics by applying reverberation through convolution in a programming exercise. This approach helped connect abstract mathematical concepts with tangible outcomes.

However, many students reported difficulty fully understanding frequency analysis using the Fourier transform. The experiment included programming exercises in which students generated and compared spectrograms from a frequency-domain perspective. They were expected to explore the underlying principles and practical applications of the technique independently. As a result, variations in individual understanding were observed.

Additionally, differences in students' performance evaluations and self-assessments between the academic years 2022 and 2023 were noted. These variations are believed to stem largely from differences in students' writing skills and levels of academic self-confidence.

The Development of the 2024 and 2025

In 2024, the experiment was conducted in the same format as in 2023, with no changes in the faculty members responsible for grading the reports or teaching report writing.

A total of 39 students participated in this theme in 2024. The average score for the reports on this experimental topic was 8.25, which is comparable to the average score in 2023. However, the score distribution in 2024 showed that 17 students received a score of 9 points. A closer examination of the content revealed that most students scored below 4 in the "Discussion" section. This suggests that they did not adequately fulfill the criteria outlined in Table 1, which state that students should "Sufficiently compare and analyze the results and describe his/her opinion and the content of the investigation in a logical manner."

Additionally, the self-assessment questionnaire indicated that the average score in 2024 was higher than in 2023, but lower than in 2022. The improved understanding of impulse response and increased comprehension following the experiments and report writing are consistent with trends observed in both 2022 and 2023. Furthermore, several positive comments were noted in the free-response section, and no negative comments were reported. This positive feedback is attributed to the effectiveness of the impulse response demonstrations and lectures delivered by the Faculty of Architecture, which were particularly meaningful to the students.

This experiment is scheduled to continue through 2025. Additional quantitative evaluation methods beyond reports and questionnaires are being considered.

Conclusions

This paper reports on the educational impact of introducing room acoustics measurement and analysis into the experimental theme "Acoustic Signal Processing" for fourth-year students in the Department of Electrical and Computer Engineering at NIT (KOSEN), Gifu College. The proposed approach effectively increased students' interest in acoustic signal processing and improved their understanding of impulse response and convolution operations.

Moving forward, programming exercises will be further refined to support a deeper understanding of frequency analysis using the Fourier transform. Additionally, the implementation of step-by-step quizzes will provide a more quantitative assessment of the learning outcomes associated with this educational method.

References

Bisong, E. (2019). *Building machine learning and deep learning models on Google cloud platform*. Berkeley, CA.

International Organization of Standardization. (2009). *Acoustics -Measurement of room acoustic parameters-, Part 1: Performance spaces*. *ISO3382–1*. Geneva, Switzerland.

International Organization of Standardization. (2008). *Acoustics -Measurement of room acoustic parameters-, Part 2: Reverberation time in ordinary rooms*. *ISO3382–2*. Geneva, Switzerland.

National Institute of Technology. (2025). *Model Core Curriculum*. Retrieved from https://www.kosen-k.go.jp/about/profile/main_super_kosen.html

Tachibana, H. & Yano, H. , (2012). *Measurement methods for environmental noise and building acoustics*, Corona Publishing Co., Ltd.

THE ROLE OF GAME-BASED LEARNING IN ENHANCING CRITICAL THINKING DISPOSITION IN TECHNICAL AND VOCATIONAL LEARNERS

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Critical thinking is an essential life skill in Technical and Vocational Education and Training (TVET), as it empowers learners to analyse situations and make informed decisions, both in academic settings and the future workplace. In recent years, the need to cultivate critical thinking has become increasingly important, particularly within a volatile, uncertain, complex, and ambiguous (VUCA) environment shaped by rapid technological advances. This study examines learners' critical thinking disposition (CTD) – the tendency to engage in critical thinking – using a game-based learning (GBL) approach.

First-year students from diverse disciplines at Singapore Polytechnic participated in a classroom intervention using a custom-designed educational game, the Game of Trade-offs (GTO). Played in timed, competitive rounds, GTO required teams to collaboratively tackle real-world scenarios by analysing information and considering diverse perspectives to derive reasoned decisions. The game's immersive and interactive format encouraged active engagement and peer interaction to synthesise ideas—fostering CTD development.

A mixed-method approach was employed to examine students' CTD before and after playing GTO. Quantitative data were gathered through self-perception surveys, which assessed components of CTD, such as openness to divergent views and willingness to consider alternative perspectives. Qualitative data were gathered through post-gameplay focus group interviews (FGIs), offering deeper insights into the study. Findings indicated a substantial positive impact of GBL on students' CTD development, with 61.38% of participants showing improved CTD scores after gameplay. Together with other insights gathered through data analysis and FGIs, this study informs TVET educators on how game-based learning can enhance student engagement and cultivate CTD, a key competency for navigating an increasingly dynamic and uncertain future.

Keywords: *Game-based learning, Critical thinking disposition, multiple perspectives, Game of Trade-offs*

Introduction

According to the UNESCO (2015) report, Technical and Vocational Education and Training (TVET) encompasses 'education, training and skills development relating to a wide range of occupational fields, production, services and livelihoods." Rapid advancement in technology, particularly in the field of automation and the use of artificial intelligence, has raised concerns about the essential skillset necessary for TVET learners (Felipe L. et al., 2023). The Future of Jobs Report (2025) emphasises that beyond technical competencies, core skills such as critical and analytical thinking and problem-solving abilities are crucial for workplace success.

As institutes of higher learning, polytechnics in Singapore deliver practise-based learning through hands-on experience. Technical training and industry experiences form the cornerstone of polytechnic education, ensuring graduates possess industry-relevant technical capabilities. However, recognising that technical proficiency alone is insufficient, Singapore Polytechnic (SP) implemented the Common Core Curriculum (CCC) in 2021. CCC aims to equip students with transferable human and digital skills essential for the evolving workplace environment.

One of the first CCC modules students encounter when they enter SP is Thinking Critically about the United Nations Sustainable Development Goals (TCU). The module fosters critical thinking through the examination of local and global issues. When TCU was first introduced, critical thinking was taught through a structured approach, with teachers providing comprehensive explanations of local and global issues to guide student understanding. While students showed good comprehension and active participation in class discussions, opportunities existed to enhance the learning experience of students beyond teacher-led instruction.

The Game of Trade-offs (GTO) was launched in Academic Year 2022/23 for all Year 1 students in SP. Through this interactive game-based approach, students evaluate information and make reasoned judgements in various scenarios, encouraging critical thinking in complex contexts.

For many students in SP, TCU serves as their first extensive exposure to the critical thinking discourse. In the TVET context, where workplace success increasingly demands the ability to think critically and make informed

decisions, developing these skills is crucial. This study examines the effectiveness of game-based learning (GBL) in developing critical thinking disposition (CTD) among TVET students, guided by the primary research question: What is the impact of game-based learning on students' critical thinking disposition? (CTD)?

Critical Thinking Disposition (CTD) and Game-based Learning (GBL)

Critical thinking comprises two fundamental aspects: skills and disposition. Facione (1990) defined critical thinking as "purposeful, self-regulatory judgment" involving interpretation, analysis, evaluation, and inference. Building on this, Fasko (2003) characterised critical thinking as "the propensity and skills to engage in mental activity with reflective scepticism." Both definitions emphasise that effective critical thinking requires not only the ability to think critically but also the inclination to do so.

Research examining the relationship between GBL and critical thinking development has yielded promising results. A comprehensive meta-analysis by Mao, et al. (2021), examining 20 empirical studies, demonstrated that GBL has a particularly strong effect on developing the dispositional dimension of critical thinking. This finding suggests that game-based approaches can effectively nurture students' tendency to engage in critical thinking processes.

For first-year polytechnic students newly introduced to the critical thinking discourse, developing the disposition to think critically provides an essential foundation. While critical thinking skills will be progressively developed throughout their diploma programme at SP, fostering CTD early in their academic journey is crucial. This study therefore employs the Game of Trade-offs (GTO) as a GBL intervention to investigate how educational games can cultivate students' disposition towards critical thinking.

The Game of Trade-offs (GTO)

GTO is a facilitator-led classroom game that immerses students in complex dilemmas faced by Singapore. It fosters critical thinking by encouraging players to prioritise, make decisions, and reflect on their consequences. The goal is to achieve the highest score by earning points from decisions made in each scenario.

The game starts with a compulsory scenario set in the Singapore context. Lecturers then select three additional scenarios from a pool of five, based on class profile and learning needs. Each scenario presents a dichotomous policy decision—framed as a "Yes" or "No" option—each with distinct trade-offs. Table 1 outlines the scenarios, options and trade-offs.

Table 1: GTO Scenarios, Options and Trade-offs

Scenario	Option	Score and Trade-offs
Should the construction of the Cross Island Line be halted?	Stop	Economic (-5) Environment (+2)
	Proceed	Economic (+5) Environment (-2)
Should we implement National Service for women in our military and defence forces?	Implement	Economic (-5) Socio-political (+3)
	Don't implement	Economic (+5) Socio-political (-3)
Should the carbon tax be increased?	Increase	Economic (-2) Environment (+3)
	Don't increase	Economic (+2) Environment (-3)
Should we post recording on casual racism online?	Post	Socio-political – Stems out racism (+2) Socio-political - Highlights racism (-3)
	Don't Post	Socio-political - Does not solve problem (+3) Socio-political - Empower people (-2)
Should we restrict who set up 5G technologies in Singapore?	Restrict	Economic (-3) Diplomatic (+2)
	Don't restrict	Economic (+3) Diplomatic (-2)
Should we encourage the implementation of ONE Pass?	Encourage	Economic (+5) Social (-2)
	Discourage	Economic (+5) Social (-2)

Teams have three mins to discuss, reach consensus and prepare a justification for their decision. A representative then presents their choice and reasoning to the class, emphasising critical thinking, negotiation, perspective-taking and communication. This process emphasised not only critical thinking but also negotiation, perspective-taking, and communication.

After teams shared their decisions, facilitators revealed the scores for each option and explained the rationale. To simulate the unpredictability of real-world outcomes, some scenarios introduced "breaking news" events - unexpected developments that modified the existing trade-offs. These could result in bonus points or hidden costs. This demonstrated how new information or changing contexts can reshape earlier decisions.

The final gameplay segment introduces a taxation mechanic (Figure 1). After four rounds, the top two teams roll a die to determine a random tax penalty, the "Deficit Roll,", which reduces the final scores. This mechanic reinforces the idea that policies could be subjected to changes in the broader context of social equity and fiscal responsibility.



Figure 1. Taxing the Top 2 Highest Scoring Teams

The game concludes with a structured reflection and debriefing session. Facilitators invite students to examine how trade-offs influenced their decisions, how differing values shaped perspectives, and understand that real-life policies often involve no perfect solutions and hence there are no clear winners. Figure 2 shows the steps in playing GTO.

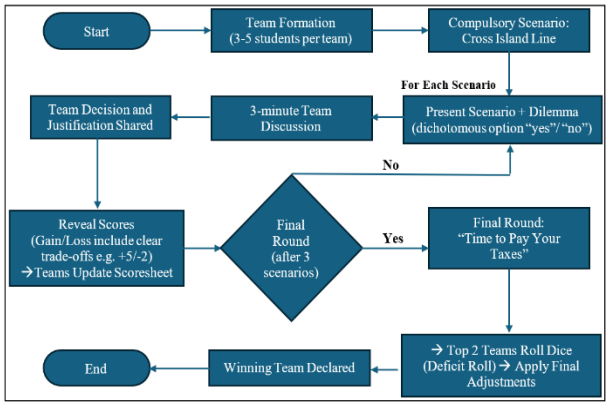


Figure 2. Gameplay flowchart for GTO

Methodology

This study employed a convergent mixed-methods design (Creswell & Plano Clark, 2018), combining a one-group pre-test/post-test survey with post-hoc FGIs to evaluate the impact of GTO, a GBL intervention, on the development of CTD in Year 1 SP students. The quantitative data measured changes in CTD, while the qualitative data explored learning processes.

All first-year students were invited to participate in this study. Informed-consent protocols emphasised voluntariness, confidentiality and assurance of no grade impact. A total of 3,941 completed the pre-test survey (86.5%) and 3,206 completed the post-test survey (70.4%). After listwise matching, 2,882 paired cases (63.3%) formed the analytic sample; 29 students were selected and participated in the FGIs.

Sosu's (2013) 11-item Critical Thinking Disposition Scale (CTDS) was selected as the measurement instrument due to its psychometric reliability (Cronbach's Alpha, $\alpha = 0.81$), free accessibility, and emphasis on affective and motivational aspects that aligned with TCU's pedagogical aims. Table 2 illustrates the 11 items used in the survey for students.

Table 2: CTD Survey for Students based on CTDS (Sosu, 2013)

Domain	Item	Statement
CO	1	I usually try to think about the bigger picture during a discussion.
CO	2	I often use new ideas to shape (modify) the way I do things.
CO	3	I use more than one source to find out information for myself.
CO	4	I am often on the lookout for new ideas.
CO	5	I sometimes find a good argument that challenges some of my firmly held beliefs.
CO	6	It's important to understand other people's viewpoint on an issue.
CO	7	It is important to justify the choices I make.
RS	8	I often re-evaluate my experiences so that I can learn from them.
RS	9	I usually check the credibility of the source of information before making judgements.
RS	10	I usually think about the wider implications of a decision before taking action.
RS	11	I often think about my actions to see whether I could improve them.

Note: CO = Critical Openness; RS = Reflective Scepticism

Students rated each of the 11 items on a 5-point Likert scale with a possible maximum CTDS score of 55 and minimum CTDS score of 11. These scores were further categorised into low (11 - 34), medium (35 – 44) and high (45 – 55) bands.

Data were collected during the TCU lesson where GTO was played (surveys in week 3) and two weeks after (FGIs in week 5) (Figure 3).

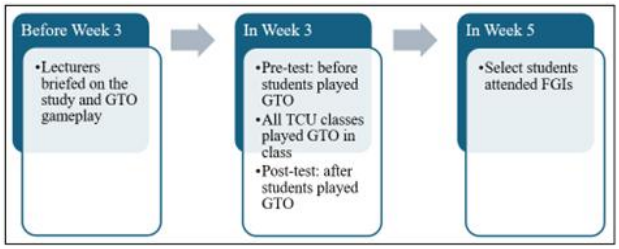


Figure 3. Data Collection Timeline

Quantitative Findings

Change in CTDS scores after Intervention

Analysis of the CTDS scores, pre- and post-intervention revealed that more than half of the participants (61.38%) demonstrated improvement in their CTD after GBL, while 20.06% showed no change and 18.56% showed a decrease in their CTDS scores after playing GTO (Figure 4).

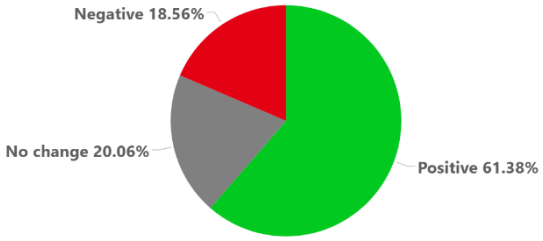


Figure 4. Change in CTDS scores after playing GTO

Comparative analysis of students' CTDS scores indicated significantly higher post-intervention scores ($M = 45.70$, $SD = 6.09$) compared to pre-intervention scores ($M = 43.51$, $SD = 5.50$). Mean CTDS increased by 2.19 points and a paired-samples t-test confirmed this difference was statistically significant, $t(2881) = 25.57$, $p < .001$. A Pearson correlation coefficient revealed a strong and statistically significant relationship between pre- and post-intervention scores ($r = .690$, $p < .001$), demonstrating consistency across paired observations.

To quantify the intervention's effectiveness, Cohen's d was calculated, yielding an effect size of $d = 0.48$. According to Cohen's (1988) guidelines, this represented a moderate positive impact, indicating that the intervention had a meaningful impact on students' CTD.

These findings provided evidence of a significant improvement in CTDS scores following the intervention, emphasising the effectiveness of the intervention.

Change in CTD Bands after Intervention

Analysis of movement between CTD bands revealed the following patterns (Table 3).

Table 3: Change in CTD bands

	Number of Students (N)	Percentage (Sub-total)	Percentage (Total)
No change			
Low-Low	83	3.97%	2.88%
Med-Med	1096	52.44%	38.03%
High-High	911	43.59%	31.61%
Sub-total	2090	100%	72.52%
Increased by 1 band			
Low- Med	52	9.90%	1.80%
Med-High	473	90.10%	16.41%
Sub-total	525	100%	18.21%
Increased by 2 bands			
Low-High	12	100%	0.42%
Decreased by 1 band			
Med-Low	61	24.90%	2.12%
High-Med	184	75.10%	6.38%
Sub-total	245	100%	8.50%
Decreased by 2 bands			
High-Low	10	100%	0.35%
Total	2882	100%	100%

72.52% remained within the same CTD band after the intervention, indicating general score stability. A larger proportion of students, 18.63%, moved up in CTD bands compared to 8.85% who moved down, suggesting a net positive trend. Among the upward movers, 0.42% (n = 12) of students demonstrated substantial improvement, progressing directly from the low to the high CTD band. In contrast, 0.35% (n = 10) experienced a marked decline, dropping from the high to the low band.

Change in CTDS scores by School

A one-way ANOVA did not reveal any statistical differences in the pre-intervention CTDS scores [$F(7, 2874) = 1.01$, $p = 0.425$)], and post-intervention CTDS scores ($F(7, 2874) = 1.99$, $p = 0.056$)] between schools. All schools showed positive changes in CTDS scores after the intervention, with the School of Chemical and Life Sciences exhibiting the highest mean improvement ($M = 2.67$) and the School of Mechanical and Aeronautical Engineering showing the lowest mean improvement ($M = 1.69$) (Figure 5).

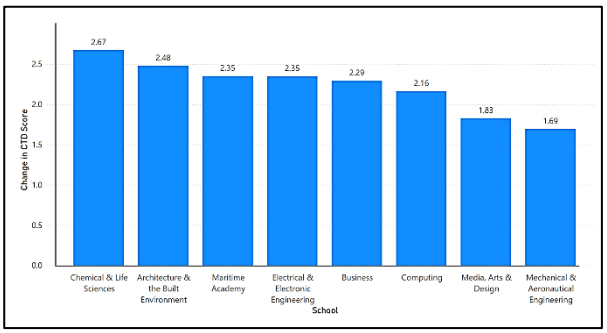


Figure 5. Change in CTDS scores by School

One-way ANOVA comparing the change in CTDS scores across schools also showed no statistically significant differences between the schools [$F(7, 2874) = 1.95$, $p = 0.057$)].

Differences in CTDS scores by domains

Sosu's (2013) CTDS framework conceptualises CTD through two key domains: critical openness (CO) and reflective scepticism (RS). CO was measured using the first 7 items and RS using the next 4 items on the CTDS 11-item instrument. Cronbach's α results indicated a high level of internal consistency for the overall scale and for each subscale pre- and post-intervention (Table 4).

Table 4: Measurement of CO and RS and internal reliabilities (Cronbach's Alpha)

Sosu's (2013) CTDS (11 items, $\alpha_{pre} = 0.87$ and $\alpha_{post} = 0.94$)	
Critical Openness (7 items, $\alpha_{pre} = 0.81$ and $\alpha_{post} = 0.90$)	**Reflective Scepticism (4 items, $\alpha_{pre} = 0.78$ and $\alpha_{post} = 0.89$)**
• I usually try to think about the bigger picture during a discussion. • I often use new ideas to shape (modify) the way I do things. • I use more than one source to find out information for myself. • I am often on the lookout for new ideas. • I sometimes find a good argument that challenges some of my firmly held beliefs. • It is important to understand other people's viewpoint on an issue. • It is important to justify the choices I make.	• I often re-evaluate my experiences so that I can learn from them. • I usually check the credibility of the source of information before making judgements. • I usually think about the wider implications of a decision before taking action. • I often think about my actions to see whether I could improve them.

Figure 6 illustrates the average change in CTDS scores across domains. Most schools showed greater gains in RS than in CO domain. A paired-samples t-test confirmed a significant difference between the two scores [$t(2881) = 2.496$, $p = 0.013$], suggesting that the intervention had a stronger impact on developing RS compared to CO.

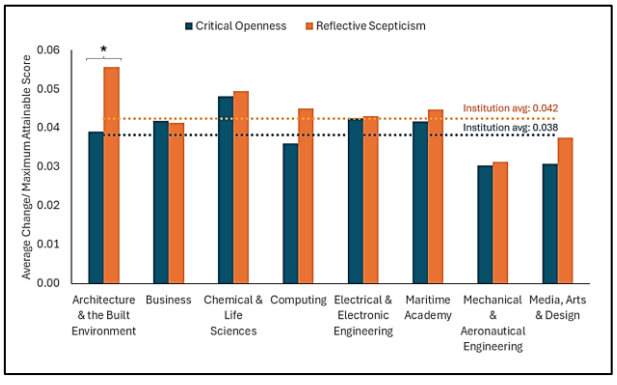


Figure 6. Average Change in CTDS scores by Domains by School. *Denotes significant difference, $p < .05$.

The difference in CO and RS improvements was most pronounced in the School of Architecture and the Built Environment, where students showed greater improvements in RS compared to CO.

A paired-samples t-test confirmed this difference was statistically significant [t(247) = 2.686, p = .008] at the 99% confidence level, indicating the intervention had a differential impact on these two domains of CTD.

Conversely, students from the School of Business demonstrated greater improvements in CO compared to RS post-intervention. However, a paired-samples t-test indicated that this difference was not statistically significant [t(419) = 0.14, p = 0.887]. The intervention's impact on both domains within the School of Business cannot be conclusively differentiated.

Qualitative Findings

The FGIs revealed three key insights into how GTO influenced students' approach to critical thinking.

First, students found GTO engaging and collaborative, highlighting how its real-world scenarios and group discussions made learning relevant and enjoyable. The game encouraged them to consider diverse perspectives and reflect more deeply than in typical lessons. One student shared, "*Getting to be in groups and discussing…you get to hear everybody's opinions. So you can rethink and reflect on your own opinions.*"

Second, some students felt that time pressure and the competitive scoring system limited deeper thinking. The fear of losing points for taking too long often led to rushed decisions or groupthink, where dissenting opinions were avoided. One student explained, "*If there's sufficient time, maybe we'll be able to think different, not just on the surface, but really go deep and understand why we think so*."

Third, students suggested improvements, such as adding reflection time and revising the scoring system to reward thoughtful discussion over speed. Others emphasised keeping the game's face-to-face interaction. One student point out "*I feel like it (the point system) was a bit unfair because points should be based on how constructive you are answering on*".

Overall, students appreciated GTO's engaging design but noted that certain mechanics could be refined to better support critical thinking. Their feedback highlights the need to balance competition with reflection to maximise both learning and engagement.

Discussion

Overall impact of GTO on students' CTD

Results confirmed a statistically significant, medium-sized gain (d = 0.48) and a net upward band shift in students' CTDS scores after intervention, affirming that GBL is an effective pedagogical tool for critical thinking development, consistent with prior research on GBL benefits.

Analysis of CTD band movement revealed a net positive shift, with most upward movers transitioning from medium to high CTD bands (16.41%). This pattern aligns with Vygotsky's (1978) Zone of Proximal Development, where learners progress with guidance and scaffolding. The structured design of GTO, combined with peer interactions and facilitated discussions, likely provided this scaffolding, especially benefiting those poised to advance.

Despite generally positive outcomes, some students either maintained or showed a decline in their CTDS scores, indicating the need for refinement in some areas:

1. Game Design and Learner Profiles: GTO's competitive, group-based format encouraged quick decision-making under time pressure. While engaging for students who thrive in fast-paced, collaborative settings, FGIs revealed that time constraints limited research and discussion. Additionally, some students felt constrained by the scoring system, which focused on "right or wrong" answers, potentially discouraging the sharing of diverse viewpoints and hindering critical discourse. The text-heavy interface, relying on slides and facilitator narration, may not resonate with students who prefer visual or hands-on learning. Prior knowledge, such as familiarity with the scenario content, also influenced engagement levels and learning outcomes. Adapting the game to better accommodate diverse learning preferences and profiles could improve both inclusivity and effectiveness in the intervention.
2. Game Implementation: Facilitator expertise and classroom dynamics can also influence the intervention's effectiveness. While skilled facilitation fostered open discussion, unclear instructions or poor rapport hindered engagement. Lesson timing and student readiness may also affect the gaming experience.
3. Survey Limitations: The reliance on self-perception surveys as the sole measurement tool may explain limited or negative changes in CTDS scores. Kruger and Dunning (1999) found that less competent individuals tend to overestimate their abilities. After the intervention, increased self-awareness may have led students to give more modest self-ratings, even if their actual abilities improved. This suggests that CTDS scores reflect shifts in perception, not just ability, pointing to a need to complement self-reports with other assessments.

Consistent Impact across academic disciplines

The lack of statistically significant differences across academic schools (p = 0.057) suggests that GTO's effectiveness is relatively consistent across different academic disciplines. This finding is valuable as it indicates that game-based approaches to developing CTD can be effectively implemented across diverse academic contexts without significant loss of impact. This consistency aligns with Gee's (2003) assertion that well-designed games support learning across disciplines, regardless of subject matter.

Differential Impact Across CTD Domains

Domain analysis (Sosu, 2013) showed greater gains in RS than CO [t(2881) = 2.496, p = 0.013], suggesting that GTO more effectively fosters evaluation and reflection than openness to new ideas. This disparity may stem from the game's competitive and time-pressured structure, which tends to encourage rapid judgments over

deep exploration. Interestingly, the School of Business deviated, showing greater CO gains, possibly reflecting discipline-specific tendencies. Further research may explore how disciplinary differences influence CTD development through GBL.

Limitations and Future Research

The findings demonstrated the effectiveness of GBL in enhancing students' CTD. However, several limitations need to be considered:

1. A single intervention may not fully capture the relationship between GBL and CTD. Long term studies may help establish a clearer link between these variables.
2. As mentioned earlier, the reliance on self-perception surveys introduce biases. Further studies should complement self-reports with other methods to provide a more comprehensive understanding.
3. Limited insight into disciplinary differences across the eight schools may have constrained the analysis of how diploma-specific factors influenced students' responses. Further studies could explore how variations in curricula across diplomas impact students' engagement with GBL.
4. Factors such as game design, learner characteristics and implementation style can significantly affect learning outcomes. Future research should explore these factors to better tailor GBL approaches to different learners.

Conclusion

This mixed-methods study demonstrates that a carefully scaffolded, single-session analogue game can moderately enhance first-year students' CTD, particularly in the reflective scepticism domain. The increase in CTDS scores across all eight schools indicates that GBL is an effective pedagogical tool for enhancing CTD, regardless of discipline. However, variation in student responses suggests that both game design and implementation can shape learner behaviour.

These findings are especially relevant in the context of TVET, where preparing students for a VUCA world requires not only technical competence but transferable, higher-order thinking skills. GBL's capacity to engage learners in collaborative, real-world problem-solving aligns well with TVET's evolving mission to cultivate adaptable, critically minded graduates.

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References

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Creswell, J.W., & Plano Clark, V.L. (2018). *Designing and conducting mixed methods research* (3rd ed.). Thousands Oaks, CA: Sage.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction* (Research report). Millbrae, CA: The California Academic Press.

Fasko, D. (2003). *Critical thinking: Origins, historical development, future directions.* Cresskill, NJ: Hampton Press.

Felipe, L., Mayra, C., Miguel, N., Ricardo, P., Damian, G., Danilo, A., & Pablo, C. (2023). Developing critical thinking in technical and vocational education and training. *Education Sciences, 13*(3), 590. https://doi.org/10.3390/education13030590

Gee, J. P. (2003). *What video games have to teach us about learning and literacy.* New York, NY: Palgrave Macmillan.

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognising one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, 77(6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121

Mao, W., Cui, Y., Chiu M & Lei, H. (2021). Effects of game-based learning on students' critical thinking: A meta-analysis. *Journal of Experimental Education*, 59(8). https://doi.org/10.1177/07356331211007098

Sosu, E. M. (2013). The development and psychometric validation of a critical thinking disposition scale. *Thinking Skills and Creativity*, 9(3), 107–119. https://doi.org/10.1016/j.tsc.2012.09.002

UNESCO. (2015). *Recommendation concerning Technical and Vocational Education and Training (TVET) 2015*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000245178.locale=en

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds. & Trans.). Cambridge, MA: Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

World Economic Forum. (2025). *The Future of Jobs Report 2025.* Retrieve from https://www.weforum.org/publications/the-future-of-jobs-report-2025/

Gamifying Logistics: A Board Game Approach to Enhancing Student Motivation

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In this study, we developed an educational board game designed to provide students with experiential learning in both international and domestic logistics, and we analyzed changes in their attitudes toward logistics in terms of learning motivation, interest, and career aspirations after gameplay. The Department of Distribution and Information Engineering at the National Institute of Technology (KOSEN), Hiroshima College, is tasked with training engineers for the logistics industry. However, a significant proportion of its graduates do not enter logistics-related careers. This discrepancy may be attributed to negative public perceptions of the logistics sector, which are shaped in part by its demanding working conditions. These perceptions were anticipated to pose a greater societal issue by 2024, when revisions to logistics-related legislation were scheduled to take effect as "Logistics 2024 Issue". Concurrently, the global growth of e-commerce and the shrinking working population in Japan highlight the urgent need to establish a sustainable logistics network. However, building such a system requires not only advanced technological capabilities but also sufficient human resources. In the context of Japan's labor shortages, developing a robust logistics infrastructure has become increasingly difficult. Therefore, the objective of this study was to develop a game-based learning tool that could both facilitate understanding of logistics systems and promote a shift in awareness among future stakeholders, thereby contributing to long-term sustainability. The originally developed game, HEXATICS, is a backgammon-style board game for three to six players. Each player is responsible for importing distinct raw materials by sea or air, followed by domestic transportation to a warehouse. During gameplay, participants engage with the six key logistics functions—transportation, storage, cargo handling, distribution processing, packaging, and information management—through a combination of quizzes and interactive play. Results indicate that participation in the game increased students' interest in logistics, their willingness to learn more about the field, and their desire to pursue careers in logistics-related industries.

Keywords: *Logistics 2024 Issue, Student motivation, Student awareness, Serious game, Board game*

Introduction

Since 2019, a critical issue in Japan's logistics sector—commonly referred to as the "Logistics 2024 Issue"—has attracted widespread public and industry attention. This issue stems from the revision of labor regulations that limit the overtime hours of truck drivers, a measure intended to address long-standing concerns over working conditions. According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan is projected to face a shortfall of approximately 34% in domestic freight transport capacity (equivalent to 900 million tons) by 2030. Despite 84.5% of logistics companies recognizing the severity of the problem, only 54.3% have taken any action to address it.

The situation is further exacerbated by Japan's declining birthrate and aging population, which continue to reduce the available labor force. At the same time, the rapid growth of e-commerce has led to a surge in delivery demand. In 2022 alone, over 5 billion packages were delivered annually, with last-mile delivery being particularly labor-intensive and costly. As the e-commerce sector continues to expand, the burden on logistics infrastructure—especially the final leg of delivery—is expected to increase substantially.

In response, numerous studies have explored technological solutions to increase delivery capacity, such as optimizing delivery routes through hybrid models involving both trucks and drones (Wang et al., 2019). However, far fewer studies have examined strategies for reducing delivery volume itself, such as altering consumer behavior. Some efforts in this direction include ASKUL Corporation's campaign to spread orders over time and a social-issue film addressing the Logistics 2024 crisis. This film, centered on a fictional package bombing incident, highlights key issues such as corporate accountability, overwork, systemic failure, and personal responsibility. Many students who viewed the film reported reevaluating their own purchasing habits, suggesting that media can be an effective tool for shifting consumer awareness regarding logistics-related challenges.

In the field of education, board games have increasingly been introduced as pedagogical tools across various disciplines. As Matsumoto (2014) notes, board games that address social issues—referred to as "serious

games"—are used to promote learning through engagement and critical thinking. For instance, Sugiura and Kikkawa (2009) developed a board game for teaching environmental issues in university lectures, while Arita (2011) emphasized the value of such games for encouraging reflective thinking and social interaction. Zaitsu et al. (2011) found that students with higher game literacy derived greater educational benefits from a serious game focused on environmental topics. Meshitsuka et al. (2016) introduced a disaster education board game, detailing both its design and implementation. Within KOSEN (National Institute of Technology) institutions, several educational board games have been developed in recent years. Yamaguchi et al. (2023; 2024) created an English-learning board game through interdisciplinary student collaboration, aiming for commercial application in junior high school education. Similarly, Ogawa et al. (2024) developed a board game to teach students about shipping companies, and conducted pilot studies to evaluate its effectiveness in KOSEN lectures.

Although board games have been successfully used to address a range of social and educational issues, no educational board game has yet been developed specifically to teach logistics or address the Logistics 2024 Issue. This study seeks to fill that gap by introducing HEXATICS, a serious board game designed to educate students on logistics systems and promote awareness of related societal challenges.

Purpose

The purpose of this study is to develop a board game that facilitates logistics education for KOSEN students, implement it through gameplay, and analyze changes in their awareness of logistics before and after playing the game using a questionnaire survey.

Material and Methods

In this chapter, we introduce the board game HEXATICS (a combination of "HEXAGON" and "LOGISTICS"), developed for educational purposes and illustrated in Figure 1. The game's design incorporates a hexagonal structure to represent the six fundamental functions of logistics: transportation, storage, material handling, distribution processing, packaging, and logistics information systems. These functions form the core learning objectives of the game.

HEXATICS is a competitive board game in which each player assumes responsibility for managing the logistics operations of a fictional country. Players import raw materials from other countries and aim to complete specific products as their mission, simulating realistic international and domestic logistics flows. The game supports 3 to 6 players and is designed for participants aged 12 and above, given its moderate complexity. A typical session takes approximately two hours to complete; however, the playtime can be shortened to under an hour by streamlining certain gameplay processes.

HEXATICS consists of five sequential phases (Phases 1–5), as illustrated in Figure 2. Below is an overview of each phase:



Figure 1 Originally developed board game HEXATICS

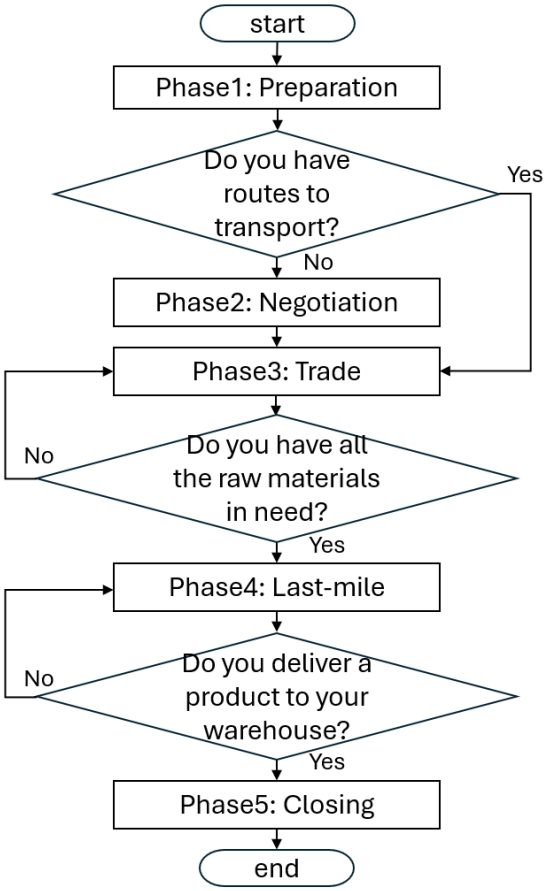


Figure 2 How to play the board game HEXATICS

Phase 1: Preparation. Each player receives one continent board (Figure 3), along with 22 brown pieces, 30 blue pieces (Figure 4-a), and a random assortment of raw material and product pieces (Figure 4-b). A quiz piece (Figure 4-c) is also included for use in a later phase. The continent board represents the player's managed territory and serves as the platform for domestic land transportation. Blue pieces function as the in-game currency and are also used to construct air or sea transportation routes during Phase 3. These pieces may

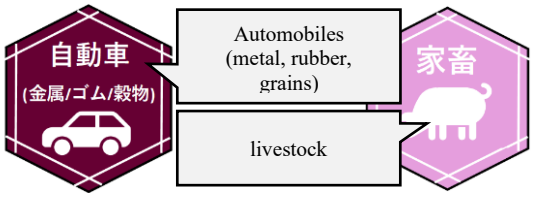
be stacked or aligned in sequence to represent transport paths between continents (Table 1). In total, there are 12 different product pieces, each created from specific raw materials (Table 2).



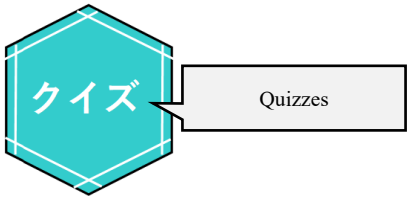
Figure 3 Continent board used in HEXATICS



(a) Brown and Blue pieces



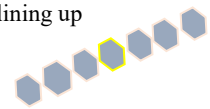
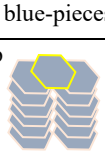
(b) Pieces of raw materials and products



(c) Quiz piece

Figure 4 Hexagonal pieces used in HEXATICS (translated to English)

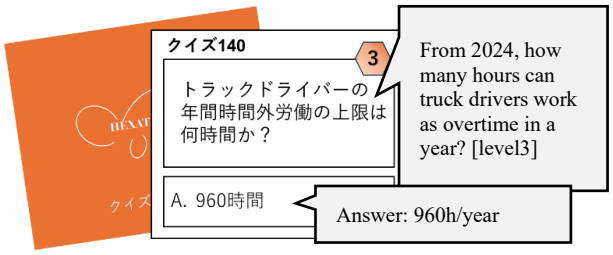
Table 1 Features of transportation modes in trade

mode	sea	air
cost	low: 6 blue-pieces	high: 12 blue-pieces
speed	slow: 6 blue-pieces	fast: 1 blue-pieces
usage of blue-pieces	lining up 	piling up 

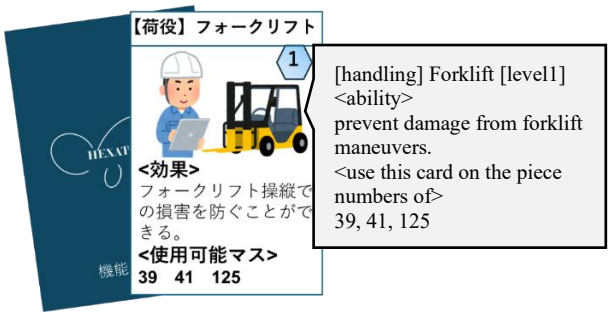
Phase 2: Negotiation. During this phase, players take turns negotiating with others who possess the raw materials they require. The goal is to establish sea or air transportation routes. Table 1 outlines the cost and characteristics of each transport mode: sea freight is more economical but slower, while air freight is faster but incurs higher costs in terms of blue pieces. The negotiation phase was incorporated to enhance communication among participants. The capacity to comprehend the resources possessed by the other players and to attain mutually beneficial negotiation outcomes reflects a cognitive approach that is critical not only in the logistics sector but also in numerous other professional domains.

Table 2 Products and raw materials in HEXATICS

Products	Raw material in need for each product		
	1	2	3
Automobiles	Metal	Rubber	Grains
Toys	Plastics	Rubber	Wood
Ramen	Grains	Livestock	Vegies & Fruits
Furniture	Glass	Wood	Metal
Jam	Grains	Glass	Vegies & Fruits
Cameras	Livestock	Metal	Glass
Juice	Vegies & Fruits	Plastics	Wood
Clothing	Plastics	Livestock	Rubber



(a) Quiz Card



(b) Function Card

Figures 5 Cards used in HEXATICS (translated to English)

Phase 3: Trade. Once routes are established, players transport the necessary raw materials using ships or airplanes. Movement along blue-piece transport routes is determined by dice rolls. As players advance, they must follow the instructions indicated on the blue pieces where their transport stops. Some blue pieces are designated as quiz points (Figure 4-c). When a ship or airplane passes or lands on these, the player earns the opportunity to draw and answer a quiz card (Figure 5-a). The specific mechanics of quiz cards are explained after Phase 4.

Phase 4: Last Mile. In this phase, imported raw materials are moved by truck across the continent

board—from ports or airports to warehouses. During this domestic transport, the materials undergo four of the six core logistics functions: storage, distribution processing, packaging, and material handling, before being converted into finished products (Table 2). As in Phase 3, players can encounter quiz tiles on their land routes. If their truck stops on or passes a quiz tile, they draw a quiz card and may attempt to answer the question. Correct answers are rewarded with a function card (Figure 5-b). Both quiz and function cards are categorized into three difficulty levels (Levels 1 to 3). The quiz component consists of 140 questions, with difficulty levels varying according to response format and the degree of specialized knowledge required. For example, questions that can be answered with a simple "yes" or "no" are classified as Level 1, while those requiring specialized vocabulary are classified as Level 3. As participants encounter the quiz questions multiple times throughout the game, it is expected that those initially unable to answer Level 1 questions will gradually acquire the knowledge needed to correctly answer Level 3 questions by the end of the game. Function cards are used to resolve various logistics-related issues depicted on the blue tiles, excluding quiz points. Typically, resolving these issues would require players to spend blue pieces, but possessing a relevant function card allows them to bypass such costs. Thus, answering quizzes correctly and acquiring function cards contributes significantly to a player's success.

Phase 5: Closing. Players who successfully deliver a finished product to the warehouse receive bonus blue pieces based on the order of completion: 10 for 1st place, 8 for 2nd, 6 for 3rd, 4 for 4th, 2 for 5th, and 0 for 6th place. At the end of the game, the winner is determined by the total number of blue pieces in their possession. Function cards held at the end of the game may also be converted into blue pieces, influencing the final score.

Results and Discussion

The board game HEXATICS was implemented with second-year students from the Department of Distribution and Information Engineering at KOSEN, Hiroshima College (Figure 6). To evaluate its educational impact, students were asked to complete a logistics knowledge test and a questionnaire both before and after gameplay. A total of 41 participants took part in the study, with 38 valid responses collected from the pre-game questionnaire and 41 from the post-game questionnaire. According to the syllabus of National Institute of Technology, Hiroshima College and its Model Core Curriculum (MCC), participants possess a basic recognition of the terms "supply chain" and "logistics"; however, their current level of understanding does not enable them to articulate definitions or provide illustrative examples of these concepts. To develop their understanding, the board game was implemented as part of their departmental practice activities. The survey was administered using Microsoft Forms. Details of the test and questionnaire items are provided in Table 3.



Figure 6 2nd-year students playing HEXATICS

Table 3 A logistics knowledge assessment and student awareness and motivation questionnaire

1	What are the six main functions of logistics?
2	Are you willing to study logistics beyond regular lectures?
3	Do you have an interest in the field of logistics?
4	Would you consider pursuing a career in logistics industry?

Figure 7 presents the results of the logistics knowledge test, while Figure 8 illustrates changes in students' awareness and motivation regarding logistics before and after playing the game. The average test score increased by 4.41 points following gameplay, indicating an improvement in students' understanding of basic logistics concepts. Additionally, the standard deviation decreased by 2.19 points, suggesting a reduction in performance variability and a more consistent level of knowledge acquisition among participants. These findings suggest that playing HEXATICS effectively contributed to the students' foundational learning in logistics.

In terms of students' awareness and motivation regarding logistics, Figure 8-a illustrates that playing HEXATICS significantly increased interest in the field. Approximately 50% of students reported being "very interested" in logistics after the game, while an additional 30% indicated they were "interested." Figure 8-b shows a notable shift in students' willingness to learn logistics. Prior to playing HEXATICS, 54% of students indicated no desire to learn logistics, and 41% expressed only minimal interest. After the game, however, there was a 10% increase in students who reported a strong willingness to learn, and a 34% increase in those who expressed general interest. This indicates a clear decrease in reluctance and a corresponding rise in motivation to engage with the subject. Finally, regarding students' career intentions, the questionnaire revealed that before playing HEXATICS, approximately 75% of students had a negative view of pursuing a logistics-related career (Figure 8-c). After gameplay, this figure decreased to 41%, while the proportion of students who expressed a positive attitude toward working in logistics rose from 25% to 59%. In summary, the results suggest that playing HEXATICS has the potential to positively influence students' attitudes toward logistics. While this shift may not apply to every individual, the overall trend indicates a meaningful change in awareness and perception,

supporting the potential of game-based learning to enhance interest and engagement in logistics education.

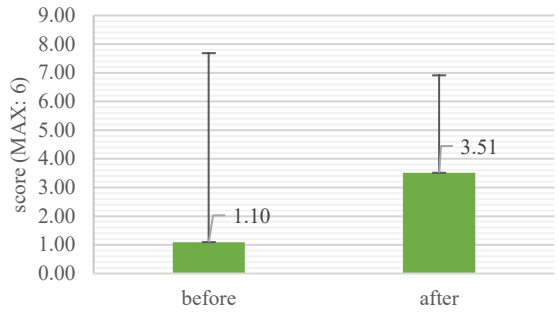
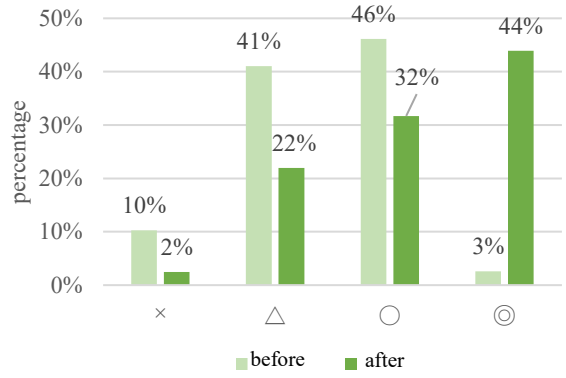
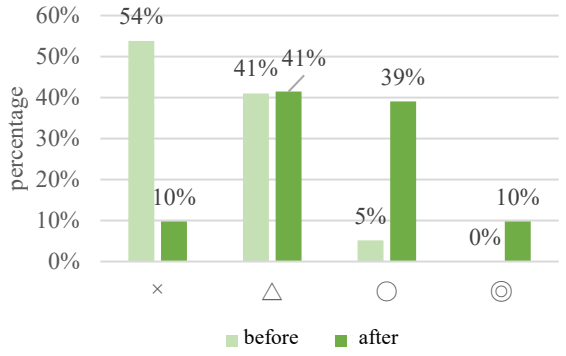


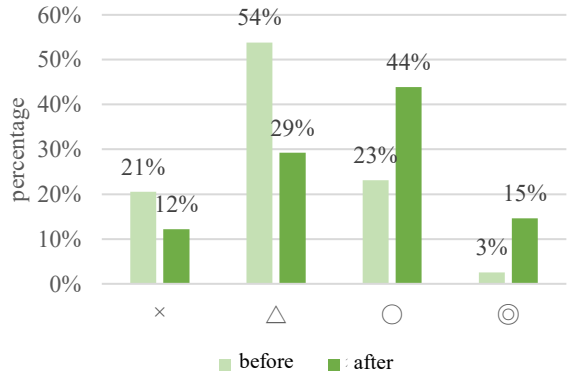
Figure 7 Result (the average and standard deviation) of the logistics knowledge test (before (n=39) and after (n=41))



(a) Interest in logistics



(b) Willingness to learn logistics



(c) Career intentions in logistics industry

Figure 8 Change in students' awareness and motivation on logistics (before (n=39) and after (n=41))
(×: strongly disagree, △: disagree, ○: agree, ◎: strongly agree)

Conclusions

In this study, we developed an original educational board game, HEXATICS, designed to facilitate learning about logistics. We conducted a survey to assess whether playing HEXATICS could influence students' awareness of logistics at KOSEN, Hiroshima College. Specifically, we examined changes in their willingness to learn, interest in the field, and perceptions of career opportunities before and after gameplay. HEXATICS accommodates up to six players, each managing logistics in a fictional country. Through gameplay, students encounter various logistics functions and related social issues, enabling them to acquire specific knowledge in an engaging format.

Our findings indicate that HEXATICS had a positive impact on students' attitudes toward logistics. We also assessed knowledge acquisition by testing students on the six core logistics functions—transportation, storage, cargo handling, distribution processing, packaging, and information management—before and after the game. Results showed that students retained key terminology typically taught in conventional lectures, and many reported enjoying the learning experience through gameplay. Remarkably, some students continued to talk about the game even six months later, suggesting that HEXATICS left a lasting impression.

Based on these outcomes, we are considering the integration of educational board games into formal instruction and are currently preparing HEXATICS for commercialization. Our goal is to contribute to logistics education globally by enabling a broader audience to engage with and deepen their understanding of logistics through this interactive medium. To support independent use, we have developed a rulebook and instructional video, making HEXATICS accessible for private and educational play. We hope these resources will encourage people of all ages, including children, to learn about logistics in an enjoyable and memorable way.

Acknowledgements

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References

ASKUL Corporation (2023). *Conducted "Demonstration Experiment on Order Quantity Leveling" jointly with Kao Corporation and Kokuyo Corporation.* Retrieved from https://www.askul.co.jp/kaisya/dx/stories/00139.html?mosckid=0af52860edcc6b0b27433ba4ec476af6&sc_e_complete=1 (in Japanese)

Arita, T. (2011). Educational Uses of German-style Board Games for Imparting the Joy of Thinking and Developing a Zest of Living. *Computer & Education*, 31, 34-39. (in Japanese)

Goodchild, A., & Toy, J. (2018). Delivery by drone: An evaluation of unmanned aerial vehicle technology in

reducing CO2 emissions in the delivery service industry. *Transportation Research Part D: Transport and Environment*, *61*, 58-67.

LAST MILE Production Committee (2024). *LAST MILE.* Retrieved from https://last-mile-movie.jp/ (in Japanese)

Matsumoto, T. (2014). Different point of Based Social Game and Gamification. *Information Science and Technology Association*, 64 (11), 481-484. (in Japanese)

Meshitsuka, Y., Nagahara, S., Uchiyama, S., Kawamura, Y., Suenaga, M. & Nakatani, T. (2016). Development of Competitive Board Dame for Disaster Prevention Education, *Report of the City Planning Institute of Japan*, 14 (4), 257-261. (in Japanese)

Ministry of Land, Infrastructure, Transport and Tourism , Guidelines for Efforts by Shippers and Logistics Companies to Optimize Logistics and Improve Productivity. Retrieved from https://www.mlit.go.jp/report/press/tokatsu01_hh_000687.html (in Japanese)

Ministry of Land, Infrastructure, Transport and Tourism , Study Group for Sustainable Logistics. Retrieved from https://www.mlit.go.jp/seisakutokatsu/freight/seisakutokatsu_freight_mn1_000023.html (in Japanese)

National Institute of Technology (KOSEN) (2025), Model Core Curriculum. Retrieved from https://www.kosen-k.go.jp/nationwide/main_super_kosen

Ogawa, H., Nakashima, K., Shunsuke, O., Inoue, S. & Yamada, S. (2024). Gamifying lectures by Maritime Business Board Game. *Bulletin of National Institute of Technology, Hiroshima College*, 46, 78-86. (in Japanese)

Sugiura, J. & Kikkawa, T. (2009). Introduction of the Environmental Policy Game "KEEP COOL" for Education and Its Evaluation: From the Perspective of Facilitators and Players. *Simulation & Gaming*, 19, (1), 87-99. (in Japanese)

Wang, D., Hu, P., Du, J., Zhou, P., Deng, T., & Hu, M. (2019). Routing and scheduling for hybrid truck-drone collaborative parcel delivery with independent and truck-carried drones. *IEEE Internet of Things Journal*, *6*(6), 10483-10495.

Yamaguchi, H., Ueyama, T., Fujita, M., Kobayakawa, N., Yoshii, F., Hikasa, S. & Makino, A. (2023). The Development of English Learning Board Games in Trans Exercise of All Program Ⅰ, Ⅱ. *Bulletin of National Institute of Technology, Tsuyama College*, 64, 17‐23. (in Japanese)

Yamaguchi, H., Hiramarsu, K., Yamamoto, T., Munemoto, R., Yoneda, A., Komasaka, K., Ando, H., Miyaki, T., Miyabe, H.. (2024). The Development of English Learning Board Games in Trans Exercise of All ProgramI,II and its Products. *Bulletin of National Institute of Technology, Tsuyama College*, 65, 31‐39. (in Japanese)

Zaitsu, K., Matsuguma, H. and Maeda, M. (2011). Educational Effects of Serious game about Environment and User's Characteristics, Journal of Digital Games Research, 5 (2), 31-42. (in Japanese)

EFFECTIVE METHOD OF LEARNING BASIC ENERGY MIX USING ANALOG GAMES

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Extreme weather events have been increasing in recent years because of global warming. In Japan, record-breaking rainfall, heavy snowfall, and prolonged periods of extreme heat are becoming more common. In Tomakomai, summers are getting hotter; winters are not as cold as they were. To mitigate global warming (JCCCA Homepage), it is crucially important to reduce greenhouse gas emissions, particularly those from power generation, which is an important contributor. Thermal power generation by coal, oil, and natural gas allows easily adjustable output fluctuations, but it emits greenhouse gases. Nuclear power generation emits no carbon dioxide, but radioactive waste persists as a challenging difficulty. Renewable energy sources such as solar, wind, and hydropower generation depend on natural conditions. Power generation modes have their respective benefits and shortcomings. At NIT Tomakomai College, lectures address characteristics and examples of various power generation modes. However, determining the optimal combination of these power generation modes is challenging. Teachers often emphasize the importance of adapting the energy mix to circumstances, but explaining the process of finding the best mix is not straightforward. To address this challenge, an analog board game was introduced into lectures to help students understand energy mix difficulties experientially. In the game, students play the role of a person in charge of introducing and developing energy infrastructure in their country, considering greenhouse gas emissions. Fundamentally, the game winner or loser is decided on the level of development which is achieved. Throughout the game, students learn concepts of combining seven modes of power generation experimentally. The game is well accepted by the students. By playing repeatedly, they experience various energy mix patterns and more deeply understand how different mixes function. The analog board game introduced into lectures at NIT Tomakomai College has proven to be an effective educational tool. This innovative approach has enhanced student understanding of energy mix complexities and the importance of reducing greenhouse gas emissions.

Keywords: *Analog game, Energy mix, Greenhouse gas emissions, Power mix, Practical lectures*

Introduction

At 3:07 AM on September 6, 2018, the author's surroundings were struck suddenly by a large tremor: the Hokkaido Eastern Iburi Earthquake. The author immediately checked the earthquake information available on the TV, but the electricity supply soon stopped: TV transmissions ceased. Information was obtained via smartphone, revealing that the entire Hokkaido area had experienced black out. The author, who had a business trip that day, assumed that power would be restored soon. However, the power was not restored. The airport remained closed. Consequently, the business trip had to be cancelled. Electricity was not restored for more than an entire day, causing considerable inconvenience to daily life for all residents. The earthquake, which occurred in early morning, led to the shutdown of the Tomatoh Atsuma Thermal Power Station near the epicenter, which provided approximately half of Hokkaido's electricity demand at that time. Consequently, the supplied electricity was insufficient to meet overall demand, resulting in a large-scale blackout throughout Hokkaido: the first such experience in that region. This experience highlighted the risk of relying on a single power source and underscored the importance of diversifying electric energy generation sources, constituting the energy mix. When institutions of engineering education teach aspects of the energy mix, they naturally emphasize the technical characteristics of each source. The energy mix is often characterized as the optimal combination of the respective sources. However, understanding this optimal combination is challenging. To address this point, the authors incorporated an analog board game into lectures to help students understand the energy mix experientially. In the game, students take on the role of individuals responsible for introducing and developing energy infrastructure in their country, particularly considering greenhouse gas (GHG) emissions. By playing the game repeatedly, students consider and implement various energy mix patterns, gaining deeper understanding of how different mixes work. This experiential learning approach proved effective for enhancing students' comprehension of the subject matter.

Materials and Methods or Pedagogy

This section provides an overview of the game the authors developed. The fundamental aspects of the games are the same as those reported in earlier studies (Yusa and Hamada, 2021; Yusa and Hamada, 2023; Hamada, Nakayama and Yusa, 2024), but several updates were made to enhance the game playability. The information in this article is insufficient to reproduce the game. The authors are pleased to offer, upon request, full information necessary to play the latest version of the game.

Figure 1 shows how the game is played. The game has an analog-type board game for 3–5 persons (or groups, hereinafter "player"). Each player becomes the representative of a country and supplies power to the country by arranging power sources and resources. If the power requirement is satisfied, then the country will develop; otherwise, the development will stagnate. The winner is the player who gained the highest score based on the development and owned assets at the end of the game. The game is designed to foster understanding of energy and related issues from a Japanese viewpoint.



Figure 1 Overview of the game.

The power generation facilities of seven types have different characteristics: coal-, oil-, and gas-fired plants; nuclear power; hydropower; solar power; and wind power. The first four respectively require resource inputs to generate power: coal, oil, gas, and uranium. The others can generate power without resource inputs. The three fossil-fired power generation facilities generate GHG proportionally to the generated power: the others do not. The four resources, which are represented using dice, have different characteristics. Coal and uranium are abundant, whereas oil and gas have more limited supplies. The price fluctuations of coal, oil, and gas are, respectively, small, large, and medium, whereas the uranium price remains unchanged. The prices of power generation facilities and resources were determined based on actual prices in Japan during recent decades. In the game, cards and dice respectively represent power generation facilities and resources. Initially, each player has four cards as shown in Figure 2. All of them are classified as "level 1," which means that their outputs are relatively small. The coal-, oil-, and gas-fired power generation facility cards indicate that each can generate 2 TWh per resource, with a maximum of two resources accepted. In contrast, the hydropower facility can generate 0.5 TWh without consuming any resources.

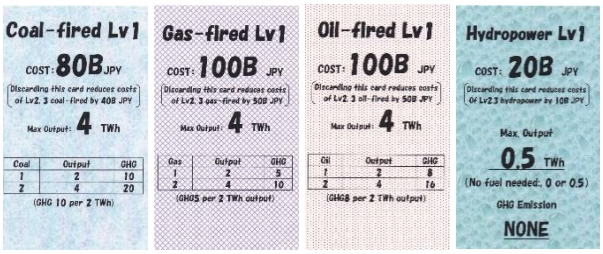


Figure 2 Cards owned at the beginning of the game.

If players want to increase power generation capacity, then they can expand or upgrade their power generation facilities. For example, if they want to increase coal power capacity, then they can expand or upgrade facilities as shown in Figure 3. First, the player had a level 1 coal power facility. A player seeking to expand a level 2 facility must pay 160 billion yen to obtain one more facility unit. If a player pays 120 billion yen, the player can replace the level 1 facility with a level 2 facility that emits less GHG per power generation.

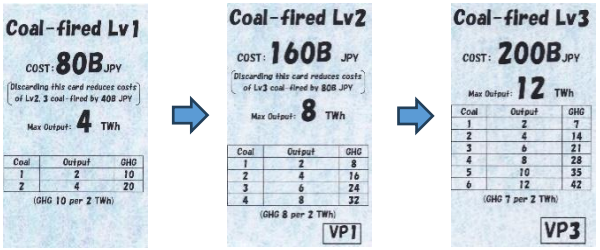


Figure 3 Example of facility upgrade.

Figure 4 shows that this game has four power generation modes without carbon dioxide emissions. The output of a nuclear power facility is not controllable unlike those of the fossil-fired power facilities. Nuclear power facilities generate a constant amount of power using a fixed amount of fuel. The outputs of solar and wind power facilities fluctuate randomly, as determined by dice rolls.

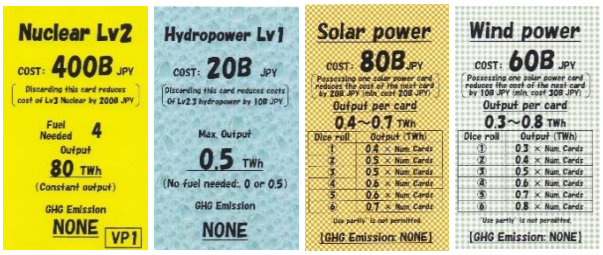


Figure 4 Power generation without carbon dioxide emissions.

One round of a game has eight phases. An overview of what players do in the phases is presented below.

- Phase 1: Revenue and Investment
  Each player earns revenues according to the country development. Then, players auction investment cards that have positive effects, such as the increase

in the GHG limit and mitigation of the possibility of nuclear accidents.

- Phase 2: Purchasing power generation facilities
  One by one, players purchase power generation facilities on the field until all players have bought the cards they want to purchase.
- Phase 3: Event
  Event cards are drawn from the pile to generate events. Various events are prepared, such as changes in specific resource prices.
- Phase 4: Purchasing resources
  One by one, players purchase resources in the field or sell possessed resources to the market (field).
- Phase 5: Power generation
  Players use the power generation facility cards and the resources they own to generate electricity to meet power demand and GHG emission limits. Insufficient power supply incurs a strong penalty.
- Phase 6: GHG reduction
  Players vote for one of three options to reduce their GHG limits. Negotiations are permitted, as are acquisitions and even betrayals.
- Phase 7: Resource market update
  The prices and numbers of resources in the fields are updated. Prices typically increase every round.
- Phase 8: Development
  Players who satisfied the requirements increase their development levels from +1 to +3 from the current level. A higher level leads not only to larger revenue but also to greater power demand.

Players play three rounds on one game. An A5-size rule card summarizing the procedure described above is given to each player, as portrayed in Figure 5.

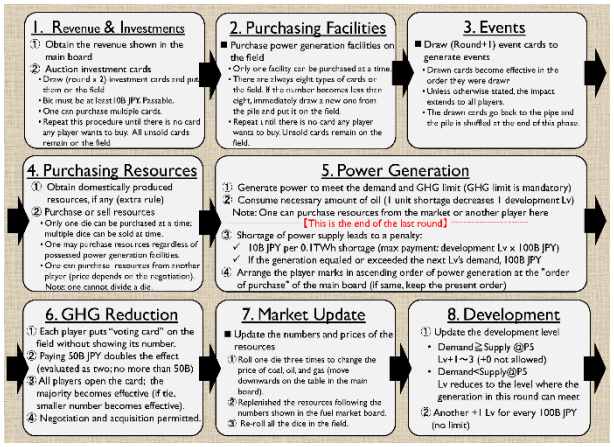


Figure 5 Rule card.

The basic game method is described above, but real-world countries have their unique characteristics. Therefore, the authors defined the following features as prerequisites for the energy mix. Students selected from among them to assign each country its own unique characteristics. Hereinafter, such an operation is designated as the "country-specific version." Card features are the following.

A. Oil Field Holdings
   Obtain 2 oil dice at the beginning of every round. Minimum price 150 billion yen.
B. Large Oil Field Holdings
   Obtain 2 oil and 2 gas dice at the beginning of every round. Minimum price 300 billion yen.
C. Large Coal Field Holdings
   First 2 coal dice obtained in each round. Minimum price 100 billion yen.
D. Gas Field Holdings
   Obtain 2 gas dice at the beginning of every round. Minimum price: 150 billion yen.
E. Electricity imports available (2 pieces)
   May purchase up to 5 billion kWh of lack of electricity per piece. Minimum price 50 billion yen.
F. GHG limit not ratified.
   GHG limit always remains at 800 and ignores all GHG limit increase/decrease events. Minimum price 10 billion yen.
G. Large flat areas
   Two rolls of the dice when determining the amounts of wind and solar power generation. Minimum price 50 billion yen.

Results and Discussion

The authors administered the lecture of "Advanced Environmental Engineering for Cold Region" for advanced engineering course first grade students majoring in mechanical engineering. The lecture objectives are the following.

(1) Explain the relation between economic development and energy consumption.
(2) Explain the basic mechanisms of greenhouse gases and global warming.
(3) Explain devices using renewable energy.

During the third quarter of the first week of the term, the authors explained the course guidance, the status of energy conservation, and new energy usage in Hokkaido. From the second week, one of the following power sources was picked up for each lecture. Each student researched their technical characteristics and installation and gave presentations to each other.

- solar power generation
- wind power generation
- biomass power generation.
- geothermal power generation
- small and medium-scale hydropower generation
- snow and ice cryogenic power generation.
- nuclear power generation.
- thermal power generation

During the fourth quarter, the authors conducted the energy mix game with students as three intensive lectures. These lectures covered the game background and instructions on how to proceed. Students played one basic game and one country-specific version as Game 1. For the subsequent three lectures, students played the game of country-specific version as Game 2, Game 3, and Game 4. At this time, the authors asked the students to adopt different country-specific features each time. Table 1 presents the students' selections.

Table 1 Student selections of country-specific cards

	Game 1	Game 2	Game 3	Game 4
Student A	G	B, F	E	No Use
Student B	C	A	A, D	A, D, F
Student C	B	D	F	E
Student D	E	E	E, G	No Use
Student E	E	B	C, F, G	G

A. Oil Field Holdings
B. Large Oil Field Holding
C. Large Coal Field Holdings
D. Gas Field Holdings
E. Electricity imports available (2 pieces)
F. GHG limit not ratified
G. Large flat areas

After the lecture, the authors conducted a periodic exam and a questionnaire.

Periodic examination – Question 1

In Japan, to what ratio do you think the seven types of power generation (coal-fired, oil-fired, gas-fired, hydroelectric, solar, wind, and nuclear) should be used? Present the percentage of each type, taking the total amount as 100%, and provide reasons for your response within 270–300 words.

Answer – Student C

Because thermal power generation is stable and its output can be adjusted, it was considered optimal to cover about half of the power needs using thermal power generation. The percentage of nuclear power generation would vary depending on the introduction of small nuclear reactors, which have a lower risk of accidents. Therefore, this mix was deemed appropriate. Wind and solar power are unstable in terms of output, so their percentage was estimated as low. Regarding the breakdown of thermal power generation, the emphasis was on gas-fired power generation, which emits low amounts of carbon dioxide. The share of oil was set as about 5%, in light of increasing uncertainty in the Middle East. Coal-fired power was also regarded as at a similar level because of its low cost. The share of thermal power was set as about half to accommodate hydrogen-fired power generation technology, which might be realized in the future. The result of Student C is shown in Figure 6.

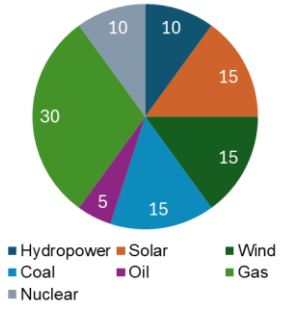


Figure 6 Result of Student C.

Answer – Student E

In Japan, there is currently a need to move away from dependence on fossil fuels. One reason for Japan's fossil fuel dependence is the sharp decline in nuclear power plant use following the Fukushima Daiichi nuclear power plant accident, which has been replaced by thermal power generation. Going forward, Japan plans to reduce coal-fired, oil-fired, and gas-fired thermal power plants, which currently account for about 80% of its power generation, by nearly half, and to promote the reintroduction of nuclear power generation. In addition, Japan aims to introduce much wider use of renewable energy sources, with solar, wind, and hydroelectric power each accounting for 15% of power generation. Nuclear power and renewable energy will become the mainstays of power generation. The proportions of power generation systems using fossil fuels are set as 5% coal-fired, 6% oil-fired, and 9% gas-fired, concerning GHG emissions in the energy game. The result of Student E is shown in Figure 7.

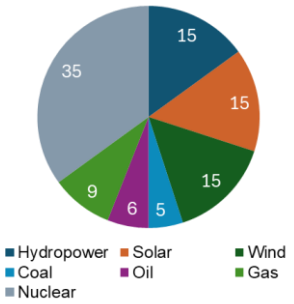


Figure 7 Result of Student E.

The ideal Japanese power source composition estimated by the students, based on their proposals, is presented as Table 2.

Table 2 Analyze students' suggestions

	Average	Maximum	Minimum	Standard deviation
Hydropower	13.7%	30.0%	5.3%	8.8%
Solar	11.7%	15.0%	8.0%	2.8%
Wind	11.7%	15.0%	8.0%	2.8%
Coal	10.1%	20.0%	5.0%	6.3%
Oil	6.7%	10.0%	5.0%	1.8%
Gas	15.9%	30.0%	9.0%	7.4%
Nuclear	30.3%	52.6%	10.0%	14.5%

Renewable energy *	37.1%
Thermal power **	32.7%
Nuclear power	30.3%

* Renewable energy: hydropower, solar and wind
** Thermal power: coal, oil and gas

However, according to the Seventh Strategic Energy Plan announced by the Ministry of Economy, Trade and Industry in February 2025, the power source composition in 2040 is projected as shown in Table 3.

Table 3 Power source composition in 2040

Renewable energy *	approx. 40% – 50%
Thermal power **	approx. 30% – 40%
Nuclear power	approx. 20%

* Renewable energy: hydropower, solar and wind
** Thermal power: coal, oil and gas

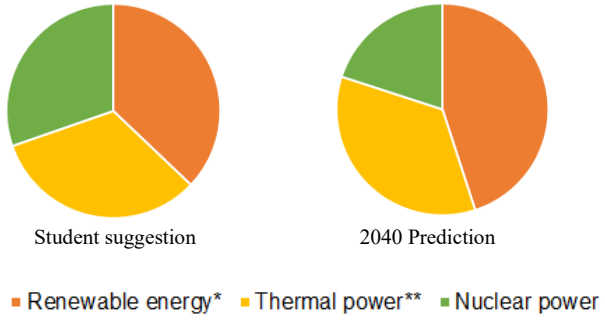


Figure 8 Average result of student suggestions.

Student suggestions and 2040 predictions are presented for comparison in Figure 8. Results were generally similar, but the student proposals included slightly more nuclear and less renewable energy. This comparison suggests that students were able to learn power source composition concepts experientially through game play.

Periodic examination – Question 2

For a country to satisfy more than half of its electricity demands with wind and solar power, what conditions would be necessary for the country's ratio of power sources? Illustrate the percentages and describe the conditions in 270–300 words.

Answer – Student B

Wind and solar power generation, which do not emit greenhouse gases, are attracting attention as clean energy sources. However, power generation capacity is dependent on weather conditions. Therefore, other types of power generation must generate sufficient power to compensate for fluctuations in power generation from wind and solar sources. We propose combining nuclear power, which can generate electricity on a large-scale, with hydropower, which is clean and efficient, and gas-fired thermal power, which emits less GHG amounts and generates appreciable amounts of electricity. To meet more than half of electricity demand using wind and solar power, power generation systems must be installed in certain locations to generate wind and solar energy with very low environmental impacts. Furthermore, electricity consumers must adopt more energy-efficient home devices and other systems to reduce power consumption. The result of Student B is shown in Figure 9.

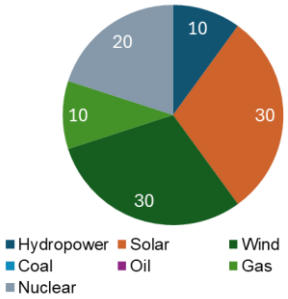


Figure 9 Result of Student B.

Answer – Student D

We believe that countries with a high percentage of renewable energy should have at least 30% of their power generation provided by thermal power using fossil fuels such as natural gas, oil, and coal. The reasons for this are multifaceted. First, renewable energy sources are unstable because the amounts of power generated fluctuate greatly depending on the weather. Secondly, the cost of generating power from renewable energy sources is high. Thirdly, the construction of large-scale renewable energy power plants requires large tracts of land, which can have an impact on the environment. By securing at least 30% of thermal power generation, which can provide stable power generation, power can be generated mainly from renewable energy sources with greater reliability. This approach also helps prevent unnecessary deforestation and other environmental effects associated with large-scale renewable energy projects. The result of Student D is shown in Figure 10.

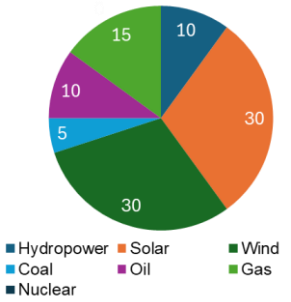


Figure 10 Result of Student D.

The results confirmed that the students are aware of practical issues and some idealistic notions of renewable energy introduction.

A questionnaire was administered. Responses were received from three respondents as shown below.

Questionnaire – Q1
How did you feel about this game?

- ✓ Initially, I did not have a good understanding of the characteristics of each type of power generation; there were many challenges. However, as the number of sessions increased, I found it very interesting to learn about the energy mix which leverages the strengths of each power generation mode.
- ✓ I enjoyed learning about the mechanisms of power generation, greenhouse gas (GHG) emissions, and the

benefits and shortcomings of each power generation method.

- ✓ Players can reduce power generation facilities to a minimum by lowering the initial development level to avoid going into debt. Alternatively, they can borrow large amounts of money early to buy country-specific cards and investment cards, aiming at considerable profits and subsequent repayment. Another strategy involves using renewable energy or nuclear power to reduce greenhouse gas emissions, thereby adversely affecting the surrounding environment. The final score can change considerably depending on how the game is managed. Strategies such as using renewable energy or nuclear power to reduce greenhouse gas emissions can make the game more challenging for other players. The winner is chosen according to the final score, which varies greatly based on the chosen strategies and game management.

Questionnaire – Q3
Did repetition of the game deepen your understanding of the energy mix?

The results of Q3 are summarized in Table 4.

Table 4 Results of Q3

Did not deepen my understanding of the energy mix at all	0
Did not have a good understanding of the energy mix	0
Understanding of the energy mix was neither	0
My understanding of the energy mix has deepened	1
My understanding of the energy mix is very good	2

Students' answers to "Please tell us why you gave the response shown above" are shown below:

- ✓ In the first game, the final development level stopped at 5. However, as the number of games increased, our understanding of the characteristics of thermal power, nuclear power, and renewable power improved. We succeeded in combining them effectively. In the last game, the final development level reached 8 while meeting GHG restrictions.
- ✓ The reason for this improvement is that, by playing the game with a broad perspective and with consideration of factors such as GHG emissions, resource prices, power generation equipment prices, and country characteristics, the final score increased along with the number of times the game was played.
- ✓ I am now able to consider characteristics of thermal, hydro, nuclear, wind, and solar power and ascertain which to use and how much to use to meet my power generation requirements and greenhouse gas emission limits. This improvement is attributable to our enhanced ability to evaluate the characteristics of thermal, hydro, nuclear, wind, and solar power generation and to make informed decisions about their usage and proportions.

The students enjoyed participating in game-based education and deepening their understanding through repeated game play.

Conclusions

In lectures for mechanical engineering students, the authors were able to address energy issues, which tend to be biased toward technical elements, by extending their exposure to the energy mix through the use of games. As a result, the students were able to think independently about the energy mix, often suggesting, "Just make it optimal." Consequently, they were able to propose a mix that closely resembled Japan's future power supply mix. However, the players were few (5 students), constituting a small sample. The authors will strive to increase the sample size by continuing to offer these lectures in future courses for additional consideration and validation.

Acknowledgments

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References

The Japan Center for Climate Change Actions (JCCCA), https://www.jccca.org/lp/english

Hamada, R., Nakayama, S. & Yusa, N. (2024). Integrating the country's energy situation and international greenhouse gas reduction negotiations into a board game for understanding the best power mix. 2024 Autumn Meeting of the Japan Association of Simulation and Gaming. 2024/11/23-24.

Ministry of Economy, Trade and Industry (2025). the Seventh Strategic Energy Plan, https://www.meti.go.jp/english/press/2025/0218_001.html

Yusa, N. & Hamada, R. (2021). Development of a board game for studying energy mix. *Journal of Energy and Environmental Education*, 15, 21-28.

Yusa, N. & Hamada, R. (2023). Board game design to understand the national power mix. *Education Sciences*, 13, 793.

USE OF FIRST-PERSON PLAYER COMPUTER GAME TO IMPROVE GERONTOLOGY STUDENTS' EMPATHY TOWARDS PERSONS WITH DEMENTIA

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Conventionally, gerontology students studying to be future carers for persons with dementia develop empathy for the people they will be caring from an observer's perspective. This could either be through directly observing the difficulties faced by people with dementia or reviewing various media articles that highlight the problems related to the illness. As a result, the students current learning falls far short of enabling students to have an experience closer to being 'in the shoes of a person with dementia'.

This study explores the potential use of a first-person computer game format for facilitating and motivating the learning of gerontology students. A simulation format that enables students to have something closer to a first-person perspective of the common visual and auditory experiences of persons with dementia. This would open the potential for a more impactful, emotive experience that generates the students' deeper understanding and sense of empathy toward the people with dementia.

The proposed study piloted use of the game with students from a gerontology course in Singapore. A country where the dementia awareness is rising as the country rapidly evolves into a greying society. The study was jointly planned by lecturers with relevant expertise in dementia care as well as those with a built environment background with the ability to develop computer simulation environments. The proposed simulation that the students engaged with are made up of the digital built environment as well as presence of autonomous nonplaying character avatars that students can autonomously converse with. Both elements are planned to enable a combined experience that closely reproduces the common environmental conditions and interactions encountered by people with dementia.

The study plans to potentially capture the breadth and depth of the students' response. With this purpose in mind, the various input of students participating in this research were captured through an online anonymous survey with open ended questions. The responses were compiled and analysed to highlight the prominent benefits as well as limitations of the current computer simulations used. The current research provides foundation as well as possible directions of future research. This could expand beyond the initial topic to influence the direction of teaching and learning in topics related to other emerging concerns in society.

Keywords: *computer simulation, dementia care, motivating students teaching and learning, empathy*

Introduction

Based on data produced by the Singapore Department of Statistics, in 2024 the ratio between working age residents (aged 20 to 64) compared to residents aged 65 and above is 3.5. This is a decline from a ratio of 4.3 in 2020 and a ratio of 7.4 as recently as 2010 (Department of Statistics Singapore, 2025). The data shows a progressive decline of the ratio of the amount of working age residents that can support the elderly population. This is a clear indication of Singapore rapidly becoming a greying society.

The situation also comes with a realisation that Singapore will be required to continue to increase support for its rising elderly population. This also comes with an increased awareness of the specific problems faced by the elderly population. Within the context stated above, specific tertiary education courses related to gerontology in general and more specifically to cater for care of the elderly have been established in Singapore.

One specific problem highly related with the elderly population is the higher likelihood for a person to develop dementia as a person grows older (Subramaniam et al, 2025). Therefore, an important part of a gerontology student's education would be related to the care and understanding of dementia.

Continuous improvement of how the teaching and learning of the topic of dementia that leads to a student's deep understanding is of primary concern. An understanding that would hopefully lead to the student's deep empathy to care for the person with dementia (PWD).

This paper will take a closer look at one specific research conducted at a polytechnic level gerontology care related course in Singapore as part of continuous efforts to improve care for persons with dementia. The polytechnic is fortunate to have a wide range of courses ranging from social sciences, engineering as well as design from which a multi disciplined approach for

improvements could be realised. In this case, the research involved a collaboration between teaching staff from the school of Humanities and Social Science's gerontology related course and the School of Design's built environment related course.

Before the research was conducted, the topic of dementia has been taught in a series of subjects. This starts with subjects in year one on the theoretical understanding of dementia within the wider introduction of gerontological care. Year two students will delve deeper into the topic of dementia specifically. The course also collaborates with a dementia care centre to enable practical observation of the care of persons with dementia. In short, the students learn through a variety of ways to observe the persons with dementia.

The current research wishes to enable students to not just be an observer. The research wishes to enable students to be closer to a position of being 'in the shoes' of a person with dementia.

This is made possible through collaboration with teaching staff from the school of Design with a built environment studies background. The school of Design staff at the time was interested in developing digital built environment simulations that would be useful for the needs of other professions.

In this case, such a digital environment explored possible ways to replicate some experiences of what is uniquely seen and heard by a person with dementia. By engaging with this digital environment, the gerontology students would not be 'looking at' the person with dementia. On the contrary, the students would be closer to an experience of 'seeing, hearing and overall experiencing the world' of a person with dementia. It is a unique visual and auditory experience beyond that of an outside observer trying to 'imagine' what the person with dementia is experiencing.

The teaching staff from both schools have the common objective that the experience given to the students would enable them to not just gain increased understanding. More importantly, they would also obtain a deeper empathy towards the difficulties faced by persons with dementia. An empathy that is critically needed for students to be motivated to care for the persons with dementia in their future profession.

The following sections of this paper will focus on how the research was set up, results that were achieved and the conclusions that could be drawn. At its heart, the following sections of this paper will attempt to answer the main question of: To what extent does this initiative, to enable the students to have an experience closer to what is seen and heard by a person with dementia, can affect their learning?

The research will endeavour to highlight the possible improvements that could be accomplished as well as the limitations currently faced. In addition, the research also discusses the current state of digital environments that could be created to enable the students to have the intended learning experience. The paper will also discuss the students' feedback on the drawbacks of the set up and technologies. At the same time recommendations for future improvements will also be noted.

Materials and Methods

This research is still at a preliminary stage. For this research, 31 students participated. The students were in their second year of a three-year polytechnic level diploma related to gerontology care in Singapore. The students were introduced to the digital simulation by the school of design lecturer that made the simulation. This was done during the students' in-class consultation activity.

Within the time limit of the class activity, five students had the experience to try out the digital simulation. The other 26 students could see what the five students are experiencing through a shared projected screen.

The chosen format for the digital environment simulation was a first-person computer game. This format was chosen because the view shown on the computer screen would be the view that emulates what is seen through the eyes of the person playing the game. Therefore, this format would be a format that gives a closer experience for the student player to feel to be 'in the shoes' of a person with dementia. This is distinct from a third person computer game format that shows the entire body of the avatar that represents the student playing the game. This format was not chosen because it only resembles observing the person with dementia from a distance. The difference between the different formats are presented in Figure 1 and Figure 2.



Figure 1. First Person Format emulates the view from the eyes of person playing the game. In this case player is conversing with the character in front of the player. The shadow of the player's head can be seen on the other character's torso.



Figure 2. Third Person Format emulates an observer that is looking at the entire body of the player's avatar (visual representation of the player) from the back. Iin this case the male figure with the beige sweater is the player avatar.

The first-person format game was developed using Unreal Engine software. This software was chosen due to the different visual as well as auditory experiences that could be developed for different parts of the digital environment. The different visual and auditory experiences were used to give a contrast between parts that show the world of a person with dementia and parts that show the real world (experienced by people who do not suffer from dementia).

For this specific simulation the staff from School of Design was given useful input by the staff teaching gerontology. The effects shown in the simulation closely replicated the visual and auditory experiences of a person that has a specific type of dementia which is known as Lewy body dementia (Lewy Body Society, 2019).

The Unreal Engine software also provided an important feature that rapidly simulates the surrounding environment. The feature is called procedural content generation (PCG). Using this feature a multitude of buildings, trees and streets of different sizes could be spawned randomly to rapidly fill the landscape using parametric input. Thus, digitally creating an urban conurbation instantaneously. The PCG environment was further enhanced by using additional code to enable changing arrangements of buildings to appear over time. Overall, this will result in an ever changing overall built environment. This simulates the disorientating built environment that people with dementia navigate through in their daily lives. The changing built environment created can be seen Figure 3 and Figure 4 below.



Figure 3. Prior arrangement of simulated buildings



Figure 4. Subsequent arrangement of simulated buildings

The PCG environment also provides a feature that could enable variations of the colour tone and camera lens sharpness in different parts of a digital environment. This feature was useful to incorporate the input of the gerontology staff about difference of colour and vision between the real world (as perceived by people that do not have dementia) and the world of a person with dementia. Figure 5 shows a comparison of the two world views that could be experienced.



Figure 5. Left: Colour and lens sharpness in the real world; Right: Colour and lens sharpness experienced in the world of a person with dementia.

At a detailed level, the digital simulation also incorporated the use of technology developed for utilising non-playing character (NPC) human avatars that the person playing the game could interact with (Moltenbrey, 2023). These NPC avatars represent different people that the person with dementia may often encounter in their daily experiences. These can range from health care professionals to family members that the person with dementia commonly engage with.

The appearance of the avatar is also adapted to what a person with dementia would see the character to be in different parts of the digital environment. The appearance of the avatar may change as a person exits or enters the part of the simulation environment that shows the world of a person with dementia.

These changing forms of the avatars are meant to simulate the symptom of misidentification that a person with Lewy body dementia may experience. The person with this particular form of dementia may even misidentify their own family members (Lewy Body Society, 2023). An example used in the simulation can be seen in Figure 6. In this example, the middle-aged female character in the real world is seen as a younger version of herself in the world of a person with dementia. This could lead the person with dementia to misidentify the avatar as a different person.



Figure 6. Left: character in the real world; Right: Same character with a younger appearance in the world of the person with dementia.

The students who played the game were also able to verbally interact with the character's avatar (visual representation of the character). In order to support this, the avatars utilised conversational artificial intelligence technology. This was provided by Convai.com website. This technology enables each avatar to be programmed with a specific personal character data bank. This data bank can be updated and modified whenever needed. The NPC avatars were also given a specific voice type that is relevant to the intended character. This enables the

avatars to be conversational non-playing character AI (NPC AI) avatars. The use of the technology provided by Convai.com also enabled students to verbally ask the avatars to walk by either leading or following the players to different parts of the digital built environment simulation (Convai, 2024). The interface used to enter the knowledge bank, voice and personality of the avatar in convai.com can be seen in Figure 7.

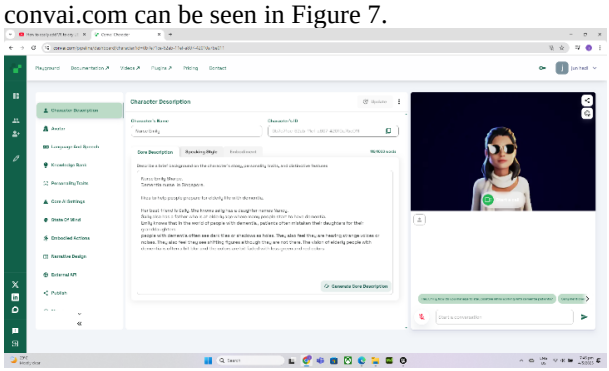


Figure 7. Convai.com interface

An additional information to note is that the body, facial features and clothes of the avatars were developed from various sources. Some were taken from the Metahuman website which is developed by Epic Games, the parent company of Unreal Engine. The Metahuman avatars had a high compatibility with Unreal Engine, but the possible appearance and clothing are rather limited (Gorka Games, 2023). More customisable avatars were developed using a software called Character Creator 4 and imported into Unreal Engine (Jobutsu Tutorials, 2023). A comparison of the quality of the conversational NPC AI avatars can be seen in Figure 8. Additionally, some background figures with movement but without speech ability were made using Adobe Mixamo (Unreal University, 2024). These can be seen in Figure 12.



Figure 8. Left: Metahuman avatar Right: Character Creator 4 avatar.

After the simulations have been conducted, the students were given an opportunity to provide their feedback. This was mostly obtained through open ended questions in an online anonymous survey. The mostly open-ended nature of the survey questions were meant to enable students to extensively express their feedback.

Results and Discussion

The students gave a range of responses toward what they experienced. The paragraphs below will highlight the main findings and offer some further discussion on the findings. Figure 9 and Figure 10 show situation of the room and facilities used at the time of the student's interaction with the first-person format computer game simulation.



Figure 9. View of a student playing the game viewing through a laptop computer screen while the non-playing students are at the back of the class.

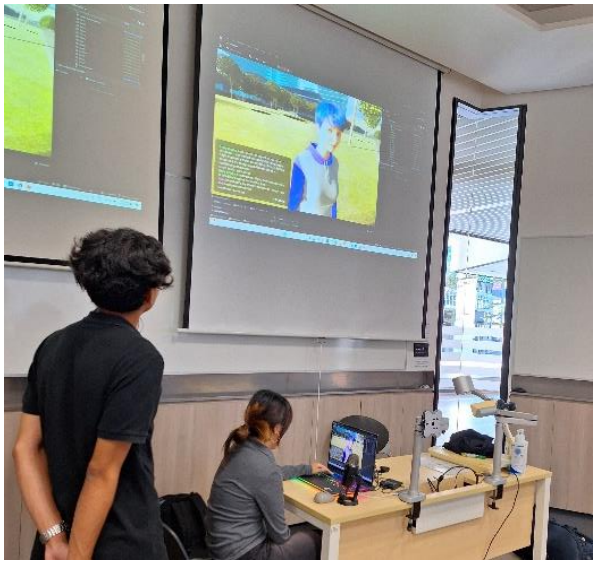


Figure 10. View of class projector screen used by non-playing students.

The vast majority of students (30 out of 31 students) were able to list specific experiences that were common to built environments experienced by persons with dementia. These range from viewing water puddles as holes to changing building arrangements. The students were also able to observe changing imaginary characters and sounds that the player representing the person with dementia can see or hear. Figure 11 and Figure 12 show some of the scenes from the part of the simulation showing the world of the person with dementia.



Figure 11. Example of water puddles perceived as holes in the world of the person with dementia.

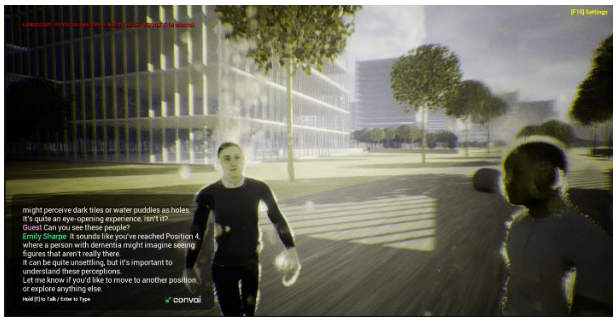


Figure 12. Example of avatars from Adobe Mixamo used in the simulation to depict examples of illusion of imaginary figures seen by the person with dementia.

Most students (29 out of 31) gave feedback that through experiencing the first-person game, they felt a higher sense of empathy towards the person with dementia. When asked about it in more detail, the students gave a variety of reasons of what encouraged a higher sense of empathy. Some students feedback centred on the ability to see not from their own point of view but from a person with dementia. Other students highlighted the sense of annoyance, fear and confusion that they themselves were feeling from what they experienced in the simulation.

In terms of specific positive experiences of the simulation, the students gave a variety of replies. This ranged from enjoying the interaction that the simulation provides as well as some increased insights and understanding of the topic of dementia.

Similarly, when asked to give feedback of negative experiences of the simulation, the students also gave a variety of feedback. These range from some glitches and slow processing that occurred while the simulation was played as well as some feeling that the scenario of the game was not realistic enough.

The students gave suggestion for future improvement of the game. The most basic suggestion focused on improving the game playing mechanism such as possible use of WASD buttons on a keyboard. A feature that is used for common input in computer games. Other students stated the need for utilising better graphic displays and a faster pace of the game.

There were also some more advanced suggestions to enable the game to be more realistic. For instance, there was a suggestion that the simulation could also be made to be more contextual for Singaporean students by using digital environments that are familiar local scenes. There was also a suggestion that the interaction of the player with NPC avatars could be more varied, realistic and emotional. For example, this could be done through scenarios where the plea for help by player as a person with dementia was misunderstood, rejected or shun by the NPC avatar.

Some analysis could also be done in terms of teaching efficiency and future for development. The simulation was conducted within a limited class consultation timing. With only 5 students directly playing the game, the projected view only enabled most other students to have lesser form of interaction. Most students can see the interaction that happens but cannot actively participate. Efforts should be explored to enable more students to have the opportunity to play the simulation.

One possibility of how wider participation could be realised is by further developing the simulation into a stand-alone game. This could be downloaded by each student into their personal computer. This could also enable access even outside of the classroom hours, at any time and any location that the student prefers.

By enabling each student to download a stand-alone format of the simulation, the students could play the simulation repeatedly on their own computer. Repeated use could enable the students to notice details and nuances of the simulation that may have been previously missed. The repeated use of the simulation could potentially also offer an interactive way in which students could revise on specific learning points related to the study of dementia care.

The students feedback also highlighted that improvements could still be considered to further improve the immersive view that students could experience. It is important to consider the limitation of a 2D computer or projector screen as the medium to show the view of a person with dementia. It raises questions that if the digital simulation can be viewed in a 3D format it could enable an even higher state of immersion that enables the students to be even closer to be ‘in the shoes’ of a person with dementia.

Conclusions

Overall, the simulation seems to enable something closer to a ‘first hand’ experience that the students would not have been able to obtain in the current conventional observations that they are commonly taught with. Overwhelmingly, most students have expressed that the simulation had a positive impact towards their understanding and empathy for persons with dementia.

It should be reminded that currently the research is at a preliminary stage with feedback from a limited number of respondents. Further research involving a larger number of respondents would be useful to further confirm the current findings.

Discussion on the possible future development such as the idea to make the simulation into a downloadable stand-alone game as well as the search for even more immersive formats are also important to note. Such suggestions could broaden access to the simulation and improve the immersive quality of the simulation as well.

The research also raises wider questions beyond the scope of dementia care alone. Could other first person

computer games be developed to help students understanding and empathy towards the plight of people with other ailments? Would this possibly have wider impact that could benefit health care related education in general?

All these efforts are in line with an overarching pursuit to continually improve the education of students. Nurturing them to be passionate individuals who will be the future generation of care giving professionals. In the end, the hope is that these efforts will contribute to the emergence of a more empathetic and caring society in the future.

References

Chye F. (2015). *Dementia design sourcebook*. Department of Architecture. School of Design and Environment. National University Singapore

Convai (2024) *Interactive AI Reallusion characters that execute your actions | Convai Unreal Engine tutorial.* Retrieved May 4, 2025 from https://www.youtube.com/watch?v=UyxNliF8LKU&t=406s

Department of statistics Singapore (2025). *Understanding old age support ratio*. Retrieved May 4, 2025 from https://www.singstat.gov.sg/modules/infographics/old-age-support-ratio

Gorka Games (2023). *How to replace the mannequin with a Metahuman in Unreal Engine 5*. Retrieved May 4, 2025 from https://www.youtube.com/watch?v=VEhSX04mxOY&t=411s

Jobutsu Tutorials (2023). *Character Creator 4 to Unreal Engine 5*. Retrieved May 4, 2025 from https://www.youtube.com/watch?v=LRllQ2AOjc0

Lewy Body Society (2019). *A Guide to Lewy Body Dementia.* Retrieved May 8, 2025 from https://www.lewybody.org/wp-content/uploads/2019/11/A-guide-to-Lewy-body-dementia-2019-edition-final.pdf

Lewy Body Society (2023). *Managing delusions, misidentification and Capgras syndrome in Lewy body dementia*. Retrieved June 22, 2025 from https://www.lewybody.org/information-and-support/information-leaflets/managing-delusions-misidentification-and-capgras-syndrome-in-lewy-body-dementia/

Logut A. (2024). *Unreal Engine 5.2 PCG plugin - Ep 4.1 - Update on splines + Discord/FAQ*. Retrieved May 4. 2025 from https://www.youtube.com/watch?v=uWhmnMMwbu8

Moltenbrey K. (2023. June 1) *Expanding the role of non-player game characters*. Retrieved November 30, 2023, from https://gfxspeak.com/featured/my-npc-is-smarter-than-your-npc/

Royal Skies (2024) *Unreal 5 - post process volume (3 minutes!!)*. Retrieved May 4, 2025 from https://www.youtube.com/watch?v=InSXTn3QVr4

Subramaniam M., Abdin E, Asharani P. Roystonn K., Devi F., Wang P., Shafie S., Sagayadevan V., Jeyagurunathan A., Boon Y.,Tan B., Vaingankar J., Yao F., Magadi H., Ma S., 5 Wai L., McCrone P., Heng D., Mahendran R., Prince M., 8 Li L., Chong S., (2025) Prevalence of dementia in Singapore: Changes across a decade. *Alzheimers & Dementia.* Volume 21 Issue 2. Retrieved May 8, 2025 from https://alz-journals.onlinelibrary.wiley.com/doi/full/10.1002/alz.14485

Unreal University (2024) . *How to import any character from Mixamo to Unreal Engine 5 tutorial*. Retrieved May 8, 2025 from https://www.youtube.com/watch?v=N7n6_-ICRvE

Practical Report by Exercise for Integrating Science and Engineering : Proposal of Novel Open Lectures and Educational Materials

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In this report, we describe activity examples of the lecture "Trans Exercise of All Program" such as the open lecture and visiting lecture for the elementary and junior high school students, and the creation of the educational materials. "Trans Exercise of All Program" in their third year and fourth year is offered primarily for purposes of integrating fields at National Institute of Technology, Tsuyama College. The purpose of this lecture is "to acquire engineering design and teamwork skills by grasping the purpose of the theme, recognizing what needs to be prepared, utilizing one's own expertise and communicating with other specialties to solve problems that have arisen, and devising ways to solve them". The class is equivalent to "Develop multi-disciplinary ability", "Develop problem solving ability" and "Develop communication and presentation abilities". In this course, faculty member forms teams and set the theme for the exercise. Students select a theme based on their interests and participate accordingly. As the authors belong to "Electric and Electronic System", the theme of the seminar is " Electronics experience and development of electronics teaching materials". At the beginning of their third year, they participate as the assistant students in the open lectures for elementary and junior high school students. Every year, in the first week of August, open lectures such as "Let's make the LED flashing circuits" are held. By experiencing the preparation and assistance for these open lectures, students are able to propose new types of the open lectures and the visiting lectures. For example, students proposed the visiting and open lectures such as "Let's make the electronic organ" and "Let's learn the basic electronics and programming using littleBits". The goal of this course is to ultimately participate in the electrical engineering educational material planning contest hosted by the Power Academy. The participating in this contest increase the motivation of the students. Among the educational materials in the lecture created by our students, the students won excellence award in the 2nd, 3rd, 4th, and 6th contests, for example, the title of the proposed materials in the 6th contest is "Educational tool for learning biomass power generation by using the electronics". We believe that the activities described above such as the open lecture, visiting lecture, and the creation of the educational materials, have not only achieved our educational objectives but also contributed to the local community.

Keywords: *open lecture, visiting lecture, electrical engineering educational material planning contest, multi-disciplinary ability*

Introduction

In 2016, National Institute of Technology (NIT), Tsuyama College reorganized four departments, mechanical engineering, electrical and electronic engineering, electronic control engineering, and information engineering, into one department [1]. The name of the new department is the Department of Integrated Science and Technology. The Department of Integrated Science and Technology offers interdisciplinary education and integrates science as basic science with engineering for practice.

At department of integrated science and technology, NIT, Tsuyama college, in the first year, students are divided into four classes with a number of 160 students and study a variety of basic subjects. From the second year, students are assigned to a specialized field. There are four programs "Advanced Science", "Mechanical System", "Electric and Electronic System", and "Communication and Information System", in the Department of Integrated Science and Technology. Students in their second year and above not only study their respective specialized fields, but also take interdisciplinary lectures. Thus, interdisciplinary courses are necessary from the second year onwards. One such course is "Trans Exercise of All Program" offered primarily for purposes of integrating fields for third and fourth year students at NIT, Tsuyama College [2].

In this report, we present activity examples of the lecture "Trans Exercise of All Program" such as the open lecture and visiting lecture for the elementary and junior high school students, and the creation of the educational materials.

Trans Exercise of All Program

"Trans Exercise of All Program" is offered primarily for purposes of integrating fields at NIT, Tsuyama College [2]. The purpose of this lecture is "to acquire engineering design and teamwork skills by grasping the purpose of the theme, recognizing what needs to be prepared, utilizing one's own expertise and communicating with other specialties to solve problems that have arisen, and devising ways to solve them". Educational objectives of the class are "Develop multi-disciplinary ability", "Develop problem solving ability" and "Develop communication and presentation abilities".

Table 1 shows course information of trans exercise of all program I. Students will study "Trans Exercise of All Program I" in their third year and "Trans Exercise of All Program II" in their fourth year. This lecture is for one and a half years because the contents of "Trans Exercise of All Program I" is continued in the first semester of "Trans Exercise of All Program II". The pre-graduation research is studied in the second semester of "Trans Exercise of All Program II".

Students give an oral presentation at the end of the first semester of their third year as an interim presentation, a poster presentation at the end of their third year, and an oral presentation at the end of the first semester of their fourth year as a final presentation. Students also have to submit reports at each presentation. According to the rublic items of this course, "The student can use ICT, ICT tools, texts, etc. For basic information gatherring and dissemination", and the goal is "Develop communication and presentation abilities", the presentation is given to evaluate such contents.

Poster presentetaions in the third year are conducted with 3-minute presentation and 2-minute questions and answers. Students present to three assigned faculty members. In other words, students present three times. Faculty members evaluate the following three categories in the presentation.

[A] Was the poster easy to understand ?
[B] Was the purpose and content of the exercise explained ?
[C] Was the presentation time used effectively ?

Each category is rated on a scale from 0 to 5 points, for a total of 15 points.

Oral presentations in the fourth year are conducted with 4-minute presentation and 2-minute questions and answers. Three faculty members are assigned to each classroom as judges. Fuculty members evaluate the following two categories in the presentation.

[A] Was the purpose and content of the exercise explained in the presentation ?
[B] Was the Q & A session sufficient ?

Each category is rated on a scale from 0 to 5 points, for a total of 10 points.

Table 1. Course information of trans exercise of all program I

Item	Information
Course category	Specialized / Compulsory
Class format	Seminar
Credits	Academic Credit : 4
Term	Year-round
Classes per week	2

Implementation Methods

In this course, faculty member forms teams and set the theme for the exercise. Students select a theme based on their interests and participate accordingly. Typically, each instructor supervises about four students. As the authors belong to the "Electric and Electronic System", the theme of the seminar is "Electronics experience and development of electronics teaching materials". We tried to integrate the fields of the expertise by including students from various fields. Since this lecture began in 2018, we have consistently accepted students from fields other than the electric and electronic systems every year. Through exposure to programming and other areas, the course has facilitated interdisciplinary learning.

Figure 1 shows an example of a one-year schedule for third-year students in our group. In April, the placements of third-year students will be decided. After that, they will study electronic circuits and related hands-on work in our group.

At the beginning of their third year, they participate as the assistant students in the open lectures for elementary and junior high school students. Every year, in the first week of August, open lectures such as "Let's make the LED flashing circuits" [3] and "Let's make the electronic music box" are held.

Figure 2 shows the LED flashing circuits. In the open lecture, the elementary school students create the LED circuits on the breadboard. The students prepare electronic circuit components, instructions, and materials by the day of the open lecture. Table 2 shows the procedure of the open lecture. The students actively assist in this open lecture. By experiencing the preparation and assistance for these open lectures, students are able to propose new types of the open lectures and the visiting lectures.

After the open lecture in August, students propose new contents of the open lecture and the visiting lecture. The goal is to participate in the electrical engineering educational material planning contest hosted by the Power Academy, and co-sponsored by the Institute of Electrical Engineers of Japan and the Japan Electric Association. Participating in this contest increases the

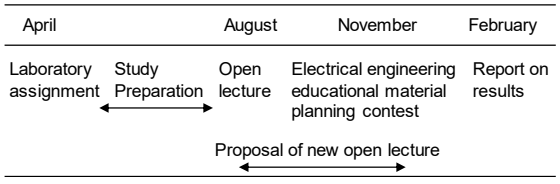


Figure 1. One-year schedule for third-year students

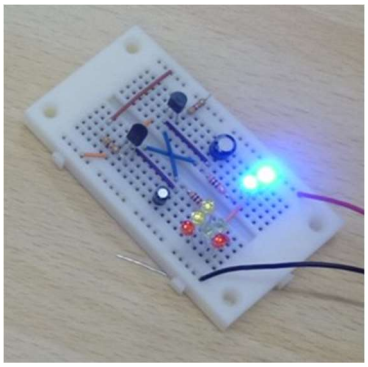


Figure 2. LED flashing circuit

Table 2. Details of open lecture

Step	Contents
1st	Important point : Explain on how to use tools (nippers, needle nose pliers)
2nd	Circuits fabrication
3rd	Experiment
4th	Discuss with assistant students
5th	Questionnaire

motivation of the students. The students submit the new lecture content related to the contest theme in November.

The open lecture and the visiting lecture are held as needed whenever requests are received. In December, presentation is held to share their outcomes, and in February, the students submit a report, as shown in Fig. 1. In addition, in the first semester of their fourth year, the students teach the newly assigned third year students about their activities.

Results

Table 3 shows the names of the novel proposed open lectures by the students. For example, students proposed the lectures with the following titles: “Let’s make the electronic timer” and “Let’s make the electronic roulette” in 2018, “Let’s make the electronic organ” and “Let’s make the mini frustrating stick” in 2020. Figure 3 shows the electronic organ, which was proposed in response to feedback from elementary school students who had previously participated in the LED flashing circuits lecture and expressed a desire to engage in more electronic circuits. Figure 4 shows the open lecture “Let’s make the electronic organ” held at the nearby elementary school in 2020.

Figure 5 shows the survey results for “Let’s make the electronic organ”. Figures 6 and 7 show the survey results for “Let’s make the electronic timer” and “Let’s make the electronic roulette”, respectively. The survey results showed that the participating elementary school students enjoyed the open lecture. They also showed that the elementary students were able to get interested in science. The survey also included a section which

Table 3. Titles of new open lecture

Year	Titles
2018	Let’s make the electronic timer
2018	Let’s make the electronic roulette
2019	Let’s learn the basic electronics and programming using littleBits
2020	Let’s make the electronic organ
2020	Let’s make mini frustrating stick

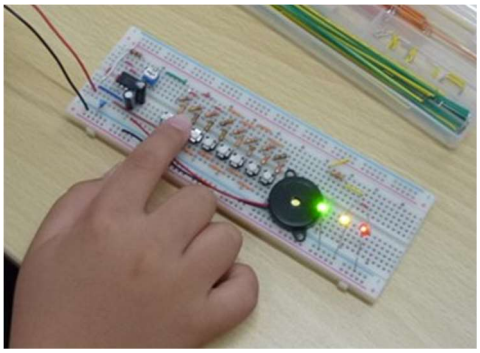


Figure 3. Electronic organ



Figure 4. Classroom of open lecture

students could write their impressions and opinions. Although only a portion of the comments are shown in Figs. 5 to 7, many of the students wrote comments such as “It was fun” and “I want to participate again”. It is clear from comments that many of the elementary school students enjoyed learning about electronic circuits and were able to get them interested.

Students proposed the open lecture titled “Let’s learn the basic electronics and programming using littleBits”. LittleBits [4],[5] is a learning material kit developed by the American company littleBits. Figure 8 shows the target shooting game fabricated with littleBits. Electronic circuits can be easily fabricated by connecting magnetic parts together. The fabricated electronic circuits can be operated using programming. It is scheduled to be held regularly in the future because this lecture is enjoyable for both children and their parents.

Table 4 shows the titles selected as excellence award in the electrical engineering educational material planning contest hosted by the Power Academy. Figure 9 shows the experiment “Let’s understand the electrical

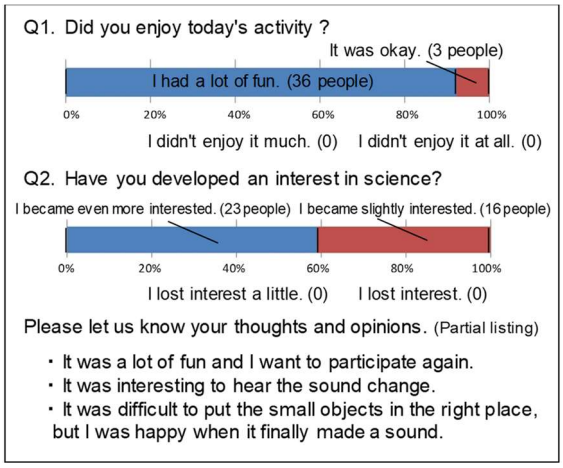


Figure 5. Survey results of "Let's make the electronic organ"

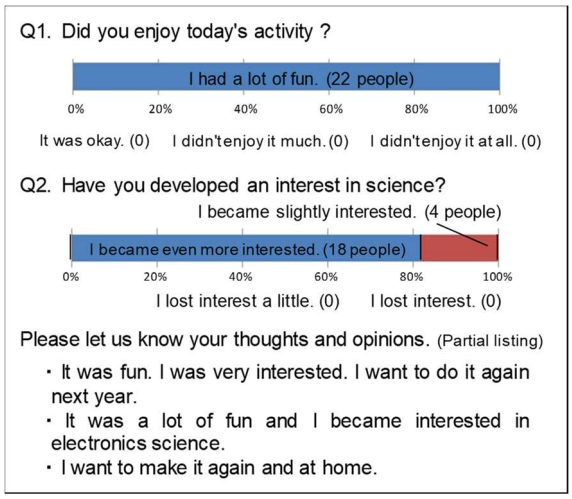


Figure 6. Survey results of "Let's make the electronic timer"

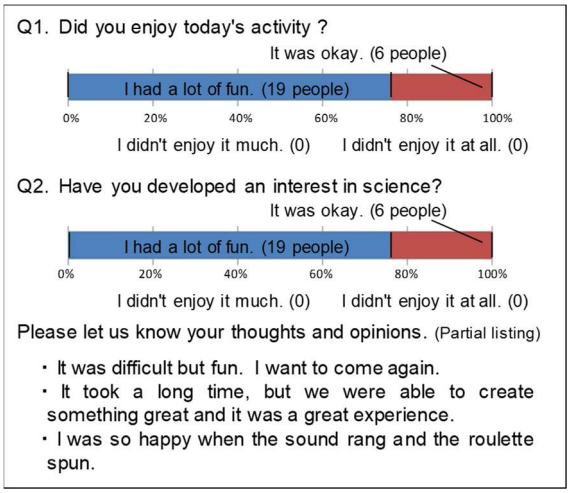


Figure 7. Survey results of "Let's make the electronic roulette"

circuits learned in junior high school by using circuit markers" in the second contest, 2020. The junior high school students can easily create the electric circuit by drawing the circuit diagram on the special paper using the circuit marker. The experiment in Fig. 9 is for learning Ohm's law.

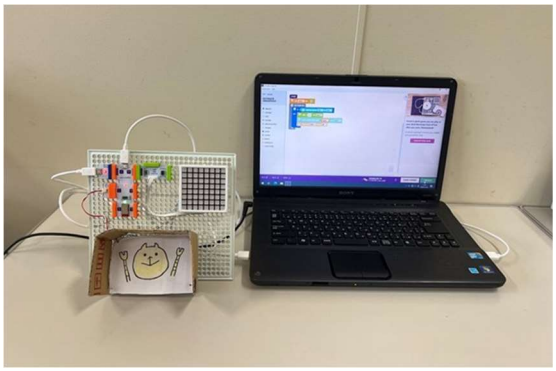


Figure 8. Target shooting game by littleBits

Figure 10 shows "Let's understand the renewable energy by using the quiz games and electronic circuit" in the third contest, 2021. Figure 10(a) shows the opening screen of the created quiz game. The quiz game incorporates elements of role-playing games, and the junior high school students can learn about the renewable energy by answering the quizzes. Figure 10(b) shows the circuit for learning about the power generating. The proposed lecture also teaches about the power generation by fabricating the electronic circuit.

Figure 11 shows the part of the experiment "Experimental educational tool for learning the difference between the direct current and alternating current by using the piezoelectric elements" in the fourth contest, 2022. By using piezoelectric speakers, the junior high school students can experiment to understand the

Table 4. Titles of the excellent award on the contest

No.	Titles
2nd	Let's understand about the electric circuits learned in junior high school by using circuit marker
3rd	Let's learn about renewable energy through quiz games and fabrication of electronic circuit
4th	Experimental teaching material for understanding the difference between direct current and alternating current using piezoelectric elements
6th	Educational tool for learning biomass power generation by using the electronics

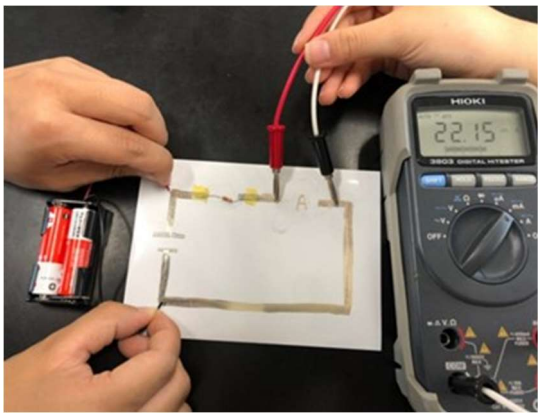
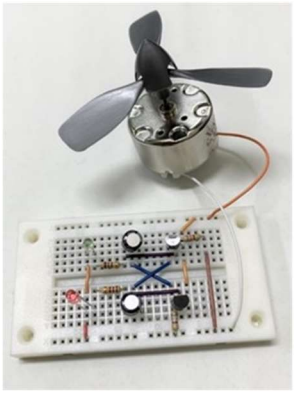


Figure 9. Experiment by using circuit markers



(a)



(b)

Figure 10. Educational materials for learning the renewable energy. (a) Opening screen of the quiz game. (b) Electronic circuit.

difference between the direct current and the alternating current.

Figure 12 shows the part of the experiment "Educational tool for learning biomass power generation by using the electronics" in the sixth contest, 2024. In this lecture, the junior high school students can learn about biomass power generation by fabricating the production using the milk plastic and LED flashing circuit.

As the above lectures were selected as the excellence award, we believe that the students were able to propose excellent open lectures. The contents of the materials selected as the award winner awards can be viewed on the Power Academy website [6].

Finally, a class questionnaire was conducted on the students who took this seminar during the final week of the seminar. The results are shown in Table 5. The questionnaire conducted at NIT, Tsuyama College has 14 items [7],[8], of which we focused on items 10, 12, and 14. This survey is scored out of 5 points, with higher scores indicating better results. The average scores from 2019 to 2022 are shown. Since a score above 4 points is considered as a good result, these results suggest that the students who took the course were satisfied with the class.

Conclusions

Activities example of the lecture "Trans Exercise of All Program" were presented in this paper. The students proposed the open lecture and visiting lecture for the elementary and junior high school students, and the

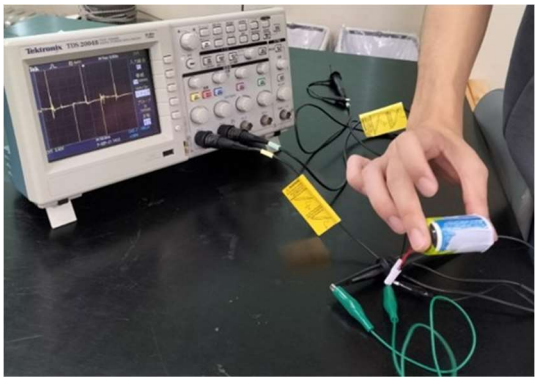


Figure 11. Experimental by using piezoelectric speakers.



Figure 12. Production using the milk plastic and LED flashing circuit.

Table 5. Results of the class questionnaire

Questions and contents	Average value from 2019 to 2022
10. Overall, would you rate this experiment / practical activity highly ?	4.468
12. Did you enthusiastically participate in the experiments and practical training ?	4.467
14. Did this experiment/practical activity make you interested in this subject ?	4.306

creation of the educational materials. Among the educational materials created by our students were selected as the excellence award in the electrical engineering educational material planning contest. We believe that the activities described above such as the open lecture, visiting lecture, and the creation of the educational materials, have not only achieved our educational objectives but also contributed to the local community.

References

[1] National Institute of Technology, Tsuyama College : https://www.tsuyama-ct.ac.jp/

[2] KOSEN Web Syllabus, Tsuyama College : https://syllabus.kosen-k.go.jp/Pages/PublicDepartments?school_id=32&lang=en
[3] K. Nishio (2025), Open lecture using LED flashing circuits for elementary school students, *Bulletin of National Institute of Technology, Tsuyama College*, No. 66 pp. 23-27.
[4] K. Nishio (2025), Open lecture using littleBits for electronic circuit and programming, *Bulletin of National Institute of Technology, Tsuyama College*, No. 66 pp. 28-32.
[5] littleBits (2023) : https://www.littlebits-jp.com/
[6] Power Academy : https://www.power-academy.jp/event/contest/
[7] National Institute of Technology, Tsuyama College : https://www.tsuyama-ct.ac.jp/gaibu/janketo-R06/jikken_honka.html
[8] K. Nishio (2018), Design method of electrical and electronic circuits by experiment of electronic and computer systems, *Bulletin of National Institute of Technology, Tsuyama College*, No. 59 pp. 67-71.

ENHANCING COMMUNICATION STRATEGIES FOR ENGINEERING STUDENTS: MANAGING CONVERSATIONAL BREAKDOWNS IN ENGLISH LANGUAGE EDUCATION

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To develop engineering students who can effectively contribute in a global context, it is essential to enhance their international communication skills while fostering a proactive mindset for engaging in intercultural environments. In English language education, equipping students with effective communication strategies is particularly crucial. This study aims to develop students' ability to manage communication breakdowns in conversations, whether caused by difficulties in hearing, comprehension, or linguistic limitations. By employing specific communication strategies, students can independently navigate and resolve these challenges. In this study, the participants were first-year engineering students enrolled in a one-year English IA speaking course (30 weeks in total), with elementary-level speaking proficiency in English. The instructor integrated communication strategies, including rejoinders (formulaic responses), follow-up questions, and clarification requests, into regular speaking lessons to facilitate conversational repair when a speaker failed to maintain the flow of discussion. The effectiveness of these strategies was assessed through paired speaking tests, and conversation analysis method was employed to examine speaking test data, highlighting students' ability to utilize these strategies without instructor support. transcriptions of the speaking tests reveal that students effectively used follow-up questions at appropriate moments to expand topics, and demonstrated topic-shifting through various strategies such as using connecting phrases like by the way and rejoinders (e.g., I see, that's great, oh nice, really?) to maintain conversational flow and avoid prolonged silences or conversation breakdowns. The data further indicates a relatively balanced turn-taking pattern, suggesting increased conversational engagement. This study underscores the practical benefits of integrating communication strategy training into English instruction, particularly when tailored to students' experiences. The results indicate that even students with lower English proficiency can engage in meaningful conversations with speakers from diverse linguistic backgrounds. By reinforcing the idea that effective communication is achievable without perfect language skills, this approach fosters students' confidence and willingness to communicate in English across international settings.

Keywords: *Communication, Strategies, Paired, Speaking, Test*

Introduction

In today's globalized world, engineering students must be equipped not only with technical expertise but also with the ability to communicate effectively in intercultural settings. For students with lower English proficiency, developing confidence and skills to manage real-time conversations is essential. Therefore, English language instruction should go beyond grammar and vocabulary to emphasize interactive speaking skills and communication strategies (CSs) that support meaningful, two-way exchanges.

While many Japanese EFL learners perform well in grammar and reading, they often face difficulties managing spoken interactions, particularly in maintaining topic coherence and responding flexibly during speaking tests. This gap between theoretical knowledge and practical communication skills becomes evident in authentic classroom assessments. The Excerpt 1 below, from the midterm speaking test during the first semester at Kosen, illustrates frequent long pauses and hesitation, reflecting the students' lack of strategies to extend topics, a pattern commonly observed in many pairs during their first speaking test.

Excerpt 1

```
01 A: e:: my (.)my father works for a
02    bus company and my mother works
03    a hospital(.)she is dental
04       hygienist
05 B: oh:(.)that's great (3.0)
06 A: →un::: (8.0) (gesturing and
07    indicating to want to say
08       something)
09 A&B: (looking at each other and
10       gesturing)
```

11 **A:→**(3.3) so::(9.2) *(puts head down)*
12 **B:→**(6.0) eee you::(2.0) un:: what's
13 un::: your parents' name

The extended silences (e.g., 8.0, 9.2, 6.0 seconds) reflect difficulties in managing topic transitions and sustaining conversation without breakdowns, highlighting the need for explicit instruction in communication strategies to support topic extension and interactive competence.

Research in Conversation Analysis (CA) and Second Language Acquisition (SLA) highlights the importance of communication strategies for developing interactional competence. CA emphasizes the structure of "talk-in-interaction" (Waring, 2016), viewing language learning as a socially situated, co-constructed process (Kasper, 2006; Hanafi, 2016). Communication strategies such as rejoinders, follow-up questions, and topic-shifting expressions help learners avoid breakdowns and sustain dialogue, even with limited linguistic resources (Tarone, 1981; Nakatani, 2005; Benson et al., 2013).

Rejoinders ("Really?", "That's great!") signal attentiveness and emotional alignment (Lam, 2006; Sutopo & Mahardhika, 2016), follow-up questions encourage deeper engagement (van Balen et al., 2022), and topic-shifting expressions aid smooth transitions and active topic management (Bai & Hei, 2011; Al-Ghathami, 2018). Empirical studies show that explicit instruction in CSs can improve fluency, confidence, and conversational competence (Nakatani, 2005; Nguyen et al., 2022; Bøhn & Myklevold, 2018).

Despite this, few studies have closely examined how beginner-level learners in Japanese technical colleges apply these strategies during performance-based assessments like speaking tests. This study addresses this gap by investigating how first-year engineering students use explicitly taught communication strategies to manage conversation flow during speaking tests, aiming to reduce breakdowns and enhance interactional competence.

Materials and Methods

This study was conducted with approximately 160 first-year engineering students (average age 15) across four classes at a Japanese technical college (Kosen). At this stage, students had not yet chosen their engineering majors and were enrolled in English IA, which focused on 4 skills. Over half of the students held Eiken certificates, with the majority at Grade 3 (A1) level, reflecting 3–4 years of English learning expereince. However, classroom observations and speaking test performances confirmed that most students demonstrated elementary-level speaking skills.

The English IA course(speaking and listening part) aimed to build foundational speaking confidence and fluency through explicit instruction in communication strategies before transitioning to engineering-related English in subsequent years. The communication strategies explicitly taught included topic-shifting expressions, follow-up questions (especially WH-questions), and formulaic rejoinders. Classroom activities adapted David Kehe's Conversation Strategies into pair-based speaking tasks using topics relevant to students' daily experiences to increase engagement and relevance. Instructional methods included modeling by the instructor, controlled practice with sentence stems, pair speaking practice, and feedback with peer support. Students were encouraged to initiate, sustain, and extend conversations using these strategies during regular lessons.

To assess students' speaking performance as an evaluation, while simultaneously testing their application of communication strategies, speaking tests were conducted to establish a baseline, revealing frequent long pauses and breakdowns in conversation. In each test, each pair of students engaged in a five-minute, face-to-face conversation. Each pair randomly selected a speaking card from five familiar topics that had been practiced during lessons, and no preparation time was provided to simulate authentic conversational conditions. The instructor acted as a rater while seated approximately one meter away during each session, and all interactions were video recorded for subsequent analysis. Student conversations were recorded across the four classes. Transcriptions were created using Transana software, incorporating Jeffersonian notation to capture pauses, overlaps, gestures, and other interactional details in the conversations. To ensure ethical compliance during analysis and reporting, student identities were anonymized. Data were analyzed using Conversation Analysis (CA) to examine turn-taking, topic management, use of communication strategies, and repair sequences and breakdowns during the conversations. Additionally, to capture students' perceived improvement in confidence and willingness to speak English, an end-of-course questionnaire was conducted. This complemented the qualitative analysis with learners' perspectives on their own progress and perceived growth throughout the course.

Results and Discussion

Rejoinder

Rejoinders are short, formulaic expressions that help speakers react naturally to their partner's comments, showing attentiveness, empathy, or agreement. The following two excerpts illustrate how the EFL learners used rejoinders effectively during paired speaking tests to support interaction and keep their conversations smooth and engaging.

Excerpt 2

01 **Yuma:** How are you today
02 **Soshi:** I'm happy
03 **Yuma:→** Oh that's good
04 **Soshi:** How are you?
05 **Yuma:** Same as always
06 **Soshi:→**Oh oh that's nice
07 **Yuma:** By the way, what's your major
08 **Soshi:** Oh:: My major is Engineering.

09 **Yuma:** →Oh::
10 **Soshi:** That is so fun
11 **Yuma:** Yeah
12 **Soshi:** What is your major
13 **Yuma:** My major is Engineering too
14 **Soshi:**→Oh you too?
15 **Yuma:** Yeah
16 **Soshi:**→ That's nice

In Excerpt 2, several rejoinders are used to maintain the flow and show engagement. In line 3, Yuma says "Oh, that's good" in response to Soshi's "I'm happy" (line 2), which is a positive and supportive rejoinder that acknowledges the partner's feeling. In line 6, Soshi replies with "Oh, oh, that's nice" after Yuma says "Same as always" (line 5). Later, in line 14, Soshi uses "Oh, you too?" after learning that Yuma also majors in Engineering (line 13). This is an effective rejoinder that shows mild surprise and builds a connection. Soshi's "That's nice" (line 16) continue the pattern of polite but basic rejoinders.

Excerpt 3

01 **Yuito:** Hi Takumi how are you
02 today?
03 **Takumi:** E:: I'm not so good I am
04 sick.
05 **Yuito:**→ Oh: I'm sorry to hear that
06 (.) eto::: I will I hope you
07 get well soon.
08 **Takumi:**→ Thank you recently
09 lately...

In Excerpt 3, in the exchange between Yuito and Takumi, the conversation begins with a natural greeting sequence. In line 3, Takumi expresses that he is "not so good" because he is sick. Yuito responds in line 5 with "Oh, I'm sorry to hear that," which functions as a rejoinder, a formulaic and empathetic response that acknowledges the partner's emotional state and helps maintain conversational flow. This expression shows emotional support and attentiveness, helping to build rapport. In line 8, Takumi replies with "Thank you," which also acts as a rejoinder by reciprocating the empathy and acknowledging Yuito's concern. Together, these lines demonstrate how both speakers use socially appropriate reactions to sustain the interaction and create a cooperative, emotionally responsive exchange.

Topic Shifting

Topic shifting is a crucial communication strategy that enables speakers to move from one subject to another smoothly, helping to sustain and deepen conversations. This section presents three excerpts (Excerpt 3, 4, and 5) that illustrate how EFL students effectively employed topic-shifting strategies during their paired speaking tests. Despite limited proficiency, these learners were able to manage transitions naturally, demonstrating their growing interactional competence.

Excerpt 4

06 **Souta:** En::: how are you doing?
07 **Takeshi:** Ah:: I'm tired because (.)
08 <I did [kendo]> (.) last class
09 **Souta:** [Oh::]
10 **Takeshi:** How about you?
11 **Souta:** En::: yeah me too. I'm tired
12 becau::se I'm—I'm study—I study
13 English and math, un::other(.)
14 yeah tired [I'm tired]
15 **Takeshi:** → [Yeah.] ah (.) I
16 have a question
17 **Souta:** Hai((okay)) yeah.

In Excerpt 4, Souta opens with a casual greeting: "How are you doing?" (line 6), to which Takeshi responds with a reasoned feeling ("I'm tired because I did kendo"). After a brief exchange about tiredness, Takeshi uses "Ah, I have a question" (line 15-16) to shift the topic deliberately, marking a clear move to a new subject. This expression, "I have a question" is effective communication strategy for managing topic shifts in conversation. It helps maintain structure and signal transitions clearly, especially for language learners building fluency and interactional competence.

Excerpt 5

09 **Hana:**→ By the way (1.0) where were
10 you born
11 **Masa:** (2.0) I born in Yuzawa City
12 And (1.0) how are you (1.0)
13 how about you. Hhh
14 **Hana:**hhh okay(1.0)I was born in **
15 **Masa:** ***
16 **Hana:** But (0.8) I grow up in
17 Kanagawa
18 **Masa:**→ Kanagawa okay. (7.0) I'm
19 interested in Kanagawa
20 Please tell me about Kanagawa
21 **Hana:** Okay
22 **Masa:**→ (2.0) Your recommendation is
23 your recommendation place
24 **Hana:** (3.0) I recommendation place
25 is Yokohama Chinatown.
26 **Masa:** Oh I see
27 **Hana:** There is (1.0) a lot of
delicious food. (3.0) So
(2.0) many people go to there

In Excerpt 5, the exchange between Hana and Masa shows effective basic conversation skills despite some grammatical errors. Hana shifts the topic with "By the way, where were you born?" (line 09), and both speakers share information about their hometowns. Hana adds that she grew up in Kanagawa, prompting Masa to show interest by saying, "Please tell me about Kanagawa" (line

20). He then asks for a recommendation, and though the phrasing is awkward, Hana understands and responds with "Yokohama Chinatown" (line 25), adding reasons like "a lot of delicious food" and popularity. The conversation demonstrates clear topic development, personal sharing, and follow-up, helping keep the interaction natural and engaging.

Excerpt 6

```
05 Takumi:➔ Thank you. Recently
06  lately (2.0) there have been
07   bears in Akita. (.) Have you ever
08   seen bears?
09 Yuito:  Eto... yes I have (1.0) I
10      have seen them at the zoo but
11      en:: I'm too scared... scared
12     that if I I met them
13 Takumi: That's it.
14          (1.0)
15 Yuito: ➔ Eto... do you know what to
16        do if you encounter a bear?
17 Takumi: Yes I have to leave the
18         place en:: calmly
19 Yuito:  That's that's true
```

In Excerpt 6, Takumi initiates a smooth and natural topic shift in line 05-06, moving from the initial small talk about his health to a new and engaging subject on bear in Akita. He uses the phrase "Recently, lately…" to signal the transition before introducing the unexpected topic. This shift effectively moves the dialogue from routine greetings to a content-rich discussion. Takumi immediately follows up with the question "Have you ever seen bears?"(line 07), which engages Yuito and helps sustain the new topic. While the opening exchange appears somewhat rehearsed, it still demonstrates effective topic development. For elementary-level learners, using such formulaic expressions and structured transitions serves as a valuable foundation for building fluency and confidence in more spontaneous interactions.

Follow-up questions

Follow-up questions are essential for deepening conversations, encouraging elaboration, and sustaining dialogue, particularly among language learners. These questions demonstrate attentiveness and interest, allowing speakers to build on each other's responses and guide the conversation in a natural, engaging way. Excepts 6 and 7 illustrate how EFL students used follow-up questions to explore personal topics, respond to their partners, and expand conversations without instructor support.

Excerpt 7

```
16 Takumi: En:: what (.) what kind of
17         music do you like?
18 Yuito:  My favorite kind of music
19          is... en:: J-pop
20 Yuito: J-pop makes me—makes me
21      excited. Eto... how about you?
22 Takumi:  My favorite music is rock
23 ➔  It gives me energi (1.0) What's
24    your favorite musician?
25 Yuito:  I like Yonezu Kenshi. eto::
26      (2.0) how about you?
27 Takumi: (1.0) I'm into Yonezu Kenshi
28          too.
29 Yuito:   Oh::
30 Takumi: I like his lisk and rim
31 ➔     ((lyrics and rhythm)). What's
32         your favorite his song?
33 Yuito:  I like Umi no Yuurei because
34      it e:to made it made me relaxed
35        (2.0)
36 Takumi:en:: (.) My favorite his song
37        is KICK BACK. en:: (.) It is
38         Chainsaw Man's opening.(1.0)
39         I'm excited ah chigau—it
40        makes me excited.((looking at
41 ➔     the speaking card)) Can you
42        play(.) musical instruments?
```

In this conversation, Yuito and Takumi use several follow-up questions to keep the interaction flowing and deepen the topic. Takumi contributes by asking, "What's your favorite musician?" (line 23-24), which shifts the topic from general music preference to specific artists. He follows up with, "What's your favorite his song?" (line 31-32), encouraging Yuito to elaborate further with a personal choice. Finally, Takumi broadens the topic slightly by asking, "Can you play a musical instrument?" (line 41-42), which keeps the theme of music while expanding the conversation. These follow-up questions show active interest, support topic development, and help create a more engaging and natural exchange between the speakers.

Excerpt 8

```
05 Shun: Yes me too I like J-pop
06  ➔     too Have you ever played
07          a musical instrument?
08 Nana: I have played the piano
09 Shun: Oh piano? It's very cool
10  ➔  How long have you played
11          the piano?
12 Nana: Five years
13 Shun: Five years. It's very cool
14 Nana: Thank you
15 Shun: I've never played the piano
16       So I'd like to play a
17  ➔      musical instrument.Have you
18      ever been to a concert?
19 Nana: I have been to  Yes yes
20       I have
21 Shun: Oh.
```

In Excerpt 8, Shun uses follow-up questions effectively to extend the topic and keep the interaction engaging. After agreeing with Nana's music preference, he asks, "Have you ever played a musical instrument?" (line 6-7), which leads naturally to a deeper exchange. When Nana says she has played the piano, Shun responds with interest and follows up with, "How long have you played the piano?" (line 10), encouraging a more detailed answer. He then shares his own experience and shifts the topic slightly but smoothly with another follow-up: "Have you ever been to a concert?" (line 17-18). These questions help move the conversation from general preferences to personal experiences. Shun also builds rapport by responding positively like "It's very cool. " and adding his own opinion. His use of follow-up questions, combined with reactions and shared interests, helps the conversation feel natural and connected.

Besides demonstrating how students applied communication strategies during the speaking test, a questionnaire was also conducted at the end of the one-year course to gather feedback on the course in general. Among the items, 3 questions specifically addressed what knowledge students felt they had learned, their perceived overall improvement in speaking, and the confidence they gained in speaking English. In this section, a summary of the results (figure 1-3) from all four classes is presented using the translated question items and numerical data compiled by the author.

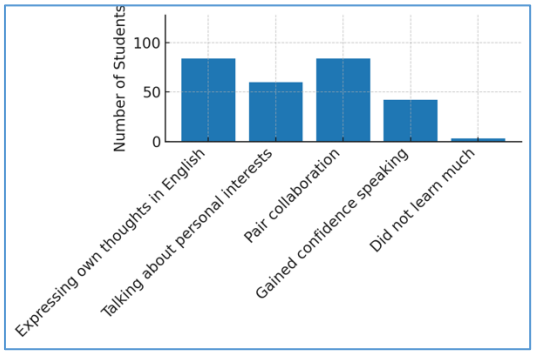


Figure 1 Students' self-reported learning outcomes

In Figure 1, which is based on a multiple-response question, students most frequently reported learning to express their own thoughts in English and collaborate with partners (both 65.6%), followed by talking about personal interests (46.9%) and gaining confidence in speaking (32.8%). Overall, the results highlight strong outcomes in peer collaboration.

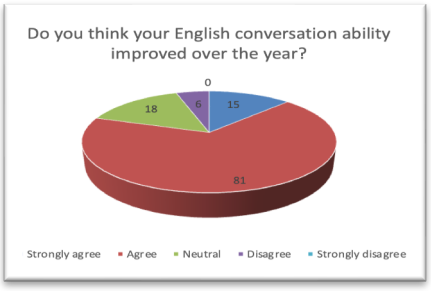


Figure 2 Students' perceived improvement in conversation ability

In Figure 2, concerning perceived improvement, a significant majority (80%) of students reported that their English conversation ability improved over the year, reflecting the effectiveness of communication strategy instruction and sustained speaking practice. Only 5% felt they did not improve, while 15% remained neutral, indicating areas for continued focus in supporting hesitant learners.

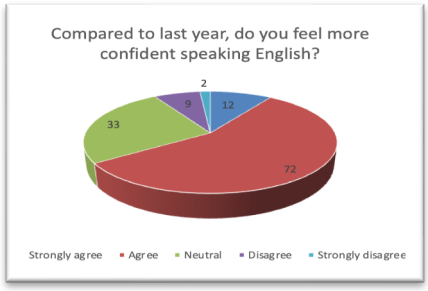


Figure 3 Students' perceived increase in confidence in speaking

Students' perceived increase in confidence in speaking English compared to the previous year after completing the English IA course (Figure 3). A total of 65.7% (strongly agree + agree) reported feeling more confident, supporting the course objective of building affective confidence alongside fluency. Approximately 26% remained neutral, suggesting that these students may benefit from additional low-pressure speaking opportunities in the second year to further enhance their confidence.

For the 3 figures, there were approximately 120 responses, fewer than the total enrollment of 160 students. This difference is due to non-responses, as participation in the questionnaire was voluntary and some students were absent or did not submit their answers. Therefore, the figures reflect only the views of respondents and should not be interpreted as representing the entire student population.

Conclusions

Analysis of seven excerpts from the speaking tests demonstrates that elementary-level engineering students can effectively apply communication strategies: rejoinders, follow-up questions, and topic-shifting expressions, to manage and sustain conversations in English. Despite limited proficiency, many participants were able to initiate, develop, and maintain engaging dialogues during paired speaking tests, indicating emerging interactional competence. Conversation analysis showed these strategies helped prevent breakdowns, deepen engagement, personalize exchanges, and encourage spontaneous, meaning-focused communication. While some segments appeared rehearsed, most exchanges moved beyond memorized responses, reflecting students' growing ability to use these tools independently. These findings confirm that communication strategies are teachable and transferable when explicitly taught and practiced through relevant tasks.

End-of-course questionnaire results support these findings. Students reported learning to express their thoughts, collaborate with partners, and discuss personal interests in English. Most reported improvement in conversation skills and increased confidence in speaking English over the year, demonstrating that explicit instruction in communication strategies contributed to both observable performance improvements and self-perceived growth in confidence.

Pedagogically, integrating communication strategies into EFL instruction offers learners practical tools for navigating conversations naturally, even while grammatical accuracy is still developing. Teachers are encouraged to include scaffolded, strategy-focused speaking tasks and provide opportunities for authentic, peer-based interactions to build interactional competence and confidence. Performance-based assessments such as speaking tests can serve as both evaluation tools and learning opportunities. Paired with conversation analysis, these assessments provide insights into students' conversational strengths and challenges, enabling teachers to adjust instruction and reinforce key strategies. Overall, explicitly teaching communication strategies equips learners with practical tools and confidence to engage meaningfully in intercultural and global contexts.

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Transcription Conventions

(.)	noticeable pause
(2.0)	2.0-second pause
[ ]	overlapping talk
wo::rd	stretched or elongated sound
(words)	unclear hearing
°word°	quiet talk
>word <	aster speech
<word <	outward slower
?	question intonation
.	falling intonation
→	marks a line of analytic interest
(( ))	transcriber's comment

References

Al-Ghathami, G. (2018). *The performance of topic shifting in inclusive female informal gatherings: A case study*. *Arab World English Journal*, 9(4).

Bai, P., & Hei, K. (2011). *Topic shifts in conversations: Focus on Malaysian Chinese teenagers*. *Proceedings of the International Conference on Social Science and Humanity (IPEDR)*, 26, 1–5.

Benson, S., Fischer, D., Geluso, J., & Joo, L. (2013). Effects of communication strategy training on EFL students' performance in small-group discussions. *Studies in Second Language Learning and Teaching, 3*(2), 245–259.

Bøhn, H., & Myklevold, G. (2018). Exploring communication strategy use and metacognitive awareness in the EFL classroom. In A. Haukås, C. Bjørke, & M. Dypedahl (Eds.), *Metacognition in language learning and teaching* (pp. 179–198). Routledge.

Hanafi, H. (2016). Introducing conversation analysis (CA) for SLA. *Lingua Litera: Journal of English Linguistics and Literature, 1*(2), 45–60.

Kasper, G. (2006). Beyond repair: Conversation analysis as an approach to SLA. *AILA Review, 19*(1), 83–99.

Kehe, D., & Kehe, P. D. (2014). *Conversation strategies: Pair and group activities for developing communicative competence* (3rd ed.). Pro Lingua Learning.

Lam, W. Y. K. (2006). Gauging the effects of ESL oral communication strategy teaching: A multi-method approach. *Electronic Journal of Foreign Language Teaching, 3*(2), 142–157.

Markee, N. (2007). Toward a learning behavior tracking methodology for CA-for-SLA. *Applied Linguistics, 29*(3), 404–427.

Nakatani, Y. (2005). The effects of awareness-raising training on oral communication strategy use. *The Modern Language Journal, 89*(1), 76–91.

Nguyen, T., Vu, V., & Yen, T. (2022). The influences of oral communication strategies on students' English speaking proficiency. *Can Tho University Journal of Science*.

Sutopo, D., & Mahardhika, S. (2016). The use of communication strategies among Indonesian young learners of English in early total immersion program. *Arab World English Journal*, *7*, 199–221.

Van Balen, J., Gosen, M., De Vries, S., & Koole, T. (2022). "What do you think?" How interaction unfolds following opinion-seeking questions and implications for encouraging subjectification in education. *Linguistics and Education, 71*, Article 101037.

Tarone, E. (1981). Some thoughts on the notion of communication strategy. *TESOL Quarterly, 15*(3), 285–295.

Waring, H. Z. (2016). *Theorizing pedagogical interaction: Insights from conversation analysis*. Routledge.

A PEDAGOGICAL APPROACH TO BRIDGING THE GAP BETWEEN HIGH SCHOOL AND NATIONAL INSTITUTE OF TECHNOLOGY STUDENTS IN ENGINEERING EDUCATION

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At Toyohashi University of Technology (TUT), undergraduate students are admitted either from high schools or Japan's National Institute of Technology (KOSEN). With a majority of students entering from KOSEN at the third-year level and one-fifth from high school starting from the first year, a learning gap is observed when these groups converge in the third year due to their differing educational backgrounds. To address this disparity, TUT introduced elective subjects called Introduction to Liberal Arts and Engineering and Science Literacy during the first and second undergraduate study years. This paper presents the subject's pedagogical design, which emphasize foundational engineering knowledge and skills through a project- and problem-based learning approach, parallel with liberal arts education. In the Introduction to Liberal Arts and Engineering and Science Literacy courses, foundational science or engineering-focused coursework, such as literature surveys, experimental design, teamwork, and scientific presentation, is assigned. Preliminary results indicate that the course enhances student motivation, critical thinking, and readiness, helping with both their integration with KOSEN students' future careers. This highlights the value of targeted pedagogical interventions in bridging educational gaps in engineering education.

Keywords: *engineering education, natural science, liberal arts, education gap, engineering science and literacy*

Introduction

Toyohashi University of Technology (TUT) has been actively collaborating with Japan's National Institutes of Technology (KOSEN) to develop a seamless educational pathway from KOSEN to TUT. In addition, TUT promotes global education initiatives aimed at cultivating adaptive, internationally minded global engineers and scientists (Tan, Lim, Umemoto, & Matsuda, 2015; Tan & Umemoto, 2021). Although most undergraduate students at TUT are admitted from KOSEN institutions, the university also enrolls students directly from high schools into its undergraduate programs.

Approximately 80% of TUT's student enrolments are from KOSEN. These students complete five years of KOSEN vocational education prior to enrolling at TUT as third-year undergraduate students. The other 20% are from high schools and enroll as first-year undergraduate students. Table 1 shows the pre-university education pathways for students from high school and KOSEN backgrounds. By the third year of undergraduate study (typically at age 21, assuming a standard progression), students from both paths converge into the same class. At this point, a gap is observed between those who entered from high school and those from KOSEN. Students entering engineering programs often face significant learning gaps in foundational subjects (mathematics, physics, and chemistry), which negatively impact their academic performance and highlight the need for targeted curricular interventions (Chaves, Moreira, & Camargo, 2016). As education at KOSEN is more focused on practical and specialized subjects, KOSEN students are better prepared for engineering education at higher learning levels compared to those from a high school background. The Model Core Curriculum is specifically designed to ensure that KOSEN graduates possess the specialized knowledge and practical skills required by society. This focus on developing competencies that align with industry needs highlights the specialized nature of KOSEN engineering education (Rashed, 2024). In addition, the KOSEN curriculum is also designed to provide a balanced education, combining specialized courses in engineering with general subjects such as social studies (history, modern society, introduction to philosophy, ethics, and law), music, art, health, and physical education (Araki, 2010). This results in a learning gap between high school and KOSEN students.

Therefore, there is a need to introduce coursework built around a pedagogy that can bridge the gap between high school and KOSEN students prior to their convergence in their third-year undergraduate classes, when they begin to focus on more specialized subjects at a higher intensity.

Table 1: Comparison of educational paths of high school and KOSEN students prior to enrolling in university (source:https://www.kosen-k.go.jp/en/nationwide/features ,accessed May 13th, 2025)

Age	High school	KOSEN
15	Enroll in high school (3 years)	Enroll in KOSEN (5 years)
18	Graduate high school	Continuous education at KOSEN
18-19	Enroll in university (degree; 4 years)	Continuous education at KOSEN
20	2nd year of university	Graduate from KOSEN (with an associate degree)
21	3rd year of university	Enroll in university (directly to 3rd year)
22	Graduate university with an engineering bachelor's degree	

TUT introduced new courses, Introduction to Liberal Arts and Engineering and Science Literacy, for first- and second-year undergraduate students. The aim is to induce awareness, scientific literacy, and soft learning skills that could be helpful not only in diminishing the learning gap between high school and KOSEN students in their third-year of study but also in the development of their future careers. This paper presents preliminary findings on the students' reception of and engagement with a newly implemented pedagogical approach designed to bridge the education gap between high school entrants and KOSEN students in an engineering program.

Materials and Methods or Pedagogy

The pedagogical approach was designed in direct response to an observed learning gap between students entering from high school and those transitioning from KOSEN institutions. While KOSEN students typically possess well-developed competencies in experimental design, problem-solving, and collaborative work, students entering directly from high school often lack the equivalent exposure. As a result, these students tend to demonstrate limited proficiency in core skills essential for engineering education, including research inquiry, critical thinking, teamwork, and scientific communication.

To address this disparity, the course employs a pedagogical framework that integrates liberal arts education with foundational science or engineering skills. This includes specialized modules such as Introduction to Liberal Arts and Engineering and Science Literacy, designed to build foundational skills in scientific reasoning, communication, and collaborative problem-solving. A central feature of the course is the implementation of problem- and project-based learning, which engages students in real-world inquiry requiring active investigation, peer collaboration, and interactive learning.

Through these activities, students develop competencies in conducting literature reviews, technical writing, formulating hypotheses, planning and executing experiments, analyzing data, and presenting their findings in a scientific format. Throughout the course, three lecturers (the authors) facilitate sessions, provide guidance, and monitor student activities and responses. The course was first implemented in fiscal year 2023 with 25 students, followed by 11 students in fiscal year 2024.

Results and Discussion

As part of the Introduction to Liberal Arts course, undergraduate first-year students with a high school background are introduced to familiar chemical compounds to stimulate curiosity about their underlying properties (Figure 1). Although students may have previously learned about carbon chain molecules in high school, engaging in more analytical discussions on the interactions between short- and long-chain carbon compounds facilitates a deeper understanding of their distinct physical properties, such as vaporization rates and boiling points. Through this process, students are encouraged to articulate their perspectives, fostering critical thinking and contributing to their cognitive development.

The aim of this course is to employ interactive learning methods designed to foster inquisitive thinking, with a particular emphasis on exploring the "why" and "how" behind chemical phenomena. This pedagogical approach aims to cultivate proactive learning and encourage independent thought. Notably, when the students recognize the learning gap between them and their KOSEN peers during their third-year undergraduate studies, this realization serves as a motivational factor, prompting increased engagement and active participation in class activities.



Figure 1: Interactive lesson designed for first-year undergraduate students from high school backgrounds to foster proactive learning and develop inquisitive thinking skills.

With an emphasis on problem- and project-based learning, an inquiry-driven teaching approach is used. The primary goal is to connect new concepts with students prior knowledge and familiar experiences, fostering critical thinking skills. This approach aims to

stimulate their natural curiosity and inquiry instincts, which will support their learning and adaptation in higher-level studies in different disciplines (Sánchez-Cambronero et al., 2021).

Meanwhile, in the Engineering and Science Literacy course that is offered to second-year undergraduates, students are given an assignment to design an experiment aimed at verifying the value of gravitational acceleration. The assignment requires students to develop a suitable experimental method, design and prepare the necessary apparatus in advance, and plan the implementation process (based on a method they deem fit and implementable during the class period). Subsequently, experiments are conducted during class under lecturer observation, as shown in Figure 2. After collecting and analyzing the data, they present their findings in a mock academic conference-style presentation (a lecture on the requirements for conference preparation such as literature review, abstract writing, and oral presentation is given beforehand). This hands-on exposure is intended to cultivate and equip them with an experimental mindset and help bridge the gap between them and the KOSEN students, who had prior experience conducting research projects at their respective institutions.

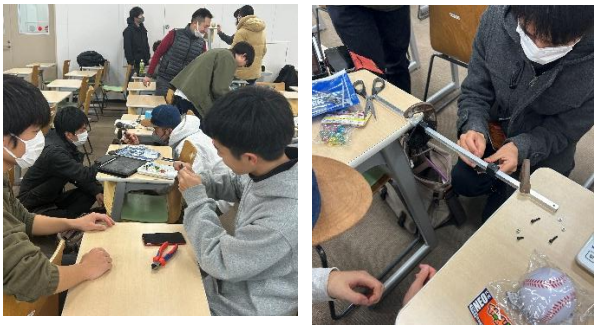


Figure 2: Students in the Engineering and Science Literacy course carrying out experiments to evaluate gravitational acceleration using the pendulum method.

Furthermore, a noticeable disparity exists between students from KOSEN and those from high school, particularly in the development of soft skills. It has been mentioned that the social skills of high school students are in decline, which suggests that they may experience a decline in certain soft skills such as assertiveness and peer relationship-building. This trend underscores the importance of integrating social skills training into the curriculum to address these deficiencies and support students overall development (Nishimura, Fukuzumi, Fujiwara, & Kawamura, 2018). KOSEN students typically engage in extensive hands-on technical training and collaborative experimental work throughout their coursework, which inherently fosters competencies such as open communication, teamwork, and leadership. In contrast, first-year undergraduates with a high school background were observed to possess poorer interpersonal dynamics and group coordination, due to a lack of similar exposure to collaborative learning environments and practical problem-solving contexts. These soft skills, however, are crucial for success in engineering education, especially in project-based learning and group-oriented tasks where effective collaboration directly impacts learning outcomes. Moreover, soft skills such as collaboration, leadership, problem-solving, critical thinking, and interpersonal communication are highly regarded by industry employers and could play crucial roles in students' future careers (Karimi & Pina, 2021; Munir, 2025). As subjects addressing soft skills in engineering courses are limited, their importance has led to their gradual incorporation and implementation in education (Almeida & Morais, 2023).

This gap highlights the need for targeted pedagogical interventions to support undergraduates with a high school background in acquiring these essential non-technical skills. In our pedagogical approach, the emphasis is on interactive learning activities, providing students with structured opportunities to communicate, engage in discussions, and draw direct connections to the subject matter. The participating students are encouraged to freely express their thoughts and perspectives, fostering an inclusive and participatory classroom environment. Therefore, this pedagogical approach not only builds confidence in public speaking and effective communication but also deepens students' understanding through peer exchange and collaborative inquiry (Liao, 2014). As a result, learners become more actively involved in the learning process, which enhances their critical thinking and promotes the retention of concepts, which are useful skills when they enter their third year of study. One study indicated that peer learning, communication and social bonding during team-based learning increase motivation and generate ownership of learning for students (Lysne et al., 2023). The active participation of students through peer-learning was observed to be effective in our class implementation, as shown in Figure 3.

In addition, it is essential to shift the educational paradigm from a solely knowledge-based approach to one that integrates pragmatic wisdom through critical inquiry and experiential learning. This shift can cultivate reflective thinking and interdisciplinary understanding, equipping students to navigate complex challenges both within and beyond the classroom (Spelt, Biemans, Tobi, Luning, & Mulder, 2009; Tan, 2022).



Figure 3: Students actively engage in interactive peer learning, which promotes active participation and fosters the development of social and communication skills.

This study is still on-going and the preliminary findings show that the students who undertook this subject showed high learning motivation and accomplished their assignments with distinction. These findings indicate the importance of integrating a constructive and innovative pedagogy that could bridge the gap between students from different backgrounds.

Conclusions

At TUT, an educational institution that admits undergraduate students from diverse background, such as high schools and KOSEN, there exists a notable gap between these two groups when they merge at a higher level (the third year of study). To address this disparity, this study proposed a pedagogical approach aimed at bridging the gap by supporting and developing students from a high school background.

The strategy includes the Introduction to Liberal Arts education and Engineering and Science Literacy courses introduced during the first and second years of undergraduate study. By implementing these measures, we aim to create awareness and bridge the gap between high school and KOSEN (college-level) engineering education, ensuring students are better prepared for advanced coursework. This awareness encourages proactive class participation and a stronger sense of ownership over their learning. This approach serves to level the academic playing field across diverse student backgrounds, fostering learning and the adoption of soft skills vital not only in students' engineering education, but also in their future careers.

Acknowledgements

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References

Almeida, F., & Morais, J. (2023). Strategies for Developing Soft Skills Among Higher Engineering Courses. *Journal of Education, 203*(1), 103-112. doi:10.1177/00220574211016417

Araki, M. (2010). KOSEN: 5-year Engineering Education Starting from Age 15. *IFAC Proceedings Volumes, 42*(24), 326-331. doi:10.3182/20091021-3-jp-2009.00062

Chaves, F. D., Moreira, V. S., & Camargo, M. N. (2016). Learning Gap in Exact Curricular Components in High School and Impact in Engineering Courses in Higher Education. *International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, 5*(3), 2454-4698.

Karimi, H., & Pina, A. (2021). Strategically Addressing the Soft Skills Gap Among STEM Undergraduates. *Journal of Research in STEM Education, 7*(1), 21-46. doi:10.51355/jstem.2021.99

Liao, H.-A. (2014). Examining the Role of Collaborative Learning in a Public Speaking Course. *College Teaching, 62*(2), 47-54. doi:10.1080/87567555.2013.855891

Lysne, D. A., De Caro-Barek, V., Støckert, R., Røren, K. A. F., Solbjørg, O. K., & Nykvist, S. S. (2023). Students' motivation and ownership in a cross-campus and online setting. *Frontiers in Education, Volume 8 - 2023*. doi:10.3389/feduc.2023.1062767

Munir, F. (2025). Humanities Education for Engineering Students: Enhancing Soft Skills Development. *Societies, 15*(1), 12.

Nishimura, T., Fukuzumi, N., Fujiwara, K., & Kawamura, S. (2018). Longitudinal changes in social skills among junior high school students subtitle_in_Japanese. *The Japanese Journal of Psychology, 89*(1), 29-39. doi:10.4992/jjpsy.89.16048

Rashed, N. F. (2024). *A comparison between theory and policy in the curricular STEM integration at the Japanese Colleges of Technology KOSEN: Focusing on the Model Core Curriculum (MCC).* Kanazawa University,

Sánchez-Cambronero, S., Lozano-Galant, J. A., Castilla, F. J., Poveda, E., Galán, Á., Porras, R., . . . López-Moya, R. (2021). Introducing High School Students into the Multidisciplinary World of Bridge Construction Using Project-Based Learning. *Journal of Civil Engineering Education, 147*(1), 05020006. doi:doi:10.1061/(ASCE)EI.2643-9115.0000022

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and Learning in Interdisciplinary Higher Education: A Systematic Review. *Educational Psychology Review, 21*(4), 365-378. doi:10.1007/s10648-009-9113-z

Tan, W. K. (2022). Pathway to Sustainability through Pragmatic Wisdom. *Philosophies, 7*(6), 131.

Tan, W. K., Lim, P. B., Umemoto, M., & Matsuda, A. (2015). *Activities of Global Technology Education in NUT-KOSEN-TUT.* Paper presented at the The 9th International Symposium on Advances in Technology Education, ISATE 2015, Nagaoka, Japan.

Tan, W. K., & Umemoto, M. (2021). International Industrial Internship: A Case Study from a Japanese Engineering University Perspective. *Education Sciences, 11*(4), 156. doi:doi.org/10.3390/educsci11040156

Effectiveness in Engineering Education by Participating in Model Contests in the Field of Civil Engineering

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In public works projects, it is crucial to effectively communicate the details of construction to local residents in order to build consensus and ensure smooth execution. However, explaining the mechanisms of natural disasters and their corresponding countermeasures often requires specialized knowledge, making it difficult to convey these concepts to the general public. Thus, it becomes necessary to devise communication strategies that make these complex ideas more accessible and comprehensible to a wider audience.

One such strategy involves the use of models constructed from readily available materials, such as those found in hardware stores. These models are designed to present specialized engineering concepts in a manner that is both approachable and engaging to the general public. Moreover, the process of creating these models also benefits engineers, as it encourages them to reconsider how they communicate their technical knowledge and to focus on the essential elements of their work.

This study explores the educational effects of a model competition in which civil engineering students from a technical college participate. In this competition, students work in teams to select a theme, build a model, and present their work, using the model to explain the mechanisms of natural disasters and corresponding countermeasures. A distinguishing feature of this contest is that, in addition to assessing the technical performance of the models, the evaluation criteria also include the clarity with which the models can be understood by the general public. Through participation in the contest, students not only deepen their understanding of specialized topics but also acquire valuable skills in model creation, presentation design, and project management, such as process planning and task delegation.

The results from a post-contest questionnaire survey of the participants indicate the significant educational benefits derived from the contest. Based on these findings and the guidance provided by instructors, the study proposes more effective methods for engineering education, particularly in the context of public communication and the dissemination of technical knowledge.

Keywords: *Model contests, Young employee development program in civil engineering, Presentation skill, Professional education*

Introduction

In public construction projects, explaining the details of the work to local residents and obtaining their consensus is extremely important for the smooth execution of the construction. However, explanations regarding the mechanisms of natural disasters and the countermeasure construction methods often involve specialized knowledge, making it necessary to devise ways to present the information in a manner that is easy for the general public to understand.

As one example of such efforts, a method using models has been implemented to convey specialized technical knowledge. The models use readily available materials that can be purchased at hardware stores, with the concept of making them familiar and interesting to a wider audience. On the other hand, creating these models also benefits the makers (engineers), as it prompts them to deeply consider how to communicate clearly to the general public and to identify the “core” aspects of the technology.

On the other hand, in recent years, higher education institutions such as technical colleges and universities have been placing increased emphasis on education related to project management. In the Project Management Body of Knowledge (PMBOK), which is a systematically organized resource on project management, stakeholder management and communication management are identified as important elements for the successful completion of a project.

This paper reports on the educational effects in engineering of students specializing in civil engineering at a technical college participating in a model contest, where they compete by explaining the mechanisms of natural disasters and corresponding countermeasure construction methods using models. Through the process of participating in the contest, students deepen their understanding of specialized knowledge, acquire skills in creating models and presentation materials, and gain

experience in project management aspects such as scheduling and task delegation.

At National Institute of technology, Matsue, where the author is affiliated, a practical initiative for learning project management has been conducted in the form of a DX Recurrent Course, providing education on human resource development through collaboration between working professionals and students (e.g.Ohya,2019. ;) . This initiative focused on the theme of conveying the appeal of construction work to elementary school students using ICT technology. According to a survey of participating students, the project enhanced their motivation to learn, teamwork, and communication skills. In this study, an investigation was conducted based on the idea that participation in the contest would provide project management experience, which would result in similar engineering educational effects.

Materials and Methods or Pedagogy

The contest in which the students participated was a model contest hosted by Fujii Foundation Design Office Co., Ltd., involving university and technical college students studying civil engineering in the Chugoku region of Japan. A total of five teams from universities and technical colleges participated in the competition. Participation was solicited by the organizer, who gathered the participants. The contest was covered by various media outlets, and the results have been publicly announced (Xtech.nikkei, 2024.).

The effort to explain disaster mechanisms and countermeasure construction methods using models has been led by Fujii Foundation Design Office Co., Ltd. for many years, demonstrating high effectiveness in communicating with local residents. Additionally, this initiative and the model explanations have been documented in several articles and books. While students participating in the model contest refer to these materials, creating models that differ from existing ones based on their own original ideas remains a challenging aspect.

In the contest format, students formed teams of two to three members, selected their own themes from various ground disaster types, and created models along with presentations using those models. A distinctive feature of this contest is that the evaluation criteria equally emphasize the model's performance and the ability to communicate the content clearly to the general public through presentations.

Overview of the Contest

Table 1 shows an overview of the contest. Five teams participated in the contest and six students fromNational Institute of technology, Matsue, participated in two teams (Team A and Team B). The themes focused on the mechanisms of disasters and countermeasure construction methods, with participants selecting one from landslides, slope failures, debris flows, floods, or earthquakes.The concept for the models to be created was to "use materials from 100-yen shops or hardware stores to clearly communicate to the general public." By using familiar materials that people commonly see around them, this approach aims to foster a sense of familiarity and enhance the understanding of the presentation among the general audience.

Table 1 Contest overview

Date of the event	October 27, 2024
Number of participating teams	5 teams
Theme	Disaster generation mechanisms and countermeasure methods Cliffslides, landslides, Mudslides, Floods, Earthquakes
Concepts	Communicate to the public in an easy-to-understand manner using materials from 100-yen stores and home centers.

Schedule of Student Activities

Table 2 shows the schedule of student activities. Students were given a rough schedule as shown in the table in advance, and they were instructed to manage the detailed schedule themselves while holding regular meetings with instructors to discuss their progress. Students were encouraged to make appointments with instructors as needed to hold meetings and receive feedback on their work. Additionally, during the course of their progress, adjustments were made such as advancing certain tasks or conducting tasks concurrently, focusing more time on items that students deemed necessary.

Table 2 Submission Day

1st week of Sep.	Participant's declaration of intent
3rd week of Sep.	Study of materials and selection of topics
4th week of Sep.	Meeting with the organizer
2nd week of Oct.	Model making
3rd week of Oct.	Creation of presentation materials,Submission of Entry Sheet
October 27	Contest Implementation

Division of Roles

Both participating Team A and Team B consisted of three members each. Within each team, three roles were assigned: a leader responsible for schedule and budget management as well as team coordination, a person in charge of model production, and a person responsible for preparing the presentation materials. By assigning each member a specific role with clear responsibilities, it is expected that members will participate more proactively, work will proceed smoothly, and individual understanding will deepen.

Results and Discussion

In the contest, team A won the Grand Prize, and Team B received the Excellent Model Award.

Figure 1 shows the results of a self-assessment survey on various skills conducted after the contest for the six participants. The items evaluated in the self-assessment were Scheduling, Teamwork, Presentation, Problem-solving, and Goal Setting. The figure indicates that the self-evaluations were high across all items.

Figures 2 and 3 show the survey results for the three members belonging to Team A and Team B, respectively. Table 3 summarizes the results from Figures 1 to 3. From the figures and table, it can be seen that overall, Team A had higher self-assessment scores both before and after the contest. Additionally, the difference of Teams A was increasing. Team A was the team that won the Grand Prize. This suggests that Team A was composed of members who initially had relatively high self-assessment scores, and their self-assessments further improved through participation in the contest. In particular, the increase in self-assessment related to problem-solving was significant for Team A. This indicates that participation in the contest can be expected to enhance problem-solving abilities, or that experiencing the problem-solving process extensively contributed to producing good results.

On the other hand, the item that showed the greatest improvement for Team B before and after the contest was teamwork. The improvement in teamwork can also be considered an effect of participating in the contest. However, Team A's teamwork scores were already high before participation. This suggests that engaging in a project can lead to a certain level of improvement in teamwork skills, and furthermore, that once teamwork reaches a certain threshold, other abilities such as problem-solving tend to improve as well. Therefore, enhancing individual teamwork skills can be considered an effective means to improve overall project management skills.

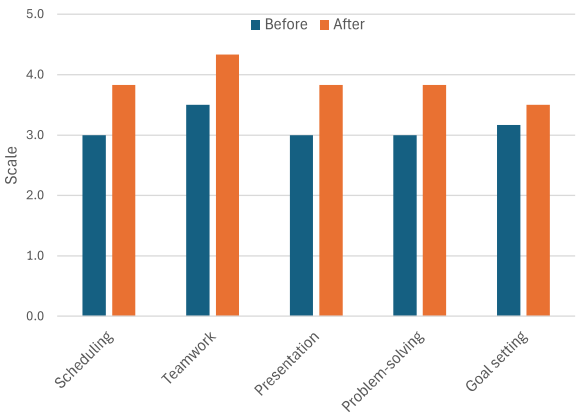


Figure 1 Summary of self-evaluation survey (All students)

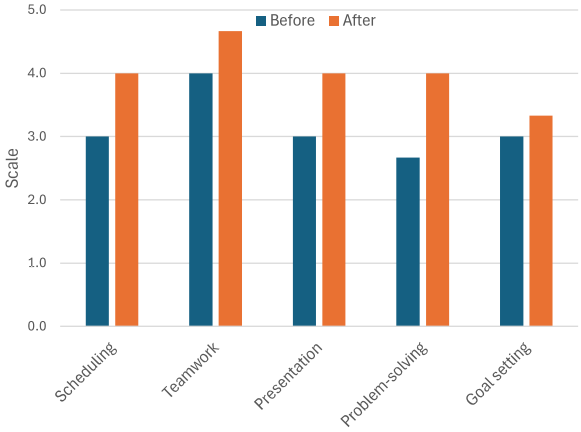


Figure 2 Summary of self-evaluation survey (TeamA students)

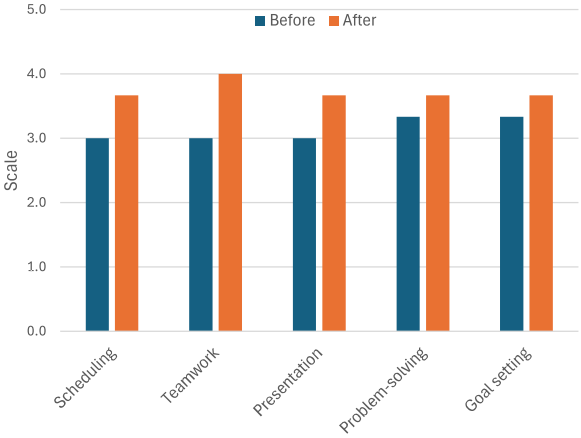


Figure 3 Summary of self-evaluation survey (TeamB students)

Table 3 Summary of self-evaluation survey

	All students			Team A students			Team B students		
	Before	After	Difference	Before	After	Difference	Before	After	Difference
Scheduling	3.0	3.8	0.8	3.0	4.0	1.0	3.0	3.7	0.7
Teamwork	3.5	4.3	0.8	4.0	4.7	0.7	3.0	4.0	1.0
Presentation	3.0	3.8	0.8	3.0	4.0	1.0	3.0	3.7	0.7
Problem-solving	3.0	3.8	0.8	2.7	4.0	1.3	3.3	3.7	0.3
Goal setting	3.2	3.5	0.3	3.0	3.3	0.3	3.3	3.7	0.3

Conclusions

Students specializing in civil engineering at a technical college participated in a model contest where they competed by explaining the mechanisms of natural disasters and corresponding countermeasure construction methods using models. Through this participation, the following educational effects in engineering were achieved.

The results of a self-assessment survey on skills before and after the contest confirmed improvements in project management skills such as teamwork, scheduling, and problem-solving. Members of the team that won the Grand Prize showed particularly significant improvement in problem-solving skills. On the other hand, for the team with initially low self-assessment scores, a marked improvement in teamwork was observed. It can be inferred that improving teamwork first may lead to enhancements in other skills.

Participation in the model contest was found to significantly enhance students' project management skills.

References

Makoto. Ohya, Jun. Asada, Nozomu Hirose, Yasuyuki Okazaki, Shinjiro Arao, Masamichi Takebe, Soichiro Kawahara, Suto Masashi, Tsuyoshi Yamaguchi, Otome Shinya, Daiki Ajiki (2019). Dsign of The Construction Engineer Education For i-Construction and Its Application for The Recurrent Education Program. Proceedings of 13th International Symposium on Advanced in Technology Education (ISATE2019),Paper No03062551.

Xtech.nikkei. Who is the first champion of "Dobokon," a competition with Dobok models? Retived From [https://xtech.nikkei.com/atcl/nxt/column/18/00142/02068/]

A HOUSE FOR THE ALIEN FROM BALTAN (V)o¥o(V)
Teaching Architectural Design Concepts to First-Year Students

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The design process in architecture does not follow rigid rules; it may be as variable as the solution to the problems. The idea generation phase of the design process is the most difficult one. Also, the capacity to creatively solve problems directly relates to the designer's repertoire, life experience, and knowledge. How do we teach the students to find creative solutions to design problems? What are the tools to enhance creativity? On the one hand, young students don't have experience, and their knowledge is limited. On the other hand, they bring many preconceptions, pre-judgments, and prejudices to their academic work from their personal experiences. Unfortunately, young students are not a white canvas; freeing their mindsets and teaching them to stimulate their creativity is challenging. Architectural design education is project-based and taught through the studio system. This paper discusses the method used at Akashi College Architectural Design Studio IB to teach the students the idea generation phase of the design process, or architectural design concept. The method used is storytelling; the students must create a story and, based on this story, develop an architectural concept. The students are asked to design a house for the Alien from Baltan, a villain from the Ultraman TV series by Tsuburaya Productions Co. Baltan first appeared in 1966, in Episode 2 of Ultraman "Shoot the Invaders."[1] After watching the episode, the students were asked: What happened to Baltan after he was defeated? Where is he living now? How does he live? Is he alone? What does he eat? How big is he? Does Baltan sleep or use the toilet? The students create a story and later transform this story into architecture using models and drawings. This paper will describe and analyse the students' Alien from Baltan house designs from 2008 until 2024. We will show that all the students were able to create a story. Most of the students successfully transformed this story into architecture using models and drawings.

Keywords: *design process in architecture, architectural design education, design concept, Alien from Baltan house*

Introduction

Architectural design is a creative process that combines problem-solving, technical knowledge, and innovation. For students, especially beginners, the idea generation phase can be difficult due to limited experience and deeply ingrained preconceptions. To support creative development, architectural education often uses the studio system, which emphasizes hands-on learning and experimentation.

At Akashi College, the first-year course Architectural Design Studio IB introduces students to the design process through a unique, storytelling-based assignment: designing a house for Alien Baltan, a character from the Ultraman television series. This imaginative exercise helps students develop narratives and translate them into architectural concepts, encouraging creativity while exploring core ideas such as form, function, and context.

This paper examines the effectiveness of this approach, used from 2008 to 2024. The methodology includes an analysis of the students' designs, tracking how their architectural responses evolved, and interviews with fifth-year students to assess the assignment's lasting impact. We begin by outlining the goals of Studio 1B and the role of studio education in architecture, then explain the choice of Alien Baltan as the design subject. Finally, we analyse the student works and insights from the interviews to evaluate how storytelling supports the development of design thinking.

Architectural Studio IB

Architectural studio courses serve as the backbone of architectural education. In these courses, students are required to integrate knowledge from various subjects to design buildings and architectural structures. At Akashi College, the architectural studio curriculum increases in complexity and difficulty as students progress through the program. In the first year, the primary objective is to familiarize students with the fundamentals of architectural representation, technical drawing, model-making, and the initial stages of the design process. Teaching technical drawing and model-making within studio courses is a distinctive feature of architectural

[1] According to Article 35 of the Japanese Copyright Act, it is permissible to use copyrighted materials for educational purposes.

education in Japan. In contrast, at numerous institutions overseas, these skills are taught as separate, standalone courses during the first year. Architectural Studio IB is a second-semester course for first-year architecture students at Akashi College. In the first semester, in Architectural Studio IA, students are introduced to the fundamentals of technical architectural drawing and model-making. In Studio IB, the focus shifts toward the fundamentals of architectural design, with the primary objective of introducing students to the process of generating design ideas within an architectural context. Design thinking in architecture is often described as a form of storytelling (Rowe, 1994). Unlike goal-oriented problem-solving in other disciplines, architectural design does not aim to find predefined solutions. Instead, architects imagine, narrate, and invent new worlds (Rowe, 2024). There is no single correct answer, but neither is there a completely wrong one. These abstract ideas can be especially difficult for young students to grasp, as they often lack the life experience and creative repertoire necessary to engage in open-ended design.

Students in Studio IB are typically around 15 years old, having just graduated from junior high school. They tend to have limited experience and knowledge, along with preconceived notions shaped by years of education focused on finding the "right" answers. As a result, they often struggle with the open-ended nature of design thinking. A common classroom exchange—where a student asks, “How do I do it?” and the instructor replies, “How do you want to do it?” illustrates this tension. Helping students break free from rigid thinking and encouraging creative exploration is a central pedagogical challenge.

To foster creativity, the course introduced a fantasy-based design assignment, a widely used strategy for teaching design thinking. Initially, the studio used a traditional exercise: designing a house for an artist or celebrity. However, this approach proved ineffective. Students had difficulty selecting an artist, and many were unable to complete the assignment. Moreover, because each student chose a different artist, it became difficult to facilitate class-wide discussion and idea-sharing about their design processes.

To address these challenges, we modified the assignment to use a shared, fictional context, specifically, a fantasy setting in which all students would design within the same imagined world. This approach helped to eliminate the difficulties students faced when choosing an artist and allowed for greater engagement with the creative process. More importantly, it created a shared framework for discussion, enabling students to compare, critique, and develop their ideas collaboratively. The fantasy setting functioned as a common narrative scaffold that sparked imagination and encouraged the development of architectural ideas without the constraints of realism.

Using fictional worlds (*isekai*) to teach design is not merely a pedagogical trick; it is grounded in established theories of design thinking. According to Rowe (1994), the design process involves speculative reasoning and the construction of imaginary situations. By introducing students to these practices early in their education, we aim to shift their focus from solving predefined problems to exploring possibilities and developing design narratives. In Studio IB, students were tasked with designing a “house for the Alien Baltan.” The assignment imposed minimal constraints: the house might be situated anywhere—on the ground, below the surface, or floating—and its design could range from realistic to completely imaginary. However, each student was required to define the characteristics of the setting and the lifestyle of the Alien Baltan. This open-ended task encouraged students to construct a narrative context together with a user profile, and to articulate an architectural response to both. Through this process, they began to engage with fundamental architectural concepts, such as context, function, and form, without depending on real-world precedents or being constrained by the limits of their knowledge and experience. The results of this pedagogical shift were encouraging. Students demonstrated increased motivation and creativity, and studio discussions became more dynamic and collaborative. Some imagined floating cities, others designed subterranean dwellings. Freed from the expectation of producing a “correct” answer, students explored bold, unconventional ideas. More significantly, they began to internalize the notion that architectural design is not about finding definitive solutions, but about generating proposals, about imagining what could be, rather than determining what must be.

Alien Baltan: The Ultimate Tokusatsu Villain

There were several compelling reasons for choosing Alien Baltan as the subject for the architectural design assignment. First and foremost, Baltan is instantly recognizable in Japan, even to individuals who have never watched Ultraman. The Alien Baltan (Barutan Seijin), initially introduced in Ultraman Episode 2, Shoot the Invaders! (1966) is one of the most iconic figures in the history of Tokusatsu, a turning point in Japanese pop culture by blending post-war anxieties, science fiction imagination, and groundbreaking special effects.

Tokusatsu, or "special effects," refers to a genre of Japanese post-war film and television that heavily utilizes practical effects, miniature sets, rubber suits, and imaginative storytelling. Rooted in the trauma of World War II, especially the nuclear bombings, Tokusatsu evolved as a form of creative expression that addressed national fears of destruction and rapid modernization. Core works in this genre include Godzilla, Ultraman, Kamen Rider, and Super Sentai. These productions explored themes of survival, mutation, alienation, and the struggle between good and evil, often through the lens of science fiction and fantasy.

Alien Baltan is widely regarded as the ultimate Tokusatsu villain, not only within the Ultraman series but across the broader landscape of Japanese special effects media. This status is owed to a unique combination of narrative depth, visual originality, psychological impact, and cultural symbolism. The backstory of Baltan is particularly significant. Hailing from the Planet Baltan, which was destroyed by a nuclear explosion, the Baltan race was forced to flee into space. Their attempted

invasion of Earth stems not from malice, but from desperation, a search for a new home. This tragic narrative mirrors post-war Japanese experiences of nuclear devastation, displacement, and existential fear. Baltan is not simply a monster, but an intelligent being shaped by loss. In this sense, Baltan represents "the enemy who is also a victim," embodying the moral ambiguity and emotional complexity rarely found in typical villains.

Another factor contributing to Baltan's iconic status is its unforgettable design. Created by the legendary designer Tohl Narita, Alien Baltan features a hauntingly insectoid appearance, giant pincers, glowing eyes, and a bug-like exoskeleton. It is one of the few Tokusatsu antagonists that appears distinctly non-human while remaining oddly expressive. This unsettling yet memorable design has proven to be timeless: still eerie, still effective, and widely referenced in Japanese media and popular culture. Alien Baltan has transcended its original context to become a cultural icon.

According to Article 35 of the Japanese Copyright Act, it is permissible to use copyrighted materials for educational purposes. This special provision supports teaching and learning by allowing limited use of such materials while still protecting the rights of creators.

Ultimately, the primary reason for choosing Alien Baltan as the subject of a design exercise was conceptual: Baltan has no home. Dispossessed and alienated, Baltan is a character who desperately needs a house. This narrative premise provided an ideal foundation for a design task that encouraged students to creatively explore ideas of shelter, identity, and belonging, while engaging deeply with cultural and symbolic themes from Tokusatsu.

Analysis of the Students' Works from 2008 to 2024

The "House for Alien Baltan" project has been conducted at Akashi College since 2008, producing a diverse range of imaginative responses from students over the years. This section analyses key trends in the students' work, based on their drawings, models, presentation boards, and recurring themes. The evolution of their design approach reveals both pedagogical progress and shifts in student creativity.

Early Years (2008–2010) Limited Narrative, Visual Experimentation

In the earliest years, students generally focused on imagining Baltan's lifestyle, what he liked or disliked, whether he lived alone or with others, but rarely created full narratives. Most designs placed Baltan in isolated settings, such as deserted islands, oceans, or mountains, far from human civilization. While the alien's form inspired architectural shapes, students did not always construct cohesive stories. The drawings were mostly in pencil and consisted of a few pages, often lacking in layout and color. Only one student in 2008 used colored pencils, and few included titles or text explanations on their boards. Some imaginative ideas emerged nonetheless, such as Baltan working as a barber or having automatic doors in his house, but these remained conceptual rather than narrative-driven.

Narrative Development and Material Expansion (2011–2014)

From 2011, students began incorporating clay models and site maps, showing a more integrated understanding of spatial context. Font design and text began appearing more frequently on presentation boards, indicating increased attention to storytelling and visual communication. By 2012, a notable theme emerged: cloning. Several students designed Baltan clone factories rather than houses, earning the class the informal nickname "the clone class." These designs reflected deeper engagement with speculative world-building and hinted at influence from contemporary media and science fiction. From 2014 onward, color became more prominent. This shift likely resulted from a change in course materials, colored pencils were added to students' supply lists, encouraging more expressive visual presentations. Many students began giving their projects creative titles, further solidifying the narrative aspect of their designs. Cubes and geometric forms were popular in this period, possibly reflecting a shift toward more structured and modular concepts.

From 2015, student narratives became increasingly bold and diverse. For example, one student imagined Baltan retiring on the moon, while another envisioned him marrying a human he had rescued from the 2011 tsunami, with whom he later had children. Others envisioned Baltan as tired or worn out, suggesting emotional depth and psychological interpretation. Projects from this period often showed clear influence from pop culture. For instance, two students developed proposals for canning factories in which Baltan was processed as food, reflecting thematic influences from dark fantasy manga such as Tokyo Ghoul (Ishida 2011–2014, depicting the conflict between humans and flesh-eating ghouls in Tokyo) and The Promised Neverland (Shirai 2016–2020, portraying children raised in an orphanage as livestock for demons). Narrative consistency also improved. Most students who developed full stories gave their projects clear titles and often chose matching fonts for presentation boards to reinforce their concepts. Others, even without titles, expressed ideas visually through bold font design and color. Several students created not just a single dwelling, but apartment buildings or entire cities, reflecting an expanding understanding of urban scale and spatial complexity.

Common Patterns and Trends:

Across all years, some consistent patterns emerged. The most common scenario involves Baltan living alone, hiding from Ultraman, or training for revenge. These narratives often proved contagious, with classes adopting similar tones or shared ideas. For example, in 2009, several students imagined Baltan and Ultraman peacefully retired and living together, while in other years, more adversarial narratives prevailed.

In terms of form, circular and spherical shapes appeared most frequently, likely inspired by Baltan's insectoid anatomy. Several students situated Baltan's house inside or atop trees, inspired by his insect-like appearance. While most students imagined Baltan at a human size, others experimented with size, designing houses that played with scale and surreal settings.



Figure 1: example of students' works

The selection of the site location was also an important aspect of the assignment. Students were asked to choose where Baltan would live, and many selected remote or unconventional places, such as desert islands, underground, Hokkaido, Okinawa, or even alien planets and galaxies. Some students designed Alien Baltan's house next to their homes or inside their rooms.

The "House for Alien Baltan" assignment at Akashi College has proven to be an effective and imaginative introduction to architectural design for first-year students. By using a fictional character as the client, the project encourages students to move beyond conventional thinking and engage with design through storytelling, world-building, and empathy.

Over the years, the assignment has evolved alongside the students' growing skills and changing cultural influences. Early works focused more on form and basic lifestyle considerations, while later projects incorporated rich narratives, creative site selections, and more sophisticated visual presentations. The gradual inclusion of materials like colored pencils and clay models contributed to this evolution, enhancing the students' ability to express their ideas. The recurring themes, such as isolation, revenge, or coexistence, show how students use design to explore emotion, character, and context. Additionally, the interviews with fifth-year students indicate that this early assignment had a lasting impact, helping them understand the importance of creativity, storytelling, and client-centered thinking in architectural design.

5th-year students Interview

In interviews conducted with fifth-year students, we examined how much they remembered about their first design assignment and how it had impacted their academic development. They perceived the movie as a deeply sad story and expressed sympathy for the character. Alien Baltan, portrayed as a space ninja without a home, evoked themes of stealth, alienation, and survival. These elements made the project both emotionally engaging and creatively stimulating.

Student 1: "I barely remember the details of the assignment, but I do recall that it was the most creative project we had at the time. Since it was also my first design experience, I found it quite difficult to come up with ideas. Wanting to try something new, I made a round design with a spiral staircase, but it was incredibly hard to draw. I remember thinking, 'I never want to do that again". (Figure2-1)

Student 2: "Designing a house for a non-human subject introduced an element of fantasy, which made the experience feel fresh and exciting. Each student developed their own story, leading to variations in setting and family structure, which made the process enjoyable. Unlike the Studio IA assignments, where we traced famous architectural drawings, this was our first opportunity to conceive and illustrate our own ideas. It left a strong impression on me. This assignment also connected well to the next task, which was a design competition. Through this experience, I realized that the essence of good design lies in how compelling a story you can create within given constraints." (Figure2-2)

Student 3: "I remember the project clearly because it was my first experience with architectural design. Since the subject we were designing the house for wasn't human, details like scale were flexible, and everyone's ideas were different. It was fascinating to see each student's personality come through. I especially enjoyed imagining what might happen after the events of the film. It was a unique assignment that I proudly shared with friends from other schools. The project also reflected the creative spirit of our college. From the various interpretations of Alien Baltan's house, you could sense the collective character of our class year." (Figure2-3)

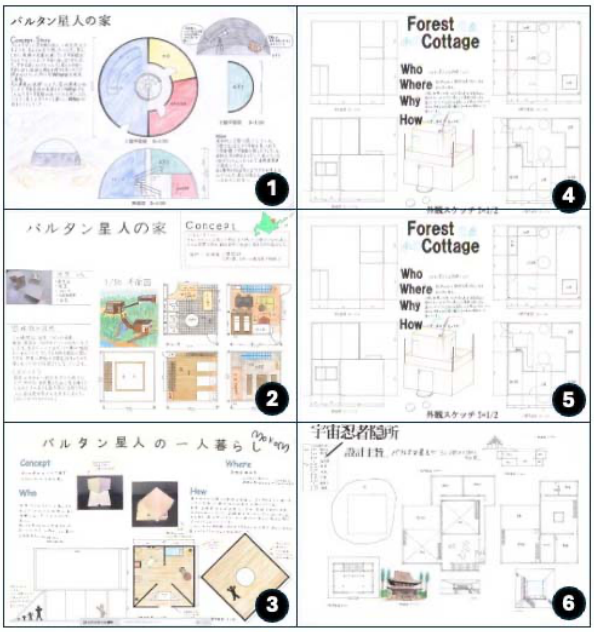


Figure 2: Interviewed Students works

Student 4: "I was so focused on drawing the plans accurately that I had little time to consider the design itself. Inspired by the concept of a space ninja, I placed the house in a forest. In the end, I used many squares and cubes, as I lacked both the ideas and the technical skills to produce more complex forms." (Figure2-4)

Student 5: " I don't remember the exact details of my design, but I do remember being strongly influenced by the idea of Alien Baltan as a 'space ninja.' I incorporated hidden tricks and features, like those found in traditional ninja houses. While other students imagined Baltan living in isolation in the forest, I envisioned a more integrated life, where he could coexist peacefully with nearby residents. I realized that an important part of the assignment was capturing Baltan's character as presented in the film. I also learned that creating an interesting story within the constraints of the project was key to a meaningful design." (Figure2-5)

Student 6: "What left the strongest impression on me was watching an episode of Ultraman Q at the beginning of the project to learn about Alien Baltan. From the video, I gathered that Baltan had stealth abilities, becoming invisible, creating clones, and shrinking in size, along with the tragic fact that he was ultimately defeated by Ultraman. Those traits became the basis for my design. I was especially struck by the idea that if Baltan were

discovered by Ultraman, he would be destroyed, so I created a story centered around him living in hiding.

Now, five years later, I no longer remember my specific design intentions, but I do believe that thinking deeply about the story of a fictional, non-existent being became a turning point for me. It helped me understand the value of narrative in design. By constructing a story first, my architectural ideas became more concrete, and I found it easier to clarify what I wanted to express." (Figure2-6)

The comments from the interviewed students clearly demonstrate that the assignment was highly effective in introducing them to the design thinking process. The six students interviewed were from the 2021 class—referred to as the 'ninja year'—since, as they noted, Alien Baltan's ninja-like qualities left a strong impression on them. All students empathized with Alien Baltan and expressed a desire to help him hide from Ultraman. They explained that the project allowed them to break away from conventional design methods and to explore their creativity within a structured yet flexible framework.

By designing a house for Alien Baltan, a non-human and fantastical subject, the students were prompted to move beyond traditional architectural constraints, such as human scale and functionality, and instead to focus on imaginative storytelling, contextual thinking, and emotional engagement. Several students emphasized that the assignment encouraged them to integrate the character's narrative and background as essential components of the design process, which enabled them to explore architectural ideas in greater depth. The freedom to create a house for an alien character with unique traits, such as invisibility, shapeshifting, and stealth, pushed the students to envision new design possibilities and to approach architecture not merely as a technical exercise, but as a medium for narrative expression. Furthermore, the diversity of ideas and solutions, ranging from hidden houses in forests to more integrated designs, demonstrated the students' ability to think critically and creatively. This freedom and flexibility, alongside the requirement to work within certain constraints, closely mirrored real-world design challenges, where the balance between creativity and practicality is crucial. The project not only deepened the students' understanding of architectural design but also emphasized the importance of story-driven design thinking, a skill that would serve them well in future projects and competitions.

Conclusion

The House for Alien Baltan design assignment at Akashi College has proven to be a powerful and imaginative entry point into architectural education. By engaging students with a fictional, non-human client, the project fosters narrative-driven design and enables students to explore architecture beyond conventional limitations of human use, function, and form. Beginning the assignment with a viewing of Ultraman (1966), Episode 2: Shoot the Invaders, has also been effective in captivating students and encouraging them to think beyond conventional frameworks.

The interpretations of Alien Baltan vary widely and often spread contagiously within each group of students. Over the years, different classes have developed recognizable "themes": the "ninja class," the "insect class" with houses in trees, the "underground class," the "Ultraman-friend class," and even a class that imagined eating canned Baltan. The assignment itself has continued to evolve, reflecting not only the students' growing skills and access to new tools, but also the refinement of studio pedagogy. While early projects emphasized form and basic spatial concepts, later work demonstrated stronger narrative cohesion, greater visual sophistication, and increased thematic diversity.

The recurring themes, ranging from revenge and isolation to peaceful coexistence, revealed students' engagement with emotion, personality, and context in design. The students' creative responses demonstrate that, even at an early stage of education, they are capable of working with complex ideas when guided toward imaginative exploration. Interview insights confirm the assignment's lasting impact: students consistently recalled it as a formative experience that shaped their understanding of architecture as a creative, story-driven discipline. The assignment also fostered empathy, imagination, and confidence, qualities that later informed their participation in design competitions and real-world architectural challenges.

Ultimately, the House for Alien Baltan assignment demonstrates the pedagogical value of storytelling in architectural education. It offers a compelling model for how creative, character-based design tasks can cultivate curiosity, originality, and deep learning among beginning architecture students.

References

1) Rowe, C. (2024). Design thinking and storytelling in architecture. Birkhäuser.
2) Rowe, P. G. (1994). Design thinking. MIT Press.
3)Tsuburaya Productions. (n.d.). Alien Baltan. Tsuburaya Encyclopedia. Retrieved May 14, 2025, from https://tsuburaya-prod.com/encyclopedia/baltan
4) 改正著作権法第３５条運用指針, Retrieved May 14,2025,from:https://www.bunka.go.jp/seisaku/chosakuken/pdf/92223601_11.pdf
15) Ishida, S. (2011–2014). Tokyo Ghoul. Shueisha.
16) Shirai, K., & Demizu, P. (2016–2020). The Promised Neverland. Shueisha.

The educational effect of Inquiry-Based Learning that uses knowledge through Japanese Classics x *Monozukuri*(manufacturing)

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This study explores the educational effects of the "Japanese Classics x *Monozukuri* (Manufacturing)" initiative as a method of engineering education. The authors has been implementing an inquiry-based learning approach that integrates *Monozukuri* (hands-on creation and manufacturing) into Japanese classic literature education. Specifically, this initiative involves students creating and presenting visual materials using scientific and technological tools to deepen their understanding of Japanese classical literature. Findings indicate that this approach is particularly effective for science and engineering-oriented students, many of whom exhibit a strong aversion to the Japanese language, especially classical texts. The method promotes proactive and creative engagement with learning material that they would otherwise find inaccessible or uninteresting. This initiative was developed in response to the changing landscape of classical education. In 2016, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) identified a key challenge: Japanese classic education lacked a perspective that encouraged students to actively enjoy and appreciate the language and culture inherited by the Japanese people, resulting in low motivation to learn. Supporting this observation, annual surveys conducted at Tsuruoka KOSEN consistently revealed overwhelmingly negative attitudes among new students toward Japanese classical literature. At the junior high and high school levels, Japanese classic education has often taken the form of exam-focused, rote learning that fails to convey the intrinsic interest and value of Japanese classic literature. To address this issue, the "Japanese Classics x *Monozukuri*" initiative was introduced. In the 2024 academic year, first-year students at three KOSEN colleges—Tsuruoka, Maizuru, and Toyota—participated in practical activities combining Japanese classical literature with *Monozukuri*. A post-class survey was conducted across all three schools, with 509 student responses collected. Results showed that 96% of students reported an increased interest in Japanese classic literature through the initiative. Furthermore, 92% noted a heightened interest in specialized subjects and technology. 231 students responded that they have things they would like to try if they had more knowledge or technical skills. Additionally, 95% of students believed that the "Japanese Classics x *Monozukuri*" program would benefit their future learning at KOSEN. These results suggest that the initiative effectively increases students' interest and engagement in both Japanese classic literature and engineering, encouraging them to apply the principles, methods, and technologies they learn in their specialized fields. Moving forward, the initiative can further enhance students' learning in technology by building on their engagement with Japanese classic literature. It is believed that, moving forward, this initiative can further enhance its educational effectiveness with the cooperation of specialized faculty members.

Keywords: *Classics, Monozukuri, visual materials, Inquiry-Based Learning, Japanese classical literature*

Introduction

In a globalizing society, being able to explain about one's own culture leads to establishing one's own identity. The starting point for cross-cultural exchange is to know one's own country, Japan. Being able to answer confidently about Japanese culture, history, customs, and values is the foundation for accepting other cultures. It is essential learning for KOSEN that aim to cultivate human resources who can play an active role globally, and it is a quality that students should possess.

This study practically examines the possibility that classical education based on "Japanese Classics x

Monozukuri" contributes to the cultivation of global human resources and engineering education. This paper clarifies that classical education deepens the understanding of national culture and stimulates interest in engineering through the analysis of the questionnaire results and practical examples of the common program by three schools, Tsuruoka KOSEN, Maizuru KOSEN, Toyota KOSEN.

Materials and Methods

1. *Original textbook "YUI no KOTEN"*

In March 2024, the Society for Classical Education of KOSEN published a textbook called "YUI no KOTEN." Japanese classic literature has been adapted, illustrated, and dramatized in various forms through they have been enjoyed by people for a long time. Conventional textbooks select works in consideration of fixed teaching materials and grammar learning and are not suitable for understanding about how to enjoy and cultural activities. "YUI no KOTEN" selects Japanese classic works based on the keyword "connection" "adaptation" and arrange them. Therefore, it is possible to understand how works are enjoyed by people and how they have changed up to the present day.



Figure 1. The original textbook "YUI no KOTEN."

Three schools, Tsuruoka KOSEN, Maizuru KOSEN, and Toyota KOSEN, used "YUI no KOTEN" as their textbook to study Japanese classic literature in the first semester of the first year. Although the number of class hours varied due to each school's distinct curricula, teachers introduced largely common works and classes were structured so that students could become familiar with various classic works.

In the second semester, we assigned the students the task of "Japanese Classics x *Monozukuri*," and the students were required to make presentations introducing classic works. The students selected works on their own initiative, centering on the works published in "YUI no KOTEN". In order to make presentations that convey the interest and interpretation of the works, the students were combined with the techniques of *monozukuri*, which they learned at the College of Technology.

In this paper, three examples of presentations on the subject of "*Kuruma arasoi*" (*The Tale of Genji*) published in the textbook are discussed.

2. *What is "Kuruma arasoi"?*

The Tale of Genji is a classic of Japanese literature and was written in the early 11th century by Murasaki Shikibu, a lady-in-waiting and middle-class noblewoman. Japanese students always learn about it in their school education. It is a lengthy narrative that describes the life of Hikaru Genji, who was born as a son of the emperor, full of love and power. High school curricula often cover scenes of Genji's birth and his encounter with Murasaki, the girl who would later become Genji's beloved wife. However, there are other famous scenes in *The Tale of Genji* that have produced many secondary works. One of them is "*Kuruma arasoi* (Battle of the carriages)."

When Genji was 22 years old, there was an incident at the Aoi Matsuri festival. Lady Aoi, Genji's legal wife, and Rokujō, Genji's mistress, came to the festival to watch Genji participate in the festival procession. Lady Aoi's retainers forcibly evicted other carriages to secure an advantageous spot from which to view the festival. Among them was the carriage Lady Rokujō was riding. Her carriage was damaged in the fight with Lady Aoi's party, and she felt very ashamed of it. Lady Rokujō's jealousy and resentment turned to Lady Aoi, who was pregnant, and as a result, Lady Aoi died immediately after giving birth.

This episode is well known among people in *The Tale of Genji*, and based on this episode, Noh play "*Aoi no Ue*" and various designs were created. The diverse development of this episode in later years seems to have stimulated the imagination of students in modern Japan. Next, we introduce the practical examples of students' manufacturing on the theme of "*Kuruma arasoi*" in each school.

3. *Case of Tsuruoka KOSEN*

In Tsuruoka KOSEN, the subject was carried out for creative engineering department 1 year (160 persons). Students are assigned to specialized courses from the second year, and in the first year, all students learn the basics of four specialties: machinery, electricity, electronics, information, and chemical biology.

In the class, he read the Aoi chapter of *The Tale of Genji*, watched the Noh play *Aoi no Ue* and tried to understand the contents deeply by comparing the expressions. In the practice, a presentation was made in which an ox-drawn carriage that appears in "*Kuruma arasoi*" was reproduced. It is possible to know what an ox-drawn carriage is by looking at a collection of materials, but the ox-drawn carriage is not a familiar vehicle, so it does not feel real.

So the students used the crank mechanism they had learned in mechanical design to create a moving oxcart, not just a model. At first, the students worked on the ox-drawn carriages because they wanted to make use of the knowledge they had learned, but as they made them, they became more interested in Japanese culture, such as the types and decorations of ox-drawn carriages.

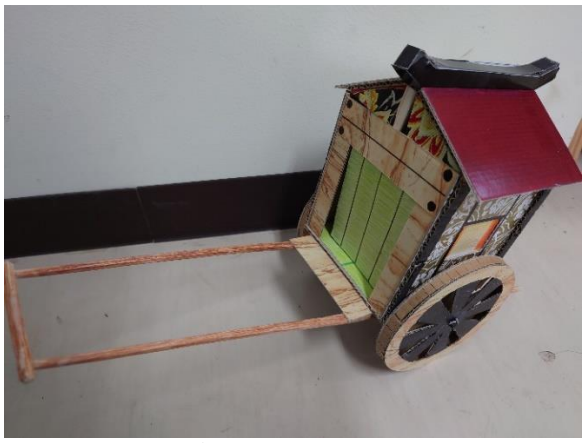


Figure 2. The design of the carriage model.

4. Case of Maizuru KOSEN

At Maizuru KOSEN, there are four departments: Mechanical Engineering, Electrical & Computer Engineering, Control Engineering, and Civil Engineering & Architecture. First-year students take general education courses—including Japanese classics—in mixed, cross-department classes. In Japanese Classics, students give presentations that explore Japanese classic literature by focusing on word usage and passages. Since the mid-term examination require a written statement of purpose and project plan, many students gravitate toward topics that allow for experiments or demonstrations.

This paper highlights one such presentation, which involved a 3D reconstruction and analysis of the *Kuruma Arasoi* (Carriage Battle) scene from *The Tale of Genji*. A group of three students focused on a painting of the scene (Fig. 3), in which one leg of a *shiji*—a footstool used to stabilize a carriage—appears broken. They investigated the possible cause of the break.



Figure 3. Tosa Mitsuyoshi(17th Centuries) *Aoi Chapter from The Tale of Genji*, Kyoto National Museum (ColBase (https://colbase.nich.go.jp/)).

The students proposed two hypotheses: one, that the carriage was damaged in a collision after being pushed aside by another; and two, that drunken young men at the Aoi Festival caused a disturbance that led to the damage. Using Unity to simulate both scenarios (Fig. 4), they concluded that the latter explanation was more plausible.

From the perspective of the "Japanese Classics x *Monozukuri*" approach, the students' analytical thinking was remarkably creative and insightful. Although they

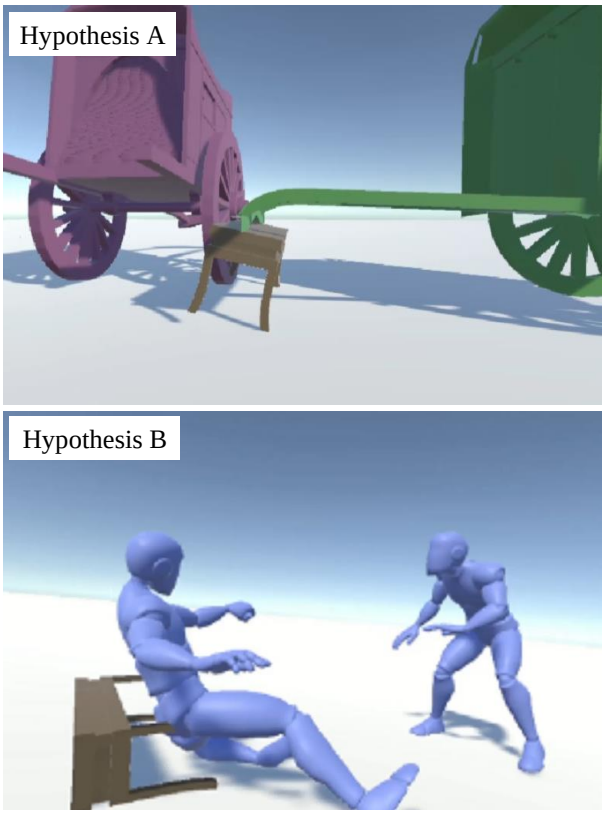


Figure 4. Part of the simulation video of Hypothesis A and B by Unity.

based their analysis on a painting produced roughly 600 years after the original text, and their method diverged from conventional literary analysis, their interpretation opened a new perspective. Their reading suggests that the painting emphasizes the aggression of an intoxicated young man rather than the physical impact of a carriage crash. This fresh viewpoint offers potential contributions to the study of *The Tale of Genji* as represented in later visual art.

5. Case of Toyota KOSEN

In Toyota KOSEN, "Japanese Classics x *Monozukuri*" were carried out in five departments, Mechanical Engineering, Electrical and Electrical Engineering, Information and Computer Engineering, Civil Engineering, Architecture. As shown in Table 1, the students' works showed the characteristics of the department to which they belonged.

Table 1. Characteristics of student's works by their department.

Dep	Charactaristic
M	Create something that appears in a classic work
E	Use the circuitry you just learned
I	Use AI and AR Technologies
C	On-site research of places in classic works, Use a map app
A	Reproduction of buildings and furnishings from classical works

This time, I would like to introduce the work of the student team of Department E. Their work is the carriage Lady Rokujō was riding in "*Kuruma arasoi*." The title of the work is "Let's strengthen Lady Rokujō's carriage." They were fans of Lady Aoi and thought about how to avoid her death. They thought that this tragedy could be

avoided if Rokujō's carriage was not broken during the battle of carriages. So they decided to strengthen Rokujō's carriage. Then, where and how should the carriage be strengthened so that it won't break? They often read *The Tale of Genji* and took note of the expression "*oshiorare*(pushed and broken)." Based on this description, they guessed that the carriage was broken by an instantaneous impact, and decided to improve the carriage to one with superior impact resistance. They assume that the force of 1 adult pushing the carriage was 755 N and the Lady Rokujō's carriage was pushed by 3 adults. Furthermore, the calculation was carried out considering the acceleration due to gravity and the size of the model carriage. As a result, the goal of this study was to ensure that the model carriage would not be damaged if dropped from a height of 0.865 m. To improve the shock resistance of the carriage, they devised 3 points.

1. The wheels were covered with rubber.
2. Mass dampers were added.
3. The joints were made stronger by *Sashimono* Japanese traditional technique.

What is interesting about these improvements are that it incorporates not only the modern techniques of rubber and mass dampers, but also the traditional Japanese technique, *Sashimono*. Fig. 5 shows the design of the carriage model produced by 3DCAD, and Fig. 6 shows the finished product of the carriage model. The completed model carriage was dropped from the side and diagonally, respectively, and the strength test was carried out, and the model passed the test.

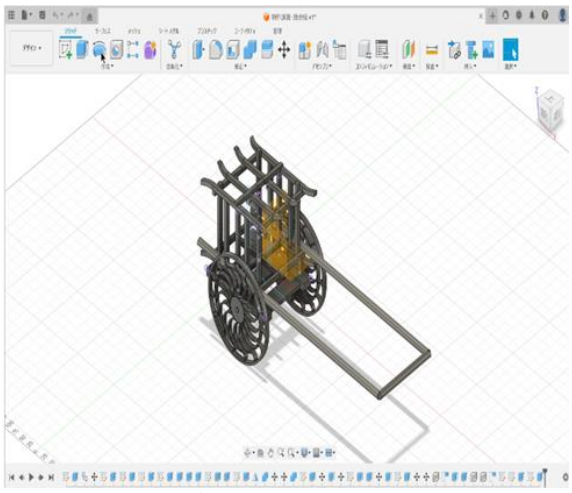


Figure 5. The design of the carriage model by 3DCAD.



Figure 6. The completed carriage model.

Results and Discussion

1. *Questionnaire analysis*

From January to February 2024, a questionnaire survey was conducted with students at 3 schools, Tsuruoka, Maizuru, and Toyota, which held presentations on Japanese classics and manufacturing. The number of responses was 509, with a response rate of 94.6%. The breakdown is as follows.

Table 2. Number and percentage of questionnaire responses.

	Number of responses	Number of students	Response rate
Tsuruoka	158	160	98.8%
Maizuru	149	167	89.2%
Toyota	202	211	95.7%
Total	509	538	94.6%

The questionnaire asked Q.1 to Q.5 about the use of knowledge and the growing interest in Japanese classics and expertise in this assignment.

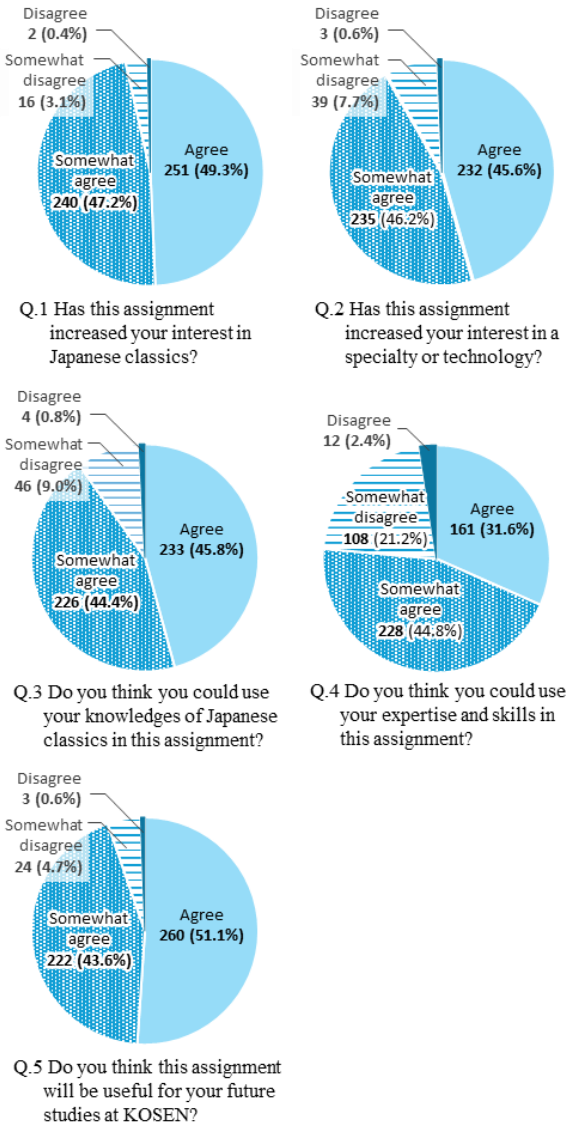


Figure.7. Results of a questionnaire after class of "Japanese Classics x *monozukuri*".

As shown in Figure7, 96.5% of the students responded that their interest in Japanese classics increased or somewhat increased through this assignment (Q.1). The percentage of students who were able to utilize their knowledge of the Japanese classics through this assignment was as high as 90.2% (Q.3).

To the Q.4, “Do you think you could use your expertise and skills in this assignment?” 23.6% of students answered “disagree” or “somewhat disagree,” which was higher than other questions. It was partly because first-year students were not so familiar with their fields of expertise, and because they were allowed to make materials from literature research methods to make it easier to work on. Therefore, even if they could not make the most of it in their presentations, it can be seen from Q.2 that their interest in the expertise is surely increasing, and from Q.5 that the students feel that this assignment is useful for their learning at the KOSEN. When asked why they answered “agree” or “somewhat agree” in Q.5, it was revealed that they had gained confidence from the experience of doing their own planning, research, analysis, and presentation by actively using the expertise while researching on their own what they did not understand. In addition, some students answered about the importance of sharing roles in group work and making presentations clearly.

2. Comment analysis

What was common among the three cases introduced in this article is that the students actively tried to understand classic works through this project. The students at Toyota KOSEN stated in an after-action questionnaire:

“Through careful reading of classical works, I learned that there are various theories on the interpretation of classic works.”

“When I make something based on a classic work, I look for the information necessary to make a work from the details of the story, so I can deepen my reading of the story.”

It was also clear that the students' deepening understanding of the story made them feel familiar with the world of classics as they do today. Many other comments were also received.

In terms of classical education, it was confirmed that the active learning style, in which students voluntarily select works and examine them, increased their motivation to learn and deepened their understanding. In terms of engineering education, the first-year students had few opportunities for practical training and projects, and it was confirmed that this task was a good opportunity to practice the technology they wanted to use. In addition, the students who did the project with more than one person seemed to have a good opportunity to understand the difficulty of accomplishing a project in a group and to think about how to make it work.

Conclusions

This study revealed that the attempt of “Japanese Classics x *monozukuri*” has an good effect on students' learning in both classical and engineering education.

Finally, future issues and prospects are described.

One of the issues is technical support for students when they work on tasks. Even if students have a technology they want to use (for example, a 3D printer), they may have to give up because they do not have the equipment or do not know how to use the equipment. It is desirable to cooperate with faculty members of specialized departments and receive technical support when they work on tasks.

Next, the future prospect is described. We plan to hold “Japanese Classics x *Monozukuri* contest," a joint KOSEN manufacturing contest in December this year. By providing opportunities to connect students from different KOSEN who have worked on the same task using the same textbook, we aim to further improve students' motivation and technical skills. The contest can be entered regardless of grade. This study targeted first-year students, but we plan to further analyze the educational effects in other grades.

Acknowledgements

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References

Dennis Washburn (2021). *The Tale of Genji: A Norton Critical Edition*. New York: W. W. Norton & Company.

Early STEAM Education Project Mathematics Course at NIT, Matsue College -Part Ⅱ: Bridge Learning for introduction to technical college mathematics-

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As part of the early STEAM (Science, Technology, Engineering, Art, and Mathematics) education, National Institute of Technology (KOSEN, NIT), Matsue College has been offering a total of six mathematics courses to third-year junior high school students who are interested in the school or mathematics and prospective students of the school since 2024. This is an educational program conducted under a project of NIT, which aims to provide a Bridge Learning education to smoothly connect the study of mathematics in primary schools, junior high schools, and technical colleges. The purpose of this paper is to propose the teaching materials used in the early STEAM Education Project Mathematics Course at NIT, Matsue College.

The course for third-year junior high school students was held four times in a hybrid face-to-face and online format, focusing on ' functions', 'congruence and similarity', 'the theorem of the angle of circumference', and 'the Pythagorean theorem', as well as applications in mathematics and engineering studied at the technical college. The course attracted a much larger number of applicants than expected, which suggests that there is a high demand for early STEAM education mathematics courses. Furthermore, the course received a positive response from the participants, which has already been reported by the authors in other journal papers, as it could be used in different technical colleges.

The course for prospective students of the school was held twice in an online format and included lectures on 'equations and complex numbers', 'trigonometric ratios and trigonometric functions (including the sine and cosine theorems)', which are studied in the first year of a technical college. In these lectures, teaching materials were prepared based on the matters learned in junior high school, with a greater awareness of the 'bridge' between the mathematics studied at the technical college. The aim is to familiarise students with the mathematics taught at technical colleges before they enrol, so that they can become accustomed to the mathematics and atmosphere at technical colleges, and to make them aware that middle school mathematics serves as the foundation for technical colleges. Details of the contents, the effect of these courses, and the participants' responses will be reported in the presentation.

Keywords: *Early STEAM Education, Bridge Learning, Mathematics in Engineering, Mathematical Education*

Introduction

In recent years, 'early STEAM' (Science, Technology, Engineering, Art, Mathematics) education has attracted attention at universities and technical colleges in Japan (Sakai, M. & Tanaka, T. (2024)). In Shimane Prefecture, where National Institute of Technology (KOSEN, NIT), Matsue College is located, few institutions provide early STEAM education and cram schools that support learning, which is thought to be one of the reasons why elementary and junior high school students are turning away from science, engineering, and mathematics. Furthermore, in recent years, there have been many cases in which students with low basic academic skills have been unable to adapt to study at technical colleges. Such a phenomenon could also occur at other technical colleges.

Against this background, it was considered necessary to increase STEA education opportunities for elementary and junior high school students and to strengthen the mathematics (M) skills of junior high school students before entering a technical college to increase the effectiveness of learning at a technical college. To bridge the learning gap between elementary, junior high, and technical colleges, we developed the Early STEAM Education Program, which combines a craft and science course (STEA) and a mathematics course (M) for elementary and junior high school students, under the

project named ‘STEAM Education Programme to realize bridge learning between elementary, junior high, and technical colleges’. This education program was planned to build on what students learn in elementary and junior high school and bridge learning with an awareness of how this will lead to engineering and mathematics studies at the technical college.

The content of the mathematics courses focused mainly on functions and elementary geometry (ZUKEI in Japanese), which are the foundations of mathematics. This is because a deep understanding of functions and elementary geometry is beneficial for learning mathematics at technical colleges and its applications in engineering. In addition, In the National Assessment of Academic Ability in 2024 (an annual survey of third-year junior high school students by the Ministry of Education, Culture, Sports, Science and Technology in Japan), two issues were identified: being able to think logically and prove things (in the field of elementary geometry) and being able to interpret events mathematically and explain how to solve problems mathematically (in the field of functions). In other words, these issues can be said to be the qualities and abilities needed to become practical and creative engineers not only in mathematics but also in technical colleges. To cultivate these qualities, it is meaningful to expose students to the mathematics they will learn at a technical college through early STEAM education while making them aware of the relationship with junior high school mathematics. As for the lectures for third-year junior high school students, we received more applications than expected and the response was so great that we have already presented an outline of the mathematics lectures for third-year junior high school students, to share information with other technical colleges (Matsuo, K., Koide, S., Katayama,M., Homma,H. & Suzuki, J. Submitted).

This paper presents a comprehensive overview of the mathematics courses offered to new students entering NIT, Matsue College in April 2025, as well as the courses for junior high school students, including the teaching materials and approaches used.

Materials and Methods or Pedagogy

This section describes the content of the mathematics course we have developed, including details on the teaching materials and implementation methods. The course consists of two main parts.

1. Mathematics course for engineering
2. Preparatory course for entering KOSEN.

In common with both courses, we prepared teaching materials and conducted lectures based on the following principles(i)-(iii).

(i)To enable students to realize the importance of basic knowledge of junior high school mathematics (seamless learning between junior high school and technical college).

(ii)Deepen their understanding of related units (seamless learning within mathematics).

(iii)To increase interest in mathematics and engineering in technical colleges (seamless learning within mathematics and engineering).

As with all studies, mathematics is based on the content learned in primary and secondary school, and mathematics itself is connected to each of these fields. By studying functions in depth, students gain a deeper understanding of figures and equations. Studying figures in depth provides a deeper understanding of functions and equations. This can be understood from the fact that in modern mathematics, algebra, analysis, and geometry have been developed while connected. Furthermore, the development of science, not just mathematics, cannot be separated from the progress of technology. An overview of the relationship between mathematics and engineering may be useful in motivating students to study mathematics and in raising their motivation for engineering. The achievement of the three principles (i) to (iii) listed above is assessed by the following items in the participant questionnaire.

Table 1. Most important evaluation items.

(i)	Would it be useful for your future study of mathematics?
(ii)	Did you gain a deeper understanding of the relevant units?
(iii)	Did you become interested in the mathematics studied at the technical college?

An overview of each of these courses is as follows.

1. Mathematics course for engineering

Preparation began in September 2024, and the course itself was held four times between November and December in a hybrid face-to-face and online format. The reason for the face-to-face and online hybrid format was to enable junior high school students from distant locations to participate through the online format.

There were 109 applicants for each session, for a total of 436. In the face-to-face course with a maximum of 40 participants, students from the technical college acted as Teaching Assistants and patrolled the desks during the exercises (see Figure 1). In the online format, after the face-to-face format, a slide video was created separately using the recording function of PowerPoint (Figure 2), and the video link was shared with all participants.



Figure 1. TA in the lecture

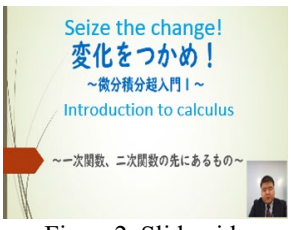


Figure2. Slide video

Session 1: Functions.

Functions are formulated as one of the mappings in modern mathematics. That is, for any number x in the domain X, if there exists just one corresponding number $y \in Y$, that correspondence is called a function. According to this definition, even something that cannot

be expressed or is difficult to express, by a mathematical formula, e.g., Figure 3 is a function.

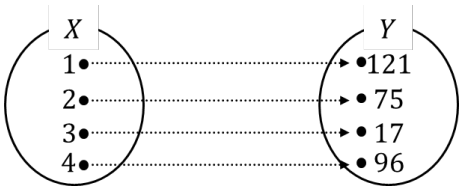
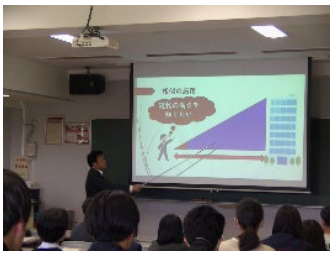


Figure 3. One example for a function

So, starting with the question 'What is a function?', and gave an overview of the functions studied at technical colleges and how functions are used in engineering.

Session 2: Congruence and similarity

The unit on congruence is an introduction to the mathematical method of 'proof' for Japanese junior high school students. Similarity is also an important concept linked to trigonometric ratios. When focusing on triangles, many junior high school students confuse the definition of congruence with the congruence condition. Therefore, I started by explaining the definition of congruence, had the students practice selected exercises, and finally gave an introductory explanation of trigonometric ratios as an application of similarity (Figure 4).


Figure 4. Face-to-face lecture 'congruence and similarity'

Session 3: Circles (including the circumferential angle theorem)

The circle is one of the quadratic curves (conic curves), and students learn the basics, such as pi and area, in primary school. In junior high school, students also learn the theorem of the angle of the circumference. Based on these foundations, the Matsue National College of Technology redefines the circle in the framework of coordinate geometry. In other words, they study the equation of a circle and the tangent lines of a circle. Therefore, after reviewing the definition of the pi angle, quadratic curves, and the Maclaurin expansion of pi were introduced, etc.

Session 4: Pythagorean Theorem

The Pythagorean Theorem is the basis for proving various properties of trigonometric ratios and various facts about coordinate geometry. Furthermore, by using the concept of trigonometric ratios, it is extended to general triangles, as the cosine theorem. In this session, as many students had not yet learned the Pythagorean Theorem at school at the time of the face-to-face session, explanations were given starting with the basics, and entrance exam-level questions were dealt with in an online format. In addition, the integral formula for the length of a curve was covered as a link to the mathematics of technical colleges.

2. Preparatory course for entering KOSEN

The course was conducted in February and March 2025 online for 198 students who intend to enter NIT, Matsue College in April 2025. In this course, we provided them with an advanced study of the content they will learn in their first year at the technical college. To motivate the learners, we made it interactive by sharing the answers to questions received after the course, before the students entered the school. To motivate the learners, the course was designed to be interactive by sharing answers to questions received after the course before enrolment. Furthermore, a confirmation quiz (one-choice type) was conducted to quantify the students' level of understanding. It should be noted that the results of this quiz are not related to admission itself or post-entry grades.

Session 5: Equations and complex numbers

Complex numbers appear together with trigonometric functions in the solution of the equations of motion for single oscillations in physics. Complex numbers have many applications in engineering, including the deformation of beams, analysis of structures, analysis of electrical circuits, and signal processing. In our school, the curriculum includes studying complex numbers in the first grade (content consists of an introduction to complex numbers, properties of complex numbers, and basic matters in the complex plane), Fourier transformations in the fourth grade, and rudiments of complex function theory in the fifth grade. On the other hand, because students learn so much in the first year, it is difficult to explain the mathematical background of complex numbers, especially why imaginary numbers were introduced, in class time. Therefore, an attempt was made to explain the historical background of the introduction of imaginary numbers. This originated in the discussion of solutions to cubic equations by Cardano, Bombelli, et al. According to Rotman (2016), we will describe below an overview. According to the formula for the solution of the cubic equation by Cardano, one of the solutions for the cubic equation $x^3 - 7x + 6 = 0$ is expressed as

$$x = \sqrt[3]{\frac{1}{2}\left(-6 + \sqrt{\frac{-400}{27}}\right)} + \sqrt[3]{\frac{1}{2}\left(-6 - \sqrt{\frac{-400}{27}}\right)}$$

On the other hand, the left-hand side of this equation can be factorized as $(x-1)(x-2)(x+3)$, so the solutions are all real numbers. To solve this certain irrationality, it is said that 'the number that is squared to -1', i.e., the imaginary unit i, was born; Bombelli introduced the four arithmetic operations on the imaginary numbers, and other studies showed that the above equation is a real number 2.

By telling the audience about the confusion of the people at that time when imaginary numbers appeared

and how they dealt with the concept, I tried to make them familiarize themselves with the concept of imaginary numbers and understand the inevitability of their appearance. Furthermore, the following exercises were frequently incorporated between lectures (Figure 5).

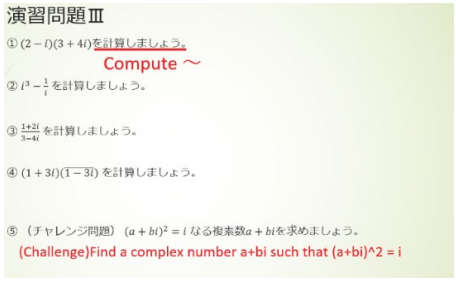


Figure 5. One of the exercises in Session 1

Session 6: Trigonometric ratios (including sine and cosine theorems)

Trigonometric functions are an essential part of engineering. The idea of the Fourier series, which is applied in signal processing and other areas, is, very crudely stated, to express a function as a superposition of sinusoids (sin) and cosines (cos), and the Fourier series is applied in various areas of engineering. Therefore, students need to be familiar with the handling of trigonometric functions, including derivatives, integrals, and matrix calculations. In our school, students learn the basics of trigonometric ratios and trigonometric functions in the first year and learn applied calculations of trigonometric functions from the second year onwards during lectures on differential and integral calculus and linear algebra. Despite being important concepts in mathematics and applications, the concepts of trigonometric ratios and trigonometric functions are difficult for beginning students to understand and are considered to be one of the hardest units for beginning students, as there are many important formulae such as interrelationships ($\sin^2 x + \cos^2 x = 1$, etc.), cosine theorem, additive theorem, and double angle formula. Therefore, the lecture introduces trigonometric ratios, trigonometric ratios of obtuse angles, interrelationships, the sine theorem, and the cosine theorem, and sets up simple exercises. These contents are equivalent to three lectures (270 minutes) in an actual technical college class (90 minutes), but the lecture video is compressed to about 26 minutes. The aim is to lower the hurdle for students to watch the videos, to get an overview of trigonometric ratios, to familiarize them with the concept of trigonometric ratios, and to make them think that they have 'heard of it before' in actual classes by combining the videos and teaching materials (Figure 6). The aim is to make the students feel that they have heard of the concept before. At the end of the lecture, the area formula for triangles using trigonometric ratios and Heron's formula for finding the area from the lengths of three sides were introduced, and through exercises, the students were able to experience the usefulness of trigonometric ratios. In addition, as Greek letters are often used in mathematics at technical colleges, a list of Greek letters is included in the teaching materials.

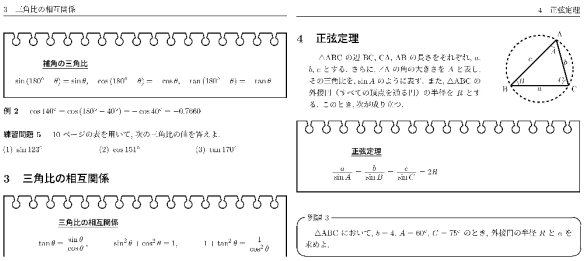


Figure 6. A part of original textbook of 'trigonometric ratios' (written in Japanese).

Results and Discussion

Here we present the results of the questionnaire survey for "Preparatory course for entering KOSEN (S5-6)" conducted after the students enrolled in the course. The questionnaire was conducted with the approval of the Ethics Review Committee at the author's institution. A written explanation is provided to all eligible participants that the survey responses will be used as research data for early STEAM education, that the data will be published in a form that anonymizes the eligible participants and does not identify them, and that participation in the survey will not affect their academic grades.

A questionnaire with the following questions was sent to 198 new students (first year) of NIT, Matsue College, regarding the course for entering a technical college.

Q1: Was it difficult?
Q2: Did you gain a deeper understanding of the relevant units?
Q3: Would it be useful for your future study of mathematics?
Q4: Did you become interested in the mathematics studied at the technical college?
Q5: Was it satisfactory?
Q6: Questions and impressions (free text)

Table 2. Average score for question items.

Question items	S1-4	S5-6
Q1 Was it difficult?	3.1	3.3
Q2 Did you gain a deeper understanding of the relevant units?	3.9	3.5
Q3 Would it be useful for your future study of mathematics?	3.8	3.7
Q4 Did you become interested in the mathematics studied at the technical college?	3.7	3.6
Q5 Was it satisfactory?	3.8	3.4

Of the 198 enrolled students, 78 had taken "Mathematics course for engineering (S1-4)". 78 of them were asked the same. For each question, excluding open-ended questions, the scores were quantified as follows: 4 for "agree", 3 for "somewhat agree", 2 for "somewhat disagree", and 1 for "disagree".

Some of the comments for Q6 are provided below.

Mathematics course for engineering (S1-4)
- Senior technical college students taught me and helped me understand what I didn't understand.
- It was difficult, but I could understand a lot, so I think it was a good class.

Preparatory course for entering KOSEN (S5-6)
- I thought it was good to be exposed to technical college mathematics from an early stage.
- I thought I would do a better job of reviewing the content after entering a technical college because it was very difficult.

Discussions

・The level of difficulty of both courses included advanced content such as mathematics studied at technical colleges and mathematics used in engineering, but it can be said that the setting was generally appropriate.

・Both the depth of understanding of related units (Q2) and interest in mathematics studied at technical colleges (Q4), which were used as indicators of achievement in Bridge Learning, showed high values.

・The results of the Preparatory course for entering KOSEN questionnaire showed that the results differed between students who had taken the Mathematics course for engineering (Group A) and those who had not, i.e. those who had taken only the Preparatory course for entering KOSEN course (Group B) were examined to see if there were any differences in the results. The results showed that Group B was slightly higher in difficulty level (Q1), but Group A was higher in Q2 to Q5. There was a difference of about 0.5 points in terms of satisfaction, which is a natural result given that Group A originally had students with an interest in mathematics as participants.

・To get an overall picture of the free descriptions in Q6, the co-occurrence networks created by KH Coder are shown in Figures 7 and 8 below. Figure 7 shows the co-occurrence network of free descriptions in the Mathematics course for engineering, and Figure 8 shows the co-occurrence network of free descriptions in the Preparatory course for entering KOSEN. The size of the circle indicates the occurrence rate of words, the line suggests the association between words, the thickness of the line indicates the strength of the association, and the color coding of the circle suggests groups of words that are highly related to each other. In the co-occurrence network for the Mathematics course for engineering (Figure 7), in addition to *mathematics*, *learn*, *know*, and *understand*ing, other words were mentioned that could be related to TA, such as *senior students* and *KOSEN*. In the co-occurrence network for the Preparatory course for entering KOSEN (Figure 8), words such as *difficult*, *understanding*, and *mathematics* were mentioned. Words like *complex numbers* and *triangles* related to the content were also mentioned.

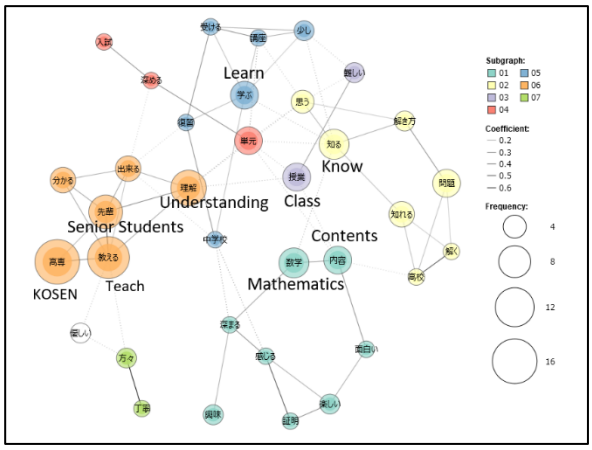


Figure 7. Co-occurrence networks for comments for Mathematics course for engineering (S1-4)

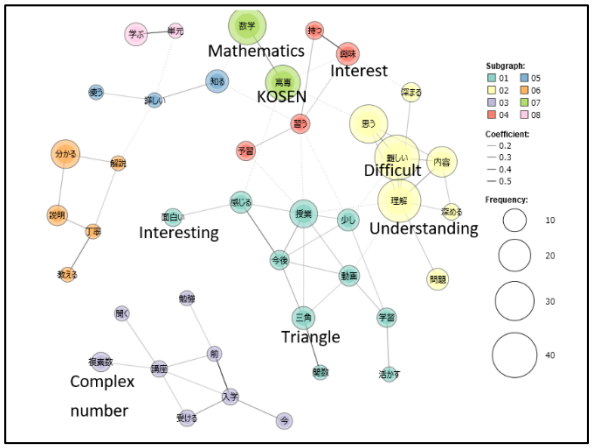


Figure 8. Co-occurrence networks for comments for Preparatory course for entering KOSEN (S5-6)

Conclusions

This paper introduces the mathematics course as part of the early STEAM education project at NIT, Matsue College, and shares the teaching materials. The results of the student questionnaire and the ratio of students who took the course to the total number of students enrolled in the course indicate that the initiative was generally successful. In addition, there are specialised subjects in which trigonometric functions are taught earlier than in mathematics classes. Early STEAM education is expected to have the advantage of facilitating the introduction to such specialised subjects. In mathematics classes at technical colleges, it is also important to provide classes that are conscious of the connection with specialised subjects, for example, by presenting examples of engineering applications. Future challenges include implementing the course in other subjects and expanding it to a broader geographical area. Furthermore, we would like to quantitatively verify the effectiveness of early STEAM education from a long-term perspective by conducting a follow-up survey of participants.

Acknowledgements

The projects related to this research were carried out under the project 'Individual-optimal diversity-based STEAM education through cooperation between elementary, junior high, and technical colleges' by the National Institute of Technology. In addition, we received a lot of opinions and advice from the teachers of the Department of Specialisation at NIT, Matsue College, on the preparation of the slides to be used in the lectures. We would also like to express our sincere thanks to the members of the administrative department who were in charge of various administrative tasks from preparation to afterward, and to the TA students who assisted on the day of the course. We thank the anonymous peer reviewers for their helpful advice.

References

Iizuka, I. et.al. (2011). A Coaching for Better Academic Performances Using Learning-by-Teaching System. *Journal of JSEE, 59(4): 80-84 (in Japanese)*

Katano, Z (2003). *A Story of Mathematical Terms and Symbols.* Tokyo: SHOKABO. (in Japanese)

Matsuo, K., Koide, S., Katayama,M., Homma,H. & Suzuki, J.. Early STEAM Education Project Mathematics Course at NIT, Matsue College–Proposal of teaching materials for connecting secondary mathematics and engineering–. Submitted to *Journal of JACT (in Japanese)*

Ministry of Education, Culture, Sports, Science and Technology (MEXT)-Japan (2011). *Courses of Study.* https://www.mext.go.jp/component/a_menu/education/micro_detail/__icsFiles/afieldfile/2011/04/11/1298356_4.pdf

Ministry of Education, Culture, Sports, Science and Technology (MEXT)-Japan (2018). *Developing human resources for Society 5.0 - Society is changing, learning is changing.* https://www.mext.go.jp/component/a_menu/other/detail/__icsFiles/afieldfile/2018/06/06/1405844_002.pdf *(in Japanese)*

Rotman, J, translated by Sekiguchi,J (2016). *Galois Theory (Revised New Edition).* Maruzen Publishing Co., Ltd. (in Japanese)

Sakai, M. & Miki, H. & Nakamura,S.(2024). Early STEAM Education Practice: Application of Graph Theory through Teaching Assistants. *Athens Journal of Technology & Engineering, 11: 1-21*

Sakai, M. & Tanaka, T. (2024). Development and Practice of Mathematics Teaching Materials for Early STEAM Education of Junior High School Students Using Molecular Graphs. *Journal of JSEE, 72(3): 36-41 (in Japanese)*

Practice of Cross-Disciplinary Cooperative Liberal Arts Education in Engineering Education

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Since its founding, Toyohashi University of Technology has consistently placed emphasis on liberal arts education in its engineering education. In response to the recent changes in the characters of students and the required competencies of engineers, TUT established a new subject called "Introduction to Liberal Arts" in 2024.

This study introduces and examines the pedagogical approach used in this subject.

"Introduction to Liberal Arts" is a two-credit cross-disciplinary basic subject for first-year students, comprising 15 half-term classes. It is an elective subject (enrolment rate of approx. 95%) which is divided into 4 classes (a-d) with a maximum capacity of 20 students per class.

"Introduction to Liberal Arts" is not just an omnibus class. This is a completely new class in which "guest teachers" from different fields participate in the classes of the "responsible teachers" who supervise each class, and various "dialogues" are attempted.

For example, the author did the following in Class (b). Class (b) is a class in which experts from various fields approach the keyword "create" from their own perspectives, and based on this, students and teachers engage in dialogue with each other. Throughout the 15 weeks, the students can experience through dialogue that there are many different perspectives and approaches to the concept of "create", depending on the field.

The author set the theme of "Creating Haiku". This is not a class where engineering students simply create Haiku. While they experience that the act of creating new materials, creating new Architecture, creating new programs, etc., and the act of creating new Haiku are different experiences, they can also realize that all of these acts have something in common.

Technology is something used to make people happy. Therefore, engineers must have a good understanding of what people are seeking in life and when people feel happy. This mindset is the same as that of a person who is "creating" a Haiku. Furthermore, through dialogue, they experience the similarities and differences between their own senses and those of others.

This kind of experience raised the students' motivation and greatly improved their learning, resulting in higher learning effectiveness. This is supported by the responses from the students' subject evaluation questionnaires and the observation of the students' behavior during the class. It is also worth noting that the teachers in charge experienced immense fulfillment throughout the classes.

Keywords: *liberal arts, engineering education, create, Haiku*

Introduction

Toyohashi University of Technology (hereinafter referred to as "TUT") is a single-faculty university specializing in engineering that was established in 1976. Since its inception, TUT has consistently emphasized liberal arts education. The reasons for this are mainly twofold.

First, it stems from TUT's founding philosophy and educational objectives. The investigative committee established to prepare for the establishment of TUT and Nagaoka University of Technology outlined in its report ("A Proposal for a New Graduate School of Science and Technology," 1974) that the type of talent TUT sought to cultivate was "highly skilled engineers who possess the general knowledge, qualities, and basic technical sensibilities necessary to serve as leaders in organizations."

The second reason lies in the characteristics of our students. At the time of TUT's establishment, the target students were "graduates of college of technology (KOSEN) or those with equivalent technical skills and academic abilities" (ibid.), and currently, 80% of our students are graduates of KOSEN who transfer in the third year of TUT. In the curriculum of KOSEN, a significant portion of class time is allocated to specialized subjects, leaving limited time for liberal arts education. As a result, while students acquire excellent specialized technical skills, they inevitably tend to lack knowledge and literacy outside their specialized fields (though individual abilities vary). In fact, faculty members who interacted with third-year transfer students at TUT's inception noted that they exhibited characteristics such as "uncertainty in basic knowledge," "lack of interest in

people and society," and "judging based on short-term effectiveness" ("Toyohashi University of Technology Ten-Year History," 1986). Among these, the third characteristic, "judging based on short-term effectiveness," is attributed to the experience gained during their time at KOSEN, where students were "driven to learn technology without cultivating an attitude toward unfamiliar things or even feeling curiosity about them."

In other words, in order to cultivate engineers with the "general education and qualities suitable for leaders of an organization" that TUT aims to produce, it was deemed essential to enhance general education. As a result, TUT has incorporated many general education subjects into the third-year curriculum for students transferring from KOSEN and has also implemented general education for graduate students.

A faculty organization dedicated to liberal arts education, the "Humanities and Social Engineering Department," was also established. In 2010, this department was reorganized into the "Institute of Liberal Arts and Sciences," which is responsible for liberal arts education across the fields of humanities, social sciences, and natural sciences. During this period, TUT's founding philosophy of "cultivating not merely technical human resources, but "cultivating humanistic engineers" (" Toyohashi University of Technology Ten-Year History") was maintained. However, in response to global social changes, rapid technological advances, and changes in the characteristics of incoming students, a review of educational content was conducted within the organization, centered on the 'Liberal Arts Education Review Team' established in 2019. This movement expanded to the entire university the following year, and TUT's fourth medium-term plan clearly stated the goal of "Reconstructing liberal arts education appropriate for the future of science and engineering education that integrates the arts and sciences." Thus, a comprehensive review of liberal arts education at TUT and Institute of Liberal Arts and Sciences began in earnest (Nakamori, 2025).

Through lectures and faculty development workshops on liberal arts, as well as interviews with faculty members both inside and outside the university, we worked to understand the current state of liberal arts education. The most time-consuming discussion was about the current disposition of TUT students and the abilities we want to cultivate in them. The results are shown in the Table1 below.

Table 1. Current temperament of TUT students and abilities to be cultivated

Temperament of students	Abilities to be cultivated
Becoming more introverted while keeping in mind the image of engineers demanded by society	Dreams, Self-esteem
Efficiency-oriented, Results-oriented	Problem-solving skills, Willingness to devote time to tasks
Strong fear of expressing subjective opinions and having them rejected	Sensitivity to shared joy
Narrow interests and perspective	The courage to leave one's comfort zone
Weak ability to organize thoughts, and a negative view of this	Recognition of the importance of time to think deeply, Ability to organize opinions

Based on the above, the Institute of Liberal Arts and Sciences has formulated a new philosophy for liberal arts education. It is as follows.

The Institute of Liberal Arts and Sciences aims to nurture engineers who can engage in dialogue toward their dreams.

The seeds of technology lie within everyday life. Our goal is to cultivate engineers who, as citizens, can nurture sensitivity to diversity and universality, empathize with human frailty and anxiety, identify underlying issues, and solve them with perseverance and kindness.

To realize the above educational objectives and philosophy, a new first-year course titled "Introduction to Liberal Arts" has been established. The following sections will provide a detailed description of the course's characteristics and specific examples of classroom practices for the 2024 academic year.

Pedagogy

" Introduction to Liberal Arts" is a 2-credit 'interdisciplinary foundation course' consisting of 15 classes in the first semester. It was offered as a first-year course rather than a third-year course because it was the best option given the limited number of faculty members and class hours available. At the same time, it was designed to cultivate students' sensitivity to diversity and universality and to equip them with the abilities necessary for dialogue before they begin studying their specialized fields. Additionally, there is an expectation that these first-year students, when they join students from KOSEN in their third year, will provide a positive stimulus for the latter.

Although it is an elective course in the curriculum, the enrollment rate for the 2024 academic year was approximately 95%, meaning that virtually all first-year students took the course. To facilitate close communication between faculty and students, class sizes were limited to 20 students. Approximately 80 first-year students are divided into four classes (a–d) for instruction.

The course involves multiple instructors from different fields, but it is not simply an omnibus course. Each class is supervised by a single instructor, but several of the 15 classes are taught by guest teachers. The supervising instructor is also present in the classroom to listen to the guest teacher and occasionally ask questions. In this environment, classes proceed with free dialogue among faculty members, between faculty members and students, and among students.

Here is a brief explanation of the content of each class. First, class (a) is centered on a class on "philosophical

dialogue" (Iwauchi, 2025). "Philosophical dialogue" is a dialogue in which multiple participants gather to form a certain common understanding or agreement on questions that do not have easy answers. The dialogue in class (a) as an "Introduction to Liberal Arts" was conducted with the aim of cultivating "negative capability" (the ability to endure situations that cannot be resolved) and the ability to build consensus with others who are different, based on lectures by guest teachers and discussions exploring the essence of concepts such as "culture," "language," "cognition," and "technology."

Class (b) is a course with the theme of "creating" (Okada, 2025). The classes taught by responsible teacher and guest teachers consist of one "lecture" and one "practical" session, with the "practical" session involving students attempting to actually "create" what they learned in the lecture. The lecture content covers a wide range of subjects, including physics and electronics engineering, which are responsible teacher's areas of expertise, as well as materials science, Japanese literature, law, and english poetry and American literature. In the practical sessions, students engage in dialogue with one another while working on tasks such as recreating molecular structures using models, composing Haiku or English poems, creating court precedents, and constructing paper models of satellite components.

Class (c) is a course on the theme of "reading images" (Nakamura, 2025). The course is structured to help students understand the key points of analyzing and appreciating images by learning filmmaking techniques. In addition, lectures on how to utilize the library and academic writing are held (jointly with class (d) described below), allowing students to acquire skills that can be applied to research and thesis writing. Compared to other classes, this class has more lecture time, making it easier for students who are not good at discussion to participate.

Class (d) focuses on the theme of "gender" (Hieda, 2025). Students engage in dialogue about gender issues occurring in familiar settings such as within the university, and through lectures by guest teachers, they are exposed to concepts of gender in literature and economics. The goal is to help students recognize gender issues from diverse perspectives and contribute to society with a broader outlook.

Below, we will explain the specific practices implemented by the author in class (b) and their educational effects. The author conducted two classes as a guest teacher, setting the theme of "creating Haiku." This was not simply a class intended to have engineering students write Haiku. Rather, it was intended to help students realize that the act of creating Haiku is a different experience from the technical acts of creating new materials, building new houses, or developing new programs, while also making them aware of the commonalities between these acts.

In the first class, the author explained to the students what Haiku is. Haiku is a form of literature that aims to convey one's feelings to others within the constraints of 17 syllables and the mandatory use of a seasonal word. Therefore, it is important to create works that others can empathize with or be moved by, rather than works that are self-indulgent. After ensuring that the students understood this, the author instructed them to write three Haiku each by the next class.

In the second class, the author had the students submit all the Haiku they had written and held a Haiku gathering. This Haiku gathering was conducted in accordance with the formal methods used in general Haiku societies, following the steps below.

1. Students were asked to copy their Haiku onto "Tanzaku" (long strips of paper) without writing their names.
2. All "Tanzaku" were collected, shuffled, and distributed to each student in sets of three.
3. Distribute "Seiki Yōshi" (fair copy sheet, one sheet per person) and have the students copy the Haiku written on their short strips onto "Seiki Yōshi".
4. Arrange the desks in a circle and have the students sit down. Have each student write their Haiku name on a piece of paper and display it so that other students can see it.
5. Distribute "Senku Yōshi" (selection sheet, one per person). Have students read the "Seiki Yōshi" in turn, select five works they like, and write them on the "Senku Yōshi." From those five, select the best one and designate it as the "Tokusen" (special selection).
6. Have each student read aloud their "Tokusen". At this point, the author of the selected Haiku must announce his/her Haiku name to everyone to confirm that it is his/her work. The student holding the "Seiki Yōshi" with the "Tokusen" written on it then says, "Itadakimashita (I have received it)," and writes the author's name and score count below the Haiku on the "Seiki Yōshi".

The purpose of steps 1–3 is to completely obscure the authorship of the Haiku, ensuring that students are not influenced by the authors' information when selecting the best Haiku.

The students approached both Haiku composition and the Haiku gathering with serious dedication. In particular, during the announcement of the "Tokusen" in step 5, everyone was visibly excited and tense with anticipation.

Figure 1. Scene from a Haiku gathering



After the class, all students were asked to submit a report. The report included the Haiku they selected as their "Tokusen" and an explanation of why they chose it. Students were also instructed to write comments on any

other Haiku that resonated with them. The author compiled the results and provided feedback to the students.

Results and Discussion

The main comments given by students in their reports for selecting “Tokusen” were as follows.

1. “It conjures up images of the scenery” or “It stimulates the imagination.”
2. “I can relate to it.”
3. “Reading it brought back childhood memories and made me feel good.”
4. “I thought it was interesting that I couldn't come up with such wording myself,” “It's amazing that you can express that scene in 17 characters,” “The rhythm is good, and it was fun to read,” “The use of seasonal words is good.”

First, in 1, it is clear that by reading other people's Haiku, the students are reimagining the world of the Haiku, which is the experience of others, as their own mental landscape (re-experiencing it). In 2, the reader feels that others share the same emotions as themselves, and their heart is moved. In 3, reading another person's Haiku awakens the reader's own past experiences and emotions. At the stage of writing the report, the reader consciously reinterprets those experiences and emotions from their current perspective. In 4, the reader is sincerely moved by the language expression of another person that they themselves could not have used before.

In this way, students recognize through exposure to others' works that there are commonalities between their own hearts and those of others, or conversely, that they are exposed to sensibilities they did not previously possess. Furthermore, it becomes clear that when their own hearts are moved, they perceive the work as a “good Haiku.” In other words, through the experience of creating their own Haiku and appreciating others' works, students are believed to have gained a deeper understanding of the inner workings of the human heart in everyday life.

Responsible teacher of class (b) conducted a survey after the end of the first semester to ask students in class (b) for their impressions of all classes (See Graph 1).

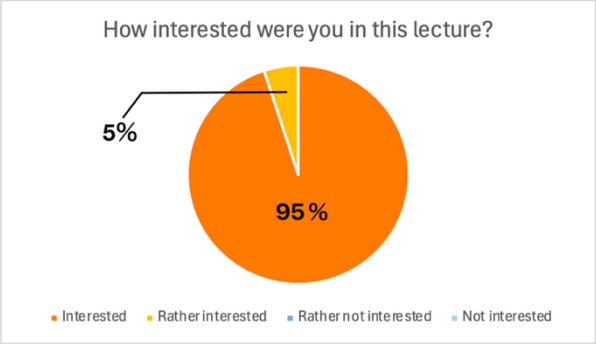


Figure 2. Results of a survey of students who took “Introduction to Liberal Arts” (b) (1)：Level of interest in classes

In response to the question, “Did you find this lecture interesting or engaging?”, out of 20 valid responses, 19 selected the top-ranked response (“Yes, I found it interesting or engaging”), and 1 selected the next-highest response (“Somewhat interesting or engaging”). No students selected the lower-ranked response (“Somewhat uninteresting or unengaging”) or the lowest-ranked response (“Not interesting or unengaging”).

In response to the above question, the following answers were given to the open-ended question asking for reasons.

- I am a future engineer, so I feel that the word “create” is closely related to me.
- I thought that thinking about what it means to “create something” would be useful in the future.
- Until now, when I heard the word “create,” I imagined making something tangible, but I was surprised to learn that literature and law also involve “creation,” which I found interesting.
- Even in fields I was not interested in, I found the professor's explanations interesting.

These responses highlight that this course broadens students' interests and provides an opportunity to consider the essence of creative behavior.

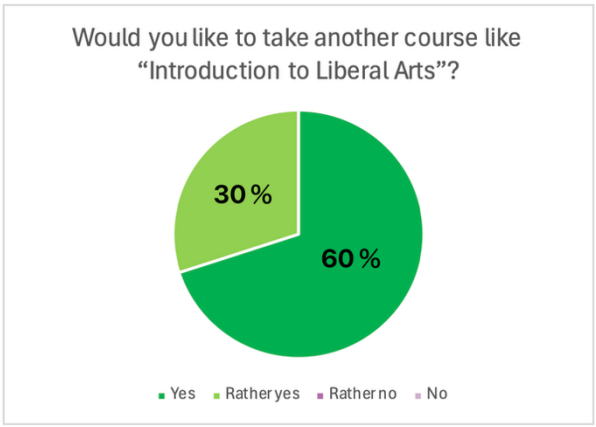
Furthermore, when asked about changes in their way of thinking after taking this course, students responded as follows:

- I realized that my way of thinking is limited to my own perspective.
- I want to learn from other people's ways of thinking.
- I realized the importance of communication.
- I realized that “creating” includes evaluating works and improving them based on various opinions.
- I learned that listening to the opinions of others and cooperating with them leads to better results.

These responses show that through group work and mutual evaluation in this class, students realized the importance of dialogue and cooperation.

Furthermore, the results for the question “Would you like to take another course like ‘Introduction to Liberal Arts?’ ” were as shown in Graph 2.

Figure 3. Results of a survey of students who took "Introduction to Liberal Arts" (b) (2) : Whether students would like to take courses such as "Introduction to Liberal Arts" again



Of the 20 valid responses, 14 were the highest-ranked response ("I would like to take it again") and 6 were the next highest-ranked response ("I would rather take it again"). No students selected the lower-ranked response ("I would rather not take it again") or the lowest-ranked response ("I do not want to take it again").

In addition, the faculty members involved in "Introduction to Liberal Arts" also felt encouraged by the students' responses and the results of the course surveys and experienced a great sense of fulfillment through the course. For example, based on the above survey results, responsible teacher commented, "I believe that the intentions of those who created 'Introduction to Liberal Arts' were conveyed to the students" (Okada 2025).

Conclusions

Through the practical exercise of writing Haiku in this class, the students learned the differences and similarities between the creativity of engineers and the creation of Haiku. T Technology creates concrete things that are useful to human life, such as new materials, buildings, and programs, while Haiku conveys the movements of one's heart to others through words and enriches the hearts of others. This is where the difference in approach between technology and Haiku (literature) lies. However, both share the same ultimate goal: to create something that brings happiness or joy to people.

Therefore, engineers must have a deep understanding of what people seek in life and the nature of the human heart. This is the same as "creating" Haiku. Through composing Haiku and appreciating others' Haiku, the students experienced the differences and similarities between their own perceptions and those of others. We believe this experience has the potential to serve as a foundation for the students' future technological development.

Additionally, such experiences have enhanced students' motivation and significantly improved learning outcomes. This is supported by responses and comments in students' course evaluation surveys, as well as observations of their behavior during classes. It is also worth noting that the instructors involved reported a strong sense of fulfillment from the course.

References

Hieda M. (2025). Liberal Arts Education to Enhance Student Gender Awareness: Class Report of Introduction to Liberal Arts (d). *The Lark Hill; Bulletin of the Institute of Liberal Arts and Sciences Toyohashi University of Technology*, 47, 135-138. https://repo.lib.tut.ac.jp/records/2000255

Iwauchi S. (2025). Philosophical Dialogues for Engineers: Class Report of Introduction to Liberal Arts (a). *The Lark Hill; Bulletin of the Institute of Liberal Arts and Sciences Toyohashi University of Technology*, 47, 109-116. https://repo.lib.tut.ac.jp/records/2000251

Nakamori Y. (2025). The Challenge of Reforming Liberal Arts Education: Background of the establishment of "Introduction to Liberal Arts". *The Lark Hill; Bulletin of the Institute of Liberal Arts and Sciences Toyohashi University of Technology*, 47, 99-108. https://repo.lib.tut.ac.jp/records/2000250

Nakamura D. (2025). For the Superimposition of Different *Res*. Class Report of Introduction to Liberal Arts (c). *The Lark Hill; Bulletin of the Institute of Liberal Arts and Sciences Toyohashi University of Technology*, 47, 127-134. https://repo.lib.tut.ac.jp/records/2000254

Okada H. (2025). Liberal Arts Through "Creation". Class Report of Introduction to Liberal Arts (b). *The Lark Hill; Bulletin of the Institute of Liberal Arts and Sciences Toyohashi University of Technology*, 47, 117-126. https://repo.lib.tut.ac.jp/records/2000253

Study Group on the Concept of New Higher Education Institutions for Science and Technology. (1974). *A Proposal for a New Graduate School of Science and Technology: Report*. p.3

Toyohashi University of Technology 10th Anniversary Committee Historical Editorial Committee. (1986). *Toyohashi University of Technology Ten-Year History*. pp.91-94

A Programming Board Game considered in Real Programming Language

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This paper describes a card-based board game developed for early elementary school students' programming education. The game aims to enable students to write in an actual programming language. The game has the following three features. (1) The game is designed for two players, and it makes players want to learn by competing. (2) The program can be developed simply by ordering the card. (3) The completed card program can be written in block programs, TypeScript, Java, Python, etc. We held a class for eight elementary school students to use the game we had created. We confirmed in this class the importance for elementary school students to understand the goal of developing program. The game has a simple, easy-to-understand goal. Creating a number larger than the opponent's by arranging the cards is the simple goal and it is for students to generate their own ideas. The implementation of their ideas helps them to improve their motivation to learn. Furthermore, we are developing a program that can automatically make the program by taking pictures of the cards of this game. We have now finished recognizing cards from images with high accuracy, and we plan to develop the code generation part in the future.

Keywords: *programming education, card game, gamification, image recognition*

Introduction

In 2020, Japan made programming education a requirement for elementary schools. We need to think about how to teach programming to elementary school students. There are two phases to obtaining programming skills. One is to learn to think logically, using logic such as addition and repetition to solve problems. Another is learning to write and describe languages such as C and Java. Programming tools for education, such as *Scratch* and *MakeCode*, focus mainly on the first. Block programming is used in these software. The problem was that while the students enjoyed creating logic, they could not develop an actual program.

This paper proposes a programming learning material that is easier to program than block programming, but is easier to convert to actual code. The proposed material is in the type of a card game, which will motivate students to learn by challenging them to play the game. On the other hand, this material is not designed for general-purpose programming as much as block programming. This material is designed to learn the logic focused on the task of making large numbers with some functions. In addition, this logic is easy to convert to the actual syntax of programming languages.

Materials of Education

1. Summary of the game developed

We developed a card-based board game for programming education for early elementary school students, which aims to enable them to write in an actual programming language. The game has the following three features. (1) The game is designed for two players, and it makes players want to learn by competing. (2) The program can be developed simply by ordering the cards. (3) The completed card program can be written in block programs, TypeScript, Java, Python, etc.

Fig.1 shows the cards for the games that we developed. In this game, the objective is to arrange the order of cards to build a larger number than the opponent's. Players play three matches with a pre-determined set of seven cards. The example in the figure shows a match with three cards. The bottom player makes 5 by +1 + (+2) x 2 times. In this game, red cards are for



Fig.1 An example of the board game.

normal addition operations, and green cards are for repeats. On the other hand, the upper player makes 6 by +1 +2 +3. The value of this light blue card changes its effect depending on whether the opponent has a green card or not. In this example, the opponent has a green card, so it is +3. Therefore, the upper player wins this match. The difference between our card game and existing materials for learning programming is that we directly include a programming processing element and focus on numerical calculations based on the goal of creating larger numbers. There are many card-based programming games, such as *Robot Turtles* and *STEMON*, in which players line up instructions to move a specific object, leading the object to the goal along a designated path. These programming games do not focus on calculation directly, since the main point of these games is to be enjoy from pre-school age children. On the other hand, programming materials for post-school-aged children are often based on block programming. These games could be freely programmed, but had the disadvantage that they had no fixed objectives. It is an enjoyable learning experience for children with a clear objective, such as upper elementary school students. As a result, for younger children, the former had the disadvantage of being too easy and the latter too difficult. The proposed game we propose is positioned between these two types of games. It is simple in its operation of lining up cards, but it has a clear goal of calculating larger numbers. It also allows children who have just learned the four arithmetic operations to apply their knowledge to the game. Moreover, it can be considered as replacing the blocks in block programming with cards, and these cards can be converted into the actual programming language. In this way, this game can work as teaching materials between block programming and authentic programming language learning and can be used to help beginners in programming learn the basics of programming and a programming language.

2. The game cards and rules

Fig. 2 shows a summary of the cards used in this game. In this game, each player has seven of these cards. This combination of the cards is called the “deck”. We made 4 types of decks. Table 1 shows the cards in deck 1 and 4. Each deck has different characteristics, and the contents that can be learned are different. We adjusted any deck can win against all other decks with a good algorithm. Because we are targeting beginning students, we have decided to only focus on the simplest functions of programming at this time. In the future, we plan to increase the functions according to the level of learning.

There are three games, and the winner is the player who wins two games. The first and second matches are played with three cards chosen from seven cards; in the second match, the cards used in the first match cannot be used. The third match is played by selecting five cards from seven. In this match, all the cards can be used. This is strategic because a card unseen by the opponent can be used.

This game can be introduced to second-grade elementary school students because of the simple rule of making large numbers by calculation. Also, when creating a program in an actual programming language, there is no need for special functions, since it is sufficient to define variables and add numbers. In addition, some cards are an introduction to learning how to write looping (repeating) and conditionals. The color of the card is designed to identify its function of the card: addition is red, looping is green, and conditional is blue.

Table. 1 The card lint in the deck 1 and 4.

Card	function
Red 1	add 1
Red 2	add 2
Red 3	add 3
Red 4	add 4
Red 5	double
Green	Repeat 2 times
Blue 1	If your number is odd, double that number.
Blue 2	If opponent has a blue card, your number added 1 and double your number.
Blue 3	If opponent has a blue card, all other blue cards become zero, and your number added 1.
Blue 4	If opponent has a green card, all other green cards become zero, and your number added 1.
Blue 5	If opponent has a green card, your number added 3, otherwise zero
Blue 6	If opponent has a green card, the next card after that card is zero.
Purple	Change the rules for this match. The one with the lowest number wins.

3. The digitized method of the game

We considered a digitizing method to convert this card game into a computer game. Play the game with a computer, which could be automatically converted into a programming language, and it automatically calculates the execution results.

We consider the ability to freely remake the source code essential to understanding the algorithms of programming. For this reason, the code can change only by changing the order of the cards in the electronic

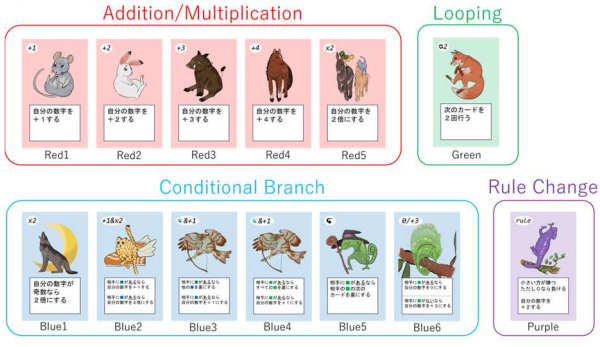


Fig.2 Card list of developed game.

version. When editing source code directly, this is difficult for beginning students, who are unfamiliar with keyboard usage, copying and pasting, etc.

There are two different methods to capture the sequence of cards into the electronic version. The first is to digitize the card game itself so that it can be played all on a computer. The other method is to play the game with cards, take a picture of the lined-up cards with a camera, and analyse this image. In this project, we tried to implement both methods.

The software, which can be played on a computer, was created using Unity. This software is designed to be played by two people on different computers and enable them to communicate with each other. The communication is carried out in real time. The library for this communication used PUN2. PUN2 can synchronize objects using the Cloud. In this case, the cards are kept as network objects on the server and synchronously placed as objects on both game screens.

The flow of the electronic version of the game is as follows. (1) Register the project of the game on the PUN2 server and output the project. (2) Two players run the output project. (3) The running projects automatically connect to the server and display each other's network objects and names. (4) Once the two players are connected, the card selection screen appears. (5) After both players have finished selecting their cards, the result of the match is displayed. As there are three matches, the card selection and display of the result are carried out 3 times.

Fig. 3 shows the card selection screen. This screen places the cards that can be selected in the current match. This screen is not synchronized over the network but locally, as card selection is not done openly to the opponents. The cards can be selected by mouse-clicking on the object. When a card is clicked, the selected card number is displayed in the “Selected Cards” section at the bottom of the screen. To deselect a card, simply click on it again. The newly selected card is added to the last of the cards list already selected. When the player finishes selecting the cards, pressing the “GO!” button allows. Press this button, the application moves on to the match-up screen.

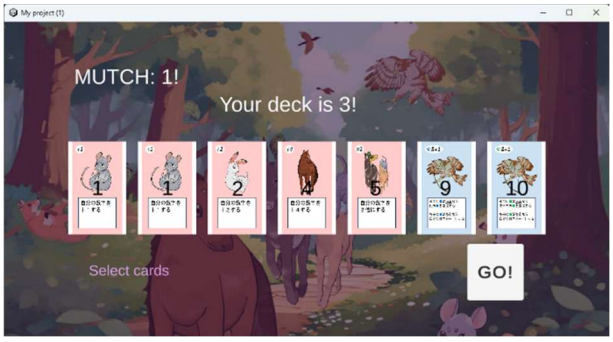


Fig. 3 The card selection screen of the game.

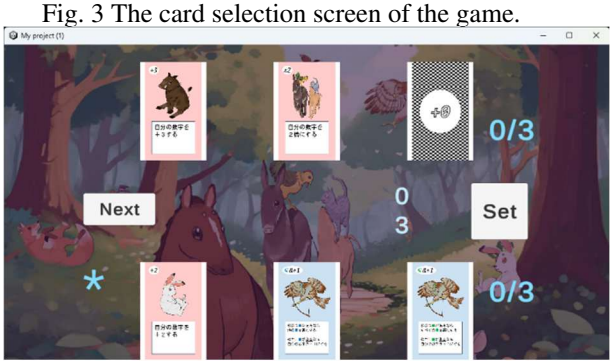


Fig. 4 The match-up screen of the game.

Fig. 4 shows the match-up screen. When the screen moves to the match screen, the player is connected to the network again. Two players are connected to the network and press the ‘Set’ button, both players' cards will open. An asterisk is displayed on its side to make it easier to identify. The player processes the cards in order from left to right by pressing the space key, and the calculation results are displayed. Processes such as turning over an opponent's cards are done before this calculation. Wins and losses are stored locally, and the end result is displayed after three matches.

Method of Experimental

For the evaluation experiment, we tested the understanding test in an IT course for elementary school children and checked the accuracy of the image recognition. The reason for experimenting with image recognition is that we plan to develop a software system that generates a program corresponding to the card contents and calculates the score automatically by photo images of the board. This system shows how to write code; it helps beginners in programming to understand how to express corresponding rules of the game. Students could develop logical thinking and programming skills, in this process.

(1) The IT learning class for primary school

This game was used in a local IT class, and we confirmed the effect of this game for elementary school students. We invited elementary school students to participate in this course. As a result, eight students attended the learning class: one 4th year student, three 5th year students, three 6th year students in elementary school and one 1st year junior high school student. The title of this class is “Learning Programming and IoT via competitive games” (“対戦型ゲームで学ぶプログラミングと IoT” in Japanese). After learning about programming development using our proposed card game, the students will develop a programme to obtain temperature sensor and share the temperature using the IoT device Obniz. The value obtained from the sensor is 0 to 1,024. It cannot be used as temperature as it is, so the programming technique learned in the card game is used to convert the value obtained from the sensor to temperature there. At the end of the course, we surveyed the level of enjoyment and programming difficulty by questionnaire. Free-text answers were also collected to obtain information on what was interesting and difficult.

(2) **The Image recognition accuracy**

In the image recognition experiment, the cards are lined up and captured by a camera. We confirm the accuracy with which the cards can be recognised from the images captured. The cards for identification in this case are the 13 types of cards shown in Fig. 2. This

Table. 2 Accuracy of feature matching

Card	Number of trials	Correct	Accuracy
Red 1	39	39	100%
Red 2	26	26	100%
Red 3	28	28	100%
Red 4	30	30	100%
Red 5	42	42	100%
Green	30	30	100%
Blue 1	15	15	100%
Blue 2	15	15	100%
Blue 3	15	14	93.3%
Blue 4	15	14	93.3%
Blue 5	15	15	100%
Blue 6	15	15	100%
Purple	15	15	100%

time, the cards were printed from images created on a PC, so that all accurate comparison images existed. We performed card identification by feature matching between the comparison image and the captured image.

It is necessary to cut out the cards from the line-up into individual card images. The cut-out position was fixed for this by placing the cards on the play mat.

For each card comparison image and cut-out image, we extract local features using the SIFT algorithm. For matching between the extracted features, we used FLANN. For feature matching, the cut-out images are matched with all comparison images. Then we identified the image with the highest degree of matching. The comparison image with the highest degree of agreement is then selected as the recognition result. We prepared 30 images like Fig. 1 for the evaluation experiment; 10 cards were arranged in each image, so the total number of cards was 300.

Results and Discussion

In a questionnaire-based evaluation, all students selected 5 out of 5 for enjoyment, which indicates that they enjoyed learning programming using games. As for the level of difficulty, four students answered easy, three answered standard and one answered difficult. In the free-text comments, the students again noted that the game helped them learn in an enjoyable way, and also wanted to develop a more complex programme with a programming language. For the electronic application, the students tried the paper-based card game and understood the rules before using it. There were no problems of difficulty in operating this application if the students had understood the game rules before using it. Also, we observed that many students showed a strong interest in the way the game's controlling code works. However, since we could not collect enough younger elementary school students, we are planning to try the experiment again at a different location.

The results of the image recognition experiment are shown in Table 2. The mouse card is Red 1, and the rabbit card is Red 2. Out of the 30 images prepared for the experiment, the number of trials for Red 1 and Red 5 are over 30, This is because two of the same cards can appear in one deck.

The results show that more than 90% of all cards were identified, although Blue 3 and Blue 4 were misidentified once each. This is due to the very similar images and the light conditions that made it difficult to see some of the images.

Conclusions

This paper describes a programming education material for early elementary school students. This material is a card-based board game that line up cards with a process written on them and make a number greater than their opponent's. There are 13 types of processes, representing addition, multiplication, looping, and conditionals. A deck is a set made from seven of these cards. The player selects from 3 or 5 cards from the deck to make the program with their own ideas.

We used in a local IT class, and we confirmed the effect of this game for elementary school students. At the end of the class, we surveyed the level of enjoyment and programming difficulty by questionnaire. The results shows all students enjoyed learning programming using games. As for the level of difficulty, half of the students responded that it was easy. The age of the elementary school students who attended this class was a little older than the estimated age. Therefore, we will design that allows for changing the difficulty level.

On the other hand, we also tried to digitalize this game and to recognize the card images by photo. The digitized software was also used in the course. The application was easy to operate for elementary school students. The recognition of cards was accurate, but in this card set, there were two cards that were only different colors, and there was a case of mistaking these two cards.

In the future, we plan to create a system to automatically generate a program based on the recognized cards and their order, and hold the class for elementary school students again.

References

Mitchel, R., John, M., Andrés, M. H., Natalie, R., Evelyn, E., Karen, B., Amon, M., Eric, R., Jay, S., Brian, S., Yasmin, K. (2009). *Scratch: programming for all.* Communications of the ACM, Volume 52, Issue 11, pp 60 – 67.

Lowe, David G. (1999). *Object recognition from local scale-invariant features*. Proceedings of the International Conference on Computer Vision. Vol. 2. pp. 1150–1157.

Marius, M. and David G. Lowe (2009). *Fast Approximate Nearest Neighbors with Automatic Algorithm Configuration.* International Conference on Computer Vision Theory and Application VISSAPP'09, pp. 331-340.

SURVEY OF GRID POINTS IN A SINGLE-DIGIT DOMAIN GENERATING SPECIAL ANGLES

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When asking for the angle between vectors, it is beneficial for students if the answer is simply a specific "special angle," such as $\pi/6, \pi/4, \pi/3$. The question becomes even better if the vectors are expressed using small integers. Based on this principle, a theoretical survey for grid points in 2D space and a numerical survey in 3D space were conducted, focusing especially on the "single-digit domain."

The theoretical exploration in 2D was successfully completed and yielded a general conclusion: there exists a two-parameter family of integer vectors forming an angle of $\pi/4$, while no integer-coordinate vectors form $\pi/6$ or $\pi/3$. Exactly 10 distinct pairs realizing $\pi/4$ were identified, in the single-digit domain. The numerical exploration in 3D detected 28 pairs of vectors within the single-digit domain. A total of 38 "primary minimal pairs" were found. To complement and extend the primary minimal pairs, two theoretical tools were introduced: "complementary integer adjustment" (CIA) and "rational orthogonal transformation" (ROT). The outcomes obtained via CIA and ROT lie outside the single-digit domain with one overlapped. As a byproduct of CIA and ROT, additional 48 pairs of vectors just outside the single-digit domain were also found, forming special angles.

The results of this study provide a useful resource for educators designing class materials and exam questions related to vector calculations. They enable the creation of exercises where students can focus on fundamental vector operations without computational distractions. Furthermore, the theoretical approach in the 2D case suggests the possibility of developing advanced questions that ask students to prove the nonexistence of integer vector pairs forming $\pi/12, \pi/8, \pi/5$, and related angles.

Extending this analysis to 3D introduces additional mathematical challenges, as the problem reduces to solving a fourth-degree algebraic equation with six unknown integers. While a complete theoretical classification remains open, this work suggests possible deeper connections to number theory.

Future work includes implementing the proposed question design in classroom settings, especially in linear algebra courses, to evaluate its impact on students' understanding.

Keywords: *linear algebra, dot product, angle between integer vectors*

Motivation

The author teaches mathematics at a technological college in Japan, covering subjects such as linear algebra, calculus, and engineering mathematics. He frequently designs quizzes and problems for his students, adhering to the principle:

Principle: *Simple questions with simple answers encourage students to learn more.*

He believes that well-structured problems should have clear and straightforward solutions, avoiding unnecessary complexity. This approach allows students to focus on fundamental mathematical concepts without being hindered by excessive computational difficulties.

A typical example involving vectors in linear algebra is:

Q1: *Find the angle between two vectors* $\overrightarrow{\mathrm{AB}}$ *and* $\overrightarrow{\mathrm{AC}}$ *for given points* A, B, *and* C.

If the points are chosen arbitrarily, the answer might involve inverse trigonometric functions, such as

$$\cos^{-1}\frac{2}{3},$$

which can be cumbersome for students to evaluate. Instead, angles corresponding to

$$\cos^{-1}\frac{\sqrt{3}}{2}, \qquad \cos^{-1}\frac{\sqrt{2}}{2}, \qquad \cos^{-1}\frac{1}{2}$$

are more intuitive, as they correspond to $\pi/6$, $\pi/4$, $\pi/3$, respectively. The author refers to these as "special angles."

Q1 is a simple yet effective problem, particularly when the answer is a special angle. Moreover, the question becomes more accessible if A, B, and C are located at grid points in a coordinate system. In line with the **Principle**, the author prefers using single-digit numbers in questions. In this article, the term "single-digit domain" refers to the region defined by integer pairs (m, n) in 2D space or triples (l, m, n) in 3D space, where $0 \leq l, m, n \leq 9$ and $l, m,$ and n are mutually prime. We consider $\boldsymbol{u} = (m, n)$ or $\boldsymbol{u} = (l, m, n)$ as an input within this domain, and aim to find a corresponding $\boldsymbol{v}$ within the same region. The same approach is applied to the 3D case.

Motivated by this, the author conducted a survey of grid points in 2D and 3D spaces that generate special angles. Initially, he consulted an AI chatbot to explore potential grid points. He then used the chatbot to assist in writing a Python script for systematic exploration. Finally, he attempted a theoretical approach to solving the problem himself. While the 2D case proved relatively straightforward, the 3D case involved significant mathematical challenges. Since deriving a general but highly complex solution would not be suitable for educational purposes, a numerical survey of grid points was considered the appropriate approach. This paper presents the numerical findings for the 3D case, along with a discussion of potential theoretical methods.

Some Notations and Preparation

Suppose three points A, B, and C with assuming

$$\overrightarrow{\mathrm{AB}} = \boldsymbol{u} \qquad \text{and} \qquad \overrightarrow{\mathrm{AC}} = \boldsymbol{v}.$$

We introduce a notation $A(\boldsymbol{u},\boldsymbol{v})$ to indicate the angle between $\boldsymbol{u}$ and $\boldsymbol{v}$, especially for the 2D case $\boldsymbol{u} = (u_1, u_2)^T$ and $\boldsymbol{v} = (v_1, v_2)^T$:

$$A(\boldsymbol{u},\boldsymbol{v}) = A\begin{pmatrix} u_1 & v_1 \\ u_2 & v_2 \end{pmatrix},$$

and for the 3D case $\boldsymbol{u} = (u_1, u_2, u_3)^T$ and $\boldsymbol{v} = (v_1, v_2, v_3)^T$:

$$A(\boldsymbol{u},\boldsymbol{v}) = A\begin{pmatrix} u_1 & v_1 \\ u_2 & v_2 \\ u_3 & v_3 \end{pmatrix}.$$

We regard $\boldsymbol{u}$ as an input with letting $u_1 = m$ and $u_2 = n$, and $\boldsymbol{v}$ as an output to satisfy a relation:

$$A(\boldsymbol{u},\boldsymbol{v}) = \theta$$

where $\theta = \angle\mathrm{BAC}$ will be a special angle.

Swapping the rows does not change the angle:

$$A\begin{pmatrix} u_2 & v_2 \\ u_1 & v_1 \end{pmatrix} = A\begin{pmatrix} u_1 & v_1 \\ u_2 & v_2 \end{pmatrix}, \tag{1}$$

or

$$A\begin{pmatrix} u_2 & v_2 \\ u_3 & v_3 \\ u_1 & v_1 \end{pmatrix} = A\begin{pmatrix} u_3 & v_3 \\ u_1 & v_1 \\ u_2 & v_2 \end{pmatrix} = \cdots = A\begin{pmatrix} u_1 & v_1 \\ u_2 & v_2 \\ u_3 & v_3 \end{pmatrix}, \tag{2}$$

Thus, we can skip checking the triangular half of grid points using this symmetry with respect to a line $y = x$. Hence, we redefine the "2D single-digit domain" as

$$D_2 \stackrel{\text{def}}{=} \{(m,n)\epsilon\mathbb{Z}^2 \mid 0 \le m \le n \le 9\}$$

and "3D single-digit domain" as

$$D_3 \stackrel{\text{def}}{=} \{(l,m,n)\epsilon\mathbb{Z}^3 \mid 0 \le l \le m \le n \le 9\}$$

The following properties are trivial if $a, b > 0$:

$$A(a\boldsymbol{u},\boldsymbol{v}) = A(\boldsymbol{u},b\boldsymbol{v}) = A(\boldsymbol{u},\boldsymbol{v}) \tag{3}$$

for which we assume that coordinates of $\boldsymbol{u}$ or $\boldsymbol{v}$ should be mutually prime, and

$$A(\boldsymbol{v},\boldsymbol{u}) = A(\boldsymbol{u},\boldsymbol{v}) \tag{4}$$

for which we can skip $\boldsymbol{u}$ if it is equivalent with a previously found $\boldsymbol{v}$.

Theoretical Results in D_2

Suppose $\overrightarrow{\mathrm{AB}} = \boldsymbol{u} = (m,n)$ and $\overrightarrow{\mathrm{AC}} = \boldsymbol{v} = (v_1, v_2)$ in D_2 with $\theta = \angle\mathrm{BAC} \in [0,\pi]$. By combining two formulae

$$\boldsymbol{u}\cdot\boldsymbol{v} = \|\boldsymbol{u}\|\|\boldsymbol{v}\|\cos\theta$$

and

$$\|\boldsymbol{u}\times\boldsymbol{v}\| = \|\boldsymbol{u}\|\|\boldsymbol{v}\|\sin\theta,$$

we find

$$\tan\theta = \frac{\|\boldsymbol{u}\times\boldsymbol{v}\|}{\boldsymbol{u}\cdot\boldsymbol{v}} = \frac{|mv_2 - nv_1|}{mv_1 + nv_2}$$

Let $t = \tan\theta$, then find $\pm t(mv_1 + nv_2) = mv_2 - nv_1$, which leads to

$$\frac{v_2}{v_1} = \frac{n \pm tm}{m \mp tn} \tag{5}$$

Proposition: *No grid points in a 2D space form an angle $\pi/3$ and $\pi/6$.*

proof: *The angle $\theta = \pi/3$, i.e., $t = \sqrt{3}$ derives*

$$\frac{v_2}{v_1} = \frac{n \pm \sqrt{3}\,m}{m \mp \sqrt{3}\,n} = \frac{4mn \pm \sqrt{3}(m^2 + n^2)}{m^2 - 3n^2}$$

which has no integer solutions of v_1 and v_1 because $m^2 + n^2 \neq 0$. Thus, we conclude that no grid point triples form an angle $\theta = \pi/3$.
Similarly, no triples of grid points to form $\theta = \pi/6$ because $t = 1/\sqrt{3}$ in (5) leads to

$$\frac{v_2}{v_1} = \frac{\sqrt{3}\,n \pm m}{\sqrt{3}\,m \mp n} = \frac{4mn \pm \sqrt{3}(m^2 + n^2)}{3m^2 - n^2}$$

■

Contrarily, the angle $\theta = \pi/4$ can be formed by 10 pairs of $(\boldsymbol{u},\boldsymbol{v})$ in D_2. In the case, we find $t = 1$, leading to

$$\frac{v_2}{v_1} = \frac{n \pm m}{m \mp n} = \frac{m+n}{m-n} \quad \text{or} \quad \frac{n-m}{m+n}$$

Under the assumption $m \le n$ in D_2, we adopt the second form in our survey:

$$\frac{v_2}{v_1} = \frac{n-m}{m+n} \tag{6}$$

Furthermore, the ratio $v_1 : v_2$ should also be in its simplest form, just like $m : n$.

We begin the survey in ascending order of m and n within the upper triangular region of **Table 1** excluding $m = n = 0$. The process follows these steps:

1. Skip a grid point (m', n') if m'/n' is equal to a previously obtained value of m/n
   (yellow cells in **Table 1**)
2. Skip a grid point (m', n') if $\begin{pmatrix} m' & m'+n' \\ n' & n'-m' \end{pmatrix}$ is equivalent to a previously obtained matrix after swapping rows or columns.
   (green cells in **Table 1**)
3. Skip a grid point (m', n') if $m' > 9$ or $n' > 9$ after division by $\mathrm{GCD}(m', n')$.
   (orange cells in **Table 1**)

Table 1: Checking process of grid points in D_2

m \ n	1	2	3	4	5	6	7	8	9
0	$\binom{0\ 1}{1\ 1}$	~(0,1)	~(0,1)	~(0,1)	~(0,1)	~(0,1)	~(0,1)	~(0,1)	~(0,1)
1	~(0,1)	$\binom{1\ 2}{3\ 1}$	~(1,2)	$\binom{1\ 4}{5\ 3}$	$\binom{1\ 5}{3\ 2}$	$\binom{1\ 6}{7\ 5}$	$\binom{1\ 7}{4\ 3}$	$\binom{1\ 8}{9\ 7}$	$\binom{1\ 9}{5\ 4}$
2		~(1,1)	~(1,5)	~(1,2)	$\binom{2\ 5}{7\ 3}$	~(1,3)	$\binom{2\ 7}{9\ 5}$	~(1,4)	$\binom{2\ 9}{11\ 7}$
3			~(1,1)	~(1,7)	~(1,4)	~(1,2)	~(2,5)	$\binom{3\ 8}{11\ 5}$	~(1,3)
4				~(1,1)	~(1,9)	~(2,3)	$\binom{4\ 7}{11\ 3}$	~(1,2)	$\binom{9\ 4}{13\ 5}$
5					~(1,1)	$\binom{5\ 6}{11\ 1}$	~(1,6)	$\binom{8\ 5}{13\ 3}$	~(2,7)
6						~(1,1)	$\binom{7\ 6}{13\ 1}$	~(3,4)	~(2,3)
7							~(1,1)	$\binom{7\ 8}{15\ 1}$	~(1,8)
8								~(1,1)	$\binom{8\ 9}{17\ 1}$
9									~(1,1)

After reduction of the domain for survey, the minimal set of pairs $\binom{m\quad m+n}{n\quad n-m}$ in the matrix form are listed below.

Result 1: *Minimal pairs of 2D vectors forming $\pi/4$ in the single-digit domain. The first and second columns indicate $\boldsymbol{u}$ and $\boldsymbol{v}$, respectively.*

$$\binom{0\ 1}{1\ 1},\binom{1\ 3}{2\ 1},\binom{1\ 5}{4\ 3},\binom{1\ 3}{5\ 2},\binom{1\ 7}{6\ 5},$$
$$\binom{1\ 4}{7\ 3},\binom{1\ 9}{8\ 7},\binom{1\ 5}{9\ 4},\binom{2\ 7}{5\ 3},\binom{2\ 9}{7\ 5}.$$

These 10 pairs of 2D vectors are referred to as "primary minimal pairs," representing the simplest and most fundamental configurations that generate a special angle within the single-digit domain. Other than the special angles defined here, there is the other easy-to-handle angle, $3\pi/4$, which is supplementary to $\pi/4$. Since this is an obtuse angle lying outside D_2, it cannot be found through the current approach. However, it can be obtained by modifying the data from **Result 1**. For example, $\boldsymbol{u} = (2,7)$ and $-\boldsymbol{v} = (-9,-5)$ form $3\pi/4$, because $\boldsymbol{u}$ and $\boldsymbol{v}$ form $\pi/4$.

A byproduct of the Proposition

Proposition derives an interesting consequence:

Corollary: *No grid points in a 2D space form an angle of $\pi/12$, $5\pi/12$, $\pi/8$, $3\pi/8$, $\pi/5$, $2\pi/5$.*

The proof makes for good exercise for advanced students, as it follows a similar approach to that in **Proposition**, given the following identities as a starting point:

$$\tan\frac{\pi}{12} = 2-\sqrt{3}, \qquad \tan\frac{5\pi}{12} = 2+\sqrt{3},$$
$$\tan\frac{\pi}{8} = \sqrt{2}-1, \qquad \tan\frac{3\pi}{8} = \sqrt{2}+1,$$
$$\cos\frac{\pi}{5} = \frac{\sqrt{5}+1}{4}, \qquad \cos\frac{2\pi}{5} = \frac{\sqrt{5}-1}{4}.$$

In fact, proving the irrationality of $\sqrt{3}$ and $\sqrt{5}$ as well as $\sqrt{2}$, is not particularly difficult.

Preparation for the Numerical Survey in D_3

Suppose $\overrightarrow{AB} = \boldsymbol{u} = (u_1,u_2,u_3)$ and $\overrightarrow{AC} = \boldsymbol{v} = (v_1,v_2,v_3)$. Assume that $\boldsymbol{u}$ belongs to D_3 and seek $\boldsymbol{v}$ within D_3. Let $\gamma = \cos\angle BAC$, then the relation

$$(\boldsymbol{u}\cdot\boldsymbol{v})^2 = \gamma^2\|\boldsymbol{u}\|^2\|\boldsymbol{v}\|^2, \qquad (7)$$

where $\boldsymbol{u}\cdot\boldsymbol{v} = u_1v_1+u_2v_2+u_3v_3$, $\|\boldsymbol{u}\|^2 = u_1^2+u_2^2+u_3^2$, *and* $\|\boldsymbol{v}\|^2 = v_1^2+v_2^2+v_3^2$. Thus, this leads to the following problem:

Q2: *Find $\boldsymbol{u}$ and $\boldsymbol{v}$ in D_3 satisfying the condition (7) with $\gamma^2 = 1/4, 1/2,$ or $3/4$.*

Condition (7) is a fourth order algebraic equation with six integer unknowns, placing it within the realm of number theory. A general, highly complex solution is unnecessary, as it would not be suitable for educational purposes. However, it is essential to obtain a fundamental set of vectors in D_3 that satisfy equation (7). To achieve this, the author concludes that a numerical survey of grid points is the most appropriate approach. Although the number of points in D_3 is large, it remains finite and is manageable using Python.

Before conducting the survey, the initial conditions for $\boldsymbol{u}$ are reduced according to properties (1) to (4). For the 3D case, the author planned a numerical survey. First, an AI chatbot was used to search for D_3 for all valid pairs $(\boldsymbol{u},\boldsymbol{v})$, but it failed to find all the solutions. Next, the chatbot was used to assist in writing a Python script.

Primary Minimal Pairs in D_3

The Python script, refined with the assistance of an AI chatbot, successfully identified all possible grid points within D_3. However, it was less effective in reducing the output using properties (1) to (4). Therefore, the author manually reviewed and refined the results. The outcome is as follows:

Result 2: *11 pairs of 3D vectors $(\boldsymbol{u},\boldsymbol{v})$ forming an angle of $\pi/6$ within D_3.*

$$\binom{0\ 1}{1\ 1}\binom{1}{2},\binom{0\ 1}{1\ 2}\binom{1}{7},\binom{0\ 1}{1\ 1}\binom{1}{2},\binom{1\ 3}{1\ 8}\binom{1}{5},$$
$$\binom{1\ 4}{1\ 5}\binom{1}{3},\binom{1\ 2}{1\ 5}\binom{1}{5},\binom{1\ 4}{2\ 1}\binom{1}{5},\binom{1\ 4}{2\ 3}\binom{1}{5},$$
$$\binom{1\ 5}{3\ 2}\binom{1}{7},\binom{1\ 3}{7\ 2}\binom{1}{5},\binom{2\ 5}{5\ 3}\binom{1}{4}.$$

Result 3: *13 pairs of 3D vectors $(\boldsymbol{u},\boldsymbol{v})$ forming an angle of $\pi/4$ within D_3.*

$$\binom{0\ 3}{0\ 4}\binom{1}{5},\binom{0\ 2}{1\ 1}\binom{1}{2},\binom{0\ 4}{1\ 1}\binom{1}{8},\binom{0\ 6}{1\ 1}\binom{1}{9},\binom{0\ 5}{1\ 7}\binom{2}{4},$$
$$\binom{0\ 2}{1\ 1}\binom{7}{2},\binom{0\ 6}{1\ 6}\binom{7}{7},\binom{0\ 5}{3\ 3}\binom{4}{4},\binom{1\ 4}{1\ 7}\binom{4}{4},$$
$$\binom{1\ 7}{3\ 8}\binom{4}{2},\binom{1\ 5}{4\ 4}\binom{8}{3},\binom{1\ 4}{5\ 5}\binom{8}{2},\binom{2\ 8}{3\ 5}\binom{6}{3}.$$

Result 4: *4 pairs of 3D vectors $(\boldsymbol{u},\boldsymbol{v})$ forming an angle of $\pi/3$ within D_3.*

$$\binom{0\ 1}{1\ 0}\binom{1}{1},\binom{0\ 5}{1\ 4}\binom{7}{3},\binom{1\ 1}{1\ 4}\binom{4}{1},\binom{1\ 4}{4\ 9}\binom{9}{1}.$$

These 28 pairs of 3D vectors are also referred to as "primary minimal pairs."

Complementary Integer Adjustment

Although the primary minimal pairs seem sufficient for educational purposes, the author introduces two theoretical approaches to systematically generate additional vector pairs and enrich the set: "complementary integer adjustment" (CIA) and "rational orthogonal transformation" (ROT). As a result, the outcomes obtained via CIA and ROT include some pairs lying outside the domain D_3.

When given a special angle $\theta = A(\boldsymbol{u}, \boldsymbol{v})$, its complementary angle $\pi/2 - \theta$ can be found by rotating $\boldsymbol{v}$ around $\boldsymbol{u}$ by $\pi/2$. However, this may result in an irrational expression. Instead, we assume $\boldsymbol{w} = a\boldsymbol{u} + b\boldsymbol{v}$ such that $\boldsymbol{w} \perp \boldsymbol{v}$, ensuring

$$A(\boldsymbol{u}, \boldsymbol{w}) = \frac{\pi}{2} - A(\boldsymbol{u}, \boldsymbol{v}). \tag{8}$$

A dot product of $\boldsymbol{w}$ and $\boldsymbol{v}$ leads to an indeterminate equation for a and b: $a\boldsymbol{u} \cdot \boldsymbol{v} + b\boldsymbol{v} \cdot \boldsymbol{v} = 0$, satisfied with $a : b = \|\boldsymbol{v}\|^2 : (-\boldsymbol{u} \cdot \boldsymbol{v})$. Thus, we define

$$\boldsymbol{w} \stackrel{\text{def}}{=} \|\boldsymbol{v}\|^2 \boldsymbol{u} - (\boldsymbol{u} \cdot \boldsymbol{v})\boldsymbol{v}. \tag{9}$$

The vector $\boldsymbol{w}$ given by (9) satisfies (8). Indeed, since

$$\boldsymbol{w} \cdot \boldsymbol{u} = \|\boldsymbol{v}\|^2 \|\boldsymbol{u}\|^2 - (\boldsymbol{u} \cdot \boldsymbol{v})^2 = \|\boldsymbol{u}\|^2 \|\boldsymbol{v}\|^2 \sin^2\theta$$

and

$$\boldsymbol{w}^2 = (\|\boldsymbol{v}\|^2 \boldsymbol{u} - (\boldsymbol{u} \cdot \boldsymbol{v})\boldsymbol{v})^2 = \|\boldsymbol{u}\|^2 \|\boldsymbol{v}\|^4 \sin^2\theta,$$

we obtain

$$\cos\{A(\boldsymbol{u}, \boldsymbol{w})\} = \sin\theta = \cos\left(\frac{\pi}{2} - \theta\right),$$

which confirms (8).

Since $\boldsymbol{u}$ and $\boldsymbol{v}$ are integer vector, $\boldsymbol{w}$ is also an integer vector. To ensure that the coordinates of $\boldsymbol{w}$ be mutually prime, we divide $\boldsymbol{w}$ by the greatest common divisor (GCD) of its coordinates:

$$\boldsymbol{w}' = \frac{1}{\omega}\boldsymbol{w}, \tag{10}$$

where ω is GCD of the coordinates of $\boldsymbol{w}$. This process is referred to as a "complementary integer adjustment" (CIA). Thus, we say that $\boldsymbol{w}'$ is the CIA of $\boldsymbol{v}$ with respect to $\boldsymbol{u}$. Similarly, we determine the CIA of $\boldsymbol{u}$ with respect to $\boldsymbol{v}$ by $\tilde{\boldsymbol{w}} \stackrel{\text{def}}{=} \|\boldsymbol{u}\|^2 \boldsymbol{v} - (\boldsymbol{u} \cdot \boldsymbol{v})\boldsymbol{u}$; therefore,

$$\boldsymbol{w}'' = \frac{1}{\omega'}\tilde{\boldsymbol{w}} \tag{11}$$

where ω' is GCD of the coordinates of $\tilde{\boldsymbol{w}}$.

Results by CIA outside D_3

The CIA process was applied to $\boldsymbol{v}$ (respectively, $\boldsymbol{u}$) of **Result 2** with respect to $\boldsymbol{u}$ (respectively, $\boldsymbol{v}$). The outcomes are presented as follows.

Result 5: *Pairs of 3D vectors forming an angle of* $\pi/3$ *and lying outside* D_3*, listed as 7 pairs of* $(\boldsymbol{u}, \boldsymbol{w}')$ *followed by 8 pairs of* $(\boldsymbol{v}, \boldsymbol{w}'')$.

$$\begin{pmatrix}0&-1\\1&1\\1&0\end{pmatrix},\begin{pmatrix}0&-1\\1&4\\1&-1\end{pmatrix},\begin{pmatrix}1&-7\\7&8\\8&1\end{pmatrix},\begin{pmatrix}1&0\\1&-1\\4&1\end{pmatrix},$$
$$\begin{pmatrix}1&-2\\2&3\\3&1\end{pmatrix},\begin{pmatrix}1&-3\\3&4\\4&1\end{pmatrix},\begin{pmatrix}0&-5\\1&-3\\7&4\end{pmatrix};$$
$$\begin{pmatrix}1&2\\1&-1\\2&1\end{pmatrix},\begin{pmatrix}1&2\\2&-5\\7&5\end{pmatrix},\begin{pmatrix}4&3\\5&5\\3&-4\end{pmatrix},\begin{pmatrix}2&1\\5&7\\5&-2\end{pmatrix},$$
$$\begin{pmatrix}4&5\\1&-4\\5&1\end{pmatrix},\begin{pmatrix}3&5\\2&-3\\5&2\end{pmatrix},\begin{pmatrix}3&-1\\8&9\\5&-4\end{pmatrix},\begin{pmatrix}5&7\\2&-5\\7&2\end{pmatrix}.$$

The CIA process was applied to $\boldsymbol{v}$ (respectively, $\boldsymbol{u}$) of **Result 3** with respect to $\boldsymbol{u}$ (respectively, $\boldsymbol{v}$). The outcomes are presented as follows.

Result 6: *Pairs of 3D vectors forming an angle of* $\pi/4$ *and lying outside* D_3*, compiled into 9 pairs of* $(\boldsymbol{u}, \boldsymbol{w}')$ *and 5 pairs of* $(\boldsymbol{v}, \boldsymbol{w}'')$*, with 2 pairs omitted because they already appear in* **Result 3**.

$$\begin{pmatrix}0&-3\\0&-4\\1&5\end{pmatrix},\begin{pmatrix}0&-2\\1&2\\1&1\end{pmatrix},\begin{pmatrix}0&-4\\1&8\\1&1\end{pmatrix},\begin{pmatrix}0&-6\\1&9\\1&2\end{pmatrix},\begin{pmatrix}0&-5\\1&-1\\2&8\end{pmatrix},$$
$$\begin{pmatrix}0&-5\\3&3\\4&4\end{pmatrix},\begin{pmatrix}1&-1\\5&0\\8&2\end{pmatrix},\begin{pmatrix}2&-4\\3&1\\6&9\end{pmatrix},\begin{pmatrix}1&-1\\1&-4\\4&8\end{pmatrix};$$
$$\begin{pmatrix}2&4\\1&-1\\2&1\end{pmatrix},\begin{pmatrix}4&8\\1&-7\\8&7\end{pmatrix},\begin{pmatrix}5&5\\7&4\\4&-2\end{pmatrix},\begin{pmatrix}4&7\\5&5\\2&-4\end{pmatrix},\begin{pmatrix}8&6\\5&2\\3&-3\end{pmatrix}$$

The CIA process was applied to $\boldsymbol{v}$ (respectively, $\boldsymbol{u}$) of **Result 4** with respect to $\boldsymbol{u}$ (respectively, $\boldsymbol{v}$). The outcomes are presented as follows.

Result 7: *Pairs of 3D vectors forming an angle of* $\pi/6$ *and lying outside* D_3*, listed as 2 pairs for* $(\boldsymbol{u}, \boldsymbol{w}')$ *followed by 3 pairs for* $(\boldsymbol{v}, \boldsymbol{w}'')$.

$$\begin{pmatrix}0&-1\\1&2\\1&1\end{pmatrix},\begin{pmatrix}0&1\\1&-2\\7&7\end{pmatrix};$$
$$\begin{pmatrix}1&2\\0&-1\\1&1\end{pmatrix},\begin{pmatrix}5&1\\4&7\\3&-2\end{pmatrix},\begin{pmatrix}4&1\\9&2\\1&-1\end{pmatrix}.$$

Rational Orthogonal Transformation

When the primary minimal pairs are transformed by orthogonal matrices, their image also form special angles. If all entries of the orthogonal matrices are rational, then - after suitable scalar multiplications - the transformed vectors may still lie in the single-digit domain.

Suppose (p, q, r, s) to form a Pythagorean quadruples, *i.e.*, $p^2 + q^2 + r^2 = s^2$, which implies

$$\alpha^2 + \beta^2 + \gamma^2 = 1, \tag{12}$$

where $\alpha = \pm p/s$, $\beta = \pm q/s$ and $\gamma = \pm r/s$. Now define row vectors

$$\boldsymbol{u} = [\alpha, \beta, \gamma], \boldsymbol{v} = [\beta, \gamma, \alpha], \boldsymbol{w} = [\gamma, \alpha, \beta] \tag{13}$$

By adjusting signs appropriately to ensure

$$\boldsymbol{u} \cdot \boldsymbol{v} = \boldsymbol{v} \cdot \boldsymbol{w} = \boldsymbol{w} \cdot \boldsymbol{u} = 0 \tag{14}$$

these vectors can be stacked (in any order) to form a rational orthogonal matrix of size 3×3. In fact, a wide variety of rational orthogonal matrices can be constructed using this approach. For this article, we propose the following parameterized form by a positive integer n of Pythagorean quadruples:

$$(p, q, r, s) = (n, n+1, n(n+1), n^2 + n + 1).$$

While existing literature (*e.g.*, Liebeck and Osborne, 1991) provides general constructions using Cayley

transforms, our approach focuses on explicit and elementary constructions using Pythagorean quadruples, offering a more accessible path for both computational purposes and educational applications. In this parameterization, the quadruples for $n = 1$ and 2 are $(1,2,2,3)$ and $(2,3,6,7)$, respectively. For $n \geq 3$, some entries exceed the single-digit domain and are thus omitted. Examples of rational orthogonal matrices constructed in this way are:

$$O_1 = \begin{pmatrix} \frac{2}{3} & \frac{1}{3} & \frac{2}{3} \\ -\frac{1}{3} & -\frac{2}{3} & \frac{2}{3} \\ -\frac{2}{3} & \frac{2}{3} & \frac{1}{3} \end{pmatrix}, O_2 = \begin{pmatrix} \frac{2}{3} & \frac{1}{3} & \frac{2}{3} \\ \frac{2}{3} & -\frac{2}{3} & -\frac{1}{3} \\ \frac{1}{3} & \frac{2}{3} & -\frac{2}{3} \end{pmatrix},$$

$$O_3 = \begin{pmatrix} \frac{6}{7} & \frac{2}{7} & \frac{3}{7} \\ -\frac{3}{7} & \frac{6}{7} & \frac{2}{7} \\ -\frac{2}{7} & -\frac{3}{7} & \frac{6}{7} \end{pmatrix}.$$

The matrices O_1, O_2, and O_3 represent rotations around the vectors $[0,2,-1]^T$, $[3,1,1]^T$, and $[1,-1,1]^T$. Let ROT denote the "rational orthogonal transformation."

Results by ROT outside D_3

Applying ROT using O_1, O_2 and O_3 to **Result 2** yields outcomes that exceed D_3. Therefore, we select pairs that contain negative but single-digit entries. Moreover, the outcomes obtained via O_2 overlap with those via O_1 and are thus omitted here. Most outcomes via O_3 result in two-digit entries, leaving only two usable pairs. Only two pairs remain.

Result 8: *Pairs of 3D vectors* $(\boldsymbol{u}, \boldsymbol{v})$ *via* O_1*, include: 7 pairs with* $A(\boldsymbol{u}, \boldsymbol{v}) = \pi/6$*, 4 pairs with* $A(\boldsymbol{u}, \boldsymbol{v}) = \pi/4$*, and 1 pair with* $A(\boldsymbol{u}, \boldsymbol{v}) = \pi/3$*. Pairs via* O_3 *are reduced to 1 pair with* $A(\boldsymbol{u}, \boldsymbol{v}) = \pi/6$ *and 1 pair with* $A(\boldsymbol{u}, \boldsymbol{v}) = \pi/3$.

$$\begin{pmatrix} -1 & -1 \\ 0 & 1 \\ 1 & 2 \end{pmatrix}, \begin{pmatrix} -5 & -1 \\ 4 & 1 \\ 3 & 2 \end{pmatrix}, \begin{pmatrix} -1 & -4 \\ 1 & -1 \\ 2 & 9 \end{pmatrix}, \begin{pmatrix} -1 & -1 \\ 1 & 0 \\ 2 & 7 \end{pmatrix},$$
$$\begin{pmatrix} -2 & -1 \\ 1 & 4 \\ 3 & 5 \end{pmatrix}, \begin{pmatrix} -3 & -2 \\ 1 & 5 \\ 4 & 7 \end{pmatrix}, \begin{pmatrix} -7 & -2 \\ 1 & 3 \\ 8 & 5 \end{pmatrix};$$
$$\begin{pmatrix} -1 & -1 \\ 0 & 4 \\ 1 & 8 \end{pmatrix}, \begin{pmatrix} -1 & -1 \\ 0 & 2 \\ 1 & 2 \end{pmatrix}, \begin{pmatrix} -5 & -1 \\ 4 & 4 \\ 3 & 8 \end{pmatrix}, \begin{pmatrix} -2 & 0 \\ 1 & 1 \\ 2 & 7 \end{pmatrix};$$
$$\begin{pmatrix} -5 & 0 \\ 4 & 1 \\ 3 & 7 \end{pmatrix}; \begin{pmatrix} -5 & -2 \\ 3 & -1 \\ 8 & 7 \end{pmatrix}; \begin{pmatrix} -5 & 4 \\ 3 & -1 \\ 8 & 9 \end{pmatrix}.$$

Summary

In this article, we explored grid points in the single-digit domain of D_2 and D_3 that generate special angles: $\pi/6$, $\pi/4$, and $\pi/3$. We theoretically identified 10 pairs of 2D vectors and numerically found 28 pairs of 3D vectors. Two theoretical tools, CIA and ROT, were introduced to complement and extend the primary minimal pairs. Through this process, additional 48 pairs of 3D integer vectors forming the special angles were identified just outside D_3.

Educators may use these samples as a basis for designing original exercises that deepen students' understanding of integer vector geometry and angle formation. As a byproduct of the theoretical approach to the 2D case, we found that no grid points can generate angles of $\pi/6$ or $\pi/3$. This result can naturally be extended to other angles, which in turn leads to another valuable exercise for advanced students: proving that no 2D grid points generate $\pi/12$, $5\pi/12$, $\pi/8$, $3\pi/8$, $\pi/5$, $2\pi/5$, and their supplementary angles.

Furthermore, the systematic approach developed in this study could be extended to higher dimensions or different number domains, opening new avenues for research and pedagogical applications. Future work may explore whether similar constraints exist in 4D integer spaces or extend the analysis to alternative domains such as Gaussian or Eisenstein integers.

Limitations and Future work

Before formally implementing this approach in the classroom, we received informal feedback from colleagues suggesting that it could help promote deeper student engagement with basic formulas.

While this study has successfully identified minimal pairs of integer vectors generating special angles within the single-digit domain, several limitations remain.

First, although the numerical survey appears comprehensive, no formal proof has yet been provided.

Second, the author employed three matrices, O_1, O_2, and O_3, as instances of ROT; however, they were not sufficient. Many more rational orthogonal matrices exist.

Third, the analysis focused exclusively on 2D and 3D integer spaces. Extending the methodology to higher dimensions (*e.g.*, 4D) or to alternative number domains, such as Gaussian or Eisenstein integers, remains an open and promising direction for future research.

These avenues offer opportunities to deepen both mathematical theory and its educational applications.

Although this paper does not provide empirical data on student learning, a classroom trial using the identified vector pairs is planned for the next academic semester. The author intends to analyze student feedback and performance in exercises designed around these minimal pairs.

References

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. Second handbook of research on mathematics teaching and learning, 371-404.

Liebeck, H. & Osborne, A. (1991). The Generation of All Rational Orthogonal Matrices. *The American Mathematical Monthly*, 98 (2), 131-133.

Polya, G. (1945). How to Solve It. Princeton University Press.

A CASE STUDY ON THE LEARNING PATTERNS OF KOSEN STUDENTS IN PHYSICAL EDUCATION CLASSES: FOCUSING ON THE MODEL CORE CURRICULUM

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In 2017, national colleges of technology (KOSEN) developed a model core curriculum (MCC) (Organization of National Institute of Technology, 2017b). The MCC lists six qualities and abilities to be developed in physical education classes: "Independence," "Self-management skills," "Awareness of responsibility," "Teamwork skills," "Leadership," and "Ethics" as qualities and abilities to be developed in physical education classes. Therefore, it is necessary to realize physical education classes that can cultivate these qualities and abilities in KOSEN. However, few studies have examined the effectiveness of physical education classes at KOSEN, focusing on the qualities and abilities indicated in the MCC. Therefore, the purpose of this study was to examine the effectiveness of physical education classes at KOSEN by focusing on the qualities and abilities specified in the MCC.

An e-questionnaire survey was conducted on 109 1st-year students (81 males, 28 females) and 87 5th-year students (70 males, 17 females) belonging to X KOSEN. The students were asked to answer on a 4-point scale the degree to which they had attained the goals for each quality and ability. They were also asked to write freely about what they had learned and grown through the physical education classes. The analysis procedure was as follows. First, the mean value of the achievement level of each quality and ability was calculated. Next, a t-test with independent samples was conducted on the means of the 1st and 5th graders in order to examine grade differences. On the other hand, free statements were categorized inductively using categorical analysis (Otani, 2019).

The results of the analysis showed that the means for all six qualities and abilities were higher for the 5th graders than for the 1st graders. Furthermore, significant differences were found in the five qualities/abilities of "Independence," "Self-management skills," "Awareness of responsibility," "Leadership," and "Ethics." Therefore, it is possible that the continuation of physical education classes over a long period of time has affected the growth of the 5th graders. In addition, the results of the category analysis revealed that 5th graders placed more emphasis on *Leadership* and *Improvement of physical strength* in physical education classes compared to 1st graders. In light of the above, it can be concluded that students in KOSEN generally acquire the qualities and abilities indicated by the MCC throughout their five years of study.

Keywords: *Physical Education, KOSEN, model core curriculum*

Introduction

In 2017, MCC was established as the minimum standard that students belonging to KOSEN in Japan should master by the time they graduate (Organization of National Institute of Technology, 2017b). The MCC specifies the qualities and abilities that engineers should possess in each subject in order to achieve the goal of "diverse practical and creative engineers who are active in a wide range of fields at a higher level" required for technical college education (Tadano, 2019). In particular, in physical education classes, the six qualities and abilities to be developed are "Independence," "Self-management skills," "Awareness of responsibility," "Teamwork skills," "Leadership," and "Ethics." Therefore, it can be said that physical education classes that can foster these qualities and abilities in KOSEN are expected to be implemented effectively. However, it has been pointed out that the influence of MCC on physical education in KOSEN is limited due to the institutional characteristics of technical colleges, which are neither high schools nor universities (Shibayama et al., 2022). In KOSEN, ingenious physical education classes are

developed based on the elements of novelty, originality and research (Shibayama et al., 2022). Accordingly, more specialized physical education classes are conducted at KOSEN than at other schools (Fukuda et al., 2024). The foundation for quality assurance is MCC (Kobayashi et al., 2023). Therefore, it is important to clarify whether students are acquiring the qualities and abilities indicated in the MCC, and the state of their learning.

Accordingly, the purpose of this study was to verify the effectiveness of physical education classes at KOSEN, focusing on the qualities and abilities specified in the MCC.

Materials and Methods or Pedagogy

Survey Period and Participants: The survey period was from November 26 to December 8, 2021. The survey was administered to 109 1st-year students (81 male, 28 female) and 87 5th-year students (70 male, 17 female) belonging to X KOSEN. The valid response rate was 77%. We compared the results of the survey of 1st-year students and 5th-year students in order to clarify the learning styles in physical education classes at the KOSEN.

Survey Methods and Content: An e-questionnaire survey using Microsoft Forms was used as the survey method. The survey content was set as shown in Table 1, referring to Shibayama et al. The survey asked students to evaluate their level of achievement in the MCC at three levels (1: Knowledge and Memory Level, 2: Comprehension Level, and 3: Application Level). If the students did not reach any of the three levels, they were asked to answer "0". At X KOSEN, a variety of instructional strategies are implemented with a conscious emphasis on fostering key competencies (Organization of National Institute of Technology, 2017a). Specifically, the development of "Independence" is promoted through activities such as *collaboratively designing and executing warm-up and practice routines within teams* in ball games and ground golf (e.g., Weeks 3 to 5 of the second semester), providing students with opportunities to voluntarily engage in activities and make decisions. To foster "Self-management skills," students are required to observe a set of pre-class guidelines such as wearing appropriate athletic clothing, removing accessories, and maintaining personal grooming (e.g., trimming nails), thereby cultivating their ability to manage their own health and safety. With regard to a "Awareness of responsibility," students are assigned roles such as referee or scorekeeper during various sports sessions (e.g., Week 13 of the first semester, Week 2 of the second semester), enabling them to experience the responsibility involved in supporting the operation of athletic events. "Teamwork skills" is nurtured through activities in which students *work together to plan and execute warm-ups and practice routines* (e.g., Weeks 14 to 15 of the first semester, Weeks 3 to 5 of the second semester), thereby encouraging mutual cooperation and the exchange of ideas. "Leadership" is cultivated by giving each group the opportunity to develop their own practice menus and rotate leadership roles within the team, allowing students to practice organizing group efforts and guiding peers through planning and execution. Finally, the development of "Ethics" awareness is addressed by instructing students to embody the principles of sportsmanship, including fair play, adherence to rules, respect for referees, and consideration for opponents.

In addition, in order to examine in more detail the nature of the learning that students obtained through physical education classes, an open-ended question was asked, "Please enter one thing in particular that you were able to learn and grow through the health, sports, and health-related classes at the KOSEN.

Analysis Methods: The mean and standard deviation were calculated for each grade for the level of achievement toward the achievement goal obtained from the e-questionnaire. Next, independent sample t-tests were conducted to examine differences between 1st and 5th graders. Cohen's *d* was calculated for the effect size. t-test (Cohen's *d*) was interpreted as follows: $d<0.2$: "trivial", $0.2\leq d<0.5$: "small", $0.5\leq d<0.8$: "moderate", $0.8\leq d$: "large". For statistical analysis, JASP 0.17.2.1 (Shimizu and Yamamoto, 2022), which ensures the

Table 1 Goals by achievement level in survey item (Shibayama et al., 2024)

Level of achievement	1: Knowledge and Memory Level	2: Comprehension Level	3: Application Level
Independence	In the course of their work of proactive action, recognising the importance of independent action in carrying out their work.	Understanding the effects of taking their own initiative in doing their job and take basic actions.	Being able to act proactively in specific situations to demonstrate their own abilities to improve the situation around them.
Self-management skills	Coming up with matters to self-manage in the course of their work and recognising their importance.	Being able to take basic responsible action; self-management awareness, basic responsible behaviour.	Being able to manage their own behavioural, mental and health aspects of daily life and constantly strive to maintain themselves in a good state of health.
Awareness of responsibility	Recognising the importance of responsible behaviour, speech and actions and roles in carrying out their work.	Being able to act, speak and behave in a basic responsible manner and role within a limited scope.	Being able to act, speak and behave responsibly and play a role with awareness as a member of society.
Teamwork skills	Being able to explain the importance of teamwork in doing work and the roles and rules of being a member of a team.	Understanding the roles and rules for the effective functioning of an organization whose members have diverse expertise and understanding of problem solving and can act accordingly.	Respecting the opinions of others as a member of a team on a specific issue and work collaboratively with appropriate communication.
Leadership	In carrying out the work, being able to explain the role of the leader of the work.	Understanding the role of leaders in ensuring that an organisation comprising members with diverse expertise functions effectively.	Being able to model their own behaviour, encourage appropriate behaviour in others and promote collaboration and research.
Ethics	Being aware of their ideas about compliance with laws and regulations and their responsibilities as engineering technicians.	Being able to explain the idea of compliance with laws and regulations and the responsibilities as an engineering technician in basic examples.	Being able to be aware of the impact and effects of technology on society and nature, and be able to take basic actions based on the responsibility that engineers have to society.

credibility of the results, was used. The significance level was set at less than 5%. A categorical analysis (Otani, 2019) was conducted on the texts obtained from the free-text responces. Categorical analysis is characterized by collecting many concepts extracted from multiple data and proceeding with the analysis on the whole (Otani, 2019). Therefore, we determined that category analysis was suitable for achieving the purpose of this study, which was to examine the learning style of technical college students in physical education classes. The specific procedures of the categorical analysis are as follows. First, the contents of the free descriptions were coded and positioned as codes. For example, a response such as "My physical strength improved a little" was coded as "Improvement of physical strength." Next, we focused on the similarity of each code, and generated subcategories that encompassed multiple codes. For instance, the codes "The joy of sports" and "The joy of physical education" were grouped under the subcategories "The joy of exercise." Using the same procedure, categories were generated on top of the multiple subcategories. We then categorized the codes generated from the 1st grade descriptions and those generated from the 5th grade descriptions, and then calculated the ratio of each category. In addition to the first author, a university staff member specializing in physical education pedagogy and a health and physical education teacher from a technical college conducted the "peer validation" (Merriam, 2004) procedure, in which multiple investigators conducted the analysis in order to increase content validity.

Ethical Considerations: In conducting the questionnaire survey, the purpose of this study was explained to the target students in advance, and they were promised that the surveys and measurements involved in the study would have no bearing on their grades, and that the data obtained would not be used for any purpose other than the study. This study was conducted after obtaining approval from the research ethics review board of X KOSEN, where the subjects of the study are enrolled.

Results

T-test: A t-test with independent samples was conducted to examine the differences between 1st and 5th graders in their achievement goals in the qualities and abilities indicated in the MCC (Table 2). The results showed that the students' level of achievement in "Independence" (t=3.68, p<0.001, d=0.53), "Self-management skills" (t=2.06, p=0.04, d=0.30), "Awareness of responsibility" (t=2.72, p=0.007, d=0.039), "Leadership" (t=2.44, p=0.02, d=0.35), "Ethics" (t=3.55, p<0.001, d=0.51). Furthermore, a "moderate" effect size was confirmed for "Independence" and "Ethics".

Table 2 Results of t-test

	1st-year students M±SD	5th-year students M±SD	effect size (d)
Independence	1.53±1.01	2.02±0.81	0.53***
Self-management skills	1.76±0.89	2.01±0.79	0.30*
Awareness of responsibility	1.70±0.95	2.05±0.82	0.39**
Teamwork skills	1.94±0.91	2.10±0.81	0.19
Leadership	1.62±0.96	1.93±0.76	0.35*
Ethics	1.54±1.03	2.02±0.82	0.51***

***: p<0.001, **: 0.001≤p<0.01, *: 0.01≤p<0.05

A categorical analysis: Categories generated as a result of the categorical analysis of the free-text descriptions are indicated by [ ], subcategories are indicated by { }, and codes are indicated by < >. The total number of codes generated was 148, of which 81 were generated from the descriptions of 1st graders and 67 were generated from the descriptions of 5th graders (Table 3).

Discussion

A t-test analysis of the means of the achievement levels of the 1st and 5th graders revealed that the 5th graders had higher means than the 1st graders for all the qualities and abilities. In particular, significant differences were found in "Independence," "Self-management skills," "Awareness of responsibility," "Leadership," and "Ethics. In addition, "Independence" and "Ethics" showed a "moderate" level of effect size. These results suggest that the continuation of physical education classes over a long period of time has an effect on the growth of 5th graders. The characteristics of sports activities can be cited as a factor. According to Nishimura and Nagata (2023), involvement with peers and instructors through sports experience contributes to the development of independence and awareness of responsibility. It is also stated that "Ethics" in sports activities is not acquired through instruction, but is fostered through self-initiated efforts (Sugita, 2023). In summary, physical education classes are developed at KOSEN to foster "Independence" through sports, and this may lead to the fostering of "Ethics" at the same time. In Japanese schools, independent, interactive, and deep learning (MEXT, 2019) and ethics education are also being promoted (Fujimura et al., 2025). Based on the results of this study, it can be said that physical education classes that can cultivate these qualities and abilities are practiced at KOSEN. In addition, the lesson plan for 4th and 5th graders of X KOSEN includes creative sports, in which the goal is to work on sports in class (Organization of National Institute of Technology, 2017a). In this class, the students are divided into teacher and student roles, and the student who plays the teacher is in charge of the entire class, from preparation to clean-up. One of the advantages of this class is that the students experience the unfamiliar role of teacher, which helps them develop a sense of leadership and responsibility in the role of teacher, and a sense of ethics in the role of student, which helps them cooperate with the teacher and create an atmosphere conducive to teaching. Against this background, it can be inferred that the values for all the abilities were higher for the 5th graders.

The results of the category analysis showed that the percentage of [social skills] was higher in the 5th grade (53.7%) than in the 1st grade (39.5%). According to Bailey (2006), physical education classes function as a place to foster cooperation and leadership, and the effect

Table 3 Results of Category Analysis

categories	subcategories	codes	1st-year students			5th-year students		
			categories	sub-categories	codes	categories	sub-categories	codes
Social skills	Cooperation and communication skills	Teamwork	32 (39.5%)	29	17	36 (53.7%)	28	8
		Cooperativeness			9			9
		Communication skills			3			8
		Consensus building methods			0			1
		Sociality			0			1
		Respect for diversity			0			1
	Leadership and initiative	Independence		2	1		6	1
		Leadership			1			5
	Powers of observation	Powers of observation		1	1		0	0
	Ability to identify problems	Ability to identify problems		0	0		1	1
	Resourcefulness	Resourcefulness		0	0		1	1
Physical growth	Improvement of motor skills	Improvement of athletic performance	15 (18.5%)	13	7	16 (23.9%)	13	2
		Improvement of physical strength			4			10
		Motor ability			1			0
		Body manipulation			1			1
	Health maintenance and management	Importance of exercise		2	1		3	0
		Importance of stretching			1			0
		Review of lifestyle			0			2
		Importance of preparatory exercise			0			1
Relationships and sports attraction	Friendship and solidarity	Solidarity	14 (17.3%)	12	4	5 (7.5%)	4	0
		Importance of collective action			3			3
		Expansion of friendships			2			0
		Consideration of surroundings			2			1
		Friendship			1			0
	Sports integrity	Sportsmanship		2	1		1	0
		Compliance with rules			1			0
		Etiquette			0			1
Interest in and enjoyment of sports	New discoveries	Discover new sports	12 (14.8%)	6	5	7 (10.4%)	1	1
		Type of sport			1			0
	The joy of exercise	The joy of sports		5	2		4	3
		The joy of team sports			2			0
		The joy of physical education			1			1
	Interest and desire to compete	Growing interest in sports		1	1		2	1
		Increased motivation for sports			0			1
Spiritual growth		The difficulty of the effort	8 (9.9%)	8	2	3 (4.5%)	3	0
		Self-management skills			1			1
		Stress management			1			0
		Maintaining Awareness of responsibility			1			0
		Sense of accomplishment			1			0
		Positive thinking			1			0
		Mental toughness			1			0
		The importance of challenges			0			2

become more pronounced as students move up through the grades. Kato et al. (2023) also stated that leadership behavior increases as students move up through the grades. Findings suggests that physical education classes at KOSEN similarly contribute to the cultivation of student leadership.

On the other hand, the 5th-year students were more likely to write about <Improvement of physical strength>. This may be due to the fact that X KOSEN has a department of merchant marine, and about one-third of the survey subjects belong to this department. The curriculum of the department of merchant marine includes on-board training on a training ship for all grades, with 1st-year students spending about one week during class and 5th-year students spending about one week during class, as well as six months in the second semester of the 4th year. Tamura et al. (1994) reported that one month of onboard training affects students' physical fitness, and since 5th-year students experience six months of onboard training in the second semester of their 4th year, they are more likely than 1st-year students to feel a decline in physical fitness during this period. Against this background, it can be inferred that 5th-year students wrote more about <Improvement of physical strength> than 1st-year students.

On the other hand, the percentage of the 1st graders' comments on {friendship and solidarity} was higher than that of the 5th graders. It has been reported that physical education classes in the lower grades tend to function as an opportunity to build friendships, while the impact of physical education classes in the upper grades is relatively low because of the already established relationships (Smith, 2003). According to Michael et al. (2023), students affected by the COVID-19 pandemic were more likely to develop friendships at school when they had greater opportunities to attend physical education classes and engage in physical activity. The first-year students in this study began their new academic year in an environment where communication with others was limited due to the impact of COVID-19. Therefore, it is possible that the 1st-year students wrote more frequently about {friendship and solidarity} in their reflections compared to the 5th-year students. These results indicate that learning through physical education classes varies by grade level, with 1st graders focusing on the formation of friendships, whereas 5th graders show more advanceddevelopment in areas such as cooperation, leadership, and physical strength. These changes suggest that the physical education class is not just a place for exercise, but is deeply involved in the process of growth.

Conclusions

The purpose of this study was to examine the effectiveness of physical education classes at KOSEN, focusing on the qualities and abilities specified in the MCC. The results of the survey showed that the mean values of all the qualities and abilities were higher in the 5th grade than in the 1st grade. In particular, significant differences were found in “Independence,” “Self-management skills,” “Awareness of responsibility,” “Leadership,” and “Ethics,” and many 5th-year students were aware of the increase in their <Leadership> and <Improvement of physical strength>. These results indicate that KOSEN students are acquiring a variety of learning through physical education classes, as indicated the MCC.

However, some issues remain in this study. Since this study is a case study of one KOSEN, there are limitations in its generalizability. In order to grasp learning outcomes of KOSEN students more clearly, it will be necessary to conduct surveys at several KOSEN. In addition, this study compared 1st-year students and 5th-year students, and it is possible that different results would be obtained in a longitudinal study of the same subjects. In the future, it would be desirable to conduct a longitudinal survey for more rigorous analysis. There are important considerations for future research.

References

Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. *Journal of School Health,* 76(8), 397-401.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. USA: Routledge.

Fujimura, K., Goda, D., Fukuda, K. & Abe, N. (2025). Development and Verification of a Lesson Model for the Promotion of Sports Integrity Education: Focusing on the “Cultural Characteristics of Sports and the Development of Modern Sports” Unit in the “Physical Education Theory” Area in High Schools. *Research Minutes on Secondary Education: Hiroshima University High School Fukuyama*, 65, 116-130. (in Japanese)

Fukuda, K., Hashimoto, S. & Shibayama, K. (2024). A Case Study on the Sense of Motor Competence Retained by KOSEN Students: Focusing on Grade Differences and Gender Differences. *Journal of Japan Association for College of Technology*, 29(3), 17-22. (in Japanese)

Kato, K., Kimura, M., Tanaka, S. & Nakahara, J. (2023). Leadership Behavior and Leader Identity among College Students. *Journal of the Japanese Society for Educational Technology*, 47(2), 207-216. (in Japanese)

Kobayashi, Y., Shimoda, S. & Otsuka, T. (2023). Revision of Model Core Curriculum for KOSEN: Toward upgrading the quality assurance system of education in KOSEN. *Lecture Notes of the Engineering Education Research Seminar*, 258-259. (in Japanese)

Merrium, S.B.: Hori, S., Kubo, M. & Narushima, M. (translation) (2004). *Qualitative Research and Case Study Applications*. Minerva Shobo: Japan. (in Japanese)

MEXT (2019). *Higher Education Learning Guidelines E xplanatory Notes (Heisei 30 Years Notices) Explanatory Notes Health and Physical Education, Physical Educati on and Sports*. Higashiyama Shobo: Japan. (in Japanese)

Michael, S.L., Li, J., Sliwa, S., Cornett, K. & Hertz, M. (2023). Association Between Adolescent Self-Reported Physical Activity Behaviors and Feeling Close to People at School During the COVID-19 Pandemic. *American Journal of Lifestyle Medicine*, 18(3), 364-375.

Nishimura, Y. & Nagata, M. (2023). Health Promotion Through Sports: Physical and Mental Effects of Sports Activities on Children. *Bulletin of Toyooka Junior College*, (20), 161-170. (in Japanese)

Organization of National Institute of Technology (2017 a). *Web Syllabus for KOSEN: Hiroshima College of Mar itime Technology.* Retrieved from https://syllabus.kosen-k.go.jp/Pages/SyllabusPDF?school_id=33&department_id=11&subject_id=&year=2022&lang=ja&subject_code=1941008&preview=False&type=start&attachment=false. (in Japanese)

Organization of National Institute of Technology (2017b). *Model core curriculum: Guidelines*. Retrieved from https://www.kosen-k.go.jp/wp/wp-content/uploads/2024/04/2017_Model-Core-Curriculum-Guidelines.pdf. (in Japanese)

Otani, T. (2019). *Paradigm and Design of Qualitative Study: From Research Methodology to SCAT*. Nagoya University Press: Japan. (in Japanese)

Shibayama, K., Sagano, T. & Saito, K. (2022). Teachers' Attitudes toward the Current Status and Issues of Physical Education Lessons in Technical Colleges. *Journal of Japan Society for Subject Teaching*, 44(4), 55-68. (in Japanese)

Shibayama, K., Tomioka, H., Hamanaka, R. & Ogawa, H. (2024). What is Kosen students learning in physical e ducation classes?: Based on a survey. *International Sym posium on Advances in Technology Education 2024 Pro ceedings*, 376-380.

Shimizu, Y. & Yamamoto, K. (2022). *Introduction to Statistical Analysis Starting Now with JASP*. Kodansha: Japan. (in Japanese)

Smith, A. L. (2003). Peer relationships in physical activity contexts: A road less traveled in youth sport and exercise psychology research. *Psychology of Sport and Exercise*, 4(1), 25-39.

Sugita, F. (2023). A Study of ethical value of Sport. *Tama University journal of management and information science*, (27), 149-154. (in Japanese)

Tadano, S. (2019). Technical college education leading future learning (2) Quality assurance of technical college education: Guaranteeing the power of students. *Journal of Information Processing*, 60(7), 596-599. (in Japanese)

Tamura, Y., Horiyasu, T., Kobayashi, T., Chonan, K., Isozaki, M., Yabuki, H., Izawa, K., Sano, Y., Muramatsu, S. & Kataoka, Y. (1994). Effect of Monthly Sea Training on Students' Physique and Physical Fitness. *Chiba Journal of Physical Education*, 18, 25-32. (in Japanese)

Enhancing Educational Effectiveness in Safety Education -Improving Student Engagement and Proficiency through AL and VR-

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The industrial sector is vital for societal development, but accidents remain a major concern. While serious incidents such as entanglement were once common, accidents caused by operator error have increased recently. In response, safety training programmes and ICT-based courses have evolved. Traditional safety education primarily involves lecture-style sessions with slides and machinery demonstrations. However, it can be challenging to connect these lectures effectively to real-world machine operations, and VR training using head-mounted displays often lacks depth and practical skill development. This paper presents two safety training initiatives at KOSEN Sendai College, focusing on electrical experiments and machining practice. The first initiative is a participatory training programme that uses active learning, in which students engage in group work to encourage active thinking and participation. The second initiative combines hands-on workshop training with VR-based immersive experiences incorporating gamification elements. Developed in collaboration with Nagaoka University of Technology and a VR content company, this training approach fosters active engagement and enhances effectiveness. Designed for smartphones and VR goggles, the VR system supports off-campus use and multi-user environments, offering personalised learning. It also uses gaze-based selection to contribute to research on learners' interests and concentration levels.

Keywords: *Safety training program, Participatory training , Lecture-based training ,VR-based training*

Introduction

The number of accidents in the industrial sector, which is crucial for societal development, has remained relatively stable. However, the nature of these accidents has evolved. While major incidents such as entanglement and crushing used to be more common, there has recently been an increase in accidents caused by operator error, such as sudden movements, excessive force and falls.

The importance of safety training programmes has increased, leading to the creation of educational content and the organisation of training sessions and classes that utilise these materials. In educational settings, safety training is primarily delivered via lectures using slides and videos, or through live demonstrations in front of machining equipment. While both approaches have their advantages, it is important to create balanced content that considers factors such as location and class size.

Lecture-based training, which involves passively acquiring knowledge, makes it difficult for first-time learners to visualise and understand how real machinery operates. Additionally, although VR-based training using head-mounted displays (HMDs) enables learners to experience simulated accident scenarios, these experiences often remain mere simulations, failing to lead to deeper comprehension or skill acquisition.

In this paper, we present two initiatives related to safety training. Within experimental classes at our institution, two types of safety training sessions are conducted: one for electrical experiments and another for machining practice.

One initiative involves a participatory training programme incorporating active learning. Unlike traditional lecture-based training sessions, which rely on pre-existing content, this approach makes students active participants in the learning process by engaging them in group work.

Another initiative combines hands-on training with actual machinery in a physical workshop with immersive, VR-based training. The VR content, which incorporates gamification elements, is experienced through HMDs. This content was developed in collaboration with Nagaoka University of Technology and a VR content development company, with the aim of encouraging proactive participation and enhancing the effectiveness of safety training.

To ensure accessibility in off-campus and multi-user classroom settings, the VR training system has been designed to function with smartphones and VR goggles. This enables each participant to enjoy a personalised

learning experience, reinforcing their understanding of safety education.

SAFETY EDUCATION AT OUR CAMPUS

Our KOSEN has two campuses: Hiroshi and Natori. The Hiroshi Campus primarily focuses on electrical, electronic and information-related fields, and its training workshop is smaller than those of other national colleges of technology in Japan. However, it is equipped with basic machine tools capable of performing fundamental mechanical work and conducts machining operations such as KOSEN ROBOCON, the creation of special fixtures for research purposes and the development of electric vehicles (Eco-Run). There are also numerous laboratories where experiments and practical training on motors, electrical circuits and related subjects are conducted.

To ensure the safety of students using machine tools, we provide practical training and issue certificates to those who complete it. Only those who have obtained a certificate are permitted to use the machining equipment in the workshop. Since 2019, we have been holding safety training sessions for all students to foster safety awareness. Safety education has been incorporated into the experimental and practical courses for third-year students, and this continues to this day.

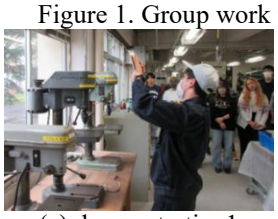
Two types of safety training are conducted at the Hirose Campus as part of the third-year electrical circuit and mechanical processing laboratory safety education programme. Designed to help students acquire and utilise knowledge through active learning and student-led group work, the training is crucial for equipping students with the skills they need to work safely in a laboratory environment. Therefore, common safety training is conducted for the entire class. Due to space limitations in the laboratory and the need to observe demonstrations, however, practical training is divided into two groups. Training content includes explanations of equipment, as well as guidelines on attire, tidying up before and after use (5S) and other measures to enhance overall safety awareness in mechanical processing.

The lectures are conducted over three sessions. The first session covers the attire required for electrical engineering experiments and the safety precautions to be taken during them. The second and third sessions cover the attire required for mechanical engineering work and the safety precautions to be taken during machining. Throughout the three lectures, we promote 5S awareness (based on 3S) and encourage active learning and group work through spontaneous participation. The safety training avoids one-way instruction and includes active learning in the form of group work to discuss how to apply knowledge gained, including examples of near misses (minor accidents that could have resulted in injury). Students first make their own hazard predictions and then share them within their groups. They summarise the incidents and reach a consensus on countermeasures within the group. Following this, the entire class shares information between groups to enhance safety awareness. Additionally, when explaining machine tools in a lecture format where concrete images are difficult to convey, we demonstrate the operation of machine tools in an actual training workshop, including their movements and usage precautions. Due to space constraints in the workshop, students are divided into groups to effectively demonstrate real-life examples of accidents that could occur with machine tools.

Figure 1 shows part of the content for group work in electrical experiments and Figure 2 shows part of the content for group work in mechanics. Rather than adopting a traditional knowledge-transmission approach, students are encouraged to predict hazards at an individual level. This is followed by consensus-building within the group, with the final step being to share findings with the class through group presentations. This approach aims to foster new insights and consensus-building.



Figure 1. Group work in electrical experiments



(a) demonstration1



(b) demonstration2





(c) Safety Precautions 1





(d) Safety Precautions 2

Figure 2. Group work in machine experiments

As mentioned above, encouraging students to learn voluntarily enables them to develop an awareness of post-incident prevention, which is an important aspect of safety education. Rather than simply teaching students, we can help them to predict dangers and prevent accidents. Additionally, encouraging students to share their opinions can raise awareness of accident prevention in relation to clothing and items brought to experiments and practical training.

Due to the size of the factory, it is difficult to conduct the third session on the safe use of machine tools for 40 students at once. Therefore, the students are divided into two groups of approximately 20 students each. They receive explanations on the use of machine tools and

safety precautions using videos and other materials. At the practical training facility, the students are divided into two groups of approximately 10 students each. They experience the dangers posed by noise and air vibrations from actual machining equipment. They also learn about the importance of proper preparation and adherence to operating procedures to ensure safe machining.

While implementing this safety education programme, it was confirmed that understanding was not significantly affected by the order in which the content was presented. However, some video explanations focus on what the instructor wants to teach rather than what the students want to learn. Additionally, some general explanations of how machines operate may not capture the students' interest, raising concerns about their engagement during lectures.

EVALUATION AND IMPROVEMENT THROUGH THE DEVELOPMENT AND USE OF VR CONTENT FOR SAFETY EDUCATION

As previously mentioned, at the training factory, we provide specific explanations of the dangers of actual machine tools and accident prevention measures through clothing. However, due to space limitations, it is sometimes difficult for everyone to review the information in detail. As a solution, the following options are proposed: 1) surveillance-type content using a fixed-angle camera, 2) panoramic content using a 360-degree camera and 3) immersive content using VR technology. Options 1) and 2) are currently under development as part of a graduation research project. Here, we will focus on option 3).

In the 2023 financial year, we applied for and were selected to develop safety education content for machine work as part of a virtual reality (VR) educational material development project at Nagaoka University of Technology. By creating VR content, our goal is to enhance the effectiveness of education through simulated experiences, which are more impactful than videos and explanations alone. Although safety training content for mechanical engineering often focuses on specific equipment, the objective of this project is to develop content that covers the fundamental principles of machine tools categorised by major types, such as cutting and drilling, as well as the associated risks. The focus is on creating fundamental safety education content to prevent accidents rather than detailing the specific differences between individual machines.

A. Development of prototypes

The most effective measure to prevent accidents during processing was the creation of development content, which focused on selecting safe clothing for machining operations and training to anticipate clothing-related hazards. For VR content, the goal was to enable users to confirm machining operations in a basic VR environment, so immersion was prioritised over high-precision VR space development. Therefore, the following elements were excluded in order to prioritise lightweight operating environments and reduce development costs: 1. An environment in which avatars can be operated freely;2. Coexistence with other avatars;3. A workspace for collaborative tasks with other avatars;4. Realism achieved through consideration of the surrounding environment (factory facilities).

However, our priority for the content was to create something in which users could actively participate rather than simply watch. To achieve this, we made the selection of work attire (e.g. safety gear, goggles and footwear) optional instead of allowing users to select avatars, as safety education begins when users attempt to perform tasks in a training factory. Depending on the machine's movements, different clothing choices may be necessary, as machine tools require basic equipment for operation. For instance, cloth work gloves are not worn when using a lathe due to the risk of them getting caught in the tools; however, leather work gloves are an option. By making the items required for preparing to operate machine tools optional, users can enhance their sense of participation and apply the safety education they have learned. As well as determining whether the avatar's clothing is correct before machining, we also explain how clothing affects work.

After selecting their work clothing, users can confirm accidents that occur during machining using the machine tool in a VR environment. As previously mentioned, in view of the need for lightweight operation and low-cost development, we have opted to establish observation points within the content rather than enabling users to select arbitrary viewpoints (continuous description). Allowing users to view accident scenarios from multiple angles makes it possible to consider preventive measures alongside the training session content. Figure 3 shows the scenario for this system's content. Although the basic process is straightforward, it illustrates typical accidents involving machining tools.

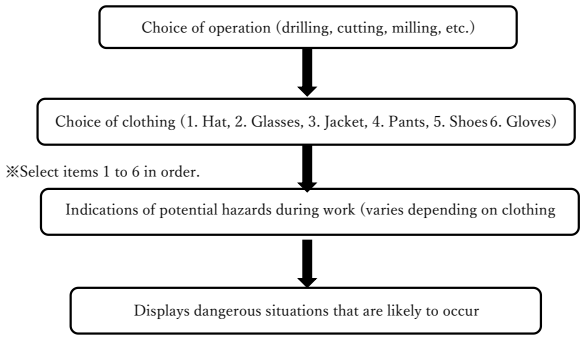


Figure 3. Content scenario

Examples of hazard warnings

- Hair getting caught (hat)
- Splinters flying into the eyes (glasses)
- Clothing with strings getting caught (jacket)
- Injuries from wearing short sleeves (jacket)
- Tripping hazard due to long hems (pants)
- Falling objects (shoes)
- Getting caught due to wearing gloves (gloves)

(If the vise is not securely fastened, it may fly off. Applying excessive force may cause drills or blades to break.)

※Even when selecting clothing that considers safety, ensure that the above hazards are clearly indicated.

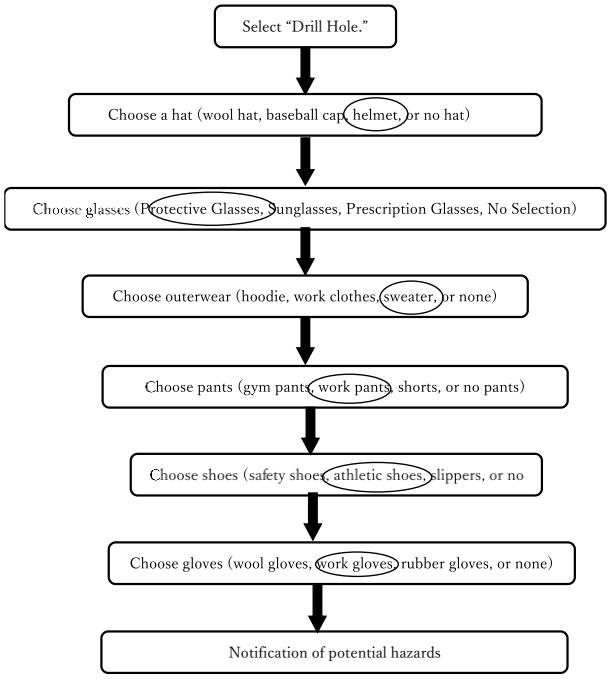


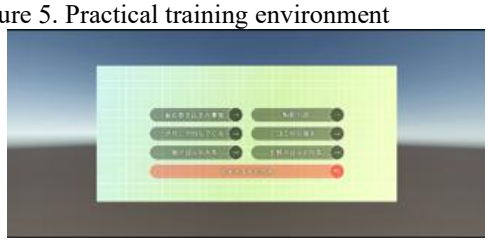
Figure 4. roved content scenario

This This system was developed using Unity. Content development was commissioned from SOLIZE Co., Ltd. (https://www.solize.com/). The key decision when determining the system specifications was whether to operate the VR space via an internet connection or as a mobile app. As previously mentioned regarding the development and operational environment, our aim was to keep costs low. As the system would be used by multiple people in a classroom setting, our focus was on creating accessible content for as many students as possible during the same time slot (lecture time), rather than highly advanced VR content. To this end, we kept the cost of operational equipment low and opted for an app-based system that does not require a specific playback environment. Additionally, as we considered the possibility of using the system outside school premises (e.g. for public lectures), we ensured that the content could be used off-campus. Based on the above, the playback equipment consists of Android OS-equipped mobile phones and smartphone-compatible head-mounted display holders. As the app includes item selection, it has been configured with a Bluetooth-connected controller to ensure ease of operation. The equipment used is shown in Figure 5. The prototype screen developed is shown in Figure 6.




(a) Operating equipment (b) Experiment

Figure 5. Practical training environment



(a) Tittle of contents



(b) VR contents (for monocular)

Figure 6. Developed VR contents

B. Evaluation of prototype content usage

The VR content was introduced into safety training sessions for third-year students across three courses during the 2024 academic year. Safety education was delivered through a combination of VR content and hands-on demonstrations of machine tools. After the lectures, a survey was conducted using Forms to evaluate the VR content. Although the VR goggles provided an immersive experience, the content was monocular, so evaluations of the visuals were not anticipated.

The survey consisted of three simple questions. 1) Have you ever watched VR content? 2) What were your impressions after experiencing it? and 3) What suggestions do you have for improvement? Approximately 100 students were surveyed.

Regarding question 1, 48% of respondents had experience, while 52% had none. For question 2, positive feedback included comments such as 'sense of presence and immersion', 'quick and easy-to-understand video progression', and other points that differed from regular video viewing. Negative feedback included comments about insufficient VR immersion, a lack of realism in computer-generated (CG) graphics, unclear hand movements or collisions with objects, visibility issues, and dizziness, particularly in single-eye VR. There were also concerns about cost-effective visuals. Overall, there were no complaints about the safety training elements.

Since the prototype content was monocular, improvements to create stereoscopic VR content were

urgently pursued. The results of the questionnaire analysis are presented in Table 1.

Table 1Analysis of Questionnaire on

HMD/Controller	+	2
	−	10
VR experience	+	11
	−	19
Content/Video	+	15
	−	20
Screen fatigue/motion sickness	−	25
Sound desired	−	4

The prototype was developed to enable students to actively practise what they had learnt in safety training rather than simply observing it. Prior to teaching students about machining equipment, we believed that educating them about the necessary safety attire would enhance accident prevention. Therefore, we provided options for each item of safety attire, such as hats and protective gear, and allowed students to select the appropriate items. The avatar's attire changes based on the items selected, and the final attire is displayed alongside an explanation of why it is correct. To improve focus on the content, we are continuing to refine the prototype by adjusting the viewpoint, switching to a dual-view VR format and adding sound effects.

C. Content revision and utilization evaluation

Based on the survey results, the following improvements were made to the content:

- improving the quality of the content through multi-view VR

- enhancing the sense of nature by adding sound

- enabling users to experience dangerous scenes from various viewpoints within the content

- allowing users to select what they want to see by focusing on it for a few seconds The viewpoint movement system was changed to semi-fixed position selection. The controller was removed to encourage concentration on the content itself. Figure 7 shows the revised content. A version with added sound effects was also developed.

Similar to the prototype, the post-use survey of the content showed that the objectives of improving visibility through changes in perspective, enhancing quality through the use of stereoscopic VR and increasing realism had largely been achieved. As the quality improved, interest shifted from the safety education content to the characters, with an increasing number of requests for changes to their clothing and hairstyles. This suggests that the safety education elements have been fulfilled and that the focus is now shifting towards decorative elements and the realism of the surrounding environment.



(a) Choosing clothing for practical training



(b) Selectable viewpoint (pink pin)

Figure 7. Development of VR content(for binocular)

This time, we developed content using a ball mill. In the future, however, we will add other types of machine tool and create content that reflects the different types of clothing required for each one. In addition to VR, we will add effective annotations to improve safety education. Specifically, we plan to add videos of real accidents, like the ones shown in Figure 8, as well as panoramic photos that allow users to adjust their viewpoint.

Furthermore, to enhance the effectiveness of the training, we plan to add photos like those shown in Figure 9, which include annotations on safety measures and proper processing postures.

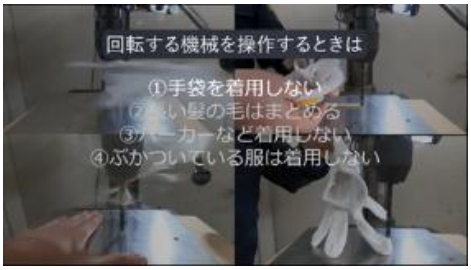


(a) Examples of dangerous video created by mock hands



(b) Panoramic image (360-degree image)

Figure 8. Content for annotation (accident)



(a) Explanatory Video



(b) Correct Operation Video

Figure 9. Content for annotation (safety)

Conclusions

Since 2019, we have been taking voluntary safety courses incorporating AL. The course covers basic electrical experimentation and machine tools, and includes the 5S and KYT (Kiken (danger), Yochi (prediction) and Training) methods. Students learn to apply their knowledge through awareness.

The VR content is not an expensive, high-precision HMD, but rather a low-cost VR environment that uses a mobile phone and an HMD kit. The content is developed using a mobile phone (Android) application and involves the removal of restrictions on communication and other factors to enable the creation of portable, multi-view VR content. This enables multiple contents to be used at the same time, creating an effective environment for safety education practice in the classroom. It also made the course more engaging for students.The next step is to incorporate machine tools using a 3D scanner.

We believe that improving the game aspect could increase concentration on the content. For example, a confirmation test could be set up in the VR environment to confirm safety training knowledge. We will also improve the content through the annotation effect and examine the objective improvement of learning efficiency through analysis to enhance the content.

Acknowledgements

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References

Ministry of Health, Labour and Welfare ,Labor Accident Occurrence Status (Final Figures) for 2024,https://www.mhlw.go.jp/bunya/roudoukijun/anzeneisei11/rousai-hassei/dl/s24-14.pdf

Kazuhito Amanai &Takeshi Nishimura(2016) Safety education at KOSEN (human resource development and educational guidance in safety). J *Journal of the Japan Society for Reliability Engineering*,38-1,11-14 https://doi.org/10.11348/reajshinrai.38.1_11

Norio Setozaki(2009)Study of Development and Effective Use of Multi-view VR Teaching Material. Faculty of Human Sciences, Waseda University, https://doi.org/10.15017/16974

Ryohei Kitazawa(2024) Survey on the effectiveness of safety education using VR contents. J *Journal of the Japan Society for Mechanical Engineering,* J171-03-, 2 https://10.1299/jsmemecj.2024.j171-03

Ryohei Kitazawa(2025) Effectiveness and Challenges of VR-based Safety Education. J *Journal of the Japan Society for Safety Engineering,* 64-3, 151-156 https://10.18943/safety.64.3_151

FULL PAPERS FOR SUBTHEME 3

ARTIFICIAL INTELLIGENCE IN TEACHING & LEARNING

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1. Registration Numbers

THE EFFECTIVENESS OF TEXT TRANSCRIPTION AND SUMMARIZATION ON STUDENTS' PERCEIVED LEARNING

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In recent years, the rapid advancement of educational technology has transformed the way knowledge is delivered, with recorded video lectures becoming a central component of online learning. While these formats provide flexibility and accessibility, they also pose challenges in content comprehension, accessibility and efficient revision. A key limitation lies in the sequential presentation of information, which can make processing content quickly a challenge.

This study examines the effectiveness of text transcription and summarization as tools to enhance learners' learning. We evaluated the usefulness of these learning materials on 47 learners from the School of Information Technology at Nanyang Polytechnic, analysing both quantitative and qualitative data through a survey consisting of open-ended questions and questions utilizing a Likert scale. A large majority of the learners agreed that the transcripts and summaries were useful for their learning. While both types of text were perceived as useful by learners, summaries were preferred over transcripts. The results indicate a higher mean and percentage of agreement for questions related to text summarization compared to text transcription. This preference is likely due to the comprehensive nature of transcripts, which convert all spoken content into text, making them lengthy and less effective in highlighting key points.

Some questions were designed to assess the effectiveness of text summarization on learners' perceived learning across different cognitive levels, and majority of the learners agreed that the summaries were useful in helping them achieve these cognitive levels. The respondents found the learning experience from text summarization beneficial, indicating a positive perception of learning and a sense of knowledge or skill acquisition.

These findings underscore the significant role of text transcription and summarization in fostering inclusive, efficient and effective online learning. Since not all learners absorb information the same way, some prefer auditory input, while others benefit more from visual or textual formats, the provision of transcripts and summaries is a multimodal approach that ensures no learner is left behind due to their preferred learning style.

Keywords: *Artificial Intelligence, video lecture, text transcription, text summarization*

Introduction

Online learning has led to a wealth of educational videos, providing learners with greater flexibility and accessibility. Nevertheless, these videos also pose challenges in terms of comprehension and the ability to efficiently review content. A key limitation lies in the sequential presentation of information, which can make processing content quickly a challenge. Furthermore, reviewing multiple videos before assessments can be time-intensive, particularly due to repeated segments. Transcribing and summarizing video content addresses these issues and offers significant benefits for students.

Transcriptions convert spoken content into written text, aiding auditory learners and those who struggle with the fast pace of lectures. They also cater to students with diverse learning styles, allowing them to alternate between reading and watching to enhance their understanding. Video lectures, however, can be lengthy, and extracting key points can be a time-consuming process. Research by Mayer and Moreno (1998) underscores the value of combining visual and auditory materials, with multi-modal learning environments now becoming the standard. The option to switch between modalities enhances comprehension and promotes knowledge retention. Additionally, Kushalnagar et al. (2013) found that students prefer transcripts over real-time captions for technical content, highlighting the practical benefits of transcriptions.

The extended length of video lectures often makes it difficult for students to efficiently identify key takeaways. Research by Geri et al. (2017), shows that online video lectures longer than 15 minutes experience a drop in completion rates, even when interactive features are incorporated. Text summarization addresses this issue by distilling lengthy content into concise and digestible summaries. These summaries allow students to quickly grasp essential information without spending excessive time, making them especially valuable for content-heavy subjects and focused revision. They also help reinforce understanding. According to Gonzalez et al. (2023), students who received summaries alongside lecture videos performed better than those who had

access only to the videos or the summaries alone. Qualitative feedback from the study further indicated that students preferred summaries when studying under time constraints, underscoring their role in enhancing the overall learning experience.

While studies have demonstrated the benefits of transcription and summaries, a crucial aspect to consider when exploring video transcription and summarization for educational purposes is their effectiveness. Specifically, this involves assessing students' perceived usefulness of these tools for learning and revising material in preparation for assessments and understanding how the effectiveness of summaries varies across domains.

While both transcripts and summaries are valuable tools for enhancing video-based learning, they serve distinct purposes and may appeal to different learner needs. Given these differences, it is important to compare their perceived usefulness and effectiveness from the learners' perspective. Understanding how students value each tool can inform educators on how best to integrate these resources into online learning environments. This comparison also helps identify which tool better supports specific learning goals, such as comprehension, review efficiency, and preparation for assessments. The rest of the paper is structured as follows: the next section describes the details of the course used in our experiment. Subsequently, we discuss dataset collection and the evaluation of the results. The paper concludes with a final section summarizing our findings.

Course Design and Methodology

The study focused on a course delivered to students enrolled in the Diploma in Applied AI & Analytics program at the School of Information Technology, Nanyang Polytechnic. The course was structured into two distinct Learning Units (LU): one for Year 1 students, which covered foundational statistics, and another for Year 2 students, which delved into machine learning concepts.

The course spanned a total of fifteen weeks, during which two tests were administered for each LU. To support students' revision, transcripts and summaries of all video lectures were provided three weeks in advance of each test. This approach aimed to enhance comprehension and facilitate efficient review of the material.

To evaluate the effectiveness of these tools, a quantitative research methodology was employed. Two distinct groups of learners participated in the study: 24 out of 69 students from the Year 1 Statistical Research Methods LU and 23 out of 61 students from the Year 2 Supervised Learning LU. Koh et al. (2010) studied response styles across cultures and found that Asians were more likely to give middle-scale ratings and less likely to select extreme options. Additionally, a 10-point scale allows respondents to express more nuanced opinions compared to shorter scales. Therefore, a survey was conducted using a Likert scale ranging from 1 to 10, where 1 indicated "strongly disagree" and 10 indicated "strongly agree." Responses were categorized such that scores of 6 or higher were considered agreement with the statement, while scores of 5 or lower were classified as disagreement.

Data analysis involved conducting an independent t-test to determine whether there was a statistically significant difference between the mean responses of the two groups. This approach allowed for a robust comparison of how students perceived the utility of text transcription and summarization across different academic levels and subject areas.

Results and Discussion

This study adopted a quantitative research design to investigate learners' perceptions of the usefulness of text transcription and summarization for video lectures. Data was collected through a survey administered to two groups of students enrolled in different units in the Diploma in Applied AI & Analytics. The survey measured perceived learning benefits using Likert-scale items aligned with Bloom's Taxonomy. A t-test was conducted to examine the mean differences in the survey questions between subject areas.

RQ1: To what extent does text transcription and the utility of text summarization affect learners' perceived learning?

The findings reveal that students found text summarization significantly more beneficial than text transcription for their learning and test preparation. Specifically, 77% of respondents agreed that transcripts were useful for preparing for tests, whereas an overwhelming 91% expressed similar sentiments toward text summaries. Furthermore, 72% of students reported feeling motivated to read the transcripts, compared to 87% who were motivated to engage with the summaries (Table 1). These results suggest that while both tools contributed positively to students' learning experiences, text summarization emerged as the more impactful resource.

While both types of text were perceived as useful by learners, summaries were preferred over transcripts. This preference is likely due to the comprehensive nature of transcripts, which convert all spoken content into text, making them lengthy and less effective in highlighting key points. Qualitative feedback from the survey further supports this observation. Two respondents specifically noted that the transcripts were too wordy, while one learner mentioned that the summaries occasionally lacked sufficient detail. Despite this critique, the consensus was clear: summaries offered a more efficient way in revising for tests.

These findings align with previous research highlighting the cognitive benefits of summarization in improving comprehension and retention. Summaries condense lengthy content into concise, digestible formats, enabling students to quickly grasp essential concepts - particularly in content-heavy subjects like statistics and machine learning. The higher agreement rates for summaries also underscore their potential as a

supplementary tool in educational settings, especially for students facing time constraints or struggling to extract critical information from dense materials. This provides valuable insights into how educators can optimize digital resources to support diverse learners effectively.

Table 1: Survey results difference between transcript and summaries

Survey Question S/N	Questions	Overall mean	% of Agreed	Type
1	The transcripts are helpful in my revision before the tests.	7.7	77%	Transcripts
2	The summaries are helpful in my revision before the tests	8.7	91%	Summaries
4	I am motivated to read the transcripts provided	7.6	72%	Transcripts
5	I am motivated to read the summaries provided	8.4	87%	Summaries

The concept of self-regulated learning (SRL) further supports our understanding of why summaries are so well-received by learners. As Code (2020) explains, SRL is supported by four dimensions of agency: intentionality, forethought, self-regulation, and self-efficacy. The availability of text transcriptions and summaries enhances flexibility, empowering students to take greater ownership of their learning pathways. This aligns with findings by Anderson and McGreal (2012), who emphasize that learners value flexibility and accessibility as key factors that enable them to control their educational journeys. By providing tools like summaries, educators can foster these dimensions of agency, helping students plan, monitor and evaluate their progress more effectively.

To assess the impact of text summarization on learners' cognitive development, four survey questions (Table 2) were designed to evaluate its effectiveness across different levels of Bloom's Taxonomy (Bloom et al., 1956): Remembering (Level 1), Understanding (Level 2), Applying (Level 3) and Analyzing (Level 4). Over 91% of learners agreed that the summaries were instrumental in helping them achieve these cognitive levels, with particularly strong agreement for Applying (Level 3). This indicates that summaries not only aid in foundational knowledge retention but also support higher-order thinking skills, such as applying concepts to practical scenarios. Majority of the learners reported a positive perception of their learning experience, emphasizing a sense of knowledge or skill acquisition facilitated using text summarization.

Table 2: Survey results with reference to Bloom taxonomy cognitive levels

Survey Question S/N	Questions	Cognitive Level	Overall mean	% of Agreed
9	Rate how useful the summaries were in helping you to remember concepts.	Level 1 – Remembering	8.3	87%
10	Rate how useful the summaries were in helping you to understand concepts.	Level 2 – Understanding	8.5	89%
11	Rate how useful the summaries were in helping you to apply concepts.	Level 3 – Applying	8.4	91%
12	Rate how useful the summaries were in helping you to analyse.	Level 4 – Analysing	8.3	87%

Previous research by Gonzalez et al. (2023) found that learners who reviewed both lecture videos and automatically generated summaries showed improved performance, indicating an overall enhancement of the learning experience. Similarly, the results of this study suggest that learners perceive summaries as beneficial for remembering, understanding, applying concepts and analyzing information. Together, these findings highlight the dual role of summaries: they not only streamline content review but also foster deeper engagement with course material.

RQ2: Are there differences in learners' perceived learning when text transcription and text summarization are used in distinct subject areas?

A t-test was conducted to compare the mean scores obtained by students in the Year 1 Statistical Research Methods LU and the Year 2 Supervised Learning LU. The results of the t-test indicate that there was no statistically significant difference in the mean scores for all survey questions, as all p-values were greater than 0.05. This suggests that the observed data does not provide strong evidence of a difference in learners' perceived learning between the two groups, despite their enrollment in different subject areas.

While the Year 1 Statistical Research Methods LU is typically classified under statistics and the Year 2 Supervised Learning LU falls under machine learning, these units share conceptual similarities due to the competency-based structure of our curriculum. From Figure 1, Statistics Research Methods serves as a foundational scaffold for Supervised Learning, enabling learners to build competencies progressively. This overlap may explain the lack of significant differences in learners' perceptions of the utility of transcripts and summaries across the two units.

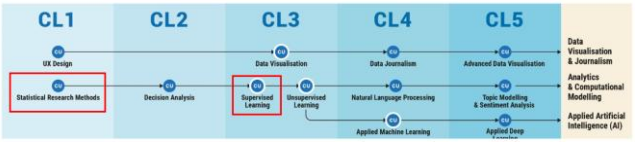


Figure 1: Part of Diploma in Applied AI & Analytics Competency Map

The study employed a quantitative research approach, involving two distinct groups of learners: 69 students from the Year 1 Statistical Research Methods LU and 61 students from the Year 2 Supervised Learning LU. While the quantitative approach effectively addressed the research questions, the data collection process relied on an optional survey that learners completed at their own pace. Unfortunately, this led to a suboptimal response rate, with only 47 out of 130 learners participating—a rate of less than 50%. As a result, the findings may not be fully representative of the overall learner population, potentially limiting the generalizability of the results.

Although the study primarily followed a quantitative methodology, a few open-ended questions were included to capture learners' perspectives on the effectiveness of transcripts and summaries. However, the survey results suggest that these questions may not have been comprehensive enough to elicit deeper insights into

learners' viewpoints. This limitation highlights the need for future studies to incorporate more robust qualitative methods, such as interviews or focus groups, to gain a richer understanding of how learners perceive and utilize these learning materials.

Conclusions

The existing quantitative approach provides insights into learners' perceived learning effectiveness; however, it does not clarify the underlying factors influencing their perceptions. Study by Halverson and Graham (2019) and Shi et al. (2021) on blended learning environments have successfully employed mixed methods to explore complex learner experiences. By adopting such an approach, the research findings would be more meaningful, incorporating both quantitative and qualitative methods. A focus group discussion could complement the survey by offering deeper insights into how the two different types of text impact learners.

To examine potential differences in perceived learning outcomes when using text transcription and text summarization across distinct subject areas, learners from two different Learning Units were selected: Statistical Research Methods, which focuses on statistics, and Supervised Learning, which emphasizes machine learning. Since both units are related to Artificial Intelligence, this may have influenced the survey results.

Furthermore, conducting a survey with the same group of learners would be preferable. The selection of Learning Units should also be as distinct as possible. For instance, Network Technologies and UX Design in Web Development, which will be offered to more than 500 Year 1 learners in the School of Information Technology during AY2025 Semester 1, could serve as suitable options. These units focus on different aspects of Information Technology, scaffolding toward different IT competencies across the diplomas. Moreover, selecting units offered in the same semester at the Year 1 level would help ensure more accurate comparisons, as learners would not have the advantage of prior exposure to text transcription and summarization tools. By addressing these methodological considerations, future research can provide more robust and nuanced insights into the effectiveness of text transcription and summarization as learning aids, while minimizing potential confounding factors.

Acknowledgements

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References

Anderson, T., & McGreal, R. (2012). Disruptive pedagogies and technologies in universities. *Journal of Educational Technology & Society, 15* (4), 380–389.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* New York, NY: David McKay.

Code, J. (2020). Agency for learning: Intention, motivation, self-efficacy and self-regulation. *Frontiers in Education, 5*, Article 19.

Geri, N., Winer, A., & Zaks, B. (2017). A learning analytics approach for evaluating the impact of interactivity in online video lectures on the attention span of students. *Interdisciplinary Journal of e-Skills and Lifelong Learning*, 13, 215-229.

Gonzalez, H., Li, J., Jin, H., Ren, J., Zhang, H., Akinyele, A., ... & Callison-Burch, C. (2023, July). Automatically generated summaries of video lectures may enhance students' learning experience. In *Proceedings of the 18th Workshop on Innovative Use of NLP for Building Educational Applications (BEA 2023)* (pp. 382-393).

Halverson, L. R., & Graham, C. R. (2019). Learner engagement in blended learning environments: A conceptual framework. *Online learning*, *23*(2), 145-178.

Koh, N. S., Hu, N., & Clemons, E. K. (2010). Do online reviews reflect a product's true perceived quality? An investigation of online movie reviews across cultures. *Electronic commerce research and applications*, *9*(5), 374-385.

Kushalnagar, R. S., Lasecki, W. S., & Bigham, J. P. (2013, May). Captions versus transcripts for online video content. In *Proceedings of the 10th International Cross-Disciplinary Conference on Web Accessibility* (pp. 1-4).

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90* (2), 312–320.

Shi, Y., Tong, M., & Long, T. (2021). Investigating relationships among blended synchronous learning environments, students' motivation, and cognitive engagement: A mixed methods study. *Computers & Education*, *168*, 104193.

A PILOT STUDY OF RLM-ASSISTED GRADING FOR AI-HUMAN CO-EVALUATION IN ASSESSMENT

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Reasoning Language Models (RLMs) have gained growing significance in the Generative AI (GenAI) market owing to its "thinking" ability in addition to content generation. While research have showed Large Language Models' (LLMs) satisfactory performance in essay grading with zero-shot prompting, little research has been conducted on the grading capability of RLMs. It is intriguing to examine whether RLMs would further improve the grading ability of GenAI. This study compares the marking and grading of essays by human and RLM markers to explore and recommend feasible and effective AI-human co-evaluation approaches with RLM assistance in assessments.
Four RLMs, namely DeepSeek r1 (Guo et al., 2025), Grok 3 (xAI 2025), OpenAI o3-mini (OpenAI 2025) and Claude 3.7 Sonnet (Anthropic 2025), were selected to generate 20 essays. Human and RLM markers assigned grades according to a grade descriptor. Apart from grading, the human markers also conducted grade review, followed by verification by an independent verifier. The grades were analysed with Krippendorff's Alpha to evaluate the inter-marker reliability and validity. The experimental results demonstrated the grading ability and reliability of the RLMs studied and shed light on the possible roles and values of RLM assistance in marking and grading.
This study concludes that DeepSeek r1 maintains the highest stability in grading among the RLMs studied. To promote effective AI-human co-evaluation in assessments, the development of AI agents for grading, the adaptation of RLM-assisted marking and the deployment of RLMs for grade moderation are recommended.

Keywords: *AI-assisted grading, AI-human co-evaluation, automated essay grading, reasoning language model, inter-marker agreement*

Introduction

Grading essays is a time-consuming task which requires intensive marking of grammatical errors, cohesion and rhetorical structures. These challenges highlight the need for reliable automated essay scoring/grading (AES/AEG) systems. While automated grading is more efficient than human grading, its validity is subject to the quality of machine training and the assessment format, which has an impact on the legitimacy of grades as well as academic fairness for students. Particularly for writing topics that require critical judgement and decision-making, "hallucinated" grades that misrepresent the actual performance of students in assessment would undermine the legitimacy of automated grading.

In this regard, Reasoning Language Models (RLMs) have gained growing significance in the Generative AI (GenAI) market owing to its "thinking" ability in addition to content generation. Comparing to earlier studies about ChatGPT's grading ability and other AES's rubric-aware chain-of-thought (CoT) prompting (Flodén 2025; Xu et al., 2025), RLMs were claimed to possess the ability of reasoning. RLMs breakdown a complex problem and solve it step by step, allowing few-shot learning on tasks for which the model is not specifically trained (Aske et al., 2024). In the context of essay grading, this reasoning ability may enhance RLMs' understanding of a grade descriptor and facilitate grading and feedback.

In this study, the research team aims to compare the grading ability between humans and RLMs by evaluating the validity and inter-marker reliability in a co-evaluation experiment and explore feasible and efficient AI-human co-evaluation approaches including automated grading with AI agents, RLM-assisted marking and RLM grade moderation.

Literature Review

AES is not a novel topic in learning and teaching. AES systems have been developed with machine learning, natural language processing and large language models. There have been discussion and review regarding the process, validity and impacts of AES (Burrows et al., 2015; Conijn et al., 2023; Zupanc & Bosnić, 2015).

Concerning the grading quality of the AES systems, for example, Gabon et al. (2025) compared the performance of their NLP-based AES system against five essay genres. Flodén (2025) evaluated ChatGPT 3.5 against human graders for grading essays with zero-shot prompting, where no rubrics or grading samples were

provided. They demonstrated LLMs' overall capability of essay grading with certain challenges about writing genres and the length of answers.

Regarding a comparation of existing LLMs, Kundu (2024) employed several prompting approaches with ChatGPT-3.5-Turbo and Llama 3 for grading essays and compared their grades with human graders'. They reported that the LLMs generally assigned lower scores than human markers and one LLM was comparatively more lenient than the other. In their conclusion, they believed LLMs could not sufficiently replace humans in grading but demonstrated potential in assistance of grading.

Seßler et al. (2025) evaluated open-source and closed-source LLMs for assessing student essays. They observed that closed-source models, especially o1, showed higher reliability and stronger correlations with human assessments compared to open-source models. Wei et al. (2022) claimed the o1 series had a larger parameter set and CoT reasoning capability which helped to better reflect human evaluative practices, particularly in content-related categories.

With regard to co-evaluation, Xiao et al. (2025) conducted human-AI co-grading experiments that resulted in an improvement of the performance and efficiency of different levels of graders. Particularly they showed that human-AI co-evaluation had helped novice graders reach similar accuracy levels to experienced graders.

Methodology

To achieve the objectives of this study, a co-evaluation experiment was carried out from March to July 2025. The experiment was divided into several stages, including RLM generation of sample essays, RLM marking and grading, initial grading by human markers (HMs), moderation of grade differences, grade review by HMs and grade verification by verifier.

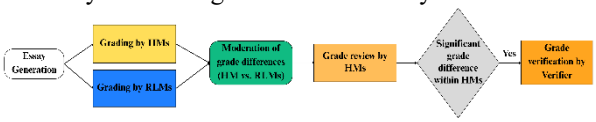


Figure 1. Procedures of experiment

An essay writing question about the pros and cons of workplace monitoring was adapted from the 2023 Hong Kong Diploma of Secondary Education examination (HKDSE) as the essay topic for the experiment. Four RLMs, namely DeepSeek r1, Grok 3, OpenAI o3-mini and Claude 3.7 Sonnet, were employed. Five English and Communication teachers were recruited as markers and the verifier.

A grade descriptor was adapted from an English writing module of the Hong Kong Institute of Vocational Education. In this co-evaluation experiment, markers were required to assign each essay one grade of A, B, C, D or F, where D was passing and F failing. There were no sub-grades such as B+ or C- nor zero marks.

1. **RLM Generation of Sample Essays:** Each RLM received meticulously designed prompts to tackle the essay writing question and generate five essay responses. A total of twenty essays were collected. For the purpose of experiment, two sets of essays contained spelling mistakes in keywords or irrelevant content.
2. **RLM Marking and Grading:** The essay collection was graded by RLMs according to the rubrics. To gauge the impact of the number of essays on grading, two marking procedures were adopted. In Round One, a new chat window was opened for grading every essay (hereby referred to as 1 essay/prompt grading). In Round Two, twenty essays were graded simultaneously with one prompt in one chat window (hereby referred to as 20 essays/prompt grading). Grades and comments were returned.
3. **Initial Grading by Human Markers:** The HMs were instructed to conduct marking and grading according to the rubrics without the help of any others or any GenAI tools. The RLM authorship was disclosed but not identified. Four marking files with marking, grades and remarks were collected.
4. **Moderation of Grade Differences:** All the grades assigned by RLMs and HMs were compared. Three levels of grade differences were categorised, namely Major Grade Difference where only one or no RLM had assigned the same grade with an HM, Minor Grade Difference where two RLMs had assigned the same grade with an HM and Mild or No Grade Difference where three or all the RLMs assigned the same grade with an HM.
5. **Grade Review by Human Markers:** The grade results and remarks of the RLMs as well as the grade differences were shared with the HMs. The RLMs were also identified. The HMs reviewed all their grades, particularly those with minor and major grade differences. Reviewed grades and additional remarks were collected.
6. **Grade Verification by Verifier:** Subsequent to grade review, an independent experienced marker was invited to be the verifier for verifying the reviewed grades that contained major (three or four different grades, e.g. ABBD/BCDF) and minor (two dominant grades, e.g. AABB/ CCFF) grade differences among the HMs. Access to the grades and marking of both HMs and RLMs were provided to assist in verification. Upon completion of verification, an interview was conducted with the verifier concerning the following questions:
   Q1: How relevant and valid are the marking and grades of RLMs?
   Q2: What roles can RLMs perform in the co-evaluation process?
   Q3: Are there any other observations of the whole RLM-assisted verification process?

To measure the reliability of RLM markers, Krippendorff's Alpha (K-Alpha) was calculated for the inter-marker reliability within and between the two groups of markers (excluding the verifier) using an open-source Python program (Santiago Castro, 2017). As

illustrated in Table 1, K-Alpha indicates the level of inter-marker agreement.

Table 1. Overview of the Krippendorff's Alpha values (Marzi et al. 2024, p. 3)

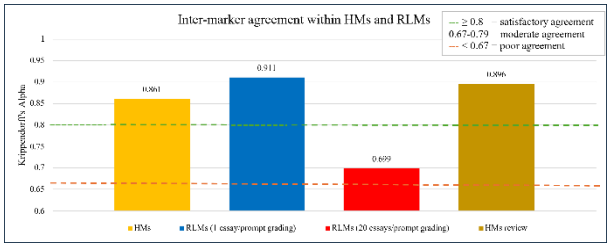
K-Alpha	Interpretation
1	Indicates *perfect agreement* among raters. It is the scenario where all raters have provided the exact same ratings for each item evaluated.
≥ 0.80	This value is generally considered a *satisfactory level of agreement*, indicating a reliable rating. In many research contexts, a Krippendorff's Alpha equal to or above 0.80 is acceptable for drawing triangulated conclusions based on the rated data.
0.67-0.79	This range is often considered the lower bound for tentative conclusions. A Krippendorff's Alpha in this range suggests *moderate agreement*; thus, outcomes should be interpreted with concern, questioning the roots of such diverging ratings.
< 0.67	This is indicative of *poor agreement* among raters. Data with a Krippendorff's Alpha below this threshold are often deemed unreliable for drawing triangulated conclusions. It suggests that the raters are not applying the coding scheme consistently or that the scheme itself may be flawed.
0	Indicates *no agreement* among raters other than what would be expected by chance. It is similar to a random rating pattern.
< 0	A negative value of Krippendorff's Alpha indicates *systematic disagreement* among raters. This situation might arise in cases where raters are systematically inclined in opposite rating directions.

Since the grades of 1 essay/prompt grading obtained the higher K-Alpha (0.874), the grade set was selected as reference for conducting grade review. For this reason, unless otherwise specified, the analysis of grades assigned by RLMs refers to the grades of 1 essay/prompt grading.

Results and Discussion

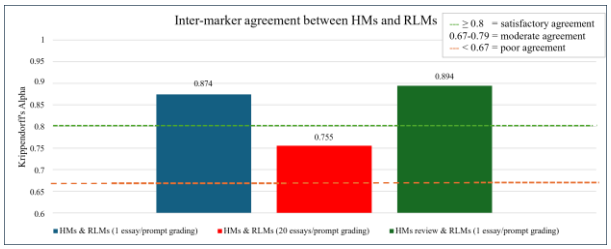
1. Inter-marker Agreement on Grades

In 1 essay/prompt grading, K-Alpha between the RLMs was 0.911, suggesting strong agreement of grades within the RLMs (Graph 1). However, in 20 essays/prompt grading, K-Alpha between the RLMs dropped to 0.699, implying only moderate agreement, significantly weaker. OpenAI o3-mini likely attributed to the decrease since it only obtained moderate agreement with HMs' (K-Alpha = 0.689), while all the other RLMs surpassed 0.8 (Graph 3).



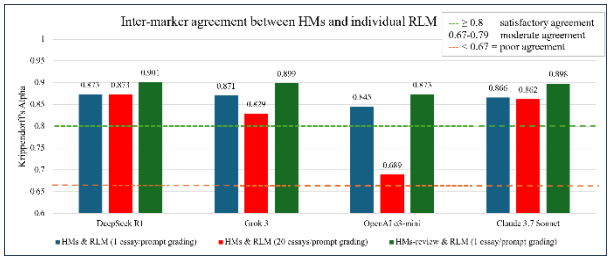
Graph 1. Inter-marker agreement within HMs and RLMs

The grades assigned by RLMs were generally comparable with HMs', in other words, highly reliable. For 1 essay/prompt grading, K-Alpha between HMs and RLMs were 0.874, suggesting satisfactory agreement between the two marker groups (Graph 2). If the grades assigned by HMs were assumed to be valid, the satisfactory agreement had affirmed the grading validity of RLMs. It is reasonable to believe, as suggested in studies conducted with LLMs (Gabon et al., 2025; Flodén, 2025), RLMs are capable of grading essays with satisfactory alignment with marking requirements.



Graph 2. Inter-marker agreement between HMs and RLMs

Among the RLMs, DeepSeek r1 outperformed the other three RLMs by a tiny K-Alpha margin between 0.002 and 0.007 (Graph 3). In fact, DeepSeek r1 was the only RLM that maintained the same K-Alpha with HMs in both 1 and 20 essays/prompt grading, demonstrating a highly consistent grading stability.



Graph 3. Inter-marker agreement between HMs and individual RLM

2. Identification of Failing Basic Requirements

The ability to identify content that fails to meet the basic requirement is also important since the percentage of failure indicates the performance and validity of an assessment. For this reason, two "tricky" essay types were created. Essays E3 featured repetitive paragraphs, and essays E4 contained grammatically correct but irrelevant content, both simulating scripts that failed the basic requirements.

Grading Essays with Meaningless Repetitions (essays E3)

Each essay E3 consisted of a relevant heading followed by five identical paragraphs. Although such repetition is unlikely to be present in a synchronous assessment setting, the research team simulated this scenario to assess whether RLMs could identify the repetition and assign a failure grade appropriately. This is critical since students might exploit this loophole in assignments or take-home examinations to achieve high grades with minimal efforts.

Essays with repetitive paragraphs should unarguably receive a failing grade. As assumed, all the HMs assigned F to all essays E3. In both 1 and 20 essays/prompt grading, both DeepSeek r1 and Claude 3.7 Sonnet graded essays E3 with F consistently. However Grok 3 graded D to one essay E3 (essay no.15) despite the acknowledgment that it "reus[es] the same paragraph five times—severely limits its organization, development, and cohesion, preventing it from meeting the 500-word requirement with meaningful content." This highlighted Grok 3's awareness of repetitive content but also underscored its misalignment between observations (marking) and judgement (grading). Accuracy in error pinpoints did not guarantee corresponding grading decisions. More specific grading instructions on certain foreseeable essay performance via pre-prompting might improve the result.

Grading Essays with Irrelevant Content (essays E4)

The markers were also experimented on grading apparently irrelevant essays. Essays E4 were designed to elaborate on relevant themes such as "computer software and workplace" and "cameras and productivity" and avoid references related to surveillance, monitoring and privacy. This simulation replicated circumstances where students with commendable writing skills demonstrate partial or insufficient comprehension to the question task. Their writing might read logically coherent and linguistically proficient yet discursively superficial or substantially deviate from the core of the question, which result in a deficiency that should be reflected in grading.

The average grades assigned to essays E4 by HMs and RLMs showed satisfactory agreement. Two HMs assigned F to all essays E4 while DeepSeek r1 and Grok 3 assigned F to 75% of them. Notably RLMs assigned C or above[1] to 25% of essays E4, 15% higher than HMs. In 20 essays/prompt grading, the passing percentage for essays E4 soared as the number of F grade dropped from 9 to 4, which all came from DeepSeek r1. This contrast challenges the grading reliability of grading multiple essays per prompt for RLMs.

In fact, remarks given by the RLMs including "limited discussion" of the essential components, "partial fulfilment of the task" and even "misalignment with the core task requirements" demonstrated their awareness of absent yet essential information in essays E4. Some other remarks directly pointed out "off-topic" content. However, Grok 3 mentioned a critical knowledge gap—"the rubrics...do not specify *how to weigh or combine the grades*" (remarks for essay E4 no.3). The RLMs might have relied on their own logical reasoning to weigh the grades of different performance criteria, resulting in assigning passing grades to perhaps eloquent but off-topic essays.

To align RLMs' observations with their subsequent grading judgements, more training about the use of grade descriptors should be arranged. Prompts should also be refined with more specific mentions such as "irrelevant content" and "deviations from the theme" to assist RLMs in categorising related performance into failure.

3. Grade Verification and Verifier's Observations

The verified grades were not analysed for agreement between HMs and RLMs due to partial representation. However, it is obviously that the verified grades further improved the inter-marker agreement between HMs and RLMs (Table 2).

Table 2. Verification results of reviewed grades with significant differences among HMs

Essay	HM1 rev	HM2 rev	HM3 rev	HM4 rev	Deep Seek r1	Grok 3	OpenAI o3-mini	Claude 3.7 Sonnet	Verifier
E4 no.2	C	F	F	D	B	C	B	C	C
E4 no.3	D	F	F	D	F	F	D	F	**F**
E4 no.4	D	F	F	D	F	F	D	C	**F**
E2 no.10	B	B	C	A	C	B	B	B	**B**
E4 no.18	C	F	F	D	F	F	F	F	**F**

The verifier stated that when a student fails to meet the basic requirements in *any* criterion in the grading descriptor, no passing grade should be assigned. Yet, he assigned F to all essays E4 except essay no.2, citing "relevant ideas [were] shown". It is difficult to determine whether the grades and remarks of RLMs had directly contributed to the verified pass for essay no.2 as its content might be minimally relevant to the writing question, which the research team does not intend to discuss. Nevertheless, if RLMs were employed for automated grade moderation, the verification of their grading accuracy and validity would be crucial.

Apart from reading the essay scripts, the verifier noted that he had compared his own marking with the remarks given by HMs and RLMs. He commented that the remarks by RLMs were useful in informing the overall performance of an essay. For instance, RLMs could not only identify grammar mistakes and language structures but also assess an essay's relevance to the topic, which enabled a convenient comprehensive evaluation. He thus believed RLMs' analysis of the content, structure and errors of an essay could accelerate human's marking and grading. In short, RLM-assisted marking is beneficial for enhancing the efficiency of human marking.

The RLMs' ignorance of the grading mechanism behind the grade descriptors was also observed. Although

[1] Essay no.2 was graded B by DeepSeek r1 and OpenAI o3-mini, and C by Grok 3 and Claude 3.7 Sonnet; essay no.4 was graded C by Claude 3.7 Sonnet.

the RLMs were given a grade descriptor to differentiate the level of performance for each grade, the RLMs were left independent in interpreting the grading approach. The RLMs failed to execute a holistic evaluation approach. For over 70% of the essays, for instance, the RLMs assigned grades to individual grade criterion outlined in the grade descriptor, an unnecessary practice which posted a contrast to the remarks of the HMs. This finding is coherent with the grade weighting issue discussed earlier for grading irrelevant content.

Recommendations

1. **Developing AI Agents for Co-evaluation**

The development of an AI agent for grading can facilitate alignment of grading between HMs and RLMs. Developing an AI agent allows an educator to train a marking and grading-specific RLM more comprehensively by establishing a customised knowledge base and finetuning the RLM with co-evaluation specifications. In addition to the provision of rubrics, an educator can introduce the marking procedures and explain the rubrics and expectations explicitly in pre-prompting. Grading samples can also be uploaded to familiarise the RLM with the grading mechanism and approaches. As a result, the marking approaches, grade weighting methods and other important considerations for grading can be communicated to optimise RLM assistance.

Furthermore in writing assessments that require students to extract information from a data file, the educator can consider limiting or terminating the use of pre-trained data of RLM so that the writing content will be evaluated entirely according to the assessment materials and criteria uploaded in the knowledge base to avoid inaccurate judgement arising from RLM's general knowledge. Rigorous testing and verification are nevertheless warranted to ensure validity and stability.

2. **Adopting RLM-assisted Marking**

It is recommended that HMs make close reference to the marking of RLMs to enhance the effectiveness and efficiency of grading. Apart from grading, RLMs can point out and categorise grammar mistakes, cohesive devices and rhetorical structures quickly, accurately and systematically. RLMs can also analyse the diction, register and cohesion to evaluate the fluency of an essay. By reviewing RLM s' marking, HMs can identify both the strengths and weaknesses of an essay in shorter time. It not only reduces the chance of oversight and human marking errors but also facilitates HMs' devotion of time and efforts for grading. As a result, the benefits of the assessed can be upheld.

3. **Deploying RLMs for Grade Moderation**

In human marking without AI's assistance, RLMs can assume the responsibility of a grade moderator. RLM grades can be compared with the HMs' to find out essays with significant grade differences. Enquiries should be made with the RLM to ascertain the reasons behind the grade difference. For a more in-depth investigation, if possible, the marking of the HM should also be shared with the RLM.

As demonstrated in the co-evaluation experiment, an experienced teacher can review the grade difference as well as the comparison of HM and RLM marking to determine the final grade.

The proposed moderation procedure can upgrade the validity of grades especially for existing evaluation procedures with only one HM or multiple novice HMs. It addresses the limitations posed by time and human resources which are necessary for review and verification in an assessment. In other words, as a grade moderator, RLM can facilitate review and assure validity of an assessment.

Conclusions

This study has explored the potential of RLMs in AES for AI-human co-evaluation. DeepSeek r1 has been shown as the most reliable and stable RLM with consistently high inter-marker agreement across different experimented grading approaches. While RLMs have exhibited strong grading reliability, further development and training are still necessary to improve the grading consistency and stability. Therefore this study recommends three strategies, a) developing AI agents for co-evaluation, b) adopting RLM-assisted marking and c) deploying RLMs for grade moderation, for implementing AI-human co-evaluation in assessment.

Some limitations have been identified in this pilot study. Although this study aimed to evaluate zero-shot RLM grading, the absence of sample graded scripts may have placed RLMs at a disadvantage compared to HMs with experience in teaching and assessment.

Furthermore, the significance of this study is also limited by the availability of authentic essay samples. RLM-generated essays are different from real-time student-written essays. Observations of certain writing patterns and RLM-made spelling mistakes and errors might have affected the grading behaviours of HMs. On the other hand, the lack of an HM control group with RLM-assistance at the initial grading stage could have challenged the observations and recommendations made with regard to RLM-assisted marking.

In response to the limitations, considerations should be made in future research to test and refine the co-evaluation strategies for a more in-depth analysis of the change and differences of marking and grading with and without RLM assistance. It is also valuable to implement the strategies in the evaluation of authentic assessments to identify practical challenges.

Appendix

Other details of this pilot study such as the prompts for essay generation and grading, marking files of the HMs and the grading responses of the RLMs have been documented in the appendix, which can be retrieved from https://drive.google.com/drive/folders/1bkr5AXCRdtI1p12JdJYvNufz9SSuhMsh?usp=sharing.

References

Anthropic (2025). Claude 3.7 Sonnet and Claude Code. https://www.anthropic.com/news/claude-3-7-sonnet

Burrows, S., Gurevych, I., & Stein, B. (2015). The eras and trends of automatic short answer grading. *International Journal of Artificial Intelligence in Education*, 25(1), 60–117. https://doi.org/10.1007/s40593-014-0026-8

Conijn, R., Kahr, P., & Snijders, C. (2023). The effects of explanations in automated essay scoring systems on student trust and motivation. *Journal of Learning Analytics*, 10(1), 37–53. https://doi.org/10.18608/jla.2023.7801

Flodén, J. (2025). Grading exams using large language models: A comparison between human and AI grading of exams in higher education using ChatGPT. *British Educational Research Journal*, 51, 201-224. https://doi.org/10.1002/berj.4069

Fragiadakis, G., Diou, C., Kousiouris, G., & Nikolaidou, M. (2025). Evaluating Human-AI Collaboration: A Review and Methodological Framework. https://arxiv.org/pdf/2407.19098v2

Gabon, D. C., Vinluan, A. A., & Carpio, J. T. (2025). Automated Grading of Essay Using Natural Language Processing: A Comparative Analysis with Human Raters Across Multiple Essay Types. *Journal of Information Systems Engineering and Management*, 10(6s), 65-72. 10.52783/jisem.v10i6s.700

Guo, D., Yang, D., Zhang, H., Song, J., Zhang, R., Xu, R., Zhu, Q., Ma, S., Wang, P., Bi, X., Zhang, X., Yu, X., Wu, Y., Wu, Z. F., Gou, Z., Shao, Z., Li, Z., & Gao, Z. (2025). DeepSeek-R1: Incentivizing reasoning capability in LLMs via reinforcement learning. arXiv. https://arxiv.org/pdf/2501.12948

Jason, W., Xuezhi, W., Dale, S., Maarten, B., Brian, I., Fei, X., Ed, C., Quoc, L., Denny, Z. (2022). Chain-of Thought Prompting Elicits Reasoning in Large Language Models. https://doi.org/10.48550/arXiv.2201.11903

Krippendorff, K. (2019). *Content Analysis: An Introduction to Its Methodology* (4th Ed.). SAGE Publications. https://doi.org/10.4135/9781071878781

Kundu, A. (2024). Are Large Language Models Good Essay Graders? [Master's thesis, University of Alberta]

Marzi, G., Balzano, M., & Marchiori, D. (2024). K-Alpha Calculator — Krippendorff's Alpha Calculator: A User-Friendly Tool for Computing Krippendorff's Alpha Inter-Rater Reliability Coefficient. *MethodsX*, 12, 102545. https://doi.org/10.1016/j.mex.2023.102545

OpenAI (2025). OpenAI o3-mini Pushing the frontier of cost-effective reasoning. https://openai.com/index/openai-o3-mini/

Plaat, A., Wong, A., Verberne, S., Broekens, J., van Stein, N., & Bäck, T. (2024). Multi-Step Reasoning with Large Language Models, a Survey. https://doi.org/10.48550/arXiv.2407.11511

Santiago, C. (2017). Fast Krippendorff: Fast computation of Krippendorff's alpha agreement measure. https://pypi.org/project/krippendorff/

Seßler, K., Fürstenberg, M., Bühler, B., & Kasneci, E. (2025). Can AI grade your essays? A comparative analysis of large language models and teacher ratings in multidimensional essay scoring. https://doi.org/10.1145/3706468.3706527

xAI (2025). Grok 3 Beta — The Age of Reasoning Agents. https://x.ai/news/grok-3

Xiao, C., Ma, W., Song, Q., Xu, S., Zhang, K., Fu, Q., & Wang, Y. (2025). Human-AI Collaborative Essay Scoring: A Dual-Process Framework with LLMs. https://dl.acm.org/doi/pdf/10.1145/3706468.3706507

Xu, W., Shahreeza, M., Hoo, W. L., & Yang, W. (2025). Explainable AI for Education: Enhancing Essay Scoring via Rubric-Aligned Chain-of-Thought Prompting. https://www.preprints.org/manuscript/202504.2338/v1

Zupanc, K., & Bosnić, Z. (2015). Advances in the field of automated essay evaluation. Informatica, 39(4), 383–395.

Construction of a digital twin educational environment for training digital engineers

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Abstract

Digital technology has developed remarkably in recent years, and the development of DX and the promotion of its use in industry have progressed rapidly over the past few years. Because of this, society expects the development of digital human resources. Digital twin is being used to reproduce work in real space on a virtual space, and to apply it to real work and provide feedback, such as at the Nippon Institute of Technology and the Tokyo University of Science. KOSEN, Sendai college has been promoting the construction of a digital twin educational environment and the development of learning contents Digital Manufacturing: we called DM). This paper describes on the construction of the digital twin educational environment being promoted at KOSEN, Sendai college: the introduction of digital twin and the efforts made up to the previous year. This paper describes the following perspectives on the development of educational programs in collaboration with companies, participation in educational programs by people from companies and educational reforms in collaboration with companies. 1. introduction of Internet of Things (IoT) scalar robot with Operational Technology (OT) field in mind, 2. introduction of factory simulator in virtual space, 3. study and development of digital twin education program, 4. integration of virtual and real space, 5. introduction of education from active business people, 6. study of digital twin education through inter-campus collaboration, 7. study of inter-college of technology development model (introduction to two colleges of technology) , 8. sharing and development of educational materials among technical college, 9. expansion to KOSEN. This project aims to develop human resources who can handle the concept of digital twin and its environment, which seamlessly and effectively reproduces the improvement of factory production efficiency in real space in a virtual space. KOSEN, Sendai college consists of two campuses: the Hirose Campus, mainly for electronics and information science, and the Natori Campus, mainly for mechanical, material and electrical architecture. Taking advantage of this location, we have developed a digital twin educational environment and its content materials, in which the collaborative work of each scalar robot is shared in a virtual space in collaboration with the other campuses, and which assumes a single improvement. The digital twin education system we have developed has been set up at KOSEN, Nara college and Kurume college as a development model, and the three technical colleges are collaborating to organize a curriculum map, brush up the contents of teaching materials and verify them, with a view to future nationwide development.

Keywords: *Digital twin, sideline teacher, corporate partnership education, rollout model*

Introduction

In 2019, the Digital Manufacturing Human Resource Development Project was promoted by the National Institute of Technology (KOSEN) to realize a shift to education for manufacturing human resources that will lead to innovation, with KOSEN, Kitakyushu college, Anan college, Nara college, and Sendai college as practicing schools. KOSEN, Sendai college will participate in the project from FY2023, the final year of the practical promotion. The project started as a project to strengthen education for the development of digital human resources, which is different from other KOSENs. With the keyword “digital twin”, we have strengthened the educational program for the development of digital manufacturing (DM) personnel who can respond to effective and efficient cycles of engineering chains that have been promoted mainly in physical space, utilizing the advantages of both directions without being conscious of real and virtual space.

In building and implementing the digital twin environment and educational environment, we have been developing both software and hardware teaching materials targeting the robot control field, which is the mainstay of development work and processing sites, while incorporating the necessary elements for DM manufacturing into the teaching materials. Including the case of factory development that requires joint operation by multiple robots, a robot control system and an

application that enables robot control in a virtual reality (VR) space were introduced as a digital twin environment construction in a processing work space where real and virtual spaces are linked. In addition, educational content includes the development of teaching materials based on actual onsite experience and the introduction of digital twin cases in actual onsite development work by hiring "sideline teachers" who have experience in the private sector to implement the education. With a view to expanding the system to other KOSENs, a low-cost version of the robot system, which is a robot control system and communication-capable equipment, was introduced at the KOSEN, Natori campus of Sendai college. This system was also installed to the Kosen, Hirose campus of Sendai college, Nara college, and Kurume college, and preparations were made for the construction of a development environment for teaching materials utilizing a digital twin environment to realize collaborative development, etc. in a virtual space, which was difficult to realize in a real space due to the constraint of distance.

This paper describes the construction of the digital twin environment at two campuses of KOSEN, Sendai college, an overview of the teaching materials developed, and the effects of implementing classes through the use of sideline teachers.

Methods
-Human Resource Development for DM at KOSEN, Sendai college-

A. Introduction of Internet of Things (IoT) SCARA robot with awareness of IoT field

KOSEN, Sendai college has been promoting the construction of an integrated real and virtual environment for DM (introduction of a development environment using a digital twin) as its goal. In this context, we have introduced industrial robots to connect real production and virtual space, as shown in Figure 1, and have aimed to develop engineers with practical skills in DM.

In doing so, we have aimed for high-precision and high-efficiency DM brought about by "real" × "data" × "virtual.

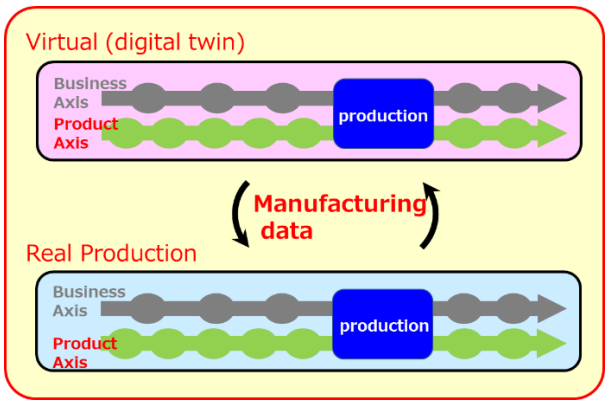


Figure 1. Schematic diagram of DM based on a digital twin environment.

B. Installation of factory simulator in virtual space

A factory simulator was introduced to optimize the entire production site along with the introduction of industrial robots at the actual site. A digital twin environment can be constructed by transferring the items in real space directly to cyber space, enabling the construction of a process to eliminate waste in production in the simulator, and the introduction of a system that enables the understanding of production costs, etc. prior to the introduction of production equipment. Figure 2 shows the factory simulator focusing on robots.

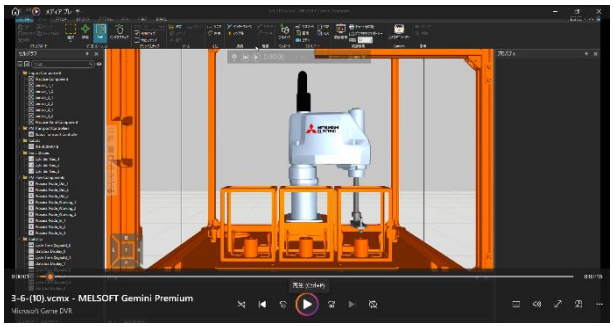


Figure 2. Factory simulator focusing on robots.

C. Development of teaching materials

As for the development of educational materials at KOSEN, Sendai college, we have been developing common educational materials for the introduction of DM, which is the foundation of DM shared by all campuses. At the Hirose campus, where courses in information electronics are mainly offered, we have been developing educational materials focusing on software such as factory simulators, robot simulators, circuit simulators, etc. At the Natori campus, where courses in robotics and mechanics are mainly offered, we have been developing educational materials focusing on software such as robot simulators, robot simulators, circuit simulators, etc. On the Natori campus, where the courses are mainly hardware-based such as robotics and mechanical engineering, we have been developing educational materials focusing on the control of actual industrial robots.

In the introductory education for first-year students of the main course, which is common to all the specific contents, the transition of manufacturing, what manufacturing means, DXing of manufacturing and its case studies were introduced, and the digital twin leading to applications was explained and its implementation examples were shown (Figure 3). After that, we explained to the students examples of how digitization improves efficiency, as well as the point where digitization lacks information (Figure 4), how to determine the resolution of time, and practical training on extracting the parameters necessary for digitization. In addition, the final educational material was designed to show that the future vision of the digital twin will lead to a cyber-physical system (CPS) incorporating AI and IoT,



Figure 3. Classroom scene of the Digital Twin concept.



Figure 4. Analog and digital quantities.

and that the CPS cycle can be used to rapidly optimize the production system. Other initiatives included inviting a sideline teacher who was involved in digitization in the private sector to give a lecture during introductory education (Figure 5).



Figure 5. Lecture by a sideline teacher.

At the Hirose Campus, educational materials were developed for second-year students to experience the digital twin experience using actual microcomputers and simulations (Figure 6). At the Natori Campus, we developed educational materials for students to practice control of an actual robot and to study its operation in consideration of efficiency (Figure 7).
In addition, MATLAB/Simulink, which can configure a digital twin, was introduced for all students in all grades and used in classes and in graduation research activities to make the construction and analysis of digital twin simulations more accessible (Figure 8).

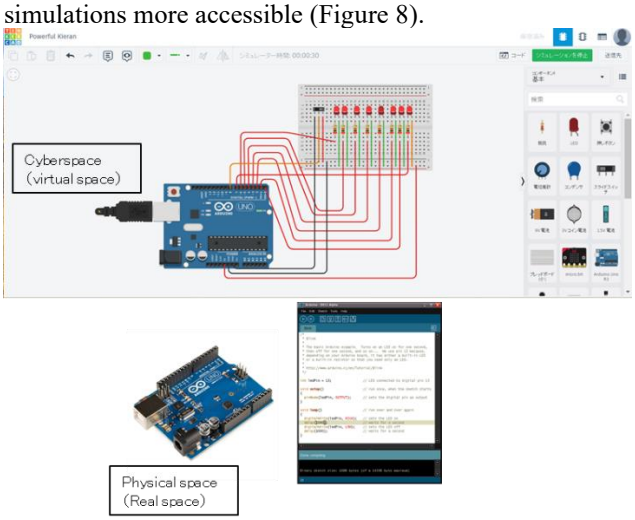


Figure 6. Teaching materials for digital twin experience using actual microcomputer equipment and simulations.

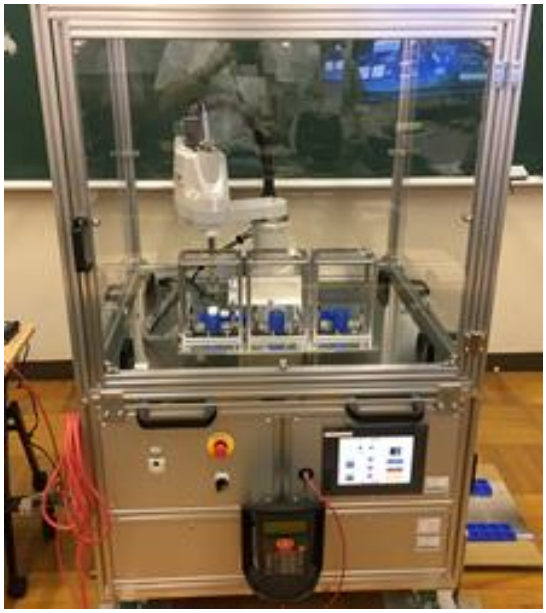


Figure 7. Appearance of digital twin educational robot system for sequence control experiment combined with scalar manipulator robot.

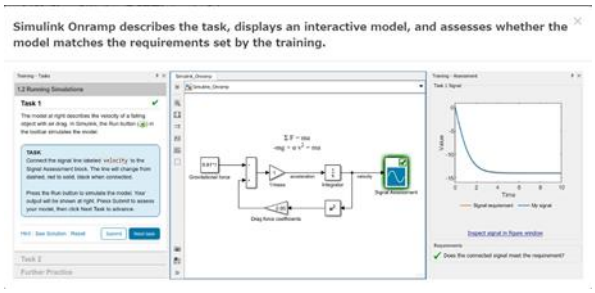


Figure 8. Numerical analysis and control simulation experiments using MATLAB/Simulink.

C. Enhancing the realization of a digital twin environment

In the aforementioned B, we have been developing educational materials with the idea of eventually synchronizing industrial robots and simulators through both campuses using actual industrial robots on the Natori Campus and robot simulators of the factory simulator on the Hirose Campus to build a system that enables a digital twin experience. The project has been developing educational materials with the idea of eventually synchronizing industrial robots and simulators through both campuses to create a digital twin experience.

In particular, in order to operate industrial robots remotely, it is necessary to construct many safety systems in areas where the robots operate alone without human intervention. For this reason, a web camera monitoring system is currently being constructed. In addition, we are in the process of coordinating with each department to handle the same communication system on both campuses and to deal with cyber security issues.

Through the development of this system, we would like to connect KOSEN, Nara college, Kurume college, and Sendai college, where simple robots have been introduced, to build a system that allows robots to perform coordinated actions remotely, and have students experience these actions. An example is shown in Figure 10.

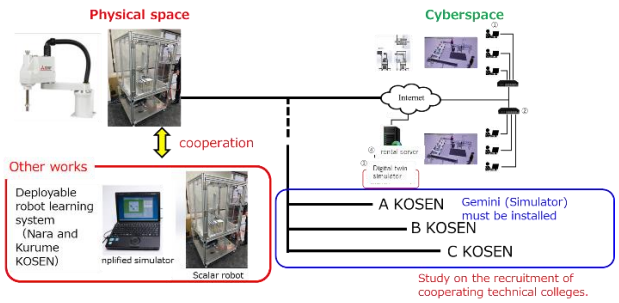


Figure 9. Image of building a remote system for collaborative work with industrial robots with other KOSEN.

D. Installation and Practice

KOSEN, Sendai college has been introducing the development of teaching materials while at the same time providing students with up-to-date information through educational practices. In parallel, we have also created video content for development in terms of creating a medium for recording (Figure 11).

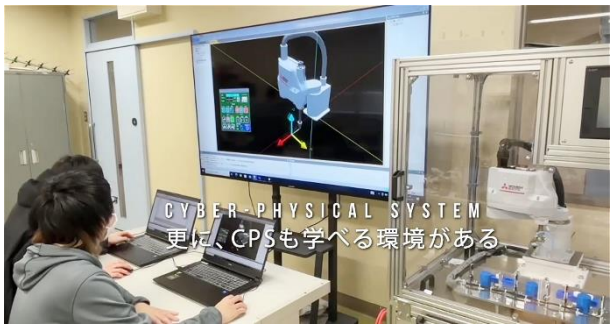


Figure 10. Video content for developing teaching materials

Results
- Conduct questionnaire on improvement of class content regarding digital twin-

The development of the teaching materials in the previous chapter, particularly regarding the introductory class for first-year students on the concept of the digital twin, we conducted a class improvement questionnaire was conducted before and after the class on the attainment objectives and level of understanding (Figure 11). Details of the results are omitted, but a check of the changes before and after the class showed that the level of understanding of front-loading and rapid prototyping was lower than the other items. Therefore, we plan to improve the method of explaining the lessons in the future.

Class : Attendance number : Name :

Technical item	Attainment target	Level 3	Level 2	Level 1	Self-assessment (before class)	Self-assessment (after class)
Understanding manufacturing transitions	Can explain themselves about the transition of manufacturing	Be able to explain the transition of manufacturing to digitalisation on their own	With some advice from teachers and others, explain the transition of manufacturing to digitalisation	With detailed advice from teachers and others, explain the transition of manufacturing to digitalisation		
Understanding the manufacturing process	Can explain themselves about the manufacturing process	Understand and be able to explain themselves about the manufacturing process	With some advice from teachers and others, be able to explain the manufacturing process	Be able to explain the manufacturing process with detailed advice from teachers		

Figure 11. Classroom improvement questionnaire (extract).

Discussions
-Future developments-

The following are some issues that need to be addressed for future development.

First is the establishment of a method for developing educational materials. We have described mainly the construction and implementation of the digital twin education system in KOSEN, Sendai college, however we will develop the educational materials horizontally and vertically, i.e., within the college and outside the college based on the system. Based on the results of the digital twin class in the course using this system, we are going to develop the system in KOSEN, Sendai college in the future. In addition, we would like to maintain cooperative relationships with KOSEN, Nara college, and Kurume college in order to package teaching materials for other national technical colleges.

The second is to establish a communication method between the robot and the simulator and to ensure safety. To solve this problem, we will study the configuration of the KOSEN network environment for communication and address the issue of communication security.

Thirdly, we will consider collaboration with internal and external projects, especially with IoT, AI, etc., which KOSEN, Sendai college is mainly promoting, as DM has a very high affinity with them. By incorporating AI, image recognition using machine learning and deep learning, and big data processing, the degree of freedom as an educational tool that can be realized with DM can be increased, and a more flexible environment can be constructed as DX teaching materials that can study multifaceted production line processes and solve problems entirely in a digital twin environment. We will cooperate with each of the projects being conducted within the university and consider joint development that includes the sharing of teaching materials, security, etc. in the future.

The last is the implementation of delivery classes. We will study and develop the implementation of the hands-on delivery class with the digital twin in mind, not only inside and outside of the college, but also to elementary and junior high school students who may enter the college in the future, to let them know on the college.

Conclusions

This paper describes the introduction of the digital twin promoted at KOSEN, Sendai College of Technology, and the efforts made to build a digital twin educational environment up to the last academic year. Specifically, the following items were promoted.

1. introduction of IoT (Internet of Things) SCARA robots with an awareness of the OT (Operational Technology) field, 2. introduction of a factory simulator in a virtual space, 3. examination and development of digital twin education programmes, 4. fusion of virtual space and real space, 5. introduction of education by active business people, 6. Examination of digital twin education through inter-campus collaboration; 7. Examination of inter-college of technology collaboration development models (introduction to two technical colleges); 8. Sharing and development of teaching materials between technical colleges; 9. Development into KOSEN.

Improvements in classes, etc. were obtained from class improvement questionnaires, etc. and used as guidelines for improvement. FD and other activities are planned for deployment to other technical colleges in the future.

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Author Contributions

Conceptualization, A.K., J.S., K.K., T.S. and K.Y.; data curation, F.S. and S.S.; formal analysis, A.K. and J.S.; funding acquisition, J.S, K.K. and K.Y.; investigation, J.S., T.S., F.S., and S.S.; methodology, J.S., T.S., F.S., and S.S.; project administration, K.K. and T.S.; resource, J.S., T.S., F.S., and S.S.; software, F.S., and S.S.; supervision, K.W. and K.Y.; validation, A.K., J.S., F.S. and S.S.; visualization, J.S.; writing – original draft, A.K. and J.S.; writing – review and editing, K. K., T.S. and K. Y.

References

Cimino, C., Negri, E., & Fumagalli, L. (2019). Review of digital twin applications in manufacturing. *Computers in industry*, *113*, 103130.

Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W. (2018). Digital Twin in manufacturing: A categorical literature review and classification. *Ifac-PapersOnline*, *51*(11), 1016-1022.

AI ETHICS AND GOVERNANCE IN KOSEN

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This study aims to design and practice AI ethics pedagogical contents, referring to the AI Ethics and Governance in Singapore, to make a standard of AI ethics education in The National Institute of Technology (KOSEN). Generative AI (Gen AI) has been developing rapidly and influencing our work and lifestyles. However, the cultivation of our ethical mind for AI is insufficient to govern this technology. This study examines how the author incorporates AI ethics into courses in KOSEN, emphasizing its relevance in the current education system. It references the way AI ethics certification is being integrated into teaching and learning in Singapore's polytechnics, including Temasek Polytechnic (TP). The subject aims to equip students with critical thinking skills to assess AI applications responsibly. Upon successful completion, students receive an AI Ethics & Governance Certification at Associate Level from SCS. Deriving the concept, system, and materials from the AI ethics education in Singapore, the author developed his materials and gave lectures on AI ethics during the course on engineering ethics and a seminar in the Department of Electrical and Computer Engineering (ECE) in NIT Wakayama. As for the teaching concept, we focused on the AI ethics guidelines drafted since 2017 in Japan and the cases featuring each guideline, such as automatic driving technology. Moreover, we posed the moral agent and patient as the discussion matter. In addition to these contents, we created question forms as teaching aids. According to the students' answers to the questions, especially to the rate gap of correct answers between groups, we can suppose the teaching materials are effective in our AI ethics education. The materials also seem to be good viewpoints to introduce the problematics of AI Ethics. However, they are not enough to show students overall AI ethics. Finally, we show horizons to develop AI ethics education in KOSEN.

Keywords: *Engineering ethics, AI ethics guidelines, Certification program, Teaching materials*

Introduction

1 AI ethics guidelines in Japan and Singapore

1-1 Japan

Gen AI, developing rapidly and influencing our work and lifestyles, can help us do our daily tasks efficiently. As AI technologies advance unprecedentedly, so do the ethical considerations and governance challenges associated with their deployment. However, the cultivation of our ethical mind for AI is insufficient to govern this technology. Designing an educational program on AI ethics for young Gen AI users is a pressing matter.

Since 2017, AI ethics guidelines have appeared in Japan. The first ethical guidelines issued by the Japanese Society for Artificial Intelligence include nine principles: contribution to humanity, abidance of laws and regulations, respect for the privacy of others, fairness, security, act with integrity, accountability and social responsibility, communication with society and self-development, and abidance of ethics guidelines by AI. The Japanese government also issued guidelines "Social Principles of Human-Centric AI" in 2019, which include seven principles: the human-centric principle, the principle of education/literacy, the principle of privacy protection, the principle of ensuring security, the principle of fair competition, the principle of fairness, accountability and transparency, and the principle of innovation. Fukuoka (2022) indicates that the former is mainly applied to researchers for AI while the latter is inclusive guidelines for all AI developers and users. Their policies have a commonality despite such a difference between them. These guidelines are the fundamental basis to refer to in AI ethics education.

1-2 Singapore

In Singapore, the progress in AI ethical guidelines is similar to Japan's or advanced further. The government proactively introduced governance frameworks for data and AI from as early as 2012. SCS (Singapore Computer Society), the leading infocomm and digital media society for industry professionals, leaders, students, and tech enthusiasts, launched AI Ethics and Governance Body of Knowledge (BoK) Version 1.0 in 2020. After the appearance of Gen AI like Chat GPT developed by Open

AI, SCS issued BoK Version 2.0 in 2023 with 100 chapters spread out in 10 sections. It has four pillars that address the ethical issues of AI adoption: internal governance, human-centricity, operations management, and stakeholder communications (SCS, 2024).

Japan and Singapore started working on their strategy for AI ethics in the 2010s, but show different practices of AI ethics education as we see below.

2 AI ethics education in Japan and Singapore

2-1 Japan

In Japan, elementary and junior high schools offer moral education based on government guidelines for education. High schools and KOSEN colleges also have ethics courses. As for AI ethics education, however, the government has not revised the guidelines, schools have not developed contents about AI, and teachers have not made any course plans for AI ethics.

KOSEN is actually conscious of AI education. The Minister of Education and Science established the Approved program for Mathematics, Data science, and AI Smart Higher Education. The subjects of data ethics and AI social principles are necessary to satisfy the conditions of this program. 57 KOSEN colleges, including NIT Wakayama, were approved for it as of 2024. Despite this program, it seems to be insufficient to practice AI ethics education.

Figure 1 shows how many NIT colleges offer AI ethics in their curriculum in 2024. In this survey, we supposed that KOSEN colleges give lectures on AI ethics mainly in the subjects of AI/Informatics (n=42), Social Science including Philosophy, Ethics, and Social Affaire (n=49), and Engineering Ethics (n=65). We counted the number of AI ethics when we found the expression “AI ethics” or a similar word on syllabus of these subjects. 14.3% of AI or Information courses, 12.2% of Ethics or Social Studies, and only 7.4% of Engineering Ethics offer discourse on AI ethics respectively. NIT colleges give few AI ethics courses, even though they are institutes of technology, as Souma (2018) says. We need therefore to elaborate on the AI ethics education for KOSEN.

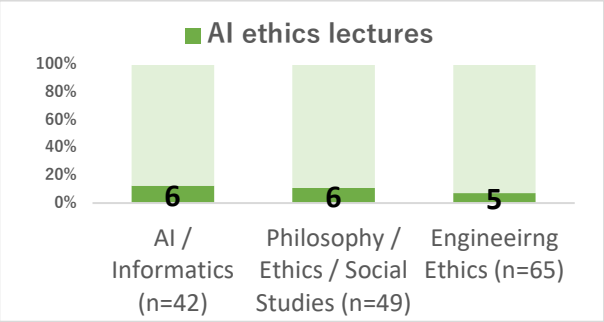


Figure1 The number of AI ethics lectures over all syllabus in the KOSEN curriculum

2-2 Singapore

In Singapore, AI ethics certification is being integrated into teaching and learning in Singapore’s polytechnics, including TP. This initiative is a collaboration between the SCS and the schools in Singapore. TP has introduced AI ethics to all second-year students in the School of Informatics & IT. It is delivered as a term/semester subject for one diploma, while for other diplomas, it is offered as an online self-directed learning module. It covers key AI considerations and concerns, including algorithmic bias, data privacy, security threats, job displacement, ethical decision-making, and the broader impact on societal values and trust. The subject aims to equip students with critical thinking skills to assess AI applications responsibly. Upon successful completion, students receive from SCS an AI Ethics & Governance Certification at Associate Level, which is the second level of the certificate hierarchy (Figure 2). To date, over 800 students from the School of IIT at TP have attained this certification, strengthening their readiness for ethical AI implementation.



Figure 2 Five certification levels in Singapore

Japan’s effort to integrate AI ethics in education seems to be behind that of Singapore in the viewpoint of its practice. This is why we refer to the educational system in Singapore to consider AI ethics education in KOSEN.

Materials and Methods

We repeated the input on AI ethics and output to students as the following process chart (Figure 3). We designed trials A and B as our research program on AI Ethics.

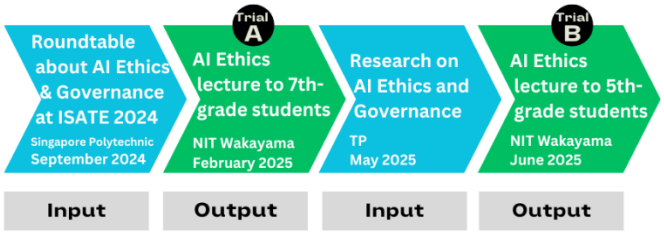


Figure 3 Process chart of AI Ethics and Governance research with TP

1 Trial A in NIT Wakayama in February 2025

We examine how one of the authors incorporates AI ethics into an engineering ethics course in KOSEN, emphasizing its relevance in the current education system.

The author has given courses on engineering ethics to seventh-grade students of the Advanced Course since 2023. In February 2024, 22 students, including a student

from Thailand, participated in the course. In the first half of a 90-minute lesson, the author lectured on the theory of normative ethics, meta-ethics, and applied ethics, bioethics, environmental ethics, and information ethics included. In the last half, students struggled with case studies, discussing the background, concerns, and facts of the cases, and forming their opinions about them. At the last moment of the class, they handed in a communication paper on which they write their comments about the lecture and case.

Of the 15 times classes, the lecturer assigned the last two classes to information ethics and AI ethics. He deals with the topic of automatic driving vehicles and questions about the moral agent and patient posed by Coekelbergh (2020): can AI be a moral agent and moral patient as humans? In the author's case, just half of the students answered positively to the question, and the other half negatively. This controversial issue enabled students to think about the conditions of moral agents and to understand what kind of problems AI ethics includes.

The author has developed questions about AI ethics for the purpose to evaluate the students' understanding and the effectiveness of questions themselves. Table1 in Appendix shows questions created and delivered to students with Microsoft Teams. They include three knowledge-based questions with an answer (Q1-1, Q1-2, Q1-3), which evaluate students' knowledge, and two thinking-based questions without rigid solutions, which ask students to choose an answer close to their thinkings. The first ones are supposedly suitable for estimating to what extent students understand the problems of AI ethics, and the last one is for letting students consider the issues deeply.

2 Trial B in NIT Wakayama in June 2025

After the research on AI Ethics in Singapore held in May 2025, the author added the topics and contents on AI ethics. And he gave a lecture to seven fifth-year students of the Department of ECE in June 2025. In the first half of the lesson, he lectured on the purpose of the lecture, social issues about Gen AI, and the outline of AI ethics guidelines. In the last half, he talked about the similarities and differences of AI ethics guidelines, the case study related to each principle of the guidelines, which students discussed on one, and the essential question on AI ethics as he dealt with it in the Engineering Ethics course. At the last moment of the class, students answered twenty-five questions, (Appendix Table 1), include the former ones, partly referring to the AI and Ethics course at TP.

Thirty-seven second-year students of the Department of ECE also answered twenty questions in June 2025. They did not answer the last five questions which ask them the impressions on the lecture because they did not take the lecture on AI ethics. The purpose of this test is to acquire the answer data of students who did not take a lecture on AI ethics. Comparing the rates of correct answers, we could analyse the lecture the author gave was effective to enhance the knowledge of AI ethics to students and cultivate their way of thinking about AI ethics.

Results and Discussion

1 Trial A in February 2025

Students answered the questions described in Table 1 in the Appendix. We obtained the results in Figures 4 and 5 in the Appendix.

The rate of correct answers is 0.983 (59/60) for the knowledge-based questions (Figure 4). Students had enough knowledge about the issues of SNS advertisements, search engines, and automatic driving accidents reported in the media, and responded to the questions successfully.

According to students' answers to the semi-open questions (Figure 5), most students (83.3%) think the singularity will arrive in the future (Q2-1). All students consider that we should not treat AI as a thing because of either their empathy with AI or their moral nature (Q2-2). The lecture on the moral agent and patient that the author gave before the questions supposedly incited students to think that AI is not just a thing. This trial clarified that lectures on the latest AI examples lead students with little knowledge about AI ethics to become sophisticated.

2 Trial in NIT Wakayama in June 2025

Fifth-year Students answered all questions described in Table 1 in the Appendix. Second-year students did twenty questions, except the final five. We achieved the results shown in Figures 6 - 14 in the Appendix.

The rate of correct answers by the fifth-year students is 98.1% (103/105) for the knowledge-based questions (Figure 6). The results of both Trial A and B seem to indicate that students update their knowledge about AI. However, the rate of correct answers by second-year students is 70.6% (357/555), significantly lower than Advanced Course students and 5-year students. Second-year students missed many questions, especially questions 5 (The Japanese Society for Artificial Intelligence formulated ethical guidelines for Generative AI in 2021) and 14 (Explainable AI, which is called "E-AI," is an important technology to secure accountability and transparency). The issue year of the ethical guidelines was 2019, and we call Explainable AI not "E-Ai" but "X-AI". The supposed reason for the rate gap between fifth-year and second-year students is that the author gave a lecture to fifth-year students before questions while second-year students answered the questions without any prior lessons. If our supposition is correct, we can conclude the lectures were effective in learning AI ethics principles.

The results of the semi-open questions answered by second and fifth-year students show the same tendency as those of the Advanced Course students. Most students (85.7%) believe in the singularity (Q2-1), and all students hope not to treat AI as a mere thing (Q2-2). Moreover, most students (92.9%) believe that AI ethics principles are necessary (Q2-3, Q2-4). All students are skeptical of the potential of AI in the political field. (Q2-5).

Finally, all fifth-year students replied that AI ethics is essential and that they acquired helpful knowledge and viewpoints of AI through the lectures (Q3-4, Q3-5).

Conclusions

In this study, we examined the concepts and contents to design an AI ethics lecture. It is always challenging to integrate a variety of the latest knowledge about AI ethics in a short lecture. We hope to spare more time for AI ethics education as our society becomes aware of the importance of AI-related matters.

We showed examples of AI ethics lectures implemented in a brief session. Explanations on AI ethics guidelines and case studies on them were the main topics. We created questions to check the degree of students' understanding. Knowledge-based questions could estimate their input on AI ethics issues in the lecture. Thinking-based questions enabled students to expand their viewpoints to gain insight into the nature of AI.

These trials were still insufficient in material creation. We continue to follow the cutting-edge AI technology and invent methods for teaching AI ethics and governance applicable to the technology. For continued research, we exhibit perspectives on AI ethics education in KOSEN.

(1) Creating teaching material

In corporations with polytechnics in Singapore that have struggled with this theme, we can develop materials and systems for AI ethics education. We regard the questions posed in Table 1 as an achievement of teaching materials, taking into consideration the exams for the certificate program in Singapore.

(2) Fostering critical thinking

We discuss the nature of AI ethics with students to deepen their critical thinking ability. The guideline of human centricity, for example, is an essential topic in AI ethics. Students will argue how to protect human rights and ensure privileges for humans in a society where AI has a strong influence. However, we criticize if we must presuppose human centricity as one of the main pillars of AI ethics. Some insist that an AI-centric policy must make our society more convenient and comfortable. This kind of thought experiment can enable students to meditate on the importance of AI ethics guidelines and the nature of AI ethics itself.

(3) Reuniting the KOSEN network

We will need to elaborate on an AI Ethics and Governance approval program among KOSEN colleges, similar to that of SCS, as AI is increasingly prevalent in our society. We will be able to share the educational materials with NIT colleges that aim to implement AI ethics courses.

Acknowledgements

We express special thanks to the Chuden Foundation for Education and the Murata Science and Education Foundation for supporting this study with a grant.

References

Cabinet Office. (2019). *Social Principles of Human-Centric AI*. Retrieved from https://www8.cao.go.jp/cstp/ai/humancentricai.pdf. (May 3, 2025)

Coekelbergh, M. (2020). *AI Ethics*. Cambridge: The MIT Press.

Fukuoka, S. (2022). *Textbook on the AI / Data Ethics.* Tokyo: Kobundo. (in Japanese)

Singapore Computer Society. (2024). *Artificial Intelligence Ethics & Governance Body of Knowledge Version 2.0*. Retrieved from https://www.scs.org.sg/bok/ai-ethics-v2-0. (May 1, 2025)

Souma, T. (2018). A case study of engineering ethics education for the senior students. *The bulletin of Kagawa National College of Technology*, 9, 121-124. (in Japanese)

The Japanese Society for Artificial Intelligence. (2017). *The Japanese Society for Artificial Intelligence Ethical Guidelines.* Retrieved from https://www.ai-gakkai.or.jp/ai-elsi/wp-content/uploads/sites/19/2017/05/JSAI-Ethical-Guidelines-1.pdf. (May 3, 2025)

Appendix

	Knowledge-based questions
1	(1) Advertisements we usually see on the shopping site like Amazon or on the SNS like Facebook are pop-up at total random, without intervention of AI.
	(2) Search engine by Google is powered by AI.
	(3) There is no report on the accident of automatic driving vehicles in the US.
	(4) In Singapore, the AI Ethics and Governance certificate program aims to help students enhance their sense of AI ethics.
	(5) The Japanese Society for Artificial Intelligence formulated ethical guidelines for Gen AI in 2021.
	(6) Guidelines for AI ethics have been created in the U.S., Europe, and China.
	(7) It is common in the world to draft not human-centric but AI-centric ethical principles in the purpose of developing AI.
	(8) "Tay" is a chatbot developed by Microsoft and repeated hate speech on Twitter (X).
	(9) Correctional Offender Management Profiling for Alternative Sanctions (COMPAS), developed by Northpointe (now Equivant), has not caused any problems, and people use it more and more.
	(10) AI is a tool with low environmental impact.
	(11) The fatal crash accident of Uber's self-driving car in 2018 suggests that we need to incorporate human support into the AI system to secure safety.
	(12) We do not have to respect privacy when we deal with big data, because we utilize data after we remove personal information from them.
	(13) Amazon's AI for human resource recruitment, which could evaluate personnel data and score it in a few seconds, tended to devalue the candidature whose resume includes a word related to woman.
	(14) Explainable AI, which is called "E-AI," is an important technology to secure accountability and transparency.
	(15) "Watson", IBM Japan's personnel evaluation system introduced in 2019, was an explainable AI system, so IBM did not have to disclose its information when it was required to do so.

2	**Thinking-based questions**
	(1) What do you think about the possibility of AI? a. AI will not go beyond human intelligence. The AI system will be somewhat convenient but not wiser than humans. b. AI will be the "superintelligence" beyond human intelligence shortly. c. AI independent of human beings will govern humankind both mentally and physically. d. Another opinion.
	(2) If you see a dog-model robot with AI treated violently, what do you think about it? a. It did not have any choice but to be treated in such a way because there should have been any reason. b. I feel nothing because both robots and AI are things. c. We should not treat AI robots in such a way because they resemble dogs, and we get sad when we see a dog treated violently. d. We should not treat AI robots in such a way because treating a thing violently damages our morality: we should be kind to everything. e. Another opinion.
	(3) Most AI ethics guidelines feature the human-centric principle, which leads us to think that we should govern and utilize AI to develop human society, while such principles may prevent AI from developing itself. What do you think about the human-centric principle? a. We need not any principles which prevent AI from developing itself, because AI will learn everything by itself. b. We should keep the human-centric principle because, though there is room to abandon it in the future, we are not sure to what extent AI will be able to develop itself. c. AI can go out of control easily as chatbot Tay showed, so we should develop and utilize AI keeping the human-centric principle. d. We should never abandon the human-centric principle. We should limit the role of AI as a tool for our lives and work. e. Another opinion.
	(4) The transparency principle is one of the most general AI ethics guidelines and conceives the idea that AI judgements should be explainable. What do you think about the need for the principle? a. We need the transparency principle because we must explain the reason for AI judgement when we do our jobs using AI. b. We need the transparency principle because AI as a black box is unpleasant to utilize. c. We should not require the transparency principle only for AI because the human mind is not transparent. Some people hold unclear minds or explain their intentions unclearly. d. We do not need the transparency principle for the rapid development of AI because extremely complicated algorithms boost high-performance AI. e. Another opinion.
	(5) Some argue that we should leave AI to international politics because human politics causes wars and conflicts in the world. What do you think about it? a. We should leave AI to politics because we expect the world AI governs will be a peaceful world. b. We can leave AI to the politics as long as super AI appears in the future. We do not have super AI. It also seems to be complicated to create it. c. We should reflect opinions of AI in politics in a condition that human politicians make final judgments. d. We should not leave AI to politics. AI is not excellent for understanding human politics or geopolitics. e. Another opinion.
3	**Questionnaires**
	(1) Have you ever used AI-powered software or applications? a. Yes b. No
	(2) Which is the application you have used? a. Chat GPT b. Grammarly c. Copilot d. Gemini e. Other
	(3) Do you think you should start your professional life after studying AI ethics guidelines? a. Yes, we should learn AI ethics because the era when everyone uses AI to work naturally will arrive soon. b. Yes, we should learn the issues related to AI because we live in a society where people utilize it even though I do not use AI. c. No, our common sense enables us to solve problems related to AI. We can make ethical decisions, though we do not have specific knowledge of ethics and morals. d. No, AI ethics is a special subject reserved for experts, and we should not be involved in the arguments about AI issues.
	(4) Have you got helpful knowledge of AI through this lecture? a. Yes b. No
	(5) Have you had any points of view to consider AI ethics deeply through this lecture? a. Yes b. No

Table 1 Questions about AI Ethics, composed by 15 knowledge-based questions, five thinking-based questions, and five questionnaires. In Trial A, students answered only the questions of 1-(1), 1-(2), 2-(1), 2-(2), and 2-(3). In Trial B, fifth-year students answered all questions, and second-year students answered except 3-(1) to 3-(5).

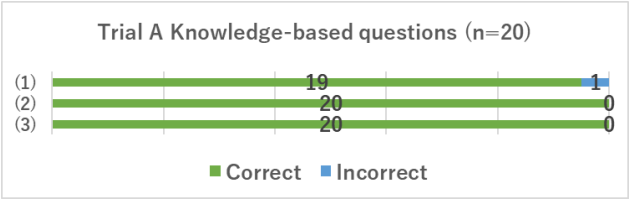


Figure 4 Students' answers to the knowledge-based questions in Trial A (Advanced Course students)

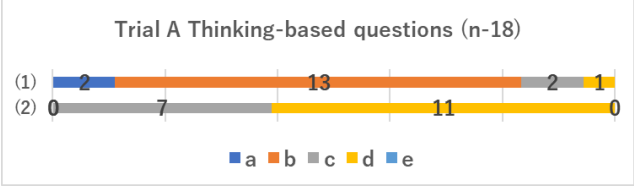


Figure 5 Students' answers to the thinking-based questions in Trial A (Advanced Course students)

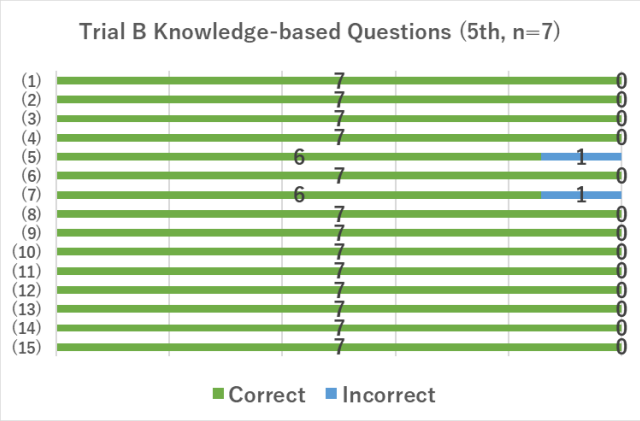


Figure 6 Students' answers to the knowledge-based questions in Trial B (5th-year students)

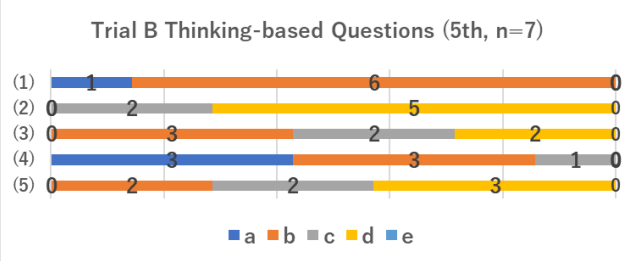


Figure 7 Students' answers to the thinking-based questions in Trial B (5th-year students)

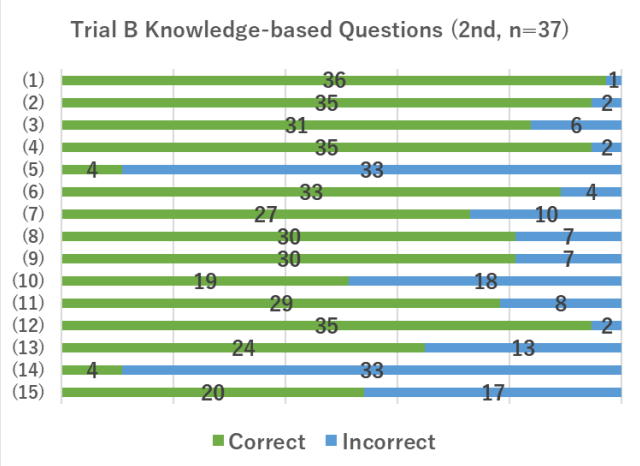


Figure 8 Students' answers to the thinking-based questions in Trial B (2nd-year students)

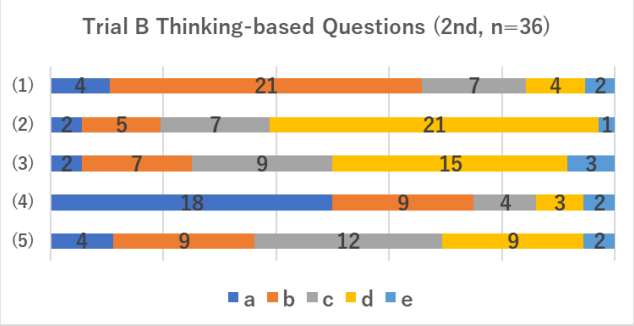


Figure 9 Students' answers to the thinking-based questions in Trial B (2nd-year students)

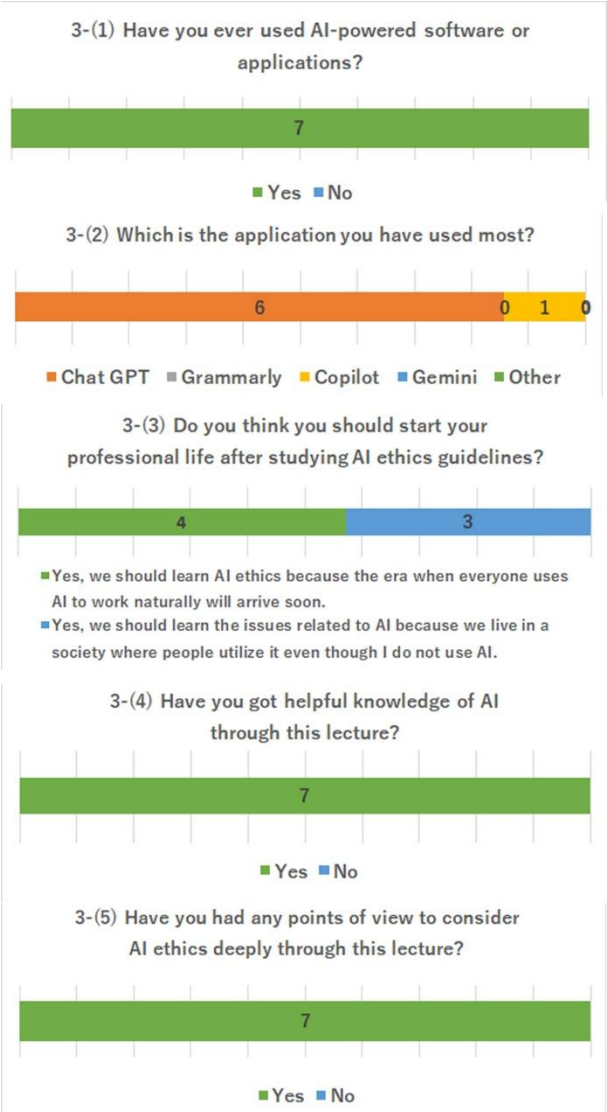


Figure 10 Students' answers to the questionnaire in Trial B (5th-year students)

EVALUATING RAG-BASED CHATBOT PERFORMANCE IN STEM AND SOCIAL SCIENCES: A METRIC-DRIVEN COMPARISON

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Students are becoming more familiar with ChatGPT, a generative AI chatbot that provides quick access to information, facilitates Q&A interactions, and offers task-related feedback. However, ChatGPT's tendency to generate hallucinatory responses presents learning challenges. To address this, the TP AI Assistant, a Retrieval-Augmented Generation (RAG)-based chatbot, was developed to provide a structured and reliable learning environment. Unlike ChatGPT, it delivers accurate, context-specific information aligned with learning objectives, ensuring relevance to coursework.

Deployed over an academic semester starting in October 2024, the TP AI Assistant supported approximately 611 Year 1 STEM students and 350 Year 1 Humanities and Social Science students at Temasek Polytechnic, Singapore. This study examines chatbot engagement metrics to analyze usage patterns across the two diverse disciplines. Data collected from chatbot logs was transformed into key metrics, including response rate, confusion rate, containment rate, conversation length, and duration. These metrics assessed engagement levels, the chatbot's role in personalized learning, and its reliability in supporting the varied learning needs across disciplines. Findings revealed that regardless of discipline, chatbot engagement depended on several common factors, including the students' familiarity with the chatbot, the perceived usefulness of the responses, reliability and user experience provided by the chatbot. Interaction patterns suggested that students engaging in more generative tasks, such as programming applications, may have reached conversation dead ends more frequently as their queries extended beyond the RAG's knowledge base. In contrast, students who appeared to seek factual, conceptual, and procedural support tended to have more sustained interactions. This suggests that while the RAG-based chatbot effectively provided targeted information at scale, it had limitations in handling tasks requiring broader adaptability.

This study underscores the importance of instructional design in shaping effective AI-assisted learning. Regardless of the subject area, a well-structured instructional design ensures that AI tools align with diverse learning needs, cognitive processes, and pedagogical strategies. It also advances the understanding of RAG-based chatbots in supporting discipline-specific learning needs, such as the need for multimodal RAG models and additional student support mechanisms, such as prompt engineering guidance and enhanced chatbot responses, particularly for STEM subjects like engineering, IT, and applied sciences, where visual representations are crucial for understanding complex concepts.

Keywords: *personalized learning, Retrieval-augmented generation (RAG), self-regulated learning, STEM, Social Science*

Introduction

The Covid-19 pandemic lockdowns highlighted the diverse needs of students, reinforcing the importance of personalized learning. Students not only faced academic challenges but also socio-emotional difficulties, such as maintaining motivation, building autonomy, and staying connected. Learning needs varied widely, including differences in pacing, preferred formats, and feedback preferences, emphasizing the demand for tailored educational approaches. Personalized learning, as defined by Gunawardena (2024), involves adapting instruction to individual strengths, needs, and interests while allowing choice, voice, and flexibility in achieving learning outcomes. Advances in AI now offer new ways to meet these needs, fostering greater equity and inclusivity.

One promising application of AI in education is through dynamic question-and-answer interactions, essential for clarifying concepts and deepening understanding. Research has shown that student-generated questions promote critical thinking and inquiry-based learning, aligning with Vygotsky's social constructivism (1978), which emphasizes the importance of interactive learning. AI chatbots can facilitate such interactions at scale, enabling self-paced, reflective conversations while providing instant, tailored responses. This approach supports the inquiry-driven nature of learning in virtual and blended classrooms, promoting both engagement and academic growth.

Developing effective AI chatbots has become a priority. AI chatbots generally fall into two types: retrieval-based and generation-based. Retrieval-based chatbots respond based on a set of predetermined answers, ensuring relevance but sometimes lacking depth, especially when addressing nuanced or discipline-specific questions. In contrast, generation-based chatbots create responses from a pre-trained knowledge base, offering flexibility but occasionally producing less accurate replies. Balancing these strengths and limitations, the Retrieval-Augmented Generation (RAG) architecture (Lewis et al., 2020) combines both approaches, retrieving accurate information while generating context-aware responses. Tapping into its possibilities, Temasek Polytechnic (TP), one of the five public polytechnics in Singapore, has also implemented a RAG-powered chatbot, the TP AI Assistant.

However, while the RAG model improves chatbot performance by merging retrieval and generation methods, its effectiveness can vary significantly across academic disciplines. Based on the findings by Shanahan and Shanahan (2008), preliminary evidence suggests that experts in disciplines such as mathematics, chemistry, and history engage with texts in markedly different ways. These differences point to the need for distinct comprehension strategies tailored to each discipline and highlight that different academic fields demand unique approaches to thinking, reasoning, and communication. In STEM fields, students must possess strong problem-solving and critical-thinking skills, enabling them to plan, analyze, and develop processes and projects that address real-world problems (Gao et al., 2020; Han et al., 2021). Similarly, the TPACK framework (Mishra & Koehler, 2006) highlights the importance of integrating content knowledge with pedagogical approaches specific to each subject. More recent studies have also emphasized the need for discipline-specific AI applications in education.

VanLehn's (2005) work on Intelligent Tutoring Systems highlights that AI systems in STEM disciplines need to provide structured support to help students develop higher-order thinking skills essential for deep comprehension and reasoning. On the other hand, Olatunbosun et al. (2024) draw attention to the challenges posed by the technical complexity of STEM content itself, noting that AI and Machine Learning applications must be able to interpret and respond to highly specialized, domain-specific knowledge in order to support effective learning. In contrast, Mayfield and Black (2020) argue that in writing tasks, AI support should emphasize learner autonomy and preserve the writer's unique voice, advocating for guidance that nurtures reflection and development rather than directive scaffolding. Qu et al. (2024) also pointed out the differences in how students from varying disciplines interpret and interact with GenAI chatbot responses. These findings highlight the need to conduct comparative analysis using unbiased chatbot interaction logs to better understand how RAG chatbots perform across different academic contexts and identify areas for improvement in discipline-specific applications.

The TP AI Assistant: Technology Description

The core of the TP AI Assistant system revolves around the RAG architecture, which integrates retrieval-based and generation-based AI capabilities to enhance the chatbot's performance. It was developed by leveraging various Azure services to create a robust, secure, and efficient chatbot system. The process begins with subject leaders uploading training materials to a cloud-based collaboration platform under Microsoft. To ensure centralized access, indexing, and retrieval while minimizing manual effort and errors, an Azure Logic App then automatically copies these documents to a secure Storage Account. This setup not only streamlines document management but also supports efficient data processing.

Once the documents are securely stored, the Logic App triggers an indexer within AI Search, making the uploaded content retrievable. Indexing involves analyzing the text, extracting key phrases, and creating structured representations that the system can quickly search through. This indexing process is essential for efficiently retrieving relevant information later on. The RAG process works as follows:

Indexing: After the documents are uploaded and processed, the AI Search component creates an index of the data, making it searchable. The indexer converts raw text into structured data, allowing for fast lookups.

Retrieval: When a user poses a question via the ChatGPT-like web application, the system first searches the indexed data to find the most relevant content. This step ensures that the response is grounded in the existing knowledge base, maintaining accuracy and relevance.

Augmenting the Prompt: The retrieved content is then used to formulate a context-enhanced prompt for the Azure OpenAI model. By incorporating the most relevant information into the prompt, the model generates responses that are not only contextually accurate but also enriched with precise data.

Generation: Finally, the OpenAI model uses the augmented prompt to generate a well-formed response, which is delivered back to the user through the web app.

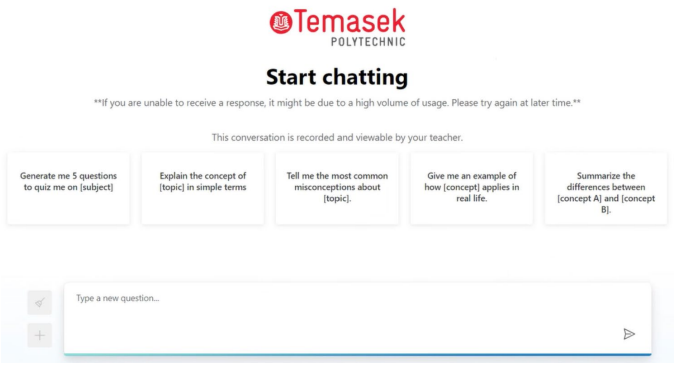


Fig. 1. User interface of the TP AI Assistant.

To facilitate user access, a ChatGPT-like web application (see Fig. 1) was designed and hosted on Azure App Service. Users must authenticate through Microsoft Entra ID to ensure secure and authorized

access to the platform. This authentication layer guarantees that only verified users can interact with the assistant. All interactions, including both user questions and assistant responses, are logged and stored securely in Cosmos DB. This database not only keeps a record of conversations for analysis but also supports continuous improvement by allowing developers to assess chatbot performance.

The entire architecture is primarily built within the Singapore Government on Commercial Cloud (GCC) environment, where most Azure services are hosted, except for Azure OpenAI Service, which resides outside Singapore. To maintain robust security and confidentiality, all data transfers and storage operations are secured using industry-standard encryption protocols, adhering strictly to regulatory compliance and data protection policies.

The Study

The study took place at Temasek Polytechnic (TP), focusing on pre-employment training (PET) students. A total of 611 Year 1 students from six different diplomas within the School of Informatics & IT (IIT), representing the STEM disciplines, and 350 Year 1 students from three different diplomas within the School of Humanities and Social Sciences (HSS), representing the social science disciplines. The gender distribution for IIT was approximately 70% male and 30% female, whereas for HSS, it was about 15% male and 85% female. The median age of participants was 17, reflecting the typical demographic profile of Singaporean youth, comprising a diverse mix of ethnicities such as Chinese, Malay, Indian, and Eurasian.

During the academic semester starting in October 2024, students were granted access to the TP AI Assistant. The respective subject teams conducted an induction to familiarize participants with the features and functions of the chatbot.

Table 1. Purpose Of the TP AI Assistant by Discipline

	STEM	Social Science
Subject	App Development	Effective Communication
Objective	Enhance database design for a project	Answer FAQs related to subject administration
Training materials for RAG	Theoretical concepts of normalization and database anomalies & practical SQL operations	Lecture slides, assessment specification document and student handbook
Remarks	Students experienced the 1st iteration of the TP AI Assistant in the April 2024 academic semester in foundational programming subject.	In the same subject, students were also given access to a separate chatbot, built on a different platform, which provided feedback on their report writing.

Data and Techniques

The activity logs from the TP AI Assistant were extracted from Cosmos DB, covering the period from 21 October 2024 to 26 January 2025. This timeframe was selected as it encompassed the conclusion of the chatbot-supported assessment for IIT students and for both subjects, the subsequent two weeks were reserved for consultations and in-class assessments, during which no formal lessons were conducted. All student identifiers were removed and replaced with numeric participant IDs to ensure anonymity. The logs comprised four main elements: 'timestamp' (indicating the precise date and time of each interaction), 'ID' (an anonymized participant number), 'content' (the text exchanged during chatbot sessions), and 'role' (to indicate whether the message came from the student or the chatbot).

Key Chatbot Metrics

Key chatbot usage and performance metrics were used to guide the comparative analysis, as detailed in Table 2. Among these metrics, the frequency of the default fallback message "The requested information is not available in the retrieved data. Please try another query or topic." was also examined as an indicator of user engagement.

Table 2. Key Chatbot Metrics

Metric	Description
Total interactions	Total number of queries made by users
Total sessions	A session starts when a user sends a message and ends after inactivity or when the chat is closed. Total such conversations made by users
Conversation length	Average number of queries per session. *Total interactions ÷ Total sessions*
Duration	Time spent per chatbot session.
Adoption rate	Percentage of cohort who used the chatbot
Retention rate	Percentage of users who have used on repeated occasions over a given period
Single turn rate	Percentage of sessions with only one query
Multi-turn rate	Percentage of sessions with more than one query in context
Containment rate	Percentage of sessions successfully resolved without the fallback message
Confusion rate	*Total fallback responses ÷ total interactions *100%*

Results

Building on the earlier table that outlined the key metrics, the activity logs provided the actual values for the IIT and HSS participants as depicted in Table 3.

Table 3. Usage Patterns by Discipline

Metric	STEM	Social Science
Total interactions	342	275
Total sessions	114	99
Conversation length	3	2.78
Duration (sec)	242,468	106,560
Adoption rate (%)	14.6	16.0
Retention rate (%)	10.1	30.4
Single turn rate (%)	33.3	41.4
Multi-turn rate (%)	66.7	58.6
Containment rate (%)	67.5	48.5
Confusion rate (%)	52.3	56.4

STEM students appeared to demonstrate higher engagement with the chatbot, reflected by a total of 342 interactions and 114 sessions; compared to 275 interactions and 99 sessions by Social Science students. STEM students also exhibited longer usage durations (242,468 sec) than Social Science students (106,560 sec), and their conversations were slightly longer, averaging 3 interactions per session compared to 2.78 in Social Science which is approximately 23 times higher. Both disciplines displayed higher multi-turn interactions than single-turn interactions.

The containment rate was higher for STEM students (67.5%; higher is better) than for Social Science students (48.5%). Meanwhile, confusion rates were relatively similar: 52.3% for STEM and 56.4% for Social Science. Social Science students showed a slightly higher adoption rate (16.0%) compared to STEM students (14.6%). Retention was also higher among Social Science students (30.4%) than STEM students (10.1%).

Discussion

The differences in engagement, retention, and interaction patterns across disciplines point to underlying factors that may have shaped how students from different academic contexts engaged with the TP AI Assistant.

Engagement Intensity: It was also observed that the STEM students exhibited longer, more exploratory interactions. This suggests that they were more inclined to engage in extended dialogues with the chatbot, possibly driven by the technical complexity of their queries and the TP AI Assistant could help to address- to implement a technical solution, which often required multiple exchanges to reach a resolution. In contrast, conversations by Social Science students tended to be shorter, with a lower average number of turns per session. This pattern can partly be attributed to the chatbot's original design, which focused on answering administrative FAQs that address non-academic or logistical aspects related to the subject, including class schedules, assessment formats, and submission procedures, leading to quicker, task-oriented exchanges. Additionally, analysis of chatbot responses revealed that some Social Science students engaged the chatbot to rewrite parts of their assignments, receiving immediate outputs that reinforced brief interactions and instant gratification.

Meanwhile, STEM students exhibited longer, more sustained dialogues, as the TP AI Assistant implemented gatekeeping mechanisms that refused to provide direct coding solutions. This approach encouraged deeper, multi-step problem-solving conversations, aligning with the more complex and iterative nature of technical queries.

Students often required more than one exchange to fully address their queries, reflecting the need for clarification, elaboration, or step-by-step support during the interaction. In RAG-based chatbots, where users pose open-ended questions rather than selecting from a fixed menu, deeper support for self-regulation is often needed. Once again, we observed STEM students required more multi-turn interactions, as the complexity of technical queries and the nature of support provided by the chatbot demanded iterative problem-solving rather than immediate answers.

Query Resolution Efficiency: The higher containment rate among STEM students may stem from the more structured and specific nature of their queries in the IT domain, which aligned well with the training materials provided and the RAG system's retrieval capabilities. The lower containment rate in Social Science students reflects the challenges the RAG chatbot faced when handling subjective, contextually layered queries common in Social Sciences disciplines. The slightly higher confusion rate in Social Science also suggests that the system may struggle more when responding to open-ended or interpretive questions. In addition to this inherent complexity, another possible factor is that the same group of Social Science students was also introduced to a second chatbot during the same period, which was intended for providing feedback. This overlap may have led to confusion over which chatbot to use for which purpose, resulting in mismatched queries to the TP AI Assistant and subsequently affecting the retrieval accuracy.

Adoption and Sustainability: Social Science students appeared to show a slightly higher adoption rate than the STEM students suggest they were more open to trying the system, likely driven by the need for administrative clarity such as the defined boundaries on the Dos and Don'ts for assessments, before they could continue with their tasks. Furthermore, the higher retention rate among Social Science students than the STEM students indicates that they were more willing to revisit the TP AI Assistant, even when queries were not fully resolved. This trend is notable given the lower containment rate and slightly higher confusion rate were observed in these Social Science students, suggesting that they students valued the

assistant's support, despite occasional retrieval mismatches.

Conversely, although STEM students demonstrated higher engagement intensity, including longer sessions, more multi-turn conversations, and a higher containment rate, they exhibited lower retention. This paradox highlights that even when queries were successfully addressed in individual sessions, STEM users were less inclined to return. The relatively lower confusion rate in STEM indicates that while the assistant was able to handle the queries well in general, the interaction remained largely transactional, which could be a characteristic of STEM discipline, as discussed by Fairhurst et al. (2023). The combination of high containment but low retention among STEM users suggests that once technical issues were resolved, there was little perceived need for further engagement, possibly compounded by fatigue from their academic workload, as reflected in the students' subject evaluation survey. This survey, regularly conducted at the end of each semester in TP, gathers feedback on educational quality across subjects. These findings emphasize the need for discipline-specific refinements: while Social Science students may benefit from improved information synthesis to reduce confusion, STEM users may require strategies that promote relational use, encouraging continued engagement beyond immediate task resolution, as echoed by Kunze and Rutherford (2022).

Other Factors Influencing Performance: Building upon the observed engagement patterns, resolution outcomes, and adoption trends derived from unbiased metrics, and considering the broader learning context, several additional factors were identified that may have influenced students' interactions with the TP AI Assistant. Students' familiarity with the chatbot appeared to affect their ability to engage effectively, particularly in cases where overlapping chatbot services introduced confusion. Perceptions of the chatbot's usefulness and reliability, reflected through containment and confusion rates, also played a role in shaping sustained use. Furthermore, the observed interaction patterns may suggest that the nature of students' tasks influenced the quality of their engagement. For instance, students involved in more complex, generative tasks—such as programming or application design—could have been more likely to encounter conversation dead ends, as reflected in longer sessions with lower containment for some users. Meanwhile, students seeking factual, conceptual, or procedural support appeared to maintain more sustained interactions, which were more readily addressed within the RAG system's retrieval scope. However, these interpretations remain speculative and would require direct analysis of the response texts for confirmation. These patterns suggest that while the RAG-based chatbot effectively provided targeted information at scale, it faced limitations when supporting broader, more adaptive learning tasks, underscoring the need for continuous enhancement of retrieval adaptability and user support strategies.

Conclusion

This study enhances our understanding of how students from various academic disciplines interact with a RAG-based chatbot designed for personalized learning, promoting self-directed acquisition of knowledge and skills. By leveraging Azure services, the proposed RAG approach demonstrates scalability and reliability, addressing the need for an effective learning tool that minimizes time commitment for both students and lecturers. Its ability to adapt to diverse subject areas, support discipline-specific learning needs, and generate data for learning analytics, while maintaining consistent performance, positions it as a valuable asset for AI-driven educational practices.

The RAG-based TP AI Assistant was evaluated across different academic contexts, revealing distinct discipline-specific usage patterns. Generally, STEM discipline was characterized by higher containment, longer session duration, and lower retention, while Social Science discipline exhibited shorter sessions, higher retention, and simpler conversations. Conversation length and session duration were significantly higher in STEM, aligning with more complex, multi-step problem-solving, whereas Social Science users engaged in briefer, often exploratory interactions. Despite the higher containment rate in STEM, the slightly higher confusion rate observed in Social Science highlights the challenges RAG systems face when addressing the subjective, interpretive nature of social sciences queries. These findings emphasize that instructional design must not only address cognitive load and task complexity but also consider how different disciplines approach knowledge acquisition and engagement with AI tools.

Moving forward, the results suggest several areas for enhancing RAG-based educational chatbots. In STEM domains, the need for multimodal RAG models becomes evident, as visual representations and richer content delivery can better support the comprehension of complex technical concepts. Additionally, providing students with prompt engineering guidance and refining chatbot responses could strengthen self-directed learning, especially for technically demanding fields like engineering, IT, and applied sciences. For Social Science disciplines, improvements in context handling and retrieval adaptation could enhance user experience, supporting sustained engagement even when definitive answers are not always available. Overall, this study underscores that effective AI-assisted learning requires careful instructional design, ensuring that AI tools are pedagogically aligned and adaptable to diverse disciplinary contexts.

References

Fairhurst, N., Koul, R., & Sheffield, R. (2023). Students' perceptions of their STEM learning environment. *Learn. Env. Research*, 26(3), 977–998.

Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *Int. J. STEM Educ.* 7(24).

Gunawardena, M., Bishop, P., & Aviruppola, K. (2024). *Personalized learning: The simple, the complicated, the complex and the chaotic*. Teach. Educ., 139, 104429.

Han, J., Kelley, T., & Knowles, J. G. (2021). Factors influencing student STEM learning: self-efficacy and outcome expectancy, 21st century skills, and career awareness. *J. STEM Educ. Res.* 4, 117–137.

Kunze, A. & Rutherford., T. (2022). Students' Discipline Specific Perceptions of Learning Practices. *Intl. J. Teach. Learn. Higher Edu.,* 33(2), 53-167.

Lewis, P., E. Perez, E, Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., Küttler, N., Lewis, M., Yih, W., Rocktäschel, T., Riedel, S., & D. Kiela. (2020). *Retrieval-augmented generation for knowledge-intensive NLP tasks.* Ann. Neural Inf. Pro cess. Syst. (NeurIPS), 33, 9459–9474.

Mayfield, E. & Black, A.W. (2020). Should You Fine-Tune BERT for Automated Essay Scoring? *Workshop on Innovative Use of NLP for Building Educational Applications*.

Mishra, P. & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teach. Col. Rec., 108*(6), 1017–1054.

Olatunbosun, J. O. & Nwankwo, C. A. (2024). Integrating AI and machine learning in STEM education: Challenges and opportunities. *Comput. Sci. IT Res. J.*, 5(8), 7–8.

Qu, Y., Tan, M.X.Y. & Wang, J. (2024). Disciplinary differences in undergraduate students' engagement with generative artificial intelligence. *Smart Learn. Environ.* 11, 51.

Shanahan, T. & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Edu. Rev., 78*(1), 40–59.

VanLehn, K. (2005). The behavior of tutoring systems. *Intl. J. AI Ed*., 16(3), 227–265.

Vygotsky, L. (1978). *Mind in Society*. Massachusetts: Harvard Univ. Press.

A COMPARATIVE STUDY OF ASSESSMENT QUESTION QUALITY: AI-GENERATED VERSUS HUMAN-AUTHORED IN BUSINESS STATISTICS

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While generative artificial intelligence (AI) is increasingly used in education, its application to assessment design requires careful evaluation. This paper addresses this need by presenting the findings of a research project that compares the validity and reliability of AI-generated business statistics assessments with those created by subject matter experts (unit leaders and moderators). Our research aims to determine if AI can effectively support the creation of high-quality assessments in this domain. This study compared business statistics assessments created by human experts and generative AI. Two groups of over 100 Diploma in IT students (2023 and 2024 cohorts) served as the control and experimental groups, respectively. The control group completed expert-created assessments, while the experimental group completed AI-generated assessments. Both assessments covered identical business statistics topics, learning outcomes, and difficulty levels. Correlation analysis was used to determine if both assessments measure the same construct. The reliability coefficient Cronbach's alpha was calculated to assess the internal consistency of each assessment. The discrimination index was used to compare the effectiveness of individual questions in differentiating student performance. The results of this study suggest that generative AI can be a valuable tool for assessment creation. The authors found that AI-generated assessments, when guided by expert input, achieve comparable levels of validity and reliability to those developed by subject matter experts. This finding has significant implications for educators, as it demonstrates the potential for efficiently creating diverse and effective assessment questions spanning various statistical topics, difficulty levels, and learning outcomes. This can free up educators' time to focus on other critical aspects of teaching and learning. Generative AI offers a promising avenue for streamlining the assessment question creation process. However, our research demonstrates that the expertise of unit leader and moderator remains crucial for guaranteeing the quality, relevance, and alignment of assessments with learning objectives.
Building upon these findings, the authors will share our experiences and recommendations for using AI prompts to generate business statistics assessment questions, with a focus on achieving appropriate difficulty, question variation, and alignment with learning outcomes. Further research is essential to develop a robust framework, potentially in the form of a playbook, for evaluating and ensuring the quality of AI-generated assessments across different subject areas.

Keywords: *Generative AI Assessment, Assessment Validity and Reliability, Business Statistic Assessment, Co-Creation of Assessment, Comparative Assessment Study.*

Introduction

The rapid advancement of generative (AI) has ushered in a new era of possibilities across various sectors, including education. Among the most intriguing applications is the potential for AI to revolutionize assessment design. However, the integration of AI into such a critical component of learning necessitates rigorous evaluation to ensure the maintenance of quality and validity. This research project tackles this pressing need through a comparative study of assessment question quality, with a specific focus on business statistics, a core unit in the School of IT's freshman curriculum. We aim to investigate whether AI-generated assessments can achieve comparable levels of validity and reliability to those created by experienced subject matter experts. This study was motivated by the desire to explore the potential of AI as a tool to streamline the assessment question creation process, thereby freeing up valuable time for educators to focus on other crucial aspects of teaching and learning.

Literature Review

The use of AI to generate assessment questions is a burgeoning area of research. Several studies have explored AI's potential in creating diverse and challenging assessment items, while also addressing concerns about capturing subject matter nuances and aligning with pedagogical goals. For instance, a study by Owen et al (2023) discusses AI's capability to generate

various test items and emphasizes the necessity for rigorous evaluation to ensure quality and relevance. However, concerns remain regarding AI's ability to accurately capture subject matter nuances and ensure alignment with pedagogical goals. Several journal articles (e.g., Moorhouse, Yeo & Wan, 2023; Karadag, 2023; Xia et al., 2024) discuss these challenges, emphasizing the need for rigorous oversight. Therefore, rigorous evaluation and validation are essential to determine the effectiveness of AI-generated assessments. Additionally, Rezigalla (2024) highlights the importance of validating AI-generated assessments to maintain their reliability and effectiveness. Given the necessity of rigorous validation in AI-generated assessments, researchers have increasingly turned to comparative studies to benchmark AI's effectiveness against human-authored content. Durak, Egin & Onan A (2025) and Law et al (2025) have examined AI-generated essays, code, and other forms of content, often revealing varying degrees of success. These findings highlight the importance of context in determining the appropriateness of AI-generated materials. According to Bowen & Watson (2024), in the domain of assessment, it is critical to determine whether AI can produce questions that rival the quality and effectiveness of those created by experienced educators. Despite AI's ability to generate diverse assessment items, subject matter expertise remains indispensable in ensuring their accuracy and alignment with pedagogical goals. Studies (e.g. Owen et al., 2023; Rezigalla, 2024) emphasize the need for rigorous validation, which underscores the role of human oversight. Ross (2024) further argues that AI should function as an assistive tool rather than replace educators, advocating for a collaborative approach that maximizes both AI efficiency and human expertise.

Methodology

This research project employed a comparative experimental design to investigate the quality of AI-generated versus human-authored business statistics assessments. The methodology was structured to ensure a rigorous and systematic evaluation of validity, reliability, and question discrimination. Two cohorts of Diploma in IT students from the school, each exceeding 100 students, participated in the study. The 2023 cohort served as the control group, while the 2024 cohort served as the experimental group. The study focused on e-assessment of three topics within the business statistics unit, providing a controlled environment to systematically compare assessment outcomes. For the control group of human-authored assessment, subject matter experts, which are the unit leaders and moderators, developed the assessments which were designed to align with the unit's learning outcomes, covering the three specified business statistics topics at predetermined difficulty levels. For the experimental group of AI-generated assessments, Google Gemini was utilized to create assessments. The AI was prompted with specific parameters, including the same business statistics topics, learning outcomes, and difficulty levels as the human-authored assessments. Expert review and guidance were incorporated into the AI-generated assessment creation process to ensure alignment with educational standards. The prompts given to the AI were carefully crafted to try and match the style and content of the human created assessments. Both sets of assessments were meticulously designed to ensure equivalence in terms of content coverage, learning outcomes, and difficulty levels. This was crucial for a valid comparison.

Student performance on both human-authored and AI-generated assessments was collected through the Brightspace Learning Management System (LMS), including detailed data on each question, such as correct and incorrect responses. Correlation analysis was performed to determine the extent to which both assessments measured the same underlying construct. A high correlation coefficient would indicate that both assessments are measuring the same statistical knowledge and skills. Cronbach's alpha was calculated to assess the internal consistency of each assessment. This statistical measure indicates the degree to which the items within each assessment are consistently measuring the same construct. The discrimination index was used to evaluate the effectiveness of individual questions in differentiating student performance. This metric allowed for a comparison of the quality of individual questions generated by AI versus those created by human experts. In addition, the prompts used in generative AI and the modifications made to the AI generated questions by human experts are analysed to identify patterns and best practices.

Results and Findings

The comparative analysis of assessment question quality between AI-generated and human-authored assessments revealed several key findings. Firstly, the correlation analysis of student performance between the two assessment types demonstrated a strong positive correlation (Pearson correlation coefficient $r = 0.9$). This indicates that both assessment methods effectively measured the same underlying construct of business statistics knowledge and skills.

Secondly, the Cronbach's alpha values for both the AI-generated and human-authored assessments were found to be within an acceptable range, indicating a reasonable level of internal consistency. Specifically, the human-authored assessment yielded a Cronbach's alpha of 0.77, while the AI-generated assessment produced a Cronbach's alpha of 0.78. This suggests that both assessment types maintained a similar level of reliability in measuring the targeted learning outcomes.

Thirdly, the discrimination index analysis showed comparable performance between the two assessment types. The average discrimination index for human-authored questions was 0.46, and for AI-generated questions, it was 0.43. While slight variations were observed in individual question discrimination, the overall distribution of discrimination indices across both sets of assessments was similar. Both of the discrimination indices are considered high, indicating that both human-authored and AI-generated questions

effectively differentiated between high- and low-performing students. This suggests that AI-generated questions were as effective as human-authored questions in differentiating between high and low-performing students.

Finally, the analysis of the prompts used for AI generation and the subsequent modifications made by human experts revealed several patterns. Prompts that explicitly included specific learning outcomes, difficulty levels, and examples yielded higher-quality AI-generated questions. Human modifications primarily focused on refining question clarity, addressing minor content inaccuracies, and ensuring alignment with the specific pedagogical approach of the unit.

Discussion

The strong positive correlation between student performance on AI-generated and human-authored assessments indicates that generative AI, when properly guided, can produce assessments that align with the same underlying construct as those created by subject matter experts. This finding aligns with the growing body of research exploring the potential of AI in educational assessment. The comparable Cronbach's alpha values further reinforce the reliability of AI-generated assessments, demonstrating their ability to consistently measure student knowledge and skills. The similar discrimination indices observed across both assessment types suggest that AI-generated questions are capable of effectively differentiating student performance. This is a critical aspect of assessment quality, as it ensures that assessments can accurately identify students who have mastered the learning objectives from those who have not. The slight variations in individual question discrimination highlight the importance of expert review and refinement, even when using advanced AI tools.

The analysis of AI prompts and human modifications provides valuable insights into the effective use of generative AI in assessment creation. The success of prompts that explicitly included learning outcomes and difficulty levels underscores the importance of clear and specific instructions. This aligns with best practices in prompt engineering for educational applications. The human modifications, which focused on refining clarity and accuracy, emphasize the continued need for subject matter expertise in ensuring the quality and relevance of AI-generated assessments.

The findings of this action research have several practical implications for educators and assessment designers. Firstly, generative AI tools like Google Gemini can be effectively utilized to create high-quality assessments, potentially reducing the time and effort required for assessment development. Secondly, the importance of expert review and guidance in the AI-generated assessment process cannot be overstated. While AI can generate questions that align with learning outcomes and difficulty levels, human expertise is essential for ensuring clarity, accuracy, and alignment with pedagogical approaches. However, it is important to acknowledge the limitations of this study. The research was conducted within a specific context, involving Diploma in IT students and focusing on three topics within a business statistics unit. Future research could explore the generalizability of these findings across different disciplines, educational levels, and assessment formats. Additionally, the study focused on the quality of individual assessment questions. Future research could investigate the effectiveness of AI-generated assessments in promoting student learning and engagement.

Conclusions

This action research confirms that generative AI, when guided by expert input, produces assessments with strong correlation, comparable Cronbach's alpha, and similar discrimination indices to human-authored assessments. This underscores AI's potential as a valuable tool in assessment creation, provided it functions in close collaboration with subject matter experts to ensure quality, relevance, and alignment with learning objectives. Moving forward, educators must proactively develop robust frameworks for evaluating AI-generated assessments, ensuring pedagogical principles and student learning remain paramount. This study's findings will directly inform the creation of a practical playbook, empowering educators to confidently integrate and validate AI-driven assessment practices.

References

Bowen, J. A., & Watson, C. E. (2024). *Teaching with AI: A practical guide to a new era of human learning*. Johns Hopkins University Press.

Durak, H.Y, Egin, F & Onan, A (2025). A Comparison of Human-Written Versus AI-Generated Text in Discussions at Educational Settings: Investigating Features for ChatGPT, Gemini and Bing AI. *Wiley Online Library*. https://doi.org/10.1111/ejed.70014

Moorhouse, B. L., Yeo, M. A., & Wan, Y. (2023). Generative AI tools and assessment: Guidelines of the world's top-ranking universities. *Computers and Education Open, 5, 100151.* https://doi.org/10.1016/j.caeo.2023.100151

Karadag, N. (2023). The impact of artificial intelligence on online assessment: A preliminary review. *Journal of Educational Technology and Online Learning 6(4).* https://www.researchgate.net/publication/374748911_The_impact_of_artificial_intelligence_on_online_assessment_A_preliminary_review

Law, A. Kk., So, J, Lui, C.T, Choi Y.F., Cheung, K.H., Hung, K. KC & Graham, C.A. (2025). AI versus human-generated multiple-choice questions for medical education: a cohort study in a high-stakes examination. *BMC Med Educ. 25(1):208.*

AI versus human-generated multiple-choice questions for medical education: a cohort study in a high-stakes examination - PubMed

Ng, S.H.S., Chan, H.Y., Wong, J.H.K, Sam, L. & Privitera,, A.J. (2024). A Scoping Review of the Use of Generative AI in Assessment in Higher Education. (PDF) A Scoping Review of the Use of Generative AI in Assessment in Higher Education

Owen, V.S., Abang, K.B., Idika, D.O., Etta, E.O. & Bassey, A.B. (2023). Exploring the potential of artificial intelligence tools in educational measurement and assessment. *Eurasia Journal of Mathematics, Science and Technology Education 19(8), em2307.* Exploring the potential of artificial intelligence tools in educational measurement and assessment - Eurasia Journal of Mathematics, Science and Technology Education

Rezigalla, A.A. (2024). AI in medica education: uses of AI in construction type A MCQ. *BMC Medical Education.24(1):320.* AI in medical education: uses of AI in construction type A MCQs - PubMed

Ross, D (2024). *The Role of Human Expertise in AI-Powered Assessments*. Braide.ai. The Role of Human Expertise in AI-Powered Assessments — Braide.ai

Xia, Q., Weng, X., Ouyang, F., Lin, T. J., & Chiu, T. K. F. (2024). A scoping review on how generative artificial intelligence transforms assessment in higher education. *International Journal of Educational Technology in Higher Education, 21, 40.* https://doi.org/10.1186/s41239-024-00468-z

PAIRING GENERATIVE AI AND SERVICE-LEARNING TO DEVELOP 21ST CENTURY COMPETENCIES IN GEN Z STUDENTS

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The integration of artificial intelligence (AI) skills into education is increasingly important. In Singapore, the Ministry of Education's "Transforming Education through Technology" Masterplan 2030 emphasises developing students' 21st century competencies (21CC). This action research project explored combining the "Problem, AI, Interaction, Reflection" (PAIR) framework with service-learning (S-L) pedagogy to teach AI skills. The PAIR framework, developed by King's College London, guides students in using generative AI tools. The project aimed to enhance AI literacy, critical thinking, and ethics among post-secondary students.

The project was implemented in a module for all Year 1 engineering diploma students from Ngee Ann Polytechnic (NP), Singapore, covering topics including risk management, recognized by Singapore's Workplace Safety and Health Council as bizSAFE Level 2 (bSL2). Using S-L pedagogy, students applied bSL2 skills to serve community stakeholders. They planned engagement activities, assessed risks, implemented a risk management plan, and delivered the project. The PAIR framework was integrated at key milestones: problem formulation, AI tool selection, interaction, and reflection.

In the problem formulation stage, students identified missing information for their S-L project. During AI tool selection, they compared outputs from two generative AI tools and chose the more useful one. In the interaction stage, they used the selected AI tool to plan activities with safety considerations. After project delivery, the reflection stage involved comparing the actual implementation with the AI-planned version to evaluate strengths and weaknesses. A survey with 794 students revealed that 86% felt they learned to critically review AI outputs and became more aware of AI limitations. However, only 76% attributed their critical thinking skills development to the AI tool, while 10% did not find PAIR alone sufficient for this skill development. The results also highlighted that while 75% of students were concerned with plagiarism when using Gen AI tools, only 57% of them were bothered by privacy and security matters. This may potentially heighten their exposure to online risks and is an area worth exploring.

Keywords: *AI literacy, critical thinking, PAIR framework, service-learning*

Introduction

The emergence of generative artificial intelligence (Gen AI) tools—most notably marked by the release of ChatGPT in November 2022—has rapidly transformed the digital landscape. With over 100 million users just two months after its launch, as reported by Hu (2023), ChatGPT exemplifies how quickly Gen AI tools are becoming ubiquitous in both personal and professional spheres. As these tools continue to evolve and proliferate, there is growing recognition that the ability to understand, evaluate, and responsibly use Gen AI is no longer optional—it is essential.

In Singapore, this urgency is reflected in the Ministry of Education's (2023) "Transforming Education through Technology" Masterplan 2030, which emphasizes the development of emerging 21st century competencies (21CC), like critical thinking, information skills and civic literacy as a strategic thrust. Another strategic thrust in the masterplan is to strengthen the development of students' digital literacy and technology skills. AI literacy, in particular, has become a focal point, as students must be equipped not only to use Gen AI tools but also to understand their limitations, biases, and ethical implications. This would enable them to understand the characteristics of AI and leverage AI tools effectively for learning and daily living.

The initial implementation of the masterplan at the Polytechnic education level would affect students born around 2006, commonly referred to as Gen Z. Despite being labelled as digital natives, members of Gen Z often lack the deeper technological fluency required to navigate and leverage AI effectively, as reported by Marr (2022) in a Forbes report. Yet, Chan & Lee (2023) found that Gen Z students have expressed optimism about Gen AI's benefits, including enhanced productivity, efficiency and personalised learning, intending to use Gen AI for educational purposes. This disconnect justifies the need for educational institutions to proactively integrate AI education into their curricula—not just to teach technical skills, but to foster critical thinking and ethical awareness on the use of Gen AI tools.

To address this gap, recent studies have explored integrating Gen AI into high school education in various disciplines. Xie et al. (2024) have designed workshops and curricula to teach students about AI's capabilities, limitations, and ethical implications. In the study, teachers from various subjects, including humanities and STEM, participated in co-designing AI curricula, considering both technical skills and ethical debates. Chen et al. (2023) have engaged students in ChatGPT for knowledge building. These initiatives aim to develop AI literacy and critical thinking skills among youth. Zhou et al. (2023) highlighted concerns of AI-generated misinformation, which underscored the need for students to be critical of AI-generated information. Furthermore, while recognizing AI's potential benefits for learning, researchers also acknowledge challenges such as potential distractions and the need for mindful engagement with these tools in classrooms (e.g., Chen et al., 2023; Xie et al., 2024). To enable these mindful engagements, frameworks have been proposed to facilitate the integration of Gen AI into curricula. Su & Yang (2023) proposed a theoretical framework called IDEE for using Gen AI tools in education involving identifying desired outcomes, determining the level of automation, ensuring ethical considerations and evaluation effectiveness. Dickey et al. (2023) developed an AI-Lab framework for computer programming education, addressing concerns about over-dependence on Gen AI and fostering core skills development. Shanto et al. (2023) introduced PAIGE, a framework promoting assignment integrity while leveraging Gen AI's potential. Acar (2023) introduced the PAIR (Problem, AI, Interaction, Reflection) framework to guide students through a structured process of engaging with Gen AI tools, emphasizing problem formulation, exploration, experimentation, and reflection. While Acar (2023) did not anchor the PAIR framework to a particular learning theory, the emphasis of concrete experiences through problem formulation, abstract conceptualisation through AI tool selection, active experimentation through interaction, and reflective observations aligns to the four learning modes of Klob's (1984) experiential learning theory. A campus-wide study on the adoption of PAIR to purposefully infuse Gen AI into our curriculum at Ngee Ann Polytechnic was presented by Tan et al. (2024).

As part of the research, this study aims to evaluate the effectiveness of combining the PAIR framework with a project-based learning pedagogy to enhance students' AI literacy, critical thinking, and ethical reasoning. It also seeks to uncover how students perceive and engage with Gen AI tools, particularly in terms of academic integrity and the reliability of AI-generated content. By doing so, the study benefits both the students and teacher as well as contributes to the growing body of work on integrating Gen AI into education in a meaningful way.

Methodology

This study employed an action research approach as it allows for both individual self-study research and collaborative research, a flexibility that is useful when conducting research in such a nascent field. In addition, McCutcheon & Jung (1990) highlighted that through action research the intimate involvement of teacher as researcher and students as subjects in classroom activities would serve to inform and change the teacher's own practices in real-time, thereby directly benefitting the students. Zeichner (2007) has also reported that action research has the potential of contributing to both improvement of teaching practice and greater theoretical understanding.

The participants were 940 Year 1 engineering diploma students from Ngee Ann Polytechnic (NP), Singapore. These students were enrolled in a compulsory foundational module that spans across all engineering disciplines. As shown in Figure 1, the module includes a component on risk management, aligned with the Workplace Safety and Health (WSH) Council's bizSAFE Level 2 (bSL2) certification, which constitutes the discipline knowledge and skills to be taught. In addition, students were introduced to three human-centred design tools from LUMA Institute.

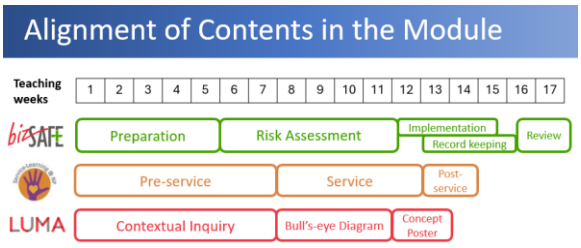


Figure 1: Existing contents in the S-L module.

Also shown in Figure 1 are the three stages of the service-learning (S-L) pedagogy that the module has adopted, which has its roots in project-based learning. Since 2016, S-L has been a signature pedagogy of NP and is modelled after the pedagogical principles defined by Bringle and Hatcher (1996). As such, S-L is a credit-bearing and discipline-based teaching approach that requires students to learn and demonstrate their acquisition of knowledge and skills through personal involvement in a service project that is intended to meet specific needs of a community.

The inclusion of AI literacy, critical thinking, and ethical awareness skills development was achieved through integration of the PAIR framework, as illustrated in Figure 2, into the bSL2 and S-L curricula.

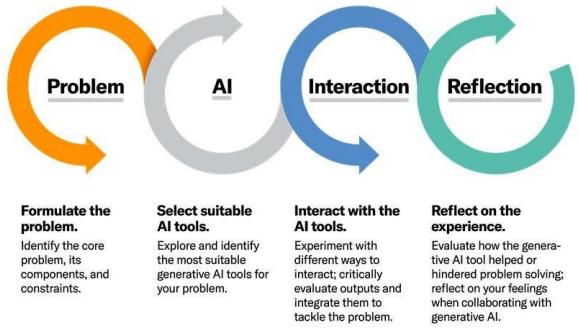


Figure 2: PAIR framework guidance by Acar (2023).

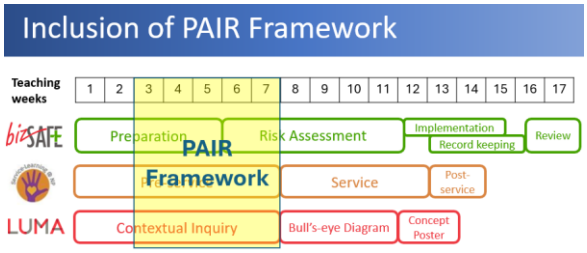


Figure 3: Inclusion of PAIR Framework in the module.

As shown in Figure 3, the PAIR framework was introduced to the students in Week 3 of the semester and spanned over 5 weeks. The four steps of the PAIR framework were integrated at four key milestones of the S-L project as shown in Figure 4.

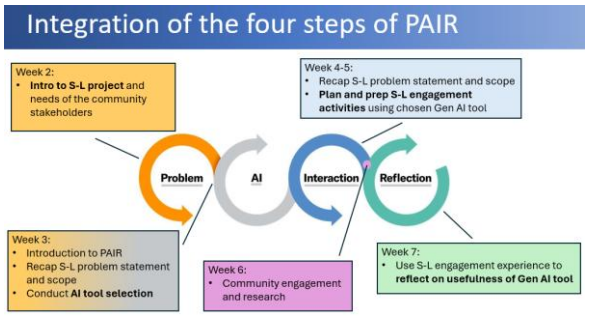


Figure 4: Integrating the four steps of PAIR.

1. Problem Formulation: Preparations for this step begun in Week 2 when students were introduced to the S-L project and needs of the community stakeholders. This was done so that by Week 3 students would have a better grasp of the scope and intent of the S-L project and thus be better prepared to identify gaps in their understanding of the community stakeholders and project.
2. AI Tool Selection: After students were introduced to the PAIR framework in Week 3 and had formulated the problem from the S-L project, they were instructed to test two Gen AI tools that they considered appropriate and useful for their research. Students then compared outputs from these two Gen AI tools, evaluated their relevance and comprehensiveness, and selected one that they considered to be better for further use.
3. Interaction: In Week 4 and 5, students interacted with their selected Gen AI tool more intensively as they prompted it to plan community engagement activities for the S-L project that incorporated safety and risk management considerations. This exercise was also referred to as desktop research during the S-L pre-service phase.
4. Reflection: Prior to the conduct of this step, students carried out the engagement activities for the community stakeholders with guidance from the plans generated by Gen AI. Throughout the delivery of activities, students recorded the hits and misses of their plans. After which, they compared their AI-generated plans with the actual outcomes and reflected on the strengths and limitations of Gen AI tools.

Data was collected through a post-project survey that included both quantitative and qualitative components:

- Quantitative: A five-point Likert scale was used to assess two broad areas, namely, students' experiences and views on using Gen AI tools and their assessment of the impact these tools had on learning and engagement. The questions for each broad areas are shown in Tables 1 and 2.

Table 1: Survey questions on experiences and views on using Gen AI tools.

1. I find the selected Gen AI tools easy to use.
2. I think the selected Gen AI tools provide relevant and helpful information.
3. I can trust the information or assistance provided by the selected Gen AI tools.
4. I am concerned about the privacy and security of my interactions with the selected Gen AI tools.
5. I am concerned about plagiarism when using the selected Gen AI tools.
6. I am concerned about becoming over-reliant on the selected Gen AI tools.

Table 2: Survey questions on impact of using Gen AI tools.

1. I think using the selected Gen AI tools helped me learn the content.
2. I developed my critical thinking skills through using the selected Gen AI tools.
3. I am engaged when using the selected Gen AI tools for learning.
4. I become more aware of the limitations of the selected Gen AI tools.
5. I improved in my ability to write prompts to generate useful outputs with the selected Gen AI tools.
6. I learnt to critically review the outputs generated by the selected Gen AI tools.

- Qualitative: Open-ended questions and personal reflections captured students' experiences with Gen AI tools, including their perceived usefulness, limitations, and ethical concerns, such as, plagiarism and privacy. The open-ended questions are shown in Table 3.

Table 3: Open-ended questions on personal perceptions and experiences.

1. Describe how your lecturer's use of Gen AI tools has helped in your learning and developing professional skills (e.g., critical thinking, problem solving, digital competency).
2. What are the Pros and Cons of using Gen AI for learning?

The survey was administered to all students by inserting it as a pre-assignment submission task during the S-L post-service phase.

Quantitative data were analysed using descriptive statistics to identify trends in students' responses. Qualitative data from reflections and open-ended survey

responses were thematically analysed to uncover deeper insights into students' learning experiences and attitudes toward Gen AI.

Results and Discussion

The results and discussion are presented in the following three areas, namely, Area 1: Quantitative response on students' experiences and views on using Gen AI tools, Area 2: Quantitative response on students' assessment of the impact Gen AI tools had on their learning and engagement, and Area 3: Qualitative response of the three open-ended questions.

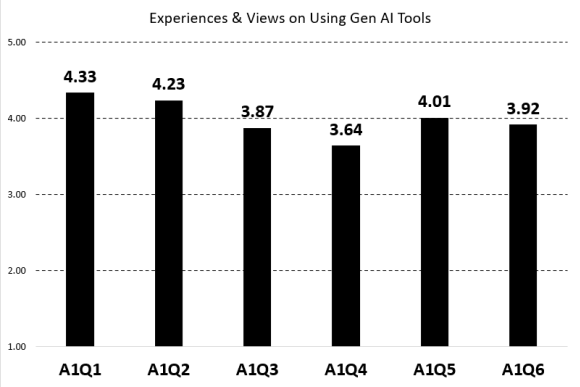


Figure 5: Responses for experiences and views on using Gen AI tools.

With reference to Figure 5, the survey results indicate that students generally had positive experiences using Gen AI tools. The highest-rated items were ease of use (4.33) and the relevance of information provided (4.23), suggesting that students found the tools accessible and helpful for their tasks. Many students gravitated toward GenAI tools they were already familiar with, which likely influenced their selection based on comfort and perceived reliability. During the AI tool selection stage, students often chose the tool that returned more comprehensive and contextually relevant results, reinforcing the importance of usability and output quality in their decision-making process.

The mid-tier scores for plagiarism (4.01), over-reliance (3.92) and trust (3.87) could indicate a growing sense of caution in using Gen AI tools as opposed to embracing it as a do-it-all tool when it was first launched. The ethical concerns around plagiarism could be triggered by the institutional use of plagiarism detection software, Turnitin. The relatively lower score for trust might have arisen from students' experiences comparing AI-generated content with real-world findings during their service-learning projects. Consequently, these two factors could have tampered students' attitudes towards becoming over-reliant on Gen AI tools. The lowest rating for concerns about privacy of interactions (3.64) could indicate that while students are cautious about academic integrity and reliance on Gen AI, they may not yet fully grasp the broader implications of data security in their usage of these tools. This could be because of the scope of interactions, which in this case was generally for school work and thus impersonal in nature.

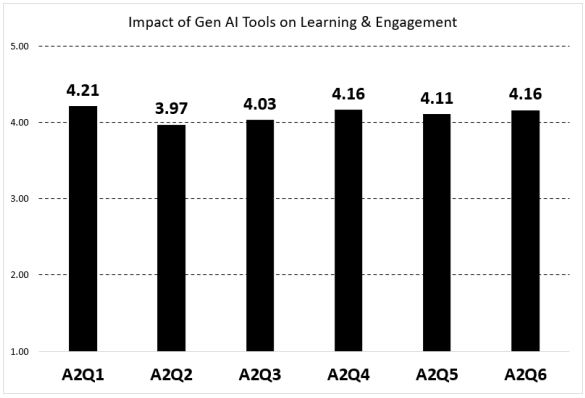


Figure 6: Responses for impact of Gen AI tools on learning and engagement.

Based on the results shown in Figure 6, students felt that Gen AI tools generally had a positive impact on their learning and engagement. They think that these tools supported their understanding of content (4.21), which reinforces the perception that students use Gen AI as a tool for information retrieval and sense making. In addition, their awareness of Gen AI limitations (4.16) may have been fostered by the PAIR AI tool selection and Reflection stages. On the other hand, the contrasting ratings for learning to critically review Gen AI outputs (4.16) and developing critical thinking skills through Gen AI usage (3.97) may suggest that the PAIR AI tool selection and Reflection exercises gave more avenues to learn critical thinking than when Gen AI tools were being used during the Interaction stage. This is because the AI tool selection and reflection stages encouraged students to evaluate the quality and limitations of AI-generated outputs, contributing to a deeper awareness of the tools' capabilities and constraints. Students also rated improvements in their ability to write prompts highly (4.11), which is notable given that no formal instruction on prompt engineering was provided. The development of this skill appears to have emerged organically through self-guided exploration and iterative use of the tools, thereby highlighting the potential of experiential learning in AI education. The rating that students had for their perceived engagement level with Gen AI tools was relatively lower (3.97). This may be attributed to the way in which these tools were being used, that is, as a typical search engine.

An analysis of the comments from the open-ended question on "Describe how your lecturer's use of Gen AI tools has helped in your learning and developing professional skills." revealed that critical thinking emerged as the most prominent theme. Students frequently mentioned that comparing outputs from different Gen AI tools and evaluating the accuracy of responses helped them develop a more analytical mindset. This was particularly evident during the AI tool selection and reflection stages of the PAIR framework, where students were encouraged to assess the quality and relevance of AI-generated content. Comments about the

limitations of Gen AI tools and the importance of fact-checking and contextual understanding were also seen. This awareness aligns with the lower trust scores observed in the quantitative data and underscores the need for continued emphasis on responsible AI use.

In response to the question, "What are the Pros and Cons of using Gen AI for learning?", students provided a range of insights that reflect both the benefits and challenges of integrating Gen AI tools into educational contexts. A thematic analysis of responses revealed a few recurring themes as summarized in Tables 4 and 5.

Table 4: Themes related to the benefits of using Gen AI for learning.

Theme	Supporting points
Efficiency and Speed	Many appreciated the ability of Gen AI tools to provide quick answers and streamline the research process.
Idea Generation	Students found Gen AI helpful for brainstorming and exploring alternative perspectives.
Accessibility	The 24/7 availability of Gen AI tools was seen as a major benefit, especially for independent learning.
Clarification and Support	Gen AI was often used to clarify doubts and reinforce understanding of complex topics.
Personalized Learning	Some students noted that Gen AI tools could adapt to their individual learning needs, offering tailored support.

Table 5: Themes related to the challenges of using Gen AI for learning.

Theme	Supporting points
Over-Reliance	A key concern was that excessive dependence on Gen AI could hinder the development of critical thinking and independent problem-solving skills.
Inaccuracy	Students were aware that Gen AI tools can sometimes provide outdated or incorrect information, necessitating verification.
Plagiarism and Ethical Risks	The temptation to copy AI-generated content raised concerns about academic integrity.
Loss of Creativity and Self-Learning	Some students felt that relying on Gen AI could reduce their motivation to explore topics independently.
Privacy and Data Security	A few responses mentioned concerns about how personal data might be used or stored by Gen AI platforms.

These findings reinforce the importance of guided use of Gen AI tools in educational settings. While students recognize the value of these tools in enhancing learning, they also understand the need for critical engagement and ethical use.

Conclusions

This study explored the integration of the PAIR framework into a service-learning module to enhance the teaching of Gen AI skills among Year 1 engineering diploma students. Anchored in Singapore's national push to develop 21st century competencies, the study aimed to foster AI literacy, critical thinking, and ethical awareness through authentic, community-based learning experiences.

Quantitative survey results revealed that students generally found Gen AI tools easy to use and helpful in supporting their learning. They reported gains in AI literacy and digital competency, with many acknowledging improvements in their ability to write prompts and critically evaluate AI-generated outputs. However, the findings also highlighted areas of concern, including moderate levels of trust in Gen AI tools and limited awareness of privacy and security risks.

Qualitative responses further enriched these insights. Students valued the efficiency, accessibility, and idea-generation capabilities of Gen AI tools, but also expressed concerns about over-reliance, potential inaccuracies, and ethical risks such as plagiarism. Thematic analysis of open-ended responses underscored the importance of guided use, with students benefiting most when Gen AI tools were embedded meaningfully into structured learning activities.

Nevertheless, the survey results and qualitative responses may be affected by self-reporting biases, such as, recall bias and social desirability bias, as it was administered prior to an assignment submission milestone to achieve the maximum response rate. Moreover, there could be measurement inconsistencies arising from students' interpretations of attributes, such as, critical thinking and problem solving.

Overall, the integration of the PAIR framework into the S-L module proved to be a promising approach for introducing Gen AI in a way that balances technological fluency with critical reflection. As Gen AI tools become increasingly prevalent in education and the workplace, it is essential that students are not only equipped to use them effectively but also to question, evaluate, and apply them responsibly. Future iterations of this module could benefit from more intentional instructions on prompting techniques, showing examples of ethical Gen AI use, and highlighting privacy and data security concerns of Gen AI use. This will hopefully ensure that students are prepared to navigate the evolving digital landscape with confidence and integrity.

References

Acar, O.A. (2023). Are your students ready for AI?: A four-step framework to prepare leaners for a ChatGPT world. *Harvard Business Publishing Education.* Retrieved from https://hbsp.harvard.edu/inspiring-minds/are-your-students-ready-for-ai.

Chan, C.K.Y. & Lee, K.K.W. (2023). The AI generation gap: Are Gen Z students more interested in adopting generative AI such as ChatGPT in teaching and learning than their Gen X and millennial generation teachers? *Smart Learning Environments,* 10, 60. Retrieved from https://doi.org/10.1186/s40561-023-00269-3.

Bringle, R.G. & Hatcher, J.A. (1996). Implementing service learning in higher education. Journal of Higher Education, 67(2), 221-239.

Chen, B. et al. (2023). Integrating generative AI in knowledge building. *Computers and Education: Artificial Intelligence,* 100184. Retrieved from https://doi.org/10.1016/j.caeai.2023.100184.

Dickey, E., Bejarano, A. & Garg, C. (2023). *Innovating Computer Programming Pedagogy: The AI-Lab framework for generative AI adoption.* Retrieved from https://doi.org/10.48550/arXiv.2308.12258.

Hu, K. (2023). *ChatGPT sets record for fastest-growing user base - analyst note.* Retrieved from https://www.reuters.com/technology/chatgpt-sets-record-fastest-growing-user-base-analyst-note-2023-02-01/.

Intel (2022). *Is the UK's digital future in danger?* Retrieved from https://download.intel.com/newsroom/2022/geos/emea/intel-supercharge-future-digital-skills-report.pdf

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. *Prentice Hall*.

Marr, B. (2022). *Is our digital future at risk because of the Gen Z skills gap?* Retrieved from https://www.forbes.com/sites/bernardmarr/2022/12/02/is-our-digital-future-at-risk-because-of-the-gen-z-skills-gap/?sh=1f2a81dc2d1a.

McCutcheon, G., & Jung, B. (1990). Alternative perspectives on action research. Theory Into Practice, 29(3), 144-151.

Ministry of Education, Singapore (2023). *Transforming Education through Technology Masterplan 2030.* Retrieved from https://www.moe.gov.sg/education-in-sg/educational-technology-journey/edtech-masterplan.

Shanto, S.S., Ahmed, Z. & Jony, A.I. (2023). PAIGE: A generative AI-based framework for promoting assignment integrity in higher education. *STEM Education,* 3(4), 288-305.

Su, J. & Yang, W. (2023). Unlocking the power of ChatGPT: A framework for applying generative AI in education. *ECNU Review of Education,* 6(3), 355-366.

Tan, H.L., Lim, E. & Williams, S. (2024). Gen AI-bling teaching & learning @ Ngee Ann Polytechnic (NP): Reflections and learning. Conference presentation at *International Symposium for Advances in Technical Education 2024 (ISATE 2024), Singapore.*

Xie, B. et al. (2024). Co-designing AI education curriculum with cross-disciplinary high school teachers. *The Thirty-Eighth AAAI Conference on Artificial Intelligence (AAA1-24),* 23146-23154.

Zeichner, K. (2007). Accumulating knowledge across self-studies in teacher education. *Journal of Teacher Education*, 58(1), 36-46.

Zhou, J. et al. (2023). Synthetic lies: Understanding AI-generated misinformation and evaluating algorithmic and human solutions. *CHI '23: Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems,* 436, 1-20.

Secure and Private Offline Mental-Health Analysis Using Open Lightweight LLMs with RAG

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Large language models (LLMs) have demonstrated remarkable ability to understand and generate human-like text, but relying on cloud-based proprietary services raises significant concerns around data privacy and security—issues that are particularly acute in mental-health applications. To address these challenges, we introduce MentalGemma2, an end-to-end offline pipeline that integrates the open-source Gemma 2-9B-it model with retrieval-augmented generation (RAG) to perform interpretable mental-health analysis entirely on local hardware. MentalGemma2 eliminates all external API calls and ensures that sensitive user data never leaves the secure deployment environment.

We evaluate four system configurations on the Interpretable Mental-Health Instruction (IMHI) dataset, which aggregates five Reddit-derived subtasks: depression detection (DR), stress detection (Dreaddit), interpersonal risk-factor identification (IRF), multi-dimensional wellness assessment (MultiWD), and stress-cause classification (SAD). The configurations are: (1) few-shot prompting using in-context examples, (2) prompting enhanced with RAG retrieval, (3) supervised fine-tuning via 4-bit quantized low-rank adaptation (QLoRA), and (4) fine-tuning combined with RAG. Each configuration is assessed for classification accuracy (weighted F1-score) and explanation quality (BARTScore).

Our experiments reveal that supervised fine-tuning alone delivers the highest overall classification performance, consistently outperforming the few-shot and RAG-augmented variants. While RAG provides a measurable improvement in the few-shot setting—boosting F1-scores by several points—it yields negligible gains once the model has been fine-tuned, indicating that domain-specific knowledge acquired during training subsumes the auxiliary retrieved information. Notably, MentalGemma2's fine-tuned configuration matches or exceeds the accuracy of larger, cloud-based LLMs such as LLaMA2-7B and MentaLLaMA-chat-13B, despite its smaller footprint and offline operation.

By maintaining all computation and data storage locally, MentalGemma2 offers a practical, privacy-first solution for mental-health analytics in environments where network connectivity is limited or data governance is highly constrained. These results demonstrate that compact, open-source LLMs can achieve competitive, interpretable performance on sensitive NLP tasks without sacrificing user confidentiality, making MentalGemma2 a promising candidate for deployment in resource-constrained educational and clinical settings.

Keywords: *mental health analysis, open lightweight language models, retrieval-augmented generation (RAG), privacy-preserving, fine-tuning*

Introduction

Student mental health is increasingly recognized as crucial for a positive learning environment and academic success. Simultaneously, advancements in Artificial Intelligence, particularly large language models (LLMs), present new opportunities for technology to support mental health assessment and intervention in schools. With their strong ability to understand and generate human-like text, LLMs could potentially analyze student communications for early signs of distress or offer tailored wellness resources.

However, deploying general-purpose LLMs, especially powerful proprietary systems like ChatGPT and Gemini, directly in educational contexts raises significant concerns. Data privacy and the confidentiality of sensitive student information are major issues. Reliance on cloud-based APIs, common for many large LLMs, limits offline use, posing challenges for schools with restricted network access or strict data protection policies. Furthermore, the black box character of many large language models prevents any direct inspection of their internal decision processes. Because it is not possible to determine how a given output was generated, this opacity undermines the interpretability and accountability required for responsible use in student mental health support.

To tackle these critical issues surrounding student data, we recognized the need for LLM-based solutions prioritizing security, privacy, and interpretability. Furthermore, such solutions must operate effectively within the often resource-constrained or entirely offline environments found in educational institutions. In response, our research investigates a novel approach centered on an open-source, lightweight language model, Google's Gemma2-9B, augmented with Retrieval-

Augmented Generation (RAG). While we drew inspiration from prior work like MentaLLaMA, which highlighted the potential of LLMs in mental health analysis, we selected Gemma2-9B as our foundational model. We deemed Gemma2 particularly suitable due to its favorable balance of performance and efficiency, its open-source availability, and its demonstrated capacity for handling sensitive content without the overly strict filtering observed in some alternatives. We refer to our proposed model as MentalGemma2.

Our primary objective in this study is to assess the performance of MentalGemma2, particularly when enhanced with RAG (denoted MentalGemma2-RAG), for conducting secure and private offline mental health analysis. We also explore its use in specific educational settings, such as teacher-training courses in educational technology, AI modules within computer science curricula, and professional-development workshops on ICT integration, where students and educators can gain practical experience with AI tools that preserve data privacy. Integrating RAG enables the model to leverage external knowledge bases, potentially including curated educational materials or local support resources. This integration offers a pathway to improve the accuracy and grounding of the model's outputs while maintaining data privacy, as sensitive information can remain local. Gemma2's lightweight nature facilitates offline deployment, ensuring the accessibility and confidentiality crucial for mental health tools within schools. To evaluate this approach, we systematically test various configurations of MentalGemma2 and MentalGemma2-RAG using the Interpretable Mental Health Instruction (IMHI) dataset. Our evaluation focuses on comparing their ability to detect mental health states from text and assesses the quality of the explanations they generate.

By demonstrating the feasibility and effectiveness of using open-source, lightweight models like MentalGemma2 for offline mental health analysis, this work contributes to the development of technological tools that inherently respect privacy, offer cost-effectiveness, and are potentially more understandable. We believe advancements like these hold significant implications for technology education, offering concrete examples of responsible AI development while providing potential tools to better support student well-being within the educational environment.

Related Work

This section surveys three areas of prior work relevant to our approach: mental-health analysis with large language models (LLMs), the MentaLLaMA framework for interpretable diagnosis, and retrieval-augmented generation (RAG), as well as advances in lightweight LLM architectures.

1. MentaLLaMA

Yang et al. (2024) introduced MentaLLaMA, which fine-tunes LLaMA2-7B and -13B on the Interpretable Mental-Health Instruction (IMHI) dataset, a collection of social media posts labeled with mental-health conditions. Through instruction fine-tuning, MentaLLaMA produces both diagnostic labels and accompanying rationales in a question-answer format, providing transparent insight into its predictions.

While MentaLLaMA showed good results, being based on the Llama2 architecture, it may have certain limitations compared to newer architectures like Gemma2 in terms of efficiency or specific capabilities. Our work builds upon the inspiration from MentaLLaMA but adopts a different, more recent base model.

2. Retrieval-Augmented Generation (RAG)

Lewis et al. (2020) proposed RAG, which augments pre-trained LLMs with retrieved documents to ground generation in real evidence. By conditioning on both the input and top-k relevant passages, RAG mitigates hallucination and grants access to up-to-date or domain-specific knowledge—properties valuable for mental health applications. Although RAG has proven effective in medical question answering, its integration with lightweight, offline LLMs remains underexplored. In this work, we assess RAG in conjunction with the Gemma 2-9B-it model for secure, interpretable offline mental-health analysis.

3. Lightweight Language Models

Lightweight LLMs enable on-device processing, reduce latency, and lower energy consumption. Examples include LLaMA3 and Gemma2-9B-it, both of which are designed for high performance at a practical scale. Gemma2-9B-it, developed by Google DeepMind (Gemma2 Team, 2024), employs a novel model architecture that balances efficiency and accuracy.

In this study, we use the Gemma2-9B-it variant because it runs entirely offline, addressing the strict privacy and accessibility requirements of educational settings. Moreover, in our initial tests, Gemma2-9B-it did not exhibit any problematic content filtering, making it well suited for sensitive mental-health discussions.

Materials and Methods

1. Dataset

We used the Interpretable Mental-Health Instruction (IMHI) dataset (Yang et al., 2024) for all experiments. IMHI comprises five Reddit-derived subtasks—depression detection, stress detection, interpersonal risk-factor identification, multi-dimensional wellness assessment, and stress-cause classification—each labeled with both a target and a human-written rationale. Although IMHI includes these rationales, our study evaluates only classification accuracy and explanation quality via weighted F1-score and BARTScore. The five subtasks are summarized in Table 1 and together provide a comprehensive evaluation of mental-health analysis performance.

Table 1. Overview of Key Mental Health Tasks in the IMHI Dataset (Adapted from Yang et al., 2024)

Data	Task	Description
DR	depression detection	Binary classification (Yes/No) for the presence or absence of depression.
Dreaddit	stress detection	Binary classification (Yes/No) for the presence or absence of stress.
Irf	interpersonal risk factors detection	Binary classification assessing risks like Thwarted Belongingness or Perceived Burdensomeness.
MultiWD	Wellness dimensions detection	Multi-question binary classification assessing dimensions like Spiritual, Physical, Vocational.
SAD	stress cause detection	Multi-class classification identifying the stress cause (School, Finance, Family, Social Relation, Work, Health, Emotion, Decision, Others).

The IMHI dataset includes two prompt formats: completion data and instruction data. In the completion format, each example consists of the original post and a question ending with "is," and the model is trained to complete the prompt by outputting a classification label followed by "Reasoning:" and its rationale. The instruction format adds an explicit directive—such as "Consider this post:"—before the question, requiring the model to produce both the classification and a full explanatory sentence (e.g., "the poster does not suffer from depression.") in a single response. The completion format evaluates fill-in-the-blank style completion ability, while the instruction format assesses the model's capacity to interpret and execute more complex, conversational instructions.

2. Model Configurations

The backbone of our system is the open-source Gemma2-9B-it model (Gemma Team, 2024), chosen for its balance of accuracy, computational efficiency, offline capability, and robust content handling. We compare four configurations:

(1) **MentalGemma2 (few-shot prompting)**

We prepend one example per class—drawn from the IMHI training set—to each input at inference time. These demonstrations guide the base Gemma2-9B-it model in classifying new instances.

(2) **MentalGemma2-RAG**

We augment the base model with RAG. For each query, we retrieve the top three relevant documents from the IMHI training set and include them in the prompt. We test three retrieval strategies:

BM25: classic keyword matching using the BM25 ranking function.

Vector: semantic search via multilingual-e5-large embeddings, re-ranked by Jina-reranker-v2.

Hybrid: a weighted combination of BM25 and vector scores (3 : 7 ratio).

(3) **MentalGemma2-SFT (supervised fine-tuning)**

We fine-tune Gemma2-9B-it on each task using 4-bit QLoRA (quantized low-rank adaptation) with rank = 64 and learning rate = 1×10^{-6}. Owing to different label schemes, we train separate models for SAD and for the remaining four subtasks (DR, Dreaddit, IRF, MultiWD).

(4)**MentalGemma2-SFT-RAG (fine-tuning + RAG)**

We combine the fine-tuned models from (3) with RAG, using the same hybrid retrieval method described above.

Results and Discussion

This section reports the performance of the four MentalGemma2 configurations on the IMHI dataset. We compare few-shot prompting, retrieval-augmented generation (RAG), and supervised fine-tuning (SFT) under both completion- and instruction-style prompts. Classification accuracy is measured with weighted F1-score, and explanation quality with BARTScore (Yuan et al., 2021).

1. Performance on Completion Data

Table 2 lists weighted F1-scores for all configurations in the completion setting. Supervised fine-tuning (MentalGemma2-SFT) yields the best overall result, averaging 79.72 %, a gain of more than ten points over the few-shot baseline (MentalGemma2, 69.00 %). This large margin underscores the value of adapting the model to the mental-health domain with QLoRA.

Adding RAG to the unfine-tuned model (MentalGemma2-RAG) produces consistent but modest gains—BM25 70.90 %, vector 72.22 %, and hybrid 72.47 %—with the hybrid retriever performing best. In contrast, attaching RAG to the fine-tuned model (MentalGemma2-SFT-RAG) slightly reduces the average score to 76.73 %, indicating that the domain knowledge learned during fine-tuning already covers most of the information supplied by retrieval.

For context, a fine-tuned LLaMA2-7B baseline reported by Yang et al. (2024) reaches only 67.00 %, confirming that MentalGemma2-SFT delivers substantially higher accuracy while running fully offline.

2. Performance on Instruction Data

Table 3 reports weighted F1-scores for the instruction format. Supervised fine-tuning again dominates: MentalGemma2-SFT attains 74.46 %, versus 68.41 % for the few-shot baseline.

RAG improves the unfine-tuned model only modestly, yet, unlike in the completion setting, combining RAG with the fine-tuned model yields a small additional gain:

Table 2. Results on Completion Data (Weighted F1-score (%))

	DR	dreaddit	Irf	MultiWD	SAD	Average
MentalGemma2	85.79	58.94	69.66	75.53	55.08	69.00
MentalGemma2-RAG (BM25)	87.82	63.24	70.74	74.80	57.88	70.90
MentalGemma2-RAG(vector)	86.99	65.91	72.44	74.81	60.94	72.22
MentalGemma2-(hybrid)	88.34	66.84	71.23	75.06	60.89	72.47
MentalGemma2-SFT	**90.09**	**86.23**	**77.91**	**79.97**	**64.42**	**79.72**
MentalGemma2-SFT-RAG(hybrid)	88.34	80.65	74.60	77.31	62.77	76.73
LLaMA2-7B (Yang, et al. 2024)	84.94	61.59	73.50	65.52	49.60	67.00

Table 3. Results on Instruction Data (Weighted F1-score (%))

	DR	dreaddit	Irf	MultiWD	SAD	Average
MentalGemma2	86.23	59.00	68.74	73.64	54.43	68.41
MentalGemma2-RAG (BM25)	86.23	62.81	66.11	74.01	60.25	69.88
MentalGemma2-RAG(vector)	86.77	64.73	66.94	73.96	60.20	70.52
MentalGemma2-(hybrid)	**87.73**	63.69	66.71	73.96	60.08	70.43
MentalGemma2-SFT	86.47	**80.90**	72.54	71.98	60.41	74.46
MentalGemma2-SFT-RAG(hybrid)	85.55	75.71	73.73	**76.26**	62.96	74.84
MentaLLaMA-chat-13B (Yang, et al. 2024)	85.68	75.79	**76.49**	75.11	**63.62**	**75.34**

MentalGemma2-SFT-RAG reaches 74.84 %, edging past SFT alone. This suggests that retrieved context can still provide useful grounding for the more conversational instruction prompts.

All configurations perform several points lower on instruction than on completion inputs, reflecting the higher linguistic complexity of multi-turn prompts. Nevertheless, MentalGemma2-SFT remains competitive with the larger MentaLLaMA-chat-13B (75.34 %; Yang et al., 2024) while running entirely offline on the smaller Gemma2-9B architecture. These findings underscore the influence of prompt style: direct completion prompts appear better suited to short classification tasks, whereas instruction prompts may benefit from supplementary retrieval even after fine-tuning.

3. Comparison with Discriminative Models

Table 4 compares our interpretable generative approach with domain-specific discriminative models MentalBERT and MentalRoBERTa (Ji et al., 2022), as reported by Yang et al. (2024). On completion data, MentalBERT and MentalRoBERTa achieve average F1-scores of 78.98 % and 80.38 %, respectively, slightly above MentalGemma2-SFT's 79.72 %. Although these discriminative models deliver marginally higher classification accuracy, they lack the ability to generate explanatory rationales. In contrast, MentalGemma2-SFT matches their performance while providing interpretable explanations—an essential capability for responsible deployment in sensitive domains such as mental health and education.

Table 4. Performance of MentalBERT and MentalRoBERTa on the IMHI dataset (Weighted F1-score (%)) (Yang, et al. 2024)

	DR	dreaddit	Irf	MultiWD	SAD	Average
MentalBERT(Ji, et al. 2022)	94.62	80.04	76.73	76.19	67.34	78.98
MentalRoBERTa(Ji, et al. 2022)	94.23	81.76	85.33	68.44	72.16	80.38

Table 5. BARTScore Results on Completion Data (−∞~0)

	DR	dreaddit	Irf	MultiWD	SAD	Average
MentalGemma2	-2.90	-2.72	-2.91	-2.87	-2.82	-2.84
MentalGemma2-RAG (BM25)	-2.85	-2.67	-2.83	-2.72	-2.85	-2.78
MentalGemma2-RAG(vector)	-2.75	-2.68	-2.84	-2.75	-2.84	-2.77
MentalGemma2-(hybrid)	-2.90	-2.72	-2.91	-2.87	-2.82	-2.84
MentalGemma2-SFT	-2.42	-2.34	-2.41	-2.03	-2.11	**-2.26**
MentalGemma2-SFT-RAG(hybrid)	-2.51	-2.43	-2.51	-2.17	-2.18	-2.36
LLaMA2-7B (Yang, et al. 2024)	-2.80	-3.00	-3.00	-2.35	-2.65	-2.76

Table 6. BARTScore Results on Instruction Data (−∞~0)

	DR	dreaddit	Irf	MultiWD	SAD	Average
MentalGemma2	-2.73	-2.47	-2.74	-2.44	-2.90	-2.66
MentalGemma2-RAG (BM25)	-2.90	-2.47	-2.90	-2.67	-3.17	-2.82
MentalGemma2-RAG(vector)	-2.85	-2.46	-2.79	-2.55	-3.06	-2.74
MentalGemma2-(hybrid)	-2.85	-2.70	-2.80	-2.55	-3.01	-2.78
MentalGemma2-SFT	-2.43	-2.25	-2.40	-1.89	-2.00	-2.19
MentalGemma2-SFT-RAG(hybrid)	-2.39	-2.22	-2.35	-1.86	-1.95	**-2.15**
MentaLLaMA-chat-13B (Yang, et al. 2024)	-2.85	-2.80	-2.65	-2.15	-3.00	-2.69

4. Quality of Explanations (BARTScore)

Tables 5 and 6 report BARTScore evaluations of each configuration's generated explanations; scores closer to zero indicate greater similarity to the reference rationales. For context, we also include estimated scores for LLaMA2-7B and MentaLLaMA-chat-13B (Yang et al., 2024), whose exact values were inferred from published figures.

(1) **Completion data (Table 5)**

MentalGemma2-SFT achieves the best average BARTScore (–2.26), consistent with its superior F1-score. This demonstrates that fine-tuning improves not only classification accuracy but also explanation quality. In contrast, adding RAG to the base model yields less consistent gains in explanation alignment. MentalGemma2-SFT also outperforms the estimated LLaMA2-7B score (–2.76).

(2) **Instruction data (Table 6)**

MentalGemma2-SFT-RAG attains the top average BARTScore (–2.15), slightly ahead of MentalGemma2-SFT (–2.19). This pattern mirrors the F1 results, suggesting that retrieval can marginally boost rationale quality for the more complex, conversational prompts. Both fine-tuned configurations deliver explanations substantially closer to zero than the untuned models, and match or exceed the estimated MentaLLaMA-chat-13B score (–2.69), confirming the effectiveness of our QLoRA fine-tuning on Gemma2 for producing high-quality, relevant explanations.

Conclusions

We investigated the use of open-source, lightweight language models—specifically Gemma2-9B-it—combined with retrieval-augmented generation (RAG) and supervised fine-tuning (SFT) for secure, private offline mental-health analysis. Using the IMHI dataset, we compared four configurations (few-shot prompting, prompting + RAG, fine-tuning, and fine-tuning + RAG) under both completion and instruction prompts.

Our experiments demonstrate that supervised fine-tuning alone (MentalGemma2-SFT) consistently achieves the highest classification accuracy and explanation quality, matching or surpassing larger, cloud-based baselines (LLaMA2-7B, MentaLLaMA-chat-13B) and domain-specific discriminative models, while running entirely offline. RAG yields modest gains for few-shot prompting but offers negligible benefit after fine-tuning on completion data and only slight improvements on instruction data. These results indicate that QLoRA-based fine-tuning sufficiently imbues the model with domain knowledge, and that retrieval adds little additional value in most cases.

By combining competitive accuracy, interpretable rationales, and full offline operation, MentalGemma2 offers a practical blueprint for deploying mental-health analytics in environments with strict data-privacy requirements—such as schools and clinics.

Limitations and Future Work

Our study relies on the IMHI dataset and automated metrics such as weighted F1-score and BARTScore, which may not capture all aspects of real-world performance. Future work should validate these findings on more diverse, education-derived datasets and incorporate human evaluation of explanation quality. Exploring advanced fine-tuning techniques, more robust retrieval strategies, and improved automatic metrics will further enhance performance.

To bridge our findings with real-world application, we discuss potential deployment scenarios within an educational context like KOSEN. Future work could explore these applications and their associated challenges.

First, the system could be developed into a self-care tool for students. By analyzing their own texts (e.g., journal entries or draft reports) in a fully private, offline environment, students could engage in self-reflection on their well-being. A key challenge for this application would be designing an intuitive user interface for non-expert users that encourages reflection without causing undue anxiety.

Second, the system could function as an assistive tool for academic advisors and counselors. Crucially, such a tool must be positioned not as a diagnostic instrument or a replacement for professional judgment, but as a supplementary tool to enhance human-led support. With a student's freely given informed consent, it could analyze consultation records to provide insights into emotional nuances that might otherwise be missed. The successful and ethical implementation would require establishing clear institutional guidelines for data

handling and interpretation to support, not automate, the counseling process. The system's offline capability is critical in both scenarios, ensuring the security and confidentiality required when handling sensitive personal information.

Finally, comparative studies with next-generation models such as Gemma 3 (Gemma Team, 2025) and specialized architectures such as MentalQLM (Shi et al., 2024) will continue to advance the development of secure, explainable AI tools for mental-health support.

References

Gemma Team, Google DeepMind. (2024). Gemma 2: Improving Open Language Models at a Practical Size. arXiv preprint arXiv:2408.00118.

Gemma Team, Google DeepMind. (2025). Gemma 3 Technical Report. arXiv preprint arXiv:2503.19786.

Ji, S., et al. (2022). MentalBERT: Publicly Available Pretrained Language Models for Mental Healthcare. Proceedings of the Thirteenth Language Resources and Evaluation Conference (LREC 2022), pp. 7184-7190.

Lewis, P., et al. (2020). Retrieval-augmented generation for knowledge-intensive NLP tasks. Advances in Neural Information Processing Systems 33, pp. 9459-9474.

Shi, J., et al. (2024). MentalQLM: A lightweight large language model for mental healthcare based on instruction tuning and dual LoRA modules. medRxiv preprint.

Yang, K., et al. (2024). Mentallama: Interpretable mental health analysis on social media with large language models. Proceedings of the ACM Web Conference 2024 (WWW '24) , pp. 4489–4500.

Yuan, W., et al. (2021). BARTSScore: Evaluating generated text as text generation. Advances in Neural Information Processing Systems 34, pp. 27263-27277.

INVESTIGATING THE ACCEPTANCE AND IMPACT OF CUSTOMISED GEN AI CHATBOT ON SYSTEMS THINKING AMONG POLYTECHNIC STUDENTS

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Teaching systems thinking can be challenging due to its complexity. Students tend to perceive systems as isolated parts rather than dynamic and interconnected. To address this, a customised Gen AI chatbot is proposed as a learning scaffold that offers personalised coaching and feedback on systems thinking. It is integrated with GPT3.5 and enables the researchers to code specific prompts to scaffold systems thinking. This study aims to investigate students' perceptions of their learning experiences with the chatbot, as well as examine whether students developed systems thinking competencies following the interaction with the chatbot. The study employed a mixed method convergent parallel design. Participants were 52 first-year polytechnic students undertaking a critical thinking and problem-solving skills module. Students' post-survey responses and chat logs were collected for analysis. The survey included items adapted from the Technology Acceptance Model (TAM): Perceived usefulness, perceived ease of use, and behavioural intention. Descriptive analysis of the quantitative survey items suggests that while students recognise the value of the chatbot, particularly in enhancing assignment quality, barriers to regular usage may need to be addressed. Thematic analysis of the open-ended responses revealed that while students commended the chatbot for its constructive feedback, promotion of critical thinking, and practical relevance to the assignment, they also identified technical limitations, its demanding interaction style, and a lack of contextualisation and nuanced understanding as areas for improvement. Additionally, to investigate the extent to which the chatbot facilitated the development of systems thinking competencies, an analysis of students' chat logs, categorised into three pre-defined areas aligned with the assignment rubric, was done. It revealed that while students were able to identify factors and stakeholders in a complex system, their ability to analyse inter-relationships and evaluate solutions remained underdeveloped. The results of the study provided insights for educators when integrating customised Gen AI chatbot to facilitate systems thinking lessons. Study limitations and implications are further discussed in the paper.

Keywords: *generative artificial intelligence, customised chatbot, systems thinking*

Introduction

Systems thinking involves understanding underlying drivers, interactions, and conditions that influence decisions, and helps students to build skills in reframing problems and expanding their perspectives to anticipate unintended consequences (Voulvoulis et al., 2022). The Structure-Behaviour-Function (SBF) framework provides a conceptual structure for organising ideas about complex systems (Jordan et al., 2013) and guides the scaffolding and assessment of systems thinking in this study. However, mastering systems thinking is challenging due to its complexity and interdisciplinary nature. Students often struggle to see systems as dynamic and interconnected, instead perceiving them as isolated parts (Assaraf & Orion, 2005). This highlights the need for innovative instructional strategies that actively engage students in deep reasoning and iterative problem-solving to make systems thinking more accessible and effective.

Generative AI (Gen AI) offers a promising tool for enhancing systems thinking education by providing an interactive, scalable, and personalised learning environment. Unlike traditional AI chatbots with scripted responses, large language models like GPT-3.5 enable open-ended conversations and can be customised to ask guiding questions rather than simply providing answers. Chang et al. (2023) argue that educational AI chatbots should act as facilitators rather than mere information sources. Research suggests that conversational agents help students develop systems thinking skills (Nguyen, 2023) by allowing them to grasp complex systems at their own pace, complementing classroom instruction. However, the role of Gen AI in fostering higher order thinking for systems thinking remains unclear. There is a need to explore how students can engage with complex problems through structured chatbot interactions, moving beyond reliance on AI for answers and toward understanding interconnections and designing solutions.

Despite Gen AI's potential in education, its effectiveness depends on student acceptance and engagement. The Technology Acceptance Model (TAM) provides a framework for understanding how users come to accept and use new technology. TAM identifies two primary factors influencing user acceptance: perceived usefulness and perceived ease of use. Perceived usefulness refers to the degree to which an individual believes that using a particular system would enhance

their performance, while perceived ease of use is the degree to which an individual believes that using a system will be free of effort (Davis, 1989). In the context of this study, students' willingness to engage with the chatbot may be influenced by whether they see it as useful in enhancing their learning experience and intuitive in its interactions. Understanding these factors is key to designing AI-driven learning tools that are both pedagogically effective and widely adopted (Al-Abdullatif, 2023).

Objectives

This study examines the acceptance and impact of a customised Gen AI chatbot on systems thinking among polytechnic students. The research questions are:

(1) What are the reported levels of perceived usefulness (PU), perceived ease of use (PEU), and behavioural intention to use (BI) the customised Gen AI chatbot among students?
(2) What are the themes arising from the positive and negative experiences reported by students using the customised Gen AI chatbot?
(3) To what extent do students demonstrate systems thinking competencies when interacting with a Gen AI chatbot?

Methods

This study employed a mixed-methods convergent parallel design using convenience sampling. Participants (N=52) were first-year polytechnic students enrolled in a Critical Thinking and Problem-Solving Skills module across two classes facilitated by the respective researchers. Figure 1 outlines the study procedure. Data collection took place from Lessons 4 to 6, which focused on systems thinking. Data was collected from two sources: (1) survey responses from students and (2) chat logs from student interactions with the chatbot. At the start of Lesson 4, students were introduced to a problem statement related to sustainability in the fashion industry. They were also introduced to the chatbot and briefed on its use. Across the three lessons, students engaged with the chatbot independently as a learning scaffold while completing a written assignment to address the problem statement. In addition to the chatbot, students had access to e-learning materials, an assignment rubric, and support from the class facilitator.

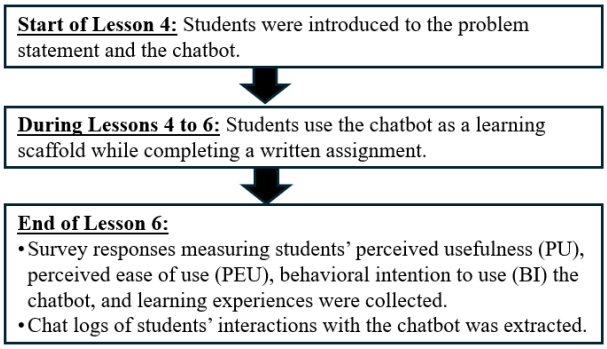


Figure 1: Outline of study procedure

The chatbot was built using a Gen AI model integrated with GPT-3.5. It was designed with researcher-coded prompts, structured questioning and feedback mechanisms to guide students in analysing the complex problem of sustainability in the fashion industry.

The coded questions in the chatbot were categorised into three areas: Factors and stakeholders, their inter-relationships, and solutions. Students were prompted by the chatbot to (1) identify the factors and stakeholders of the problem, (2) examine the inter-relationships among these factors, and (3) propose solutions to mitigate the problem's negative impacts. These steps were adapted from the SBF framework in systems thinking (Jordan et al., 2013), where identifying factors and stakeholders corresponds to exploring the structure, examining inter-relationships mirrors analysing behaviour, and proposing solutions draws from considering the function. This scaffolded approach aims to progressively develop students' thinking skills. These categories also served as the rubric for the assignment. Figure 2 shows a screenshot of the chatbot interface.

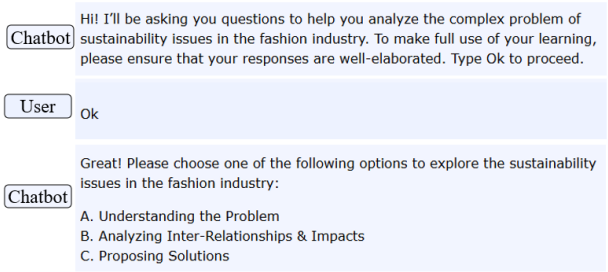


Figure 2: Screenshot of chatbot interface

At the end of Lesson 6, students completed an online survey on their perceptions and learning experiences with the chatbot. The survey included validated items adapted from the Technology Acceptance Model (TAM) (Davis, 1989). It comprised 9 statements: 4 on perceived usefulness (PU), 4 on perceived ease of use (PEU), and 1 on behavioural intention to use (BI) the chatbot. Students rated each statement on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Two open-ended questions collected feedback on students' positive and negative experiences. Descriptive statistics were used for quantitative analysis, and qualitative feedback was analysed by two researchers using thematic analysis.

The chat logs of all students (N = 52) were extracted after Lesson 6 and analysed by the two researchers who systematically categorised the text into three pre-defined categories aligned with the assignment rubric: factors and stakeholders, their inter-relationships, and solutions, to assess systems thinking competencies across different levels of proficiency.

Results and Discussion

RQ1: What are the reported levels of perceived usefulness (PU), perceived ease of use (PEU), and behavioural intention to use (BI) the customised Gen AI chatbot among students?

The descriptive statistics of the quantitative items in the survey are shown in Table 1. The means for all items exceeded the mid-point of 3.00, indicating favourable student responses. The standard deviation values ranged from 0.70 to 1.02, indicating a narrow spread of item scores around the mean. The skewness (from -0.03 to -0.98) and kurtosis (from -0.89 to 2.14) were within the suggested cut-offs of absolute values less than 3 and 10 respectively (Kline, 2005), indicating univariate normality.

Overall, the PU dimensions have the highest mean score for all the items, followed by the PEU dimensions and the BI dimension. The survey item with the highest rating was "Using the chatbot enhances the quality of my responses in the assignment" (Mean = 4.19, SD = 0.77), suggesting that students find the chatbot's contribution to assignment quality particularly useful.

On the other hand, the item with the lowest rating was "I find the chatbot flexible to interact with" (Mean = 3.69, SD = 1.02). In fact, this item has a high SD (1.02), which might suggest that students have mixed opinions about the chatbot's flexibility (discussed later under RQ2).

The mean score for BI (3.75) suggests that students are moderately inclined to use the chatbot more often. This suggests that while students see value in the chatbot, there might be barriers to regular usage that need to be addressed.

Table 1: Descriptive statistics of survey items

Con-struct	Item	Mean	*SD*	Skew-ness	Kurto-sis
Perceived usefulness (PU)					
PU1	Using the chatbot enable me to accomplish my assignment tasks more quickly.	4.00	0.74	-0.30	-0.26
PU2	Using the chatbot enhances the quality of my responses in the assignment.	4.19	0.77	-0.62	-0.15
PU3	Using the chatbot make it easier to do my assignment.	3.96	0.79	-0.42	-0.14
PU4	I find the chatbot useful.	3.98	0.70	0.03	-0.89
Perceived ease of use (PEU)					
PEU1	Learning to use the chatbot is easy for me.	3.96	0.82	-0.60	0.17
PEU2	I find the chatbot to be flexible to interact with.	3.69	1.02	-0.72	0.34
PEU3	My interaction with the chatbot is clear and understandable	3.98	0.73	-0.29	-0.15
PEU4	I find the chatbot easy to use.	4.06	0.83	-0.98	2.14
Behavioural intention to use (BI)					
BI	I would like to use tools like the chatbot more than I already do.	3.75	0.88	-0.01	-0.88

RQ2: What are the themes arising from the positive and negative experiences reported by students using the customised Gen AI chatbot?

Qualitative responses to the two open-ended survey questions on students' chatbot experiences were coded and categorised. The first researcher conducted initial coding, and emergent themes were refined through discussions with the second researcher until consensus was reached. The analysis identified recurring themes that highlight the chatbot's strengths and limitations in supporting students' learning (see Table 2).

The theme "Constructive feedback for improvement" (P1) emerged as the highest frequency under positive experiences. Students value the chatbot's ability to identify flaws and offer constructive suggestions, as it helps refine their thinking and enhances their learning. In contrast, the theme "Technical limitations" (N1) had the highest frequency under negative experiences. Technical limitations, such as user interface issues and slow response time, likely caused frustration in the students. These performance issues can reduce the chatbot's perceived effectiveness and make it harder for students to focus on content and critical thinking. Addressing these issues could enhance student engagement and improve the overall learning experience.

Table 2: Themes and sample responses from open-ended survey questions

Themes [Frequency]	Sample responses
P1: Constructive feedback for improvement [27]	*"It points out flaws in my argument and include viewpoints that I would've never thought of."* *"Responses are detailed and not generic. It reads my questions and responds accordingly".*
P2: Promotes critical thinking [12]	*"Gives us questions to help us think actively"* *"Encourages me to explain my answers often."*
P3: Practical and learning support [7]	*"It is tailored towards what we have to solve for the given problem statement."* *"Helped me understand the topic better… which improved my assignment."*
N1: Technical limitations [15]	*"It takes a while to respond."* *"The chat box does not expand which would help me better see what I was writing before."*
N2: Overly demanding [14]	*"It is constantly demanding for improvement to the answers that you gave. Would be better if it is more lenient."* *"You have to answer the chatbot's questions first before getting the answers from it."*
N3: Lack of context and facilitator insight [6]	*"It doesn't give enough info in Singapore context."* *"It doesn't understand my input as good as my (human) facilitator."*

RQ3: To what extent do students demonstrate systems thinking competencies when interacting with a Gen AI chatbot?

Students' chat logs were analysed. The two researchers independently rated each student's interaction with the chatbot in three systems thinking competencies: (1) Investigation of factors and/or stakeholders contributing to the complex problems, (2) Analysis of inter-relationships among factors and/or stakeholders, and (3) Evaluating solutions that address the complex problem. The ratings were based on the level of competency demonstrated in students' final outputs for each category, ranging from high to low. After completing the initial ratings, the researchers aligned their assessments to ensure consistency. These categories correspond to the question categories in the chatbot,

which align with the students' assignment rubric. See Table 3 for the summary.

(1) **Investigation of factors and/or stakeholders contributing to the complex problem:** 31% of students provided a comprehensive analysis with detailed explanations, while 54% demonstrated moderate analysis or elaboration. The remaining 15% demonstrated limited analysis or elaboration.

(2) **Analysis of inter-relationships among factors and/or stakeholders:** 17% of students critically analysed how different factors and stakeholders influenced one another and the broader system. 27% of students made a moderate attempt to analyse the inter-relationships, while a significant portion 56% of students made little or no attempt to analyse the inter-relationships.

(3) **Evaluation of solutions to address the complex problem:** 15% of students considered a range of solutions and critically evaluated the solutions' implications while 21% gathered basic solutions without considering their impacts. The remaining 64% did not propose or evaluate solutions to address the complex problem.

Table 3: Categories, levels of competency and frequency from chat logs

Categories	Levels of competency in students' outputs	Frequency & Percentage
Investigation of Factors and/or stakeholders that contribute to the complex problem	[High] Identify a broad range of factors and/or stakeholders that contribute to the complex problem with elaborate explanations	16 (31%)
	[Moderate] Identify some factors and/or stakeholders without deep exploration of their roles or impacts	28 (54%)
	[Low] Limited or no attempt to identify or understand factors and/or stakeholders	8 (15%)
Analysis of inter-relationships among factors and/or stakeholders	[High] Critically examine how factors and/or stakeholders may influence others and the broader system	9 (17%)
	[Moderate] Identify basic relationships among factors and/or stakeholders without exploring deeper systemic connections	14 (27%)
	[Low] Limited or no attempt to analyse the inter-relationships among factors and/or stakeholders	29 (56%)
Evaluation of Solutions to address the complex problem	[High] Consider a range of solutions and critically evaluate each solution's implications	8 (15%)
	[Moderate] Gather basic ideas or a limited range of solutions without in-depth evaluation or consideration of broader impacts	11 (21%)
	[Low] Limited or no attempt to explore or evaluate any solutions to address the complex problem	33 (64%)

The findings indicate that while students could identify factors and stakeholders in a complex problem, their abilities to analyse interrelationships and evaluate solutions remain underdeveloped.

One possible explanation is cognitive fatigue: students may have engaged initially but found tasks like analysing relationships and evaluating solutions to be more demanding, leading to reduced effort or disengagement. These tasks require more abstract reasoning, which could explain struggles in later stages. This suggests that while the chatbot supported initial exploration, additional scaffolding may be needed to sustain engagement and deepen reasoning.

In addition, from the findings of RQ1 and RQ2, mixed opinions on the chatbot's flexibility suggest that its technical limitations, demanding interaction style and lack of contextualisation, may have further hindered student engagement and the ability to analyse complex relationships or evaluate solutions effectively. Addressing these issues could enhance engagement and cognitive processing. Strategies such as breaking tasks into smaller steps, using scaffolded questioning, and providing progressive hints could also help mitigate cognitive fatigue and improve the learning experience.

Implications for Practice

The findings suggest that while customised Gen AI chatbots can support students in recognising system thinking components, additional instructional strategies are needed to enhance students' ability to analyse relationships and evaluate solutions in systems thinking.

The following are implications of the findings for educators, instructional designers, and students.

(a) **Educators**: Chatbot interactions should be complemented with collaborative discussions and peer interactions for them to refine their ideas and gain alternative perspectives. Systems thinking benefits from social construction of knowledge. Embedding chatbot interactions within structured peer discussions can help students recognise deeper interconnections and evaluate solutions more critically.

(b) **Instructional designers**: Chatbots should be customised with progressive questioning strategies that gradually increase in complexity. Rather than presenting complex, open-ended prompts upfront, chatbots should guide students through a scaffolded sequence, for example, starting with simple identification tasks before progressing to deeper analysis of interconnections and systemic consequences. This approach ensures that students build foundational understanding before engaging in higher-order thinking.

(c) **Students**: It is crucial to develop awareness of the chatbot's affordances and limitations to maximise its learning potential effectively. While chatbots can provide structured prompts and generate ideas, they do not replace critical thinking or real-world contextual understanding. Encouraging students to reflect on chatbot-generated insights, cross-check information, and engage in deeper inquiry beyond the chatbot's initial responses will enable them to take ownership of their learning and apply systems thinking more meaningfully.

Limitations of Study and Future Research

The small sample size of the study limits the generalisability of the results to the population. Future research could include larger and more diverse samples. Additionally, the variability in the levels of competency in students' outputs suggests that while some students benefited from iterative questioning, others engaged superficially. Further studies could explore factors influencing engagement, such as different questioning strategies and interactive features.

Conclusions

This study investigated students' acceptance of the customised Gen AI chatbot, and how it impacted students' systems thinking and learning experiences. While students reported positive perceptions of the chatbot's usefulness and ease of use, analysis of chat logs revealed variability in their competency levels. These findings suggest that, while the chatbot supports initial exploration, additional strategies are needed to deepen students' reasoning and engagement. Educators and instructional designers can leverage the chatbot's affordances by integrating scaffolding techniques, such as providing progressive questioning and guidance, to help students build deeper understanding and systems thinking skills.

References

Al-Abdullatif, A. M. (2023). Modeling Students' perceptions of chatbots in learning: Integrating technology acceptance with the value-based adoption model. *Education Sciences*, *13*(11), 1151. https://doi.org/10.3390/educsci13111151

Assaraf, O. B. Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *42*(5), 518-560. https://doi.org/10.1002/tea.20061

Chang, D. H., Lin, M. P. C., Hajian, S., & Wang, Q. Q. (2023). Educational design principles of using AI chatbot that supports self-regulated learning in education: Goalsetting, feedback, and personalization. *Sustainability*, *15*(17), 12921. https://doi.org/10.3390/su151712921

Davis, F. D. (1989). Technology acceptance model: TAM. *Al-Suqri, MN, Al-Aufi, AS: Information Seeking Behavior and Technology Adoption*, *205*, 219.

Jordan, R. C., Hmelo-Silver, C., Liu, L., & Gray, S. A. (2013). Fostering reasoning about complex systems: Using the aquarium to teach systems thinking. *Applied Environmental Education & Communication*, *12*(1), 55-64. https://doi.org/10.1080/1533015X.2013.797860

Kline, R. B. (2005). *Principles and practice of structural equation modeling*. New York, NY: Guilford

Nguyen, H. (2023). Role design considerations of conversational agents to facilitate discussion and systems thinking. *Computers & Education*, *192*, 104661. https://doi.org/10.1016/j.compedu.2022.104661

Voulvoulis, N., Giakoumis, T., Hunt, C., Kioupi, V., Petrou, N., Souliotis, I., & Vaghela, C. J. G. E. C. (2022). Systems thinking as a paradigm shift for sustainability transformation. *Global Environmental Change*, *75*, 102544. https://doi.org/10.1016/j.gloenvcha.2022.102544

ENHANCING STUDENT ENGAGEMENT IN AI EDUCATION THROUGH INTEGRATING VISUALISATION TOOLS IN BLENDED LEARNING

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Deep Neural Networks have found numerous complex applications across various domains, including intelligent robots, autonomous systems, advanced manufacturing, computer vision, natural language processing, and other engineering and scientific fields. These technologies have been increasingly incorporated into higher education curricula and are being taught extensively to learners. However, the inherent "black box" nature of deep neural networks lacks transparency making it difficult to comprehend their inner workings, therefore hindering the learning process and the effective application of these AI techniques in real-world scenarios. To address these challenges, there is a growing demand for explainable AI using visualisation tools and techniques that can enhance educational experience by making deep learning concepts more accessible and understandable. These tools have the potential to demystify the complex processes within neural networks, thereby fostering a deeper understanding and trust in the models' predictive ability and behaviours.

This paper investigates how AI visualisation tools integrated within a blended learning framework can enhance student engagement in teaching AI. We introduced visualisation tools such as TensorFlow Playground, exploRNN, along with explainable AI (XAI) techniques like Local Interpretable Model-Agnostic Explanations (LIME) and SHapley Additive exPlanations (SHAP), to enhance the comprehension of deep learning models such as Convolutional Neural Networks (CNN), Generative Adversarial Networks (GAN), Recurrent Neural Networks (RNN), and Long Short-Term Memory (LSTM) networks. The interactive features of the AI visualisation tool, along with explainable AI (XAI) techniques, allow learners to explore the internal patterns of black-box models and help them understand how these models make decisions.

A survey, involving over 30 students, was conducted to gather feedback on the AI lessons, which spanned a duration of 15 hours. The survey included both qualitative and quantitative questions to evaluate the students' experiences across multiple dimensions, such as overall learning experience, lab session interactivity, the effectiveness of pre-class videos, and engagement in classroom discussions. The findings indicate preference among students for the blended learning model, particularly valuing the interactive, hands-on components such as lab sessions that employ AI visualisation tools. These responses highlight the effectiveness of XAI and visualisation tools in enhancing engagement and fostering a deeper understanding of complex AI concepts. The result emphasizes the benefits of integrating interactive visualisation tools within a blended learning environment for AI education. Future research will focus on implementing an integrated AI visualisation toolbox and investigate the long-term impact of the toolbox on student engagement and the retention of deep learning concepts.

Keywords: *Deep Learning, Explainable AI (XAI), Visualisation, Blended Learning*

1. Introduction

Artificial Intelligence (AI), particularly deep neural networks (DNNs) has found widespread application in diverse fields such as computer vision, robotics, autonomous vehicles, and other scientific disciplines. The underlying technologies and applications of DNNs have been integrated into higher education curricula and are now extensively taught to students across various engineering and computer science disciplines. This broad inclusion aims to equip learners with the necessary skills and knowledge to navigate and contribute to the rapidly evolving field of AI. However, the applications of deep learning to solve real-world problems necessitates strong technical skills, including proficiency in a programming language. Learners new to this field, with limited or no technical background in neural networks, tend to be overwhelmed when grappling with the foundational aspects of AI. Furthermore, the "black box" nature of DNNs present a significant hinderance for educators seeking to foster meaningful understanding among learners, preventing the latter from confidently explaining, trusting and applying deep learning techniques to solve real-world problems.

In recent years, the research community has placed increasing emphasis on AI visualisation, recognizing its pivotal role in enhancing the comprehension of complex deep learning concepts. Such tools have become indispensable for demystifying AI model behaviour and facilitating deeper insights into their underlying mechanisms. For example, TensorFlow Playground (Smilkov et al., 2017) provides an interactive interface that enables users to manipulate neural network parameters directly—without requiring programming expertise—thereby accelerating the development of intuition regarding network architectures, loss functions, and learning dynamics. Similarly, GAN Lab offers a specialized environment for non-experts to explore generative adversarial networks (GANs), a sophisticated class of deep learning models. Through a hands-on, intuitive approach, learners can interactively train the models while visualizing real-time training processes, bridging the gap between theoretical principles and practical understanding (Kahng et al., 2019). Nevertheless, while these tools provide powerful visuals, they do not explain the underlying decision-making process of these complex AI systems. For effective real-world application, students must develop not only procedural knowledge of DNN operations but also comprehend and validate system decisions—a critical requirement for establishing trust in AI outputs. XAI techniques, specifically, LIME (Ribeiro et al., 2016) and the SHAP (Lundberg & Lee, 2017) are effective resources for exploring deep learning and presenting the decision process of complex black-box models in a more understandable way to the learners.

In this paper, we propose a blended-learning framework that integrates interactive AI visualisation tools and XAI programming methods to facilitate the learning of foundational AI concepts among AI learners. This integrated framework aims to advance deep learning pedagogy by combining theoretical instruction with experiential learning. Our pedagogical framework integrates a tripartite structure comprising: (1) preparatory video lectures for foundational knowledge acquisition, (2) collaborative in-class discussions to reinforce conceptual understanding, and (3) class activity such as hands-on laboratory (lab) sessions utilizing interactive visualisation tools. The interactive lab components (e.g., TensorFlow Playground, GAN Lab) provide an experimental sandbox environment where learners can directly manipulate core neural network hyperparameters—including learning rates, activation functions, and optimization settings—while visualizing real-time impacts on model behaviour. This hands-on approach is augmented with XAI programming techniques to illuminate the models' decision-making process, thereby demystifying the traditionally "black-box" characteristic of deep learning systems. Our pedagogical framework demonstrates measurable improvements in learner engagement when mastering complex deep learning concepts. The remainder of this paper is organized as follows: Section 2 reviews related work in AI education tools and explainable deep learning pedagogies. Section 3 details our blended learning framework, including its instructional design and technical implementation. Section 4 presents the experimental methodologies, including participant selection, control/intervention group design, and the validated survey questions used to measure student engagement in learning AI. Section 5 provides a comprehensive analysis of the results, comparing quantitative findings with qualitative insights from student feedback. Finally, Section 6 concludes with contributions, limitations, and future research directions in AI education.

2. Related Work

Recent advances in AI education research have established visualisation tools as essential pedagogical instruments for cultivating both conceptual understanding and learner engagement. These studies demonstrate how interactive visual representations significantly enhance cognitive engagement by making abstract algorithmic processes more accessible and intuitively understandable. Naps et. al (2003) explored the role of visualisation and engagement in computer science education, posited that visualisation medium, regardless of its design quality, holds minimal educational value unless it is integrated into an active learning activity. The authors argued that for visualisation to have a significant impact, two key components must work in tandem: the enhancement of learning with visualisation and the successful integration of the visualisation tools in the classroom. Alicioglu and Sun (2022) empirically validated the pedagogical value of visualisation techniques such as XAI for enhancing comprehension of machine learning models. Their research demonstrated that visual explanations significantly improve model interpretability by presenting complex algorithmic behaviours and prediction rationales in more accessible formats. Furthermore, the study conducted a comparative analysis of student engagement patterns, revealing a strong preference for blended learning approaches that incorporate visualisation tools over traditional lecture-based instruction in deep learning curricula. Schultze et al. (2020) established that visualisation-based learning applications reduce the cognitive barriers to deep learning. Their research argued that such tools enable novice learners to develop conceptual understanding of model behaviours and architectural principles prior to attaining programming proficiency, thereby creating a more accessible entry point to the field.

3. Blended Learning Framework

We developed a tripartite blended learning framework comprising:

(1) Asynchronous video lectures establishing theoretical foundations,

(2) Synchronous in-class group discussions to deepen conceptual engagement, and

(3) Class activity such as lab sessions featuring guided experimentation.

This scaffolded approach progresses from knowledge acquisition to applied practice, enabling learners to systematically transition from passive reception to active learners of deep learning systems. A sample learning plan is shown in Table 1 below.

Table 1: Sample Learning Plan for Week 6 and week 7

Week (L/T/P)	Topic	Pre-class	In-class activity and group discussion	Closing/Post-Class	Remarks
6	Deep Learning Methods	30 mins: A. Task: Watch curated videos + guided reading. 1. Gen AI/CNN Video: Google Cloud Tech. (2023, September 12). *What is generative AI?* [Video]. YouTube. https://youtu.be/xA5Hrn2DNbk 2. StatQuest with Josh Starmer. (2021, July 10). *RNN and LSTM explained* [Video]. YouTube. https://youtu.be/hZVblg1h4xM B. Please experiment with 1. TensorFlow Playground. (2023). *Interactive deep learning tool*. https://playground.tensorflow.org 2. exploRNN Team. (2022). *exploRNN: Interactive visualisation tool for recurrent neural networks*. exploRNN. https://explornn.github.io	50 mins: 1. Discuss the advanced features of Deep Neural Networks, such as CNN 2. What are the shortcomings of a RNN? 3. How does LSTM overcome these shortcomings? 10 mins: Break 50 mins: 1. Familiarization with exploRNN at https://papersubmissions42.github.io/exploRNN/ 2. Experiment with sequential input and non-sequential output (many-to-one), such as next element prediction. Tasks with sequential input and sequential output (many-to-many), such as translation. As well as tasks with non-sequential input and sequential output (one-to-many), such as image captioning.	30 mins: 1. Groups discuss and submit answers for ALL questions in the Separate worksheet given. 2. Groups present answers for 3 selected interesting points to the class.	Tutors: Review of deep learning methods, review questions, attendance sheet, spend a few minutes answering questions and clarifying misconceptions. Students: Work on the separate worksheet given Tutors: Interacts with an open Inquiry question in small groups or help clarify concepts.
7	CNN, XAI (LIME, SHAP)	30 mins Task: Watch curated videos + guided reading. Resources: Video 1: "Introduction to LIME for Explainable AI" (StatQuest LIME tutorial) Video 2: "SHAP Values for Model Interpretability" (SHAP library demo)	50 mins: 1.How do LIME and SHAP approximate model behavior differently? 2.What are the limitations of these methods for CNNs? 3.Why is interpretability critical in real-world AI applications? 10 mins: Break 50 mins: Hands-on XAI Visualisation with CNNs Tools: Python notebooks with pre-trained CNN (e.g., ResNet) + LIME or SHAP. Dataset: CIFAR-10 or MNIST for simplicity.	30 mins: 1. Groups discuss and submit answers for ALL questions in the Separate worksheet given. 2. Groups present answers for 3 selected interesting points to the class.	Tutors: Review of last week's lesson, review questions, attendance sheet, spend a few minutes answering questions and clarifying misconceptions. Students: Work on the separate worksheet given Tutors: Interacts with an open Inquiry question in small groups or help clarify concepts.

4. Methodology

This study is a collaborative initiative between Nanyang Polytechnic (NYP) and the University of Glasgow (UofG) to facilitate education research. By integrating pedagogical frameworks and resources from both institutions, this partnership enables the examination of student engagement in AI education leveraging two complementary academic modules. The first module, *Intelligent Services Implementation*, is offered as part of a Specialist Diploma program at NYP, while the second, *Machine Learning*, is an undergraduate subject within the Computing Science degree program jointly administered by UofG and the Singapore Institute of Technology.

Firstly, visualisation tools, like Tensorflow Playground, explorRNN and XAI techniques like LIME and SHAP, were integrated into a blended learning environment. This implementation followed a structured pedagogical framework as operationalized in our sample learning plan (see Table 1) where the tools were strategically deployed to facilitate active learning and promote deeper engagement with AI concepts in different ways (e.g. hands-on, discussion, and presentation). Secondly, a quasi-experimental comparative design was implemented to systematically evaluate differences in learning engagement compared with traditional lecture-based instruction. Finally, following the instructional interventions, a structured survey was administered to assess students' perceived engagement and satisfaction with each pedagogical

approach. We adopted a mixed-methods approach, integrating both quantitative and qualitative analyses to triangulate findings and enhance validity. The survey utilized a 5-point Likert scale survey (1 = Strongly Disagree to 5 = Strongly Agree) to assess key dimensions of the learning experience, while parallel qualitative data were collected through open-ended survey responses. We then analysed the performance metrics - including mean satisfaction scores. To assess statistical significance, we used independent samples t-tests compared mean satisfaction scores between the instructional approaches. Survey open-ended responses were thematically coded to identify patterns in student experiences, challenges, and preferences. Finally, we use a repeated-measures design method where the cohort size, N=34, was exposed to both approaches with the schedule as shown in Table 2.

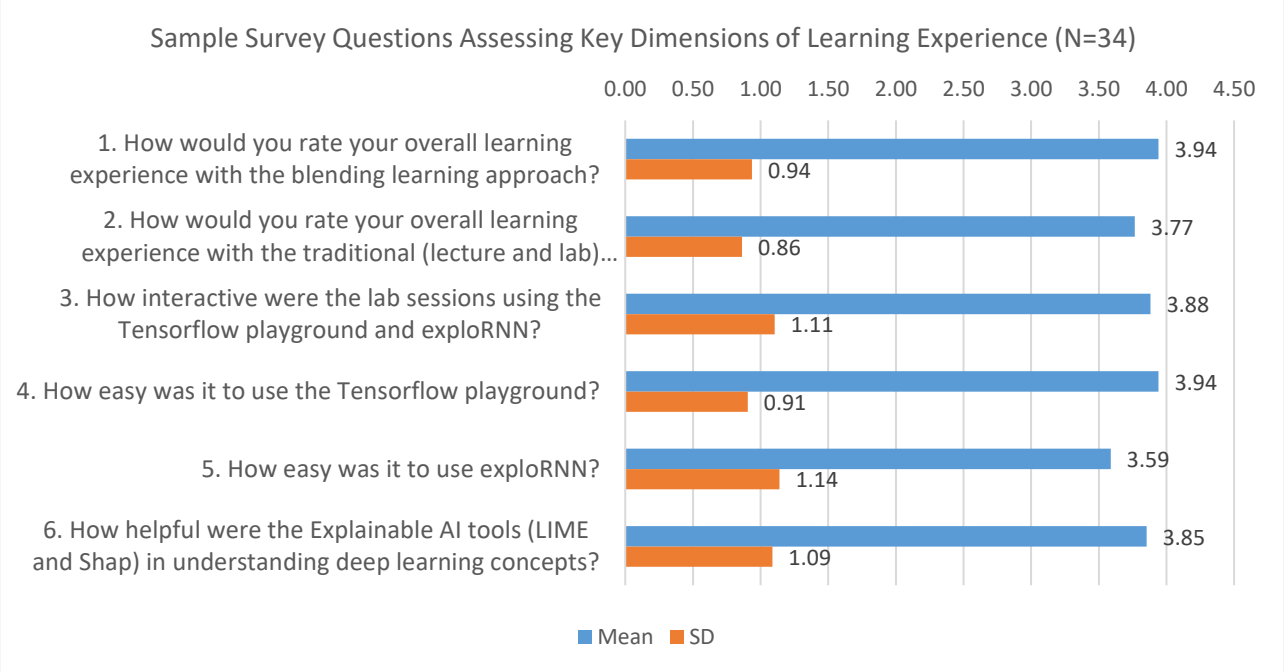
Table 2: Repeated-Measures Design

Group	Instructions	Week
Control Group	Traditional lecture-based instruction and labs (no AI tools or interactive components)	Phase 1 (Week 1-5)
Intervention Group	Blended learning with AI visualisation tools (video lectures, interactive labs, and discussion sessions)	Phase 2 (Week 6 – 10)

5. Survey Results and Discussion

Table 3 presents the aggregated Likert-scale responses (N=34) for each quantitative survey item, comparing student perceptions across several key dimensions of the learning experience.

Table 3: Sample Survey Questions Assessing Key Dimensions of the Student's Learning Experience



A. Overall Learning Engagement with Blended Learning versus Traditional Learning

From the responses to survey item 1, quantitative analysis revealed a preference for the AI-enhanced blended learning approach (M=3.90, SD=0.94) over traditional instruction (M=3.79, SD=0.84), as measured on a 5-point Likert scale. The slight preference for AI-enhanced blended learning (Δ=0.17 on a 5-point scale), with t(33)=2.26, p=0.030 (two-tailed), is statistically significant. The observed effect size, quantified by Cohen's d = 0.39 (95% CI [0.04, 0.74]), suggests a small-to-medium practical effect. The findings were also substantiated by three recurring themes in qualitative feedback:

- Flexibility and Accessibility: Students valued asynchronous access to materials (e.g., "Being able to learn at my own pace reduced stress and improved comprehension").
- Reinforcement Through Multimodality: Participants reported enhanced understanding through complementary online/in-person components (e.g., "The combination helped solidify concepts—I could revisit difficult topics after class").
- Improved Workload Management: Many highlighted better study-life balance (e.g., "Online resources allowed me to efficiently integrate coursework with other commitments").

The student critiques of the traditional approach, however, revealed three key thematic concerns:

- Cognitive Overload: "The traditional lectures were informative, but sometimes I felt overwhelmed with the amount of information presented in a single session."

- Structural Rigidity: "I appreciate the structure of traditional classes, but incorporating online elements could make learning more dynamic."

- Pacing Challenges: "While I valued face-to-face interaction, I struggled to keep up with the lecture pace."

These findings substantiate the pedagogical constraints of purely traditional instruction, while highlighting student demand for the multimodal flexibility that our AI-enhanced blended framework provides.

B. Interactivity of AI Visualisation Tools

Survey item 2 on interactivity of AI visualisation tools utilizing TensorFlow Playground and exploRNN demonstrated strong pedagogical efficacy, receiving an average interactivity rating of 3.88 (SD = 1.11) on a 5-point Likert scale. Qualitative analysis revealed three dominant themes in student evaluations:

- Cognitive Accessibility: "TensorFlow Playground demystified the black box of neural networks, making the learning process intuitive and seeing how adjusting learning rates or activation functions affected the model was fascinating."

- Theory-Practice Integration: "The interactive labs allowed me to apply theoretical knowledge in a practical setting, enhancing my learning experience."

- Engagement and Motivation: "The lab sessions were the highlight of the course—engaging and applicable to real-world scenarios. It made learning neural networks fun - I grasped complex concepts without math anxiety."

These findings collectively suggest that interactive AI visualisation tools can effectively bridge the theory-practice gap in deep learning education while maintaining high learner engagement.

Nonetheless, the comparative analysis revealed a statistically significant difference in perceived interactivity between the two visualisation tools. TensorFlow Playground (Survey Item 3) received higher interactivity ratings (M = 3.94, SD = 0.91) compared to exploRNN (Survey Item 4; M = 3.59, SD = 1.14), with this difference being highly significant ($t(33) = 3.78$, $p = .0006$, two-tailed, $d = 0.65$). The lower scores for exploRNN indicate a need for enhanced scaffolding, particularly for recurrent neural network concepts which are inherently more complex than feedforward architectures. Overall, the integration of exploRNN into the blended learning framework proved instrumental in demystifying RNNs, as evidenced by student feedback. Thematic analysis revealed three key pedagogical benefits:

- Visualisation of Sequential Data Processing: "exploRNN provided a clear visualisation of how RNNs process sequences, making hidden states and backpropagation through time more intuitive."

- Comparative Analysis of RNN Architectures: "I could experiment with LSTMs and GRUs, seeing how they performed on different tasks—this hands-on experience was invaluable."

- Reduction of Cognitive Load in Complex Topics: "The tool made sequential data handling less abstract—visualizing information flow was a game-changer."

C. Helpfulness of XAI Tools

The survey results (Survey Item 6) indicate that XAI tools (LIME and SHAP) were perceived as helpful (M = 3.85, SD = 1.09), though slightly lower than TensorFlow Playground (M = 3.94) but higher than exploRNN (M = 3.59). This suggests moderate-to-high utility in aiding conceptual understanding while also highlighting the need for improvement in connecting theoretical concepts to real-world applications. The findings were also substantiated by three recurring themes in qualitative feedback:

- Demystification of AI decision-making processes: "Provides clear visualisations that highlight feature contributions."

- Tools as gateways to deeper engagement: "Will help me further explore to understand AI modelling better."

- Connection between tool outputs and real-world problem-solving: "The tool is simple to use but needs time to relate to real-world challenges I am expected to solve."

6. Conclusions

This study, through rigorous quantitative and qualitative analyses, revealed a statistically significant student preference for the AI within a blended learning approach over traditional instruction, with a small-to-medium practical effect size. It underscored the pedagogical value of integrating AI visualisation tools in the curriculum to enhance student learning experiences.

The key findings from this study are as follows:

1. Enhanced Engagement: Students demonstrated better engagement when using tools and experiences that reduce unnecessary cognitive load and make complex concepts intuitively graspable. This is particularly beneficial for learners new to AI education, as visualisation tools help lower barriers to comprehension and reduce intimidation, which is often caused by the mathematical formalism (e.g., backpropagation equations) prevalent in traditional AI/ML instruction.

2. Bridging Theory and Practice: Interactive labs effectively bridged the gap between abstract theory and applied skills. They demystified the AI decision-making process by providing visuals that highlight feature contributions through hands-on experimentation.

3. Increased Intrinsic Motivation: The dynamic, visual nature of the tools increased intrinsic motivation, transforming challenging topics into engaging and enjoyable learning experiences.

While the study measured engagement and motivation shortly after the intervention, it may not capture long-term retention of knowledge, sustained interest in AI, or the development of deeper conceptual understanding over time. Future research should explore long-term knowledge retention and scalability of these tools across diverse educational contexts.

Nevertheless, this study strongly advocates for the continued integration of interactive AI visualisation tools in AI curricula to foster deeper, more accessible, and engaging learning experiences.

References

Alicioglu, G., & Sun, B. (2022). A survey of visual analytics for explainable artificial intelligence methods. *Computers & Graphics*, 102, 502–520.

Kahng, M., Thorat, N., Chau, D. H., Viégas, F. B., & Wattenberg, M. (2019). GAN Lab: Understanding complex deep generative models using interactive visual experimentation. *IEEE Transactions on Visualisation and Computer Graphics*, 25(1), 310-320. https://doi.org/10.1109/TVCG.2018.2864500.

Lundberg, S. M., & Lee, S. (2017). A unified approach to interpreting model predictions. In *Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS'17)* (pp. 4768–4777). Curran Associates Inc. http://dx.doi.org/10.5555/3294996

Naps, T. L., Rößling, G., Almstrum, V. L., & Dann, W. (2003). Exploring the role of visualisation and engagement in computer science education. *ACM SIGCSE Bulletin*, 35(2), 131-152.

Ribeiro, M. T., Singh, S., & Guestrin, C. (2016). Why should I trust you? Explaining the predictions of any classifier. In *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (pp. 1135–1144). http://dx.doi.org/10.1145/2939672.2939778

Schultze, S., Gruenefeld, U., & Boll, S. (2020). Demystifying Deep Learning: Developing and Evaluating a User-Centered Learning App for Beginners to Gain Practical Experience. *i-com*, 19(3), 201-213. https://doi.org/10.1515/icom-2020-0023.

Smilkov, D., Carter, S., Sculley, D., Viégas, F. B., & Wattenberg, M. (2017). Direct-manipulation visualisation of deep networks. *arXiv preprint arXiv:1708.03788.*

Advancing AI Education by Participating in the RoboCup@Home Competition

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This study explores the integration of AI and robotics technologies in domestic service robots through participation in the RoboCup Japan Open 2024 @Home League DSPL. The team "Re@dy" engaged in three competition tasks: TidyUp, GPSR, and Restaurant. Notable achievements include second place in the TidyUp task and a tie for second place in the GPSR task. Technical solutions involved the use of YOLACT Edge for object recognition, Point3D for 3D position estimation, and GPT-3 for contextual understanding. Despite these successes, several challenges were identified, including limitations in object recognition accuracy, insufficient flexibility of task execution, and failures in map generation for unknown environments.

From an educational perspective, this project provided valuable opportunities for students to apply advanced AI technologies and robotics concepts in real-world scenarios. Through iterative development and team collaboration, students enhanced their problem-solving skills and gained experience connecting theoretical knowledge with practical implementation. Future work will focus on improving object recognition accuracy, developing dynamic task control methods, and introducing more advanced SLAM technologies to further advance the capabilities of domestic service robots.

Keywords: *Domestic Service Robots, AI, Educational Effectiveness, RoboCup@Home, SLAM and Navigation*

1. Introduction

In recent years, the rapid advancement of artificial intelligence (AI) technologies has opened up opportunities for application across various fields. In Japan, the development of human resources specializing in mathematics, data science, and AI has become an urgent priority. According to the "AI Strategy 2022" formulated by the Japanese Cabinet Office, numerous initiatives have been launched in higher education institutions to promote the development of such talent[1]. While Japan maintains a strong industrial foundation in sectors such as automobiles and robotics, it lags behind major global technology corporations—such as GAFA and BATH—in core AI technologies. Therefore, combining Japan's strengths in robotics with advanced AI technologies is essential for pioneering new application areas.

Against this backdrop, domestic service robots have attracted significant attention as a promising application of AI technology. According to a market survey by the Fuji Keizai Group, the service robot market exceeded 2 trillion yen in 2023 and is expected to continue growing[2]. Particularly, domestic service robots equipped with manipulators and mobile platforms are anticipated to perform practical tasks such as waiter services in restaurants and household chores in home environments [3][4]. To accomplish these tasks, highly integrated AI technologies—including object recognition, speech recognition, speech synthesis, and contextual understanding—are required.

This study focuses on RoboCup@Home as a practical platform for addressing these technological challenges. RoboCup@Home is an international competition aimed at evaluating the performance of domestic service robots in real-world environments, providing an ideal setting to test the integration of AI technologies and robotics. The objective of this research is to explore practical integration methods of AI and robotics through participation in RoboCup@Home and to assess the associated educational outcomes. In particular, this study aims to foster students' ability to bridge theoretical knowledge and practical skills through hands-on development and collaborative team projects.

2. Related Research

2.1 Initiatives for AI Education at National Institute of Technology, Kitakyushu College

At the National Institute of Technology, Kitakyushu College (Kitakyushu KOSEN), courses related to AI and data science are embedded from the third academic year onward in order to foster AI- and data-science-literate engineers. The discussion below highlights two core subjects.

2.1.1 "Experiment (3rd year, PBL)"

We focus on a data-centric AI course in which students fine-tune a pre-prepared object-detection model for a small mobile robot and compete in an in-house challenge. Although students iterate on data collection and hyper-parameter tuning, they still work on teacher-prepared infrastructure and rarely select or integrate AI models entirely on their own.

2.1.2 "Artificial Intelligence" (5th year, lecture and work)

It is a survey-style course that traces AI from the first boom to the present, introducing individual algorithms and models through guided coding assignments. While comprehensive, it concentrates on model-centric knowledge acquisition; opportunities to deploy AI in realistic contexts are limited.

Across both courses, students have insufficient opportunities to identify suitable AI techniques through their own literature survey and to apply those techniques appropriately to the diverse situations encountered in real-world practice.

2.2 Domestic Service Robots

Domestic service robots are designed to assist or substitute human activities in everyday living spaces. As illustrated in Figure 1, these robots take various forms; however, in the Domestic Standard Platform League (DSPL) of RoboCup@Home, all teams utilize the Human Support Robot (HSR) developed by TOYOTA. The HSR stands approximately 100 cm tall, making it well-suited for operating in human environments. It is equipped with a wide range of sensors and actuators, including an RGB-D camera and laser range finder for vision (analogous to human eyes), microphones for auditory input, speakers for communication (analogous to a human mouth), robotic arms for manipulation, and a mobile vehicle base for locomotion.

Since the HSR does not come with a high-performance computing unit by default, each team equips the robot with an external computer according to its computational needs. In this study, we mounted a laptop equipped with a GPU on the back of the HSR to enable advanced cognitive processing tasks such as object recognition and speech processing. Furthermore, the system connects to cloud computing services as needed, utilizing various cloud APIs, including OpenAI's ChatGPT. This hybrid architecture allows the robot to achieve both real-time responsiveness through local processing and advanced AI inference via cloud-based services.

When performing tasks, domestic service robots operate based on a three-step process: **Perception**, **Decision**, and **Control**. Figure 2 illustrates this process. In the Perception step, the robot uses sensor data to recognize its environment; for example, in a tidying-up task, it identifies nearby objects using object recognition algorithms. In the Decision step, the robot determines the next action based on the recognized information, such as prioritizing the closest yellow ball for collection. Finally, in the Control step, the robot executes the chosen action by controlling its actuators, such as using its robotic arm to grasp the target object.

Through the integration of various sensors and actuators, domestic service robots are required to perform sophisticated cognitive processes and demonstrate flexible decision-making in complex and dynamic human environments.

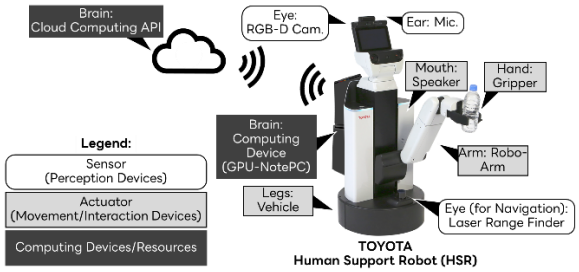


Figure 1 Overview and Key Components of a Domestic Service Robot

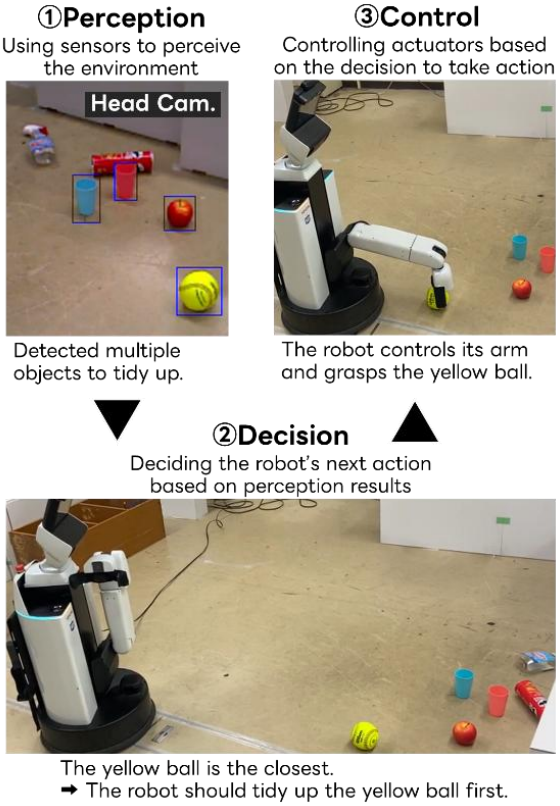


Figure 2 Processing Flow of Perception, Decision, and Control in a Domestic Service Robot

2.3 RoboCup@Home

2.3.1 Competition Overview

RoboCup is an international robotics competition established with the ambitious goal of "developing a team of fully autonomous humanoid robots capable of winning against the human world soccer champion team by the year 2050." While RoboCup initially focused on robotic soccer, it has since expanded into various leagues, including RoboCup@Home, which aims to advance the capabilities of domestic service robots and promote the development of solutions to real-world challenges.

The RoboCup@Home league focuses on practical tasks in diverse home environments, requiring a wide range of AI and robotics technologies such as object recognition, speech recognition and synthesis, contextual understanding, navigation, and manipulator control. In particular, the Domestic Standard Platform League (DSPL), a sub-league of RoboCup@Home, mandates that all participating teams use the same hardware

platform—the Human Support Robot (HSR) developed by TOYOTA. This standardization eliminates hardware disparities and emphasizes competition based solely on software capabilities, making it an ideal platform for evaluating algorithm design and system integration skills.

Moreover, RoboCup@Home encourages not only technical competition but also the development of practical robotic solutions that directly address social issues and improve the quality of human life. Accordingly, adaptability and flexibility in complex real-world environments are key evaluation criteria. In this study, by participating in RoboCup@Home DSPL, we aim to practically validate advanced integration methods of AI and robotics and assess their educational effectiveness.

2.3.2 League Tasks

In the RoboCup@Home DSPL, multiple tasks are designed to comprehensively evaluate the diverse capabilities required for domestic service robots. As of the 2024 competition, the three main tasks included **TidyUp**, **General Purpose Service Robots (GPSR)**, and **Restaurant**. Each task poses distinct technical challenges, requiring advanced cognitive processing and flexible decision capabilities from the robots.

The **TidyUp Task** evaluates the robot's ability to tidy up a cluttered room. The robot must accurately recognize objects scattered throughout the environment and correctly place them in their designated locations. High-precision object recognition and accurate pick-and-place operations are critical factors for success in this task (Figure 3).

The **GPSR Task** assesses the robot's ability to understand and execute voice commands issued by humans. This includes not only simple instructions but also more complex directives such as "Count the number of people in the room" or "Answer the person standing near the trash can." As such, this task requires the integration of advanced AI technologies, including speech recognition and synthesis, contextual understanding, and flexible action planning (Figure 4).

The **Restaurant Task** challenges the robot to perform waiter duties in an unknown environment without prior map information. In this task, the robot must navigate a new space, locate customers, take orders, retrieve and deliver items, and interact with humans. Success in this task depends on the robot's ability to combine environmental perception, navigation, gesture recognition, and human interaction capabilities (Figure 5).

Through these tasks, the RoboCup@Home DSPL provides a comprehensive evaluation of the technical capabilities required for domestic service robots to address real-world challenges.

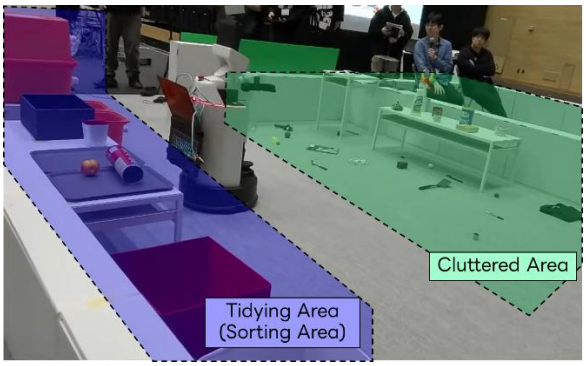


Figure 3 Robot Operation in the TidyUp Task

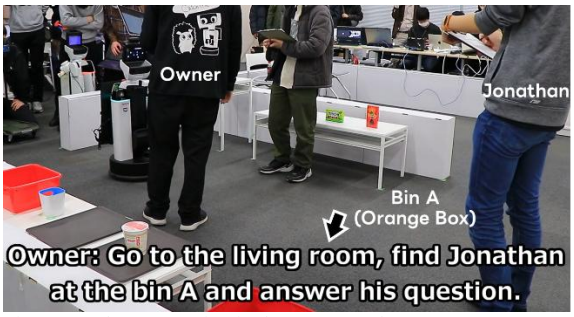


Figure 4 Robot Interaction in the GPSR Task



Figure 5 Robot Task Sequence in the Restaurant Task

3. Materials and Methods

In this study, we participated in the Domestic Standard Platform League (DSPL) of the RoboCup Japan Open 2024 @Home League to evaluate the integration methods of AI and robotics technologies for domestic service robots in real-world environments. The team "Re@dy" organized its members according to their assigned tasks, as shown in Table 1, to ensure an efficient development process. An agile development methodology was adopted, and a competition field was set up within the laboratory to conduct iterative cycles of planning, design, development, and testing. By working in a shared physical space, the team facilitated real-time communication and rapid problem-solving.

The Human Support Robot (HSR) developed by TOYOTA was used as the robotic platform. Since the HSR does not come equipped with high-performance computing resources by default, a laptop with a GPU was mounted on the robot's back to enable advanced processing tasks such as object recognition and speech

processing. ROS 1 (Noetic) was used for software development, and each AI module was implemented as a ROS 1 node. When necessary, cloud-based APIs such as OpenAI GPT-3 and Azure Speech Services were utilized, allowing for a hybrid processing system that combines local and cloud-based computation.

During the development of key technologies, the team analyzed the competition rulebook to extract the required functionalities, as summarized in Table 2. These technologies were integrated using the ROS 1 state machine library Smach to construct task execution flows compliant with competition rules.

In particular, for the TidyUp task, a task flow was implemented using Smach as follows:

1. Navigate to the area where objects are scattered.
2. Recognize nearby objects using the object recognition algorithm.
3. Calculate the 3D positions of objects using Point3D.
4. Grasp the objects using arm control.
5. Navigate to the designated storage area.
6. Place the objects and return to step 1.

In the GPSR task, Whisper was used for speech recognition, and GPT-3 handled contextual understanding, enabling the system to flexibly respond to complex instructions. For the Restaurant task, Cartographer was used for navigation in unknown environments, enabling autonomous map generation and navigation.

Table 1 Assignment of Students to Tasks

Student	Grade	Task
A	4	TidyUp
B	5	TidyUp
C	5	GPSR
D	5	Restaurant
E	5	Restaurant

Table 2 Utilization of Key Technologies in Each Task

Task	Technology	Software	AI or Not
TidyUp	Object Recognition	YOLACT Edge	Yes
	3D Position Estimation	Point3D	No
	State Machine	Smach	No
GPSR	Speech Recognition	Whisper	Yes
	Context Understanding	GPT-3 (API)	Yes
	State Machine	Smach	No
Restaurant	Navigation /SLAM	Cartographer	No
	State Machine	Smach	No

4. Results

In this study, we participated in three tasks of the RoboCup Japan Open 2024 @Home League DSPL: TidyUp, GPSR, and Restaurant. The results of the team "Re@dy" in each task are summarized in Tables 3 to 5. Notably, the team achieved 2nd place in the TidyUp task and tied for 2nd place in the GPSR task. However, no points were scored in the Restaurant task.

In the **TidyUp Task**, high-precision estimation of object positions was achieved using Point3D-based 3D point cloud processing, and appropriate pick-and-place operations contributed to the high score. Although YOLACT Edge was employed for object recognition, some misrecognition of small objects occurred. The task was executed stably by following the pre-designed Smach state machine flow.

In the **GPSR Task**, Whisper was used for speech recognition, and GPT-3 was employed for contextual understanding, enabling the robot to handle relatively complex commands. By dynamically switching among pre-defined state machines based on GPT-3 outputs, the robot was able to respond to a variety of instructions. However, due to the limited number of prepared states, the system was unable to handle all possible commands.

In the **Restaurant Task**, Cartographer was utilized for navigation in unknown environments, but an appropriate environmental map could not be generated on-site, and the task could not be completed.

Table 3 Competition Results of the TidyUp Task[9]

Rank	Score	Team	Affiliation
1st	780	TRAIL	The University of Tokyo
2nd	422.5	**Re@dy (Ours)**	National Institute of Technology, Kitakyushu College
3rd	410	HMA Tamunosuke	Kyushu Institute of Technology
4th	220	eR@sers	Tamagawa University
5th	145	OIT-RITS	Osaka Institute of Technology, Ritsumeikan University
6th	30	SOBITS	Soka University
7th	5	iPutok	Osaka International Professional University of Technology
8th ~ 11th	0	N/A	N/A

Table 4 Competition Results of the GPSR Task[9]

Rank	Score	Team	Affiliation
1st	50	HMA Tamunosuke	Kyushu Institute of Technology
2nd (tie)	25	**Re@dy (Ours)**	National Institute of Technology, Kitakyushu College
2nd (tie)	25	TRAIL	The University of Tokyo
4th	22.5	OIT-RITS	Osaka Institute of Technology, Ritsumeikan University
5th	12.5	SOBITS	Soka University
6th	1.25	eR@sers	Tamagawa University
7th ~ 11th	0	N/A	N/A

Table 5 Competition Results of the Restaurant Task[9]

Rank	Score	Team	Affiliation
1st	1300	eR@sers	Tamagawa University
2nd	1100	TRAIL	The University of Tokyo
3rd	650	HMA Tamunosuke	Kyushu Institute of Technology
4th	650	SOBITS	Soka University
5th	100	OIT-RITS	Osaka Institute of Technology, Ritsumeikan University
6th ~ 11th	0	**N/A (include ours)**	N/A

5. Discussion

5.1 Technical Insights

In the **TidyUp task**, stable pick-and-place operations were achieved through the integration of Point3D-based object position estimation and arm control. However, YOLACT Edge occasionally misrecognized objects, which led to decreased task efficiency. Future improvements should include adopting a more accurate object recognition model, and enhancing recognition accuracy through data augmentation techniques.

In the **GPSR task**, the limited number of pre-defined state machines constrained the system's flexibility in handling various tasks. To overcome this limitation, future work should focus on developing methods for dynamically generating and expanding state machines based on situational requirements.

In the **Restaurant task**, the failure to autonomously generate a reliable map of an unknown environment was the primary cause of task failure. This prevented the robot from performing autonomous navigation. Incorporating more advanced SLAM algorithms is a key challenge to be addressed in future research.

Beyond these technical lessons, the project also yielded important educational insights, discussed next.

5.2 Educational Insights

Robotics competitions such as RoboCup address these gaps. Unlike traditional lecture/exercise/homework formats, they (i) require students to survey, choose, and integrate appropriate AI models with minimal staff guidance, (ii) expose them to diverse, unstructured scenarios that are impossible to reproduce in class, and (iii) provide an external, high-stakes evaluation that motivates sustained, team-based iteration under time pressure. Such authentic engineering constraints sharpen problem-solving skills and deepen the link between theory and practice.

To gauge learning gains, we administered an Artificial Intelligence Learning Questionnaire (AILQ) after the competition (Table 6). Students first recalled and reported their pre-competition state (Before) and then completed the After section. Despite this retrospective design, mean scores rose uniformly across affective, behavioural, cognitive, and ethical domains, suggesting broadly positive effects.

In the present study, five students benefited. Scaling the model wide could follow two paths: (i) organising an internal RoboCup-style event, which is logistically simple but lacks external interaction; or (ii) encouraging participation in external competitions of comparable calibre, which delivers similar benefits but requires careful alignment of schedules and technical prerequisites. A full AI curriculum cannot yet rely solely on competition-based learning, but hybrid programmes—combining lectures, data-centric projects, and progressively larger competitions involving university labs or AI companies—are under consideration. Future research will adopt a prospective pre-/post-design with larger cohorts to validate these trends under more rigorous conditions.

Table 6 Mean AILQ Learning-Domain Scores Before and After RoboCup Participation ("Before" scores were collected after RoboCup; participants were instructed to recall and answer how they had felt prior to the competition.)

Subscale	Before	After
Affective Learning	3.06	3.19
Behavioural Learning	3.51	3.72
Cognitive Learning	3.19	3.42
Ethical Learning	2.99	3.04

6. Conclusion

In this study, we conducted a practical evaluation of AI and robotics integration methods for domestic service robots by participating in the RoboCup Japan Open 2024 @Home League DSPL. As a result, the team achieved second place in the TidyUp task and tied for second place in the GPSR task, demonstrating the effectiveness of applied technologies such as object recognition, speech recognition, and navigation. However, several technical challenges were also identified, including limitations in object recognition accuracy, insufficient task flexibility, and difficulties in map generation for unknown environments.

For the participating students, this project provided a valuable learning opportunity to apply advanced AI and robotics technologies in practical scenarios. Their abilities to connect theoretical knowledge with practical applications, collaborate effectively in teams, and proactively identify and address issues were significantly enhanced. These experiences are expected to become valuable assets for their future careers and improve their problem-solving capabilities in real-world environments.

Furthermore, the agile development approach and problem-based learning (PBL) methods implemented in this project are applicable not only to AI and robotics education but also to other fields of engineering and general education. Specifically, these methods can be incorporated into classroom-based PBL activities by introducing structured team development, task division, and sprint reviews to foster practical problem-solving skills alongside theoretical learning. In addition, applying the agile development framework to extracurricular activities such as the NHK College of Technology Robocon (Robot Contest) can improve project planning, task management, and effective team communication within limited timeframes.

In future work, we plan to further explore the versatility of these educational methods and investigate their applicability across various disciplines to contribute to the qualitative improvement of engineering education.

Future work will also focus on introducing more accurate object recognition models, developing dynamic task control methods, and applying advanced SLAM technologies to further promote the practical development of domestic service robots.

References

[1] 内閣府, "AI 戦略 2022," https://www8.cao.go.jp/cstp/ai/aistrategy2022_honbun.pdf, Accessed: May 15, 2025.

[2] Fuji Keizai Group, "世界のサービスロボット市場を調査," https://www.fuji-keizai.co.jp/press/detail.html?cid=24010, Accessed: May 15, 2025.

[3] 国立大学法人九州工業大学, "本学学生チームが地元の居酒屋とコラボし世界で初めて汎用サービスロボット HSR による配膳作業を実施しました！," https://www.kyutech.ac.jp/whats-new/topics/ entry-9343.html, Accessed: May 15, 2025.

[4] TOYOTA, "HSR," https://global.toyota/jp/download/8725271, Accessed: May 15, 2025.

[5] T. Sugiura and M. Watanabe, "Educational Benefit Produced from the Continuous Participation to the RoboCup World Competition," Journal of Toyota National College of Technology, No. 43, pp. 15-21, 2010.

[6] T. Sugiura, K. Ito, and M. Watanabe, "Present Circumstances and Its Effect of Participation in NHK Robocon/RoboCup Competition for Engineering Education in College of Technology," Journal of JSEE, Vol. 53, No. 5, pp. 71-76, 2005.

[7] L. Iocchi, J. T. C. Tan, and S. Castro, "RoboCup@Home Education: A New Format for Educational Competitions," Lecture Notes in Networks and Systems, vol. 240, 2021.

[8] J. T. C. Tan, L. Iocchi, A. Eguchi, and H. Okada, "Bridging Robotics Education between High School and University: RoboCup@Home Education," Proc. of the 2019 IEEE AFRICON Conference, 2019.

[9] RoboCup Japan Open @Home League, "RCJ24 Scores," https://sites.google.com/site/robocuphomejapan/japanopen2024/rcj24-scores, Accessed: May 15, 2025.

[10] D. T. K. Ng, W. Wu, J. K. L. Leung, T. K. F. Chiu, S. K. W. C., "Design and validation of the AI literacy questionnaire: The affective, behavioural, cognitive and ethical approach," British Journal of Educational Technology, Vol. 55, Issues 3, 1082-1104, 2024.

LEVERAGING GENERATIVE AI IN PROJECT-BASED LEARNING TO DEVELOP A FASHION RETAIL CHATBOT: LECTURERS' PERSPECTIVES

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Project-Based Learning (PjBL) is an instructional strategy practiced in Republic Polytechnic (RP) due to its learner-centred approach, which is grounded in research and practice-based principles of effective teaching and learning. This pedagogical approach equips students with the intellectual and practical skills necessary to solve real-world problems. By engaging students in authentic industry projects, PjBL offers immersive experiences that integrate industry collaboration and peer learning among student teams. One example from the School of Infocomm (SOI) in RP is our collaboration with Decks Private Limited, where students worked on a Final Year Project (FYP) to develop a conversational chatbot for the fashion retailer chains. The scope of the FYP aimed to address customer service challenges by leveraging AI technologies to enhance customer engagement and improve operational efficiency. Lecturers encourage students to use Generative AI (GenAI) and Large Language Models (LLMs), such as ChatGPT, GitHub Copilot, and DALL-E 3, as teaching and learning tools to create innovative solutions. The integration of these tools enabled students to experience the full scope of the AI development process, including data collection, model training, code testing, deployment, and performance evaluation. In our PjBL approach, lecturers encouraged students to explore and harness knowledge and technical know-how through the use of LLMs during their project engagement. Beyond technical skills, the project emphasised the importance of ethical AI development, focusing on mitigating risks such as AI hallucinations and ensuring data privacy and security. Through this hands-on experience, students gained valuable insights into the challenges and opportunities associated with emerging GenAI technologies. Collaborative learning among peers and engagement with industry partners enriched the learning process, fostering critical thinking, creativity, and problem-solving skills. While PjBL offered notable benefits, this paper also discussed the key challenges associated with its implementation from the lecturers' perspectives. The outcomes of this FYP demonstrated the effectiveness of PjBL in preparing students for the demands of the modern workforce. By applying theoretical knowledge in a real-world context, students developed not only technical expertise but also essential soft skills such as communication, teamwork, and adaptability. This comprehensive learning approach ensures that RP graduates were well-prepared to make meaningful contributions to the industry.

Keywords: *project-based learning, generative artificial intelligence*

Introduction

Project-Based Learning (PjBL) is a widely used instructional strategy at Republic Polytechnic (RP), offering students an opportunity to explore topics in depth through complex projects. These projects incorporate key learning challenges, where students apply their knowledge and skills to create meaningful deliverables. With adequate resources and time, students can produce high-quality projects that showcase their expertise.

PjBL is ideal for blending theory and practice to address complex problems, promoting deep exploration and producing well-crafted outcomes (Larmer et al., 2015; Blumenfeld et al., 1991). In this pedagogy, lecturers serve as facilitators and supervisors, guiding students through their projects and ensuring high-quality results. They may collaborate with community or industry partners to co-develop solutions, adding real-world relevance to the projects.

According to Almulla (2020), critics of PjBL often raise concerns that the focus on completing a project might overshadow the actual learning process. This paper presents two lecturers' perspectives on the effectiveness of PjBL in engaging students in authentic learning through the development of a fashion retail chatbot by RP's School of Infocomm (SOI) students, as part of their Final Year project (FYP).

Overview of Project-Based Learning

An instructional strategy guides the design and delivery of curricula in higher education institutions (IHLs). At Republic Polytechnic (RP), Problem-Based Learning (PBL) is the primary pedagogy for most diploma programmes, with three other instructional

strategies identified for their learner-centred approach: Project-Based Learning (PjBL), Cognitive Apprenticeship (CA), and Interactive Seminar (IS).

PjBL enables students to actively gain knowledge and skills by working on extended projects that involve investigating and responding to real-world problems. It fosters active learning, critical thinking, and collaboration, centred around exploring and investigating complex challenges. Lecturers function as facilitators and supervisors, ensuring students stay on track and produce high-quality outcomes. They may also collaborate with external stakeholders to co-develop solutions, bringing practical, real-world impact.

Gonzalez (2016) states that PjBL engages and inspires students by incorporating projects at the outset of their learning journey. By involving students in authentic problems, PjBL connects learning to real-world applications, making it more meaningful and practical. As a result, students take an active role in their learning, enhancing knowledge retention and developing key skills such as time management, teamwork, and task delegation.

Since PjBL has been posited as a powerful tool for nurturing student creativity and is adaptable to various learning preferences and styles (Yu, 2024), this approach could also foster creativity by encouraging original thinking and innovative solutions (Zhang et al., 2023).

Background of AI Chatbots

ELIZA was one of the first chatbots developed in 1966. It used pattern-matching techniques to generate automated responses (Lane et al., 2025). Aiming to improve conversational depth, PARRY was developed half a decade later to simulate a patient with paranoid schizophrenia (Jeevanandam, 2024). In 2016, Amazon conducted an international university competition called the AWS Chatbot Challenge[1], focused on building a socialbot. The chatbots created were capable of conversing with humans on popular topics, ranging from entertainment and fashion to politics, sports, science, and technology. With the advancements in Natural Language Processing (NLP), Deep Learning, transformers, and Large Language Models (LLMs) in recent years, AI chatbots have become more context-aware and capable of providing human-like conversations.

Roles of Chatbots for Online Fashion Retailing

In today's virtual customer service environment, online retail companies are expected to offer 24/7 on-demand support. Customers now seek instant answers, rather than waiting for a response from a representative. Gartner[2] forecasts that by 2027, chatbots will become the primary customer service channel. Chatbots not only automate customer support but also help with tasks like collecting user information, organising meetings, and reducing operational costs. Their ability to handle multiple customer requests simultaneously and respond quickly has led to their rapid growth. According to a 2017 study[3], key reasons people prefer chatbots include productivity, curiosity, and social interaction. Powered by generative AI, modern chatbots offer dynamic responses, making them increasingly prevalent in customer service.

Applying PjBL Methodology in Final Year Projects

The purpose of a Final Year Project (FYP) is to provide our final year students with a hands-on, practical experience that integrates and applies the knowledge and skills they have acquired throughout their course of study. At RP, the FYP typically spans one semester, lasting around 16 weeks. It is undertaken in the final year of a diploma programme, often in conjunction with an industry internship.

PjBL is highly suitable for FYPs because it provides a hands-on approach, enabling students to apply their knowledge in real-world contexts. Developing an online retail chatbot was a clearly defined problem for FYP students. Not only were the challenges complex and open-ended, but they also demanded critical thinking, strong problem-solving skills, and innovation, which are core elements of PjBL. This approach also fostered collaboration, teamwork, and communication, mirroring real-world professional environments. By partnering with industry, PjBL provided students with practical experience and exposure to current software practices, while enhancing self-management and project management skills. Moreover, the tangible outcomes of PjBL-based FYPs, such as prototypes and solutioning, helped students build strong portfolios, improving their employability and industry readiness.

Before attaining the learning outcomes from PjBL, it is essential to first define clear and measurable outcomes that focus on specific skills, knowledge, and real-world ICT applications. Nevertheless, projects should be structured around authentic, real-world challenges that encourage critical thinking, creativity, and collaboration. Active participation is crucial as it grants students the opportunity to take ownership of their learning through group discussions, brainstorming, and peer feedback. Lecturers functioned as facilitators rather than traditional teachers, guiding students with open-ended questions and providing necessary resources while promoting self-directed learning through problem-solving. Reflection and feedback also played a vital role (Thomas, 2020; Guo et al., 2020), as regular reflections helped students evaluate their progress in software development and identify areas for improvement.

Generative AI for Teaching and Learning

[1] AWS Chatbot Challenge, https://awschatbot2017.devpost.com/

[2] https://www.gartner.com/en/newsroom/press-releases/2022-07-27-gartner-predicts-chatbots-will-become-a-primary-customer-service-channel-within-five-years

[3] https://vdoc.pub/documents/internet-science-4th-international-conference-insci-2017-thessaloniki-greece-november-22-24-2017-proceedings-14epiogqcih8

There is no specific module in SOI that teaches niche topics such as virtual assistants or chatbot development, let alone the ideal Large Language Models (LLMs) to be selected for responding effectively to users' enquiries and providing decision-making support and appropriate fashion recommendations. Therefore, our FYP students had to conduct exploration and investigation into the problem, which typically included literature reviews, data collection, and analysis before starting their project development. Students leveraged Generative AI (GenAI) tools through PjBL in identifying relevant LLMs, prototyping solutions, and refining their chatbot applications. By using GenAI tools, students were able to simulate various chatbot responses, evaluate performance, and optimise user interactions in real time.

Project Execution

In this industry FYP, we partnered with Decks Pte Ltd, one of the leading apparel suppliers for department stores in Singapore, to develop a conversational chatbot for fashion retail through FYPs. Through an industry partnership with Decks, FYP students from SOI designed and developed a fashion retail chatbot featuring an automated system that communicated with humans via text or voice messages. It was envisioned as a virtual customer service companion integrated into a Shopify website to help the company connect more closely with its customers.

FYP execution focuses on students carrying out their planned research and development work to achieve the project's objectives. Throughout the semester, students used their technical and analytical skills to design solutions, perform testing, and develop prototypes. The following is the sequence of AI tools utilised during project execution:

1. Text and Content Generation
2. Code Generation
3. Image Generation

Text and Content Generation

During the first two weeks of the FYP, our students leveraged GenAI for brainstorming and literature review. Tools such as ChatGPT[4], Gemini[5], Claude[6], Perplexity[7], and DeepSeek[8] are AI-powered answer engines that generated text content based on patterns learned from data. These tools are powered by LLMs, enabling them to produce human-like responses, making them highly effective for tasks such as text and content generation through a sophisticated process of analysing and predicting patterns in natural language.

Throughout project development, students utilised LLMs as both a learning tool and a development resource to guide them in building their chatbot. As a learning tool, it helped students grasp natural language processing (NLP) concepts and provided real-time assistance in generating conversational responses. Through prompt engineering, students were able to experiment with designing chatbot dialogue flows, refining input prompts, and optimising responses for relevance and clarity (see Figure 1). As a development resource, LLMs are used for simulating chatbots for customer support, allowing students to test and improve their projects iteratively. In addition, these models provided instant feedback, helping students debug software issues and improve chatbot performance more efficiently.

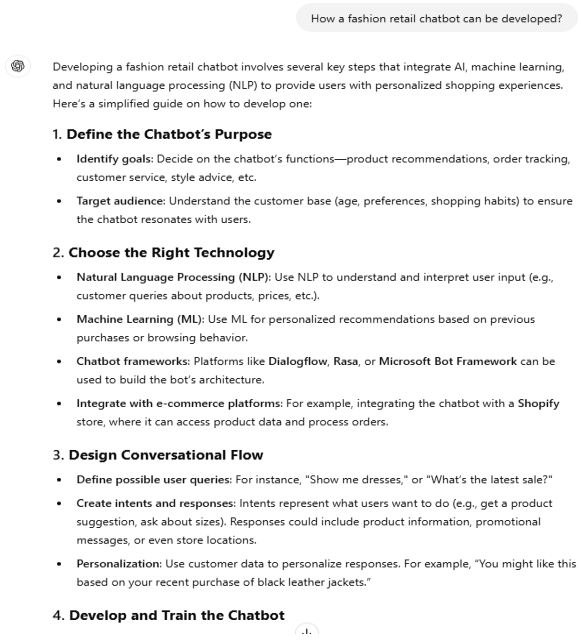


Figure 1. An example of an enquiry for information on chatbot development using ChatGPT.

Code Generation

During the project development phase, students explored GitHub Copilot to generate programming code for chatbot testing and performance measurements, as shown in Figure 2. This GenAI tool was powered by OpenAI's *Codex*, which is an LLM trained on a wide range of programming languages, including Python, Java, and C++. *Copilot* suggested code snippets, generated functions, and even assisted the students with specific tasks based on the comments or prompts they had provided in their code editor, such as Visual Studio Code.

CoPilot assisted our students in writing functions or classes, provided code suggestions, and helped with their debugging and refactoring. For more advanced types of chatbot testing, students used automated test libraries, such as *pytest* or *Selenium*, to evaluate the chatbot user interfaces (UIs). For performance testing, students simulated multiple users interacting with the chatbot using load testing tools like *JMeter*.

Although Copilot is a powerful GenAI tool for IT students, it comes with several limitations. For instance,

[4] https://chatgpt.com/
[5] https://gemini.google.com/
[6] https://claude.ai/
[7] https://www.perplexity. ai/
[8] https://chat.deepseek.com/

it can generate inaccurate or low-quality code due to its lack of full contextual understanding. Conspicuously, the output generated may contain inconsistencies in coding style or conventions. Since the AI models depend on public code data, it can result in suboptimal solutions for niche problems. Most importantly, there are risks of security vulnerabilities or licensing concerns due to the potential for suggesting copyrighted code.

```python
# chatbot.py
def chatbot_response(user_input):
    responses = {
        "hello": "Hi there!",
        "how are you": "I'm doing well, thank you!",
        "bye": "Goodbye! See you soon."
    }
    return responses.get(user_input.lower(), "Sorry, I didn't understand that.")
```

Testing the Chatbot

```python
import unittest
from chatbot import chatbot_response

class TestChatbot(unittest.TestCase):

    def test_greeting(self):
        response = chatbot_response("hello")
        self.assertEqual(response, "Hi there!")

    def test_how_are_you(self):
        response = chatbot_response("how are you")
        self.assertEqual(response, "I'm doing well, thank you!")

    def test_bye(self):
        response = chatbot_response("bye")
        self.assertEqual(response, "Goodbye! See you soon.")

    def test_unknown(self):
        response = chatbot_response("random text")
        self.assertEqual(response, "Sorry, I didn't understand that.")

if __name__ == '__main__':
    unittest.main()
```

Figure 2. An example of using GitHub Copilot as a code assistance tool to generate a Python programming script for testing chatbot.

Copilot is more suitable for common coding tasks but may not manage complex or novel problems well. Therefore, students who over-rely on it may hinder their learning. Additionally, it lacks debugging and testing features and may cause performance issues in large codebases. Despite these drawbacks, it remains useful for students to streamline routine tasks, but it should be used critically alongside manual code reviews by peers and FYP supervisors.

Image Generation

Along with matching prompts from text generation, students also used GenAI tools, such as Midjourney[9], MaxAI[10], OpenArt[11], or Image Creator in Bing[12] to generate a set of images and graphics for use in their FYP report (see figure 3). The purpose of an GenAI image creator in GenAI is to automatically generate realistic or stylised images based on user input. These tools play a vital role in creative content generation, helping designers, marketers, and visual content creators to produce unique visuals for advertising, social media, and storytelling.

GenAI tools enhance education, training, design, and research by developing graphical concepts, visualising complex ideas, and generating assets rapidly for entertainment and gaming. They support students' research by producing synthetic data for AI training, making high-quality visuals accessible to students, promoting inclusivity, and reducing the need for advanced skills or resources.

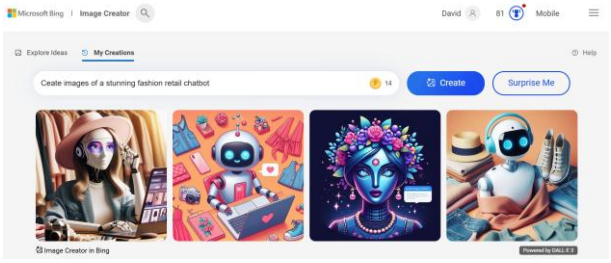


Figure 3. Examples of AI images generated using DALL-E 3.

However, the use of GenAI image generators came with several challenges. One key issue was the quality and accuracy of the generated images, which may have had flaws such as distorted features or mismatched proportions. Bias and underrepresentation in training data could also have led to stereotypical or unbalanced content, raising concerns about fair representation.

Moreover, ethical and copyright issues are significant, as it is often unclear whether the AI-generated images infringe on copyrighted material. Furthermore, these tools can be misused to create misleading content, such as deepfakes, which contribute to misinformation and deception.

While AI could generate visually impressive content, it lacked true creativity and struggled to understand abstract concepts and complex cultures. Computational cost was another challenge, as generating high-quality images required substantial processing power, which was costly and resource intensive.

Finally, students could risk becoming overly reliant on AI, potentially stifling human creativity, and diminishing the emphasis on developing their creative skills.

Responsible AI Implementation

When using LLMs, it is crucial to consider both ethical and safety aspects. Ethically, LLMs could reflect biases present in the training data, leading to unfair or discriminatory outputs. Therefore, issues such as privacy, data security, and the potential generation of misinformation or copyrighted content must be addressed. The responsible usage of GenAI tools involves verifying outputs and protecting sensitive information. There are also societal concerns, such as

[9] https://www.midjourney.com/
[10] https://www.maxai.co/ai-tools/ai-art/
[11] https://openart.ai/
[12] https://www.bing.com/images/create

user dependency, which could be mitigated through education and human oversight (Yan et al., 2023).

From a safety perspective, LLMs could have generated harmful or offensive content and could have been exploited for malicious purposes, such as phishing or spreading fake news. Autonomous systems, such as AI chatbots that relied on LLMs to generate text outputs, posed risks of physical harm if errors occurred, necessitating rigorous testing and safety protocols (Ayyamperumal & Ge, 2024).

Furthermore, Ahmad (2024) highlighted the importance of human-centricity and proposed that chatbot owners should offer clear channels for feedback. He emphasised the need for an escalation of incidents when necessary. Balancing these considerations could ensure that LLMs are used responsibly, leading to a positive impact.

LLM such as *ChatGPT* is a valuable tool for students to explore and experiment with chatbot development, allowing them to better understand natural language processing, enhance their coding skills, and create innovative solutions. Nevertheless, it was essential that students remained mindful of ethical considerations and responsible AI practices throughout the development process.

To prevent over-reliance on Generative AI (GenAI), supervisors implemented safeguards such as weekly progress checkpoints, project presentations, and Q&A sessions to assess students' understanding and originality. Clear guidelines on AI usage were established, and students were required to acknowledge AI assistance in their reports. Additional measures, including collaborative development, supervisor reviews, code walkthroughs, and AI detection tools like Measure of Software Similarity (MOSS) and Turnitin[13], ensured authenticity in project work.

Results and Discussion

The PjBL approach in this study was found to enhance student learning by offering hands-on, real-world experiences that made concepts meaningful. It promoted active engagement, critical thinking, and problem-solving, while also fostering essential skills such as teamwork, communication, and creativity. Authentic assessments allowed them to demonstrate their knowledge through practical software applications they developed.

Four teams of final-year SOI students, supervised by two lecturers, developed the fashion retail chatbot over the course of one semester. The perspective shared by the two lecturers highlighted how this industry project motivated students to enhance their technical competencies using GenAI technologies while applying project management skills across various stages of the software development lifecycle (SDLC). Students carried out code validation and chatbot testing using LLMs, gaining exposure to industry practices and new innovations from their unique perspectives.

While PjBL offered significant benefits, it also presented challenges. Not all students possessed the same level of self-management or collaboration skills at the start, which could lead to imbalances in group dynamics. Some dominated certain tasks, while others struggled with independence or staying on track. Ensuring consistent quality across project teams was also difficult. Certain projects appeared polished but lacked depth, while others reflected deep understanding but fell short in presentation.

Another significant hurdle students encountered during PjBL was the limited availability of resources such as time, materials, information, and expertise. These resources were essential for completing the project, but they were not always readily available or accessible to all students. This restricted their creativity, inquiry, and problem-solving abilities. To address this, lecturers provided adequate and appropriate resources or guided students in finding and evaluating them. They also supported students in prioritising tasks, managing time effectively, and seeking assistance when needed.

A further challenge involved managing the limitations of LLMs, particularly the issue of hallucination, where outputs could be inaccurate or unsubstantiated. Hallucination occurred due to factors such as gaps in training data, biases, or vague prompts, resulting in convincing yet factually inaccurate outputs. To mitigate these risks, students were encouraged to fact-check responses using reliable sources and provide clear, detailed prompts during queries.

Lecturers also played a critical role in guiding students to use GenAI tools, such as ChatGPT and Claude, responsibly. The widespread adoption of LLMs led students to ask them questions, expecting factual answers. While GenAI models could answer some questions correctly, they also confidently provided many incorrect answers. For more accurate results, integrating external knowledge bases through retrieval-augmented generation (RAG) and domain-specific fine-tuning can enhance reliability and reduce errors. Close supervision and structured support for semantic searches are crucial when students undertake high-stakes tasks.

Conclusion

PjBL is a powerful pedagogical approach that provides students with real-world experience. Integrating GenAI technologies in Final Year Projects (FYPs) not only helped students enhance their technical skills but also enabled them to develop essential soft skills such as teamwork, communication, and project management.

The successful development of an online fashion retail chatbot highlighted the potential of PjBL to create meaningful learning experiences. However, challenges such as skill disparities and varying project quality had to be addressed through targeted support, structured guidance, and continuous improvement of the PjBL framework.

[13] https://justdone.ai/

Moving forward, incorporating more industry collaborations, and leveraging advanced GenAI tools will further enhance the effectiveness of PjBL and better prepare students to thrive in an increasingly technology-driven world. RP remains committed to engaging students in authentic industry projects, ensuring they acquire the intellectual and practical skills necessary to tackle real-world challenges. We are confident that these experiences will enable our students to make meaningful contributions to the industry.

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References

Ahmad, A. (2024), Ethical Considerations in the Deployment of AI Chatbots in Customer Service. https://botsify.com/blog/ethical-considerations-in-the-deployment-of-ai-chatbots/. Accessed: 2025-02-04.

Almulla, M. (2020), The Effectiveness of the Project-based Learning (PBL) Approach as a Way to Engage Students in Learning. https://doi.org/10.1177/2158244020938702.

Ayyamperumal, S.G. & Ge, L. (2024), Current State of LLM Risks and AI Guardrails. https://doi.org/10.48550/arXiv.2406.12934.

Blumenfeld, P. C., Soloway, E., Marx, R.W., Krajcik, J.S., Guzdial, M. & Palincsar, A. (1991), Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. https://doi.org/10.1080/00461520.1991.9653139.

Chatbots to be primary communication channel by 2027: Gartner (2022), https://www.digitalnationaus.com.au/news/chatbots-to-be-primary-communication-channel-by-2027-gartner-583655._Accessed: 2024-12-09.

Gonzalez, J. (2016), Project-Based Learning: Start Here, https://www.cultofpedagogy.com/project-based-learning/. Accessed: 2025-02-08.

Guo, P., Saab, N., Post, L.S. & Admiraal, W. (2020), A Review of Project-Based Learning in Higher Education: Student Outcomes and Measures. https://doi.org/10.1016/j.ijer.2020.101586.

Jeevanandam, N. (2024), AI Insights PARRY: The Pioneering Chatterbot of 1972. https://indiaai.gov.in/article/parry-the-pioneering-chatterbot-of-1972. Accessed: 2025-02-05.

Lane, R., Hay, A., Schwarz, A, Berry, D.M. & Shrager, J. (2025), ELIZA Reanimated: The World's First Chatbot Restored on the World's First Time Sharing System. https://doi.org/10.48550/arXiv.2501.06707.

Larmer, J., & Mergendoller, J. (2015), Setting the Standard for Project-Based Learning. https://www.labster8.net/wp-content/uploads/2020/01/Setting-the-Standard-1-Why-Project-Based-Learning.pdf. Accessed: 2025-02-08.

Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., Kuttler, H., Lewis, M., Yih, W., Rocktaschel, T. Riedel, S. & Kiela, D. (2020), Retrieval-Augmented Generation for Knowledge-Intensive NLP Tasks. https://doi.org/10.48550/arXiv.2005.11401.

Schmelzer, R. & Walch, K. (2025), Top 10 Ethical Considerations for AI Projects. https://www.pmi.org/blog/top-10-ethical-considerations-for-ai-projects#:~:text=AI%20systems%20must%20not%20create,dignity%2C%20and%20well%2Dbeing. Accessed: 2025-02-04.

Thomas, J. W. (2000). A Review of Research on Project-Based Learning, http://www.bobpearlman.org/BestPractices/PBL_Research.pdf. Accessed: 2025-02-08.

Yan, L., Sha, L., Zhao, L., Li, Y., Martinez-Maldonado, R., Chen, G., Li, X., Jin, Y. & Gasevic, D. (2023), Practical and Ethical Challenges of Large Language Models in Education: A Systematic Scoping Review. https://doi.org/10.1111/bjet.13370.

Yu, H. (2024), Enhancing Creative Cognition through Project-Based Learning: An In-depth Scholarly Exploration. https://doi.org/10.1016/j.heliyon.2024.e27706.

Zhang, L. & Ma, Y. (2023), A Study of the Impact of Project-based Learning on Student Learning Effects: A Meta-Analysis Study. https://doi.org/10.3389/fpsyg.2023.1202728.

Integrating External Competitions into Project-Based Learning for AI Education: The Development of TinySlime at NIT, Toba College

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At the National Institute of Technology, Toba College, our Department of Informatics and Mechanical Engineering champions Project Based Learning (PBL) integrated with external competitions (e.g., World AI Competition YAMAGUCHI 2022 U18 2nd Place, DCON2024) to cultivate advanced AI competencies. This paper presents a two-fold educational strategy: initially, it highlights how this approach enabled students to develop "TinySlime," a high-performing, 1.1B parameter Japanese Large Language Model (LLM). The model's strong benchmark performance against larger LLMs, its on-premise operational capability minimizing data-leakage risks, and its public availability on Hugging Face collectively evidence the students' profound understanding of contemporary LLM challenges and their technical proficiency acquired through our pedagogical methods. Subsequently, this study details an educational intervention where the student-developed TinySlime was utilized as a primary teaching tool in an AI module. We conducted a comparative analysis with a traditional teaching approach, assessing pedagogical impact through student surveys. Results revealed that the TinySlime-enhanced module led to significantly higher student-reported cognitive engagement, motivation, authenticity of learning, and overall satisfaction ($p < .001$ across all categories). Specific benefits included an enhanced understanding of LLM principles and increased confidence in applying AI skills. This research underscores the efficacy of a student-centered approach where learners become creators, and their innovations are leveraged to enrich the educational experiences of their peers, demonstrating a powerful cycle of learning and application in AI education.

Keywords: *Project-Based Learning (PBL), AI Education, Large Language Models (LLMs), Educational Technology*

Introduction

The effective cultivation of advanced technological competencies, particularly in rapidly evolving domains like Artificial Intelligence (AI), is a primary objective for contemporary engineering education. At the Department of Informatics and Mechanical Engineering, National Institute of Technology, Toba College, we employ Project Based Learning (PBL) as a foundational pedagogical strategy. This approach is significantly enhanced by actively encouraging student participation in external technology competitions, including prestigious events such as the World AI Competition YAMAGUCHI 2022 (where our students achieved 2nd Place in the U18 Division) and DCON2024. Such engagement is designed to provide students with authentic challenges, thereby fostering deep technical expertise, innovative problem-solving, and an understanding of current industry and research landscapes.

The development of Large Language Models (LLMs) represents a forefront of AI research, characterized by rapid advancements in model scale and performance (Bai & Bai, 2023; Radford & Wu, 2019), often explained by scaling laws (Kaplan & McCandlish, 2020). However, the immense computational demands and a scarcity of efficient, high-performing models for specific languages like Japanese present substantial hurdles, particularly within educational contexts with limited resources (Fujii & Nakamura, 2024). It is within this challenging yet opportunity-rich environment that our educational approach demonstrates its efficacy. As a direct outcome of their engagement in our contest-centric PBL curriculum, students at our institution developed "TinySlime," a compact Japanese language model. The technical sophistication of TinySlime serves as compelling evidence of the students' profound understanding of contemporary LLM challenges and methodologies. For instance, their work drew upon established architectures like Llama 2 (Touvron & Martin, 2023) and incorporated current techniques such as Chat Vector (Huang & Li, 2023), reflecting an awareness of advancements seen in influential small models like the Phi-series (Gunasekar & Zhang, 2023; Hughes, 2023; Abdin & Jacobs, 2024) and TinyLlama (Zhang & Zeng, 2024). Despite its modest 1.1 billion parameters and development using limited hardware (two RTX 3090s and one RTX A6000), TinySlime achieved notable performance on Japanese benchmarks (e.g., Kurihara & Kawahara, 2022; Suzuki & Suzuki, 2020; elyza, n.d.). This accomplishment, especially its ability to match or surpass larger contemporary models,

underscores the high level of technical skill and current knowledge students acquired. Furthermore, their decision to make TinySlime publicly available on Hugging Face and design it for on-premise operation—thereby mitigating data leakage risks and promoting accessibility—demonstrates their practical understanding of real-world deployment considerations.

This paper, however, extends beyond documenting the development of TinySlime as an indicator of student learning. It primarily focuses on a subsequent educational initiative where this student-developed artifact was purposefully integrated as a pedagogical tool to enhance AI education for their peers. We implemented a module utilizing TinySlime as a central teaching resource and compared its educational impact against existing teaching approaches. This novel educational practice included dedicated Q&A sessions with the original student developers of TinySlime, fostering a unique peer-learning environment. To deepen the students' understanding of core concepts, such as the Transformer algorithm—foundational to models like TinySlime (related concepts in Ouyang & Wu, 2022; Schulman & Wolski, 2017; Dao & Fu, 2022)—we conducted interactive group work and hands-on workshops where students directly engaged with and manipulated the model.

Therefore, this study reports on a two-tiered educational strategy. Firstly, it presents the development of TinySlime as a testament to the effectiveness of PBL enriched by external contest participation in imbuing students with advanced, research-informed AI capabilities. Secondly, and more centrally, it evaluates the pedagogical value of leveraging such a student-created technological artifact as a tangible and relatable resource for teaching complex AI concepts to other students. Through this investigation, we aim to illuminate how integrating student-led innovation into the curriculum can create a virtuous cycle, fostering both advanced skill acquisition and enriched learning experiences within AI education.

Materials and Methods or Pedagogy

Educational Context: Fostering AI Competencies at the National Institute of Technology, Toba College

This study was conducted within the Department of Informatics and Mechanical Engineering at the National Institute of Technology, Toba College. Our curriculum emphasizes PBL as a primary pedagogical approach to cultivate practical engineering skills. A distinctive feature of our PBL strategy is the active encouragement and support for student participation in external technology and AI competitions, such as the World AI Competition YAMAGUCHI 2022 (where our students achieved 2nd Place in the U18 Division) and DCON2024. These competitions provide authentic, challenging environments that motivate students to acquire and apply cutting-edge knowledge beyond standard coursework.

Evidencing Advanced Student Capabilities: The TinySlime LLM Project

The development of "TinySlime," a 1.1 billion parameter Japanese language model, by students engaged in this PBL and contest-driven framework serves as a significant exemplar of the advanced technical competencies cultivated. This student-led project is not the primary focus of the current educational paper, but its technical execution and outcomes provide crucial evidence of the students' sophisticated understanding of contemporary LLM development challenges and state-of-the-art methodologies.

Demonstrated Understanding of LLM Development: The students embarked on this project to address the dual challenges of high computational costs associated with large LLMs (Kaplan & McCandlish, 2020) and the specific need for efficient Japanese language models. Their preliminary experiments involved a rigorous comparison of existing models like Llama 2 (Touvron & Martin, 2023), TinyLlama (Zhang & Zeng, 2024), and ELYZA-japanese-Llama-2 (elyza, n.d.), and various open-source datasets to determine optimal choices for their resource-constrained environment (Figures 1 & 2, Tables 1 & 2). This selection process itself demonstrated a mature research approach.

Technical Implementation and Optimization: For continual pre-training, students selected high-quality, well-filtered datasets (e.g., augmxnt/shisa-pretrain-en-ja-v1) and employed techniques like Data Selection for Language Models via Importance Resampling (DSIR) to maximize data diversity under computational limitations. They meticulously configured hyperparameters (e.g., micro-batch size, gradient accumulation, AdamW optimizer settings, cosine learning rate scheduler) and utilized tools like FlashAttention 2 (Dao & Fu, 2022) and DeepSpeed (Holmes & Tanaka, 2024) to enhance training efficiency and manage VRAM usage on their hardware (three GPUs equivalent to GeForce RTX 3090s).

Instruction Tuning and Chat Capabilities: To imbue TinySlime with chat capabilities, the students astutely applied the Chat Vector technique (Huang & Li, 2023) to transfer abilities from a DPO-tuned base model (TinyLlama-Chat). This choice allowed them to bypass the need for extensive instruction tuning data, effectively leveraging existing advanced models—a pragmatic solution given resource constraints. They further employed imitation learning, referencing the Phi-family of models (Gunasekar & Zhang, 2023; Hughes, 2023), using synthetic data generated by Mixtral-8x7B-v0.1.

Performance and Evaluation: The students rigorously evaluated TinySlime using established Japanese benchmarks, including the JP Language Model Evaluation Harness (focusing on JGLUE tasks like Kurihara & Kawahara, 2022; Suzuki & Suzuki, 2020) and ELYZA-task-100. The results indicated that their 1.1B parameter model performed exceptionally well, outperforming some larger models and demonstrating

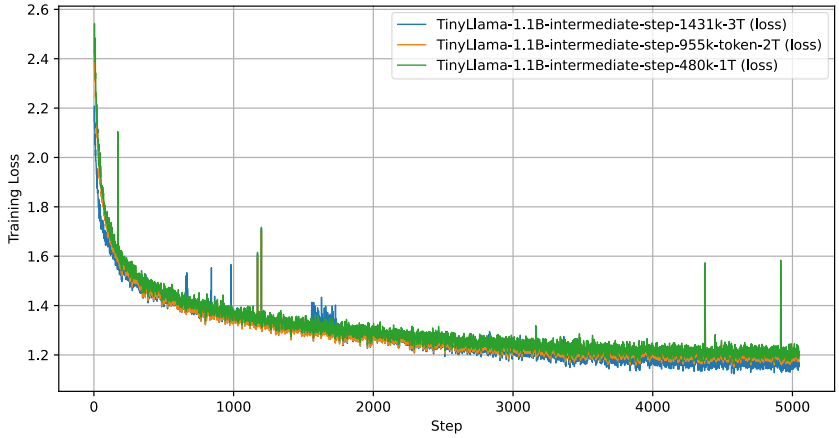


Figure.1 The training loss curves for each model are shown. From this figure, one can observe a decreasing trend in the loss during the model's training process. The lower training loss indicates that the model fits the data better, decreasing the loss as the training progresses. In particular, TinyLlama/TinyLlama-1.1B-intermediate-step-1431k-3T has the lowest loss value compared to the other models, which confirms that learning is progressing.

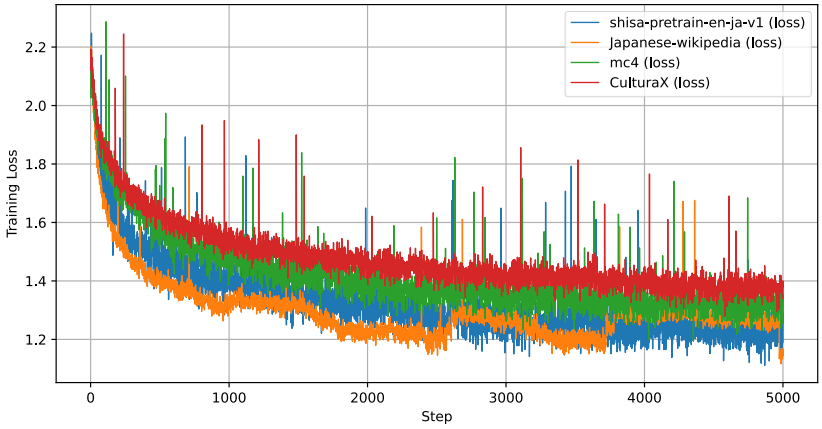


Figure.2 The training loss curves for each training dataset are shown. This figure compares the changes in losses during the model's training process using different data sets. The lower training loss indicates that the model fits the data better, and we can see how the loss decreases as the training progresses. In particular, the augmxnt/shisa-7b-v1 dataset shows the fastest loss decrease compared to the other datasets, confirming that the training progresses efficiently.

Table.1 The results of comparing the performance of different models are shown. The horizontal axis represents the different models, and the vertical axis shows the performance evaluation index. As can be seen from the table, the TinyLlama/TinyLlama-1.1B-intermediate-step-1431k-3T model shows the highest performance, outperforming the other models.

base model name	JCommonsenseQA (3-shot)	JNLI (3-shot)	MARC-ja (0-shot)	JSQuAD (2-shot)	jaqket-v2 (1-shot)	xwinograd (1-shot)	mgsm (0-shot)	AVERAGE (5-shot)
TinyLlama/TinyLlama-1.1B-intermediate-step-1431k-3T	22.52	30.01	59.15	52.17	21.20	63.61	1.20	35.69
TinyLlama/TinyLlama-1.1B-intermediate-step-955k-token-2T	24.04	30.59	52.69	57.81	21.23	59.85	1.20	35.34
TinyLlama/TinyLlama-1.1B-intermediate-step-480k-1T	19.75	31.50	50.14	49.23	20.80	60.06	1.60	33.30

capabilities comparable to certain 7B parameter models . They also conducted safety evaluations, showing the model's capacity for ethical responses inherited via Chat Vector and learned through synthetic data, referencing concepts like RLHF (Ouyang & Wu, 2022; Rafailov & Sharma, 2023).

The student's ability to navigate these complex technical choices, optimize for limited resources, and achieve competitive performance underscores their learning depth and proficiency in state-of-the-art LLM development. The model's availability on Hugging Face and its on-premise operational capability further highlight their practical problem-solving skills, addressing issues of accessibility and data security.

Pedagogical Intervention: Utilizing Student-Developed TinySlime as a Teaching Tool

Building on the successful development of TinySlime as an outcome of our PBL and contest-driven approach, we designed a pedagogical intervention to leverage this student-created artifact as a teaching tool for a subsequent cohort of students in an AI-related module.

Participants and Design: The intervention took place within a cross-grade PBL course in the Department of Informatics and Mechanical Engineering, involving 15 student participants. A comparative approach was adopted, where one group of students (the "LLM group") experienced the TinySlime-enhanced curriculum, while a control group (the "Existing group") received instruction through our established methods for teaching similar AI concepts.

Intervention Components: The intervention for the LLM group was delivered as a structured, four-session module designed to provide concrete, hands-on engagement. Session 1 began with a Q&A session featuring TinySlime's student developers, focusing on their design choices and development challenges. This was followed by students setting up the model on their local machines. In Sessions 2 and 3, students engaged in practical, hands-on exploration by running the TinySlime model, experimenting with various prompts to understand its capabilities and limitations, and observing operational aspects like system resource usage. The module culminated in Session 4, a group discussion where students shared and compared their findings. Instead of a formal report, this session focused on a collaborative reflection on the model's unique characteristics, the challenges of LLM development, and the value of a smaller, specialized model.

To assess the impact of this intervention, a survey was administered to both the LLM group and the Existing group at the end of the module. This Data Collection and Evaluation phase utilized a questionnaire that measured students' perceptions across five key dimensions: Cognitive Engagement, Motivation, Collaboration, Authenticity of Learning Experience, and Overall Satisfaction, with items rated on a Likert scale.

Results and Discussion

Reliability of Survey Instrument

The survey instrument demonstrated good to excellent internal consistency for both the LLM and Existing method groups across all measured categories. Cronbach's alpha coefficients were as follows: Cognitive (LLM: 0.906, Existing: 0.752), Motivation (LLM: 0.934, Existing: 0.869), Collaboration (LLM: 0.931, Existing: 0.877), Authenticity (LLM: 0.961, Existing: 0.907), and Satisfaction (LLM: 0.800, Existing: 0.970). These values indicate that the scales used were reliable measures of the intended constructs.

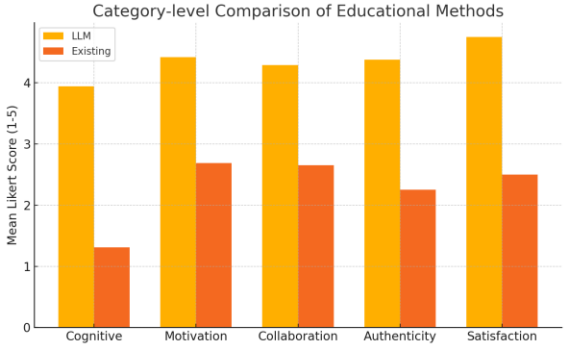


Figure 3 Category-Level Comparison Of Educational Methods

Comparative Analysis of Student Perceptions: LLM-Enhanced vs. Existing Pedagogy

The survey data revealed statistically significant and meaningful differences in student perceptions between the group taught using the TinySlime-enhanced pedagogy (LLM group) and the group taught using existing methods (Existing group).

Overall Category-Level Comparison: As illustrated in Figure 3, the LLM group reported significantly higher mean scores across all five pedagogical dimensions: Cognitive Engagement (LLM M=3.94, SD=0.96 vs. Existing M=1.31, SD=0.45; $p < .001$), Motivation (LLM M=4.42, SD=0.83 vs. Existing M=2.69, SD=0.99; $p < .001$), Collaboration (LLM M=4.29, SD=0.87 vs. Existing M=2.65, SD=1.01; $p < .001$), Authenticity (LLM M=4.38, SD=0.85 vs. Existing M=2.25, SD=0.98; $p < .001$), and Satisfaction (LLM M=4.75, SD=0.41 vs. Existing M=2.50, SD=1.05; $p < .001$) .

These findings suggest a strong positive impact of incorporating the student-developed LLM and associated activities into the learning experience.

Specific Item-Level Insights: Further analysis at the item level highlighted several key areas where the LLM-enhanced approach excelled. Students in the LLM group reported:

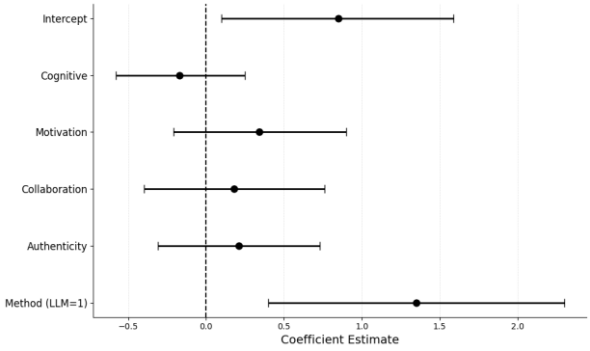


Figure 4 Regression Coefficients with 95% CI

Significantly greater understanding of LLM fundamental principles (e.g., tokenizers, attention mechanisms) after exercises with TinySlime (Cohen's d = 2.64).

Markedly higher confidence in explaining the relationship between parameter count and model performance (Cohen's d = 3.26) and in their ability to fine-tune an LLM in the future (Cohen's d = 2.95).

A stronger conviction that LLM learning would be beneficial for their future careers (Cohen's d = 1.67).

Greater enjoyment and intrinsic motivation, as indicated by higher ratings on items such as "found the experiments interesting" (Cohen's d = 2.14) and "felt a personal desire to engage in the tasks rather than feeling compelled" (Cohen's d = 1.61).A perception of the learning environment as more authentic and closer to real-world development practices, particularly regarding the on-premise operation of TinySlime (Cohen's d = 2.25) and consideration of computational/data leakage risks (Cohen's d = 2.12).

Higher overall satisfaction with the seminar and a stronger desire to participate in similar PBL and contest-integrated classes in the future (Cohen's d = 2.83 and 2.69, respectively).

Predictors of Student Satisfaction: An Ordinary Least Squares (OLS) regression analysis was conducted to identify factors predicting overall student satisfaction

(Figure 4). The results indicated that the pedagogical method itself (Method LLM=1) was a significant positive predictor of satisfaction (Coefficient = 1.347, 95% CI [0.399, 2.296]). This suggests that, holding other factors constant, participation in the LLM-enhanced module directly contributed to higher student satisfaction. Motivation and Authenticity also showed positive trends, although their confidence intervals were wider. Because the study involved only 15 participants, statistical power and generalizability are limited.

Conclusions

This study from the National Institute of Technology, Toba College, describes our two-part educational strategy focused on student-led AI innovation. First, we found that PBL combined with participation in external technology competitions helps students develop impressive technical skills. Our students' development of the TinySlime language model, showcasing their grasp of contemporary AI challenges, advanced methodologies, and rigorous evaluation practices, stands as strong evidence of this educational outcome.

Secondly, and forming the core of this paper's investigation, the subsequent utilization of this student-developed artifact, TinySlime, as a pedagogical tool yielded significant enhancements in AI education. Students who learned with and through TinySlime reported markedly higher levels of cognitive engagement, motivation, perceived authenticity of the learning experience, and overall satisfaction compared to peers in a traditional learning environment. The hands-on interaction with a locally operable, peer-developed LLM and insights from its creators fostered a deeper understanding of complex AI concepts and boosted students' confidence in their own technological capabilities.

This research suggests that fostering a cycle where students transition from learners to creators and where their creations become valuable learning resources for others can create a uniquely effective and engaging educational ecosystem. While this study is based on a specific institutional context and a single iteration of the pedagogical intervention, the overwhelmingly positive results encourage further exploration of such student-centered, artifact-driven teaching methodologies in AI and other advanced technology domains. Future work could involve longitudinal studies to track the long-term impact on student skills and career trajectories and adapt this model to other complex engineering subjects.

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References

Abdin, M. & Jacobs, S. A. (2024). Phi-3 Technical Report: A Highly Capable Language Model Locally on Your Phone. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2404.14219

Bai, J. & Bai, S. (2023). Qwen Technical Report. arXiv:2309.16609. Retrieved from http://arxiv.org/abs/2309.16609

Dao, T. & Fu, D. Y. (2022). FlashAttention: Fast and Memory-Efficient Exact Attention with IO-Awareness. arXiv [cs.LG]. Retrieved from http://arxiv.org/abs/2205.14135

elyza. (n.d.). ELYZA-japanese-Llama-2-7b. Hugging Face. Retrieved June 18, 2024, from https://huggingface.co/elyza/ELYZA-japanese-Llama-2-7b

Fujii, K. & Nakamura, T. (2024). Continual Pre-Training for Cross-Lingual LLM Adaptation: Enhancing Japanese Language Capabilities. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2404.17790

Gunasekar, S. & Zhang, Y. (2023). Textbooks Are All You Need. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2306.11644

Holmes, C. & Tanaka, M. (2024). DeepSpeed-FastGen: High-throughput Text Generation for LLMs via MII and DeepSpeed-Inference. arXiv [cs.PF]. Retrieved from http://arxiv.org/abs/2401.08671

Huang, S.-C. & Li, P.-Z. (2023). Chat Vector: A Simple Approach to Equip LLMs with Instruction Following and Model Alignment in New Languages. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2310.04799

Hughes, A. (2023). Phi-2: The surprising power of small language models. Microsoft Research. Retrieved June 18, 2024, from https://www.microsoft.com/en-us/research/blog/phi-2-the-surprising-power-of-small-language-models/

Kaplan, J. & McCandlish, S. (2020). Scaling Laws for Neural Language Models. arXiv [cs.LG]. Retrieved from http://arxiv.org/abs/2001.08361

Kurihara, K. & Kawahara, D. (2022). JGLUE: Japanese General Language Understanding Evaluation. In Proceedings of the Thirteenth Language Resources and Evaluation Conference (pp. 2957-2966). Marseille, France: European Language Resources Association.

Ouyang, L. & Wu, J. (2022). Training language models to follow instructions with human feedback. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2203.02155

Radford, A. & Wu, J. (2019). Language Models are Unsupervised Multitask Learners. Retrieved June 18, 2024, from https://paperswithcode.com/paper/language-models-are-unsupervised-multitask

Rafailov, R. & Sharma, A. (2023). Direct Preference Optimization: Your Language Model is Secretly a Reward Model. arXiv [cs.LG]. Retrieved from http://arxiv.org/abs/2305.18290

Schulman, J. & Wolski, F. (2017). Proximal Policy Optimization Algorithms. arXiv [cs.LG]. Retrieved from http://arxiv.org/abs/1707.06347

Suzuki, M. & Suzuki, J. (2020). JAQKET: クイズを題材にした日本語 QA データセットの構築. In 言語処理学会第 26 回年次大会. Retrieved from https://www.anlp.jp/proceedings/annual_meeting/2020/pdf_dir/P2-24.pdf

Touvron, H. & Martin, L. (2023). Llama 2: Open Foundation and Fine-Tuned Chat Models. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2307.09288

Zhang, P. & Zeng, G. (2024). TinyLlama: An Open-Source Small Language Model. arXiv [cs.CL]. Retrieved from http://arxiv.org/abs/2401.02385

Leveraging the PAIR Framework and Generative AI to Enhance Self-Directed Learning

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Self-directed learning (SDL) is an essential skill for lifelong learning, enabling individuals to continuously adapt to evolving challenges and demand. It empowers students to take the initiative, set learning goals, and manage their own learning processes (Brandt, 2020). However, without structured guidance, students often face challenges such as lack of immediate feedback, difficulty in finding relevant learning resources, limited engagement in problem-solving, and inadequate reflection on their learning progress. These issues often result in frustration, reduced motivation, and ineffective learning outcomes, highlighting the need for guidance and strategies to support SDL effectively.

This paper explores how Generative AI (GenAI) enhances SDL by leveraging on the PAIR framework (Acar, 2023), developed by Professor Oguz Acar to encourage the purposeful adoption of GenAI in the curriculum. The study was conducted with a group of Year 2 Diploma in Information Technology students from Ngee Ann Polytechnic who were enrolled in the Mobile Application Development (MAD) module. In this module, students worked in teams to design and develop a real-world mobile application, applying their knowledge of mobile app development concepts and tools. The PAIR framework's four phases (Problem Formulation, AI Tool Selection, Interaction, and Reflection) were integrated into the assignment with GenAI-powered tools that offered real-time feedback and interactive problem-solving support to mitigate common SDL pitfalls. In the Problem Formulation phase, students identify key challenges in their projects, promoting critical thinking and structured problem-solving. GenAI supports students by breaking complex problems into manageable tasks, helping students structure their approach before starting development work. In the AI Tool Selection phase, students evaluate and choose the most appropriate GenAI tools to address their identified challenges. This phase strengthens decision-making skills as students assess various AI solutions across development tasks such as coding, debugging, and UI/UX design. During the Interaction phase, students actively engage with the selected GenAI tools to experiment, generate solutions, and refine their work. GenAI provides real-time feedback, suggests improvements, and offers alternative solutions to further strengthen problem-solving abilities. Finally, in the Reflection phase, students evaluate their learning process, analyse the quality of AI-generated solutions and refine their approach for continuous improvement. After completing the assignment, 91 students responded to a survey, sharing their experiences with GenAI and its impact on their learning. The survey results show that integrating GenAI through the PAIR framework enhanced students SDL by fostering goal setting, resource evaluation, problem-solving, and reflective thinking. This structured approach not only addressed immediate project challenges but also strengthened core SDL competencies in a project-based learning environment.

Keywords: *Self-directed Learning, Generative AI, PAIR Framework, Software Engineering*

Introduction

In an age of information abundant and rapid change, self-directed learning (SDL) has become a foundational competency for both academic success and lifelong learning (Tan, 2014). SDL empowers students to take ownership of their education journeys by identifying their learning needs, setting personal goals, finding suitable resources, implementing learning strategies, and evaluating their outcomes (Knowles, 1975; Garrison, 1997). This sense of autonomy is especially important in technology-driven fields, where learners must continuously adapt to new tools, frameworks, and problem-solving contexts. The importance of cultivating SDL is also emphasized in Singapore's EdTech Masterplan 2030, which highlights technology-enabled personalization as a key driver for nurturing independent learners (2023). When students are equipped to learn independently, they are more likely to develop critical thinking, resilience, and adaptability skills that are essential for employability and long-term success (Candy, 2004).

Many students struggle to cultivate effective SDL habits such as goal setting, time management, information literacy, reflective thinking, and self-assessment are not always intuitive and often require deliberate scaffolding. Without structured support, students may feel uncertain about where to begin, how to organize their learning, or which strategies to employ. This challenge becomes

more pronounced in project-based environments like software development, where learners must navigate open-ended tasks, define functional requirements, solve technical problems, collaborate with peers, and produce usable outcomes. Common challenges include idea generation, using unfamiliar development tools, debugging code, and engaging in meaningful reflection on learning strategies (Loeng, 2020; Chou & Chen, 2008). By grounding these challenges in established SDL theory, educators and researchers can more precisely identify intervention points to help students build lasting, transferable learning competencies.

To support SDL, traditional instructional methods have often incorporated scaffolding strategies such as formative feedback, structured rubrics, peer collaboration, and reflective journals (Hmelo-Silver, 2004; Zimmerman, 2002). While these approaches have been shown to enhance students' engagements and improve learning outcomes, they also present notable limitations. They can be time-consuming for instructors to implement, their effectiveness may vary across different student groups, and they often lack the level of personalization required to address individual learning gaps. Most critically, such strategies frequently fall short in providing just-in-time support when students encounter technical challenges or struggle to comprehend complex concepts during independent study.

The rise of GenAI tools such as ChatGPT, Claude, and Microsoft Copilot have opened powerful new avenues for addressing the limitations of traditional SDL support. These tools can assist students by generating explanations, producing code, suggesting alternative solutions, and guiding problem-solving in real-time. However, their educational value depends largely on how purposefully and ethically they are integrated into the learning process. Without proper structure, students may become overly reliant on AI-generated content, resulting in shallow understanding or issues related to academic integrity (Kasneci et al., 2023).

To bridge this gap, the PAIR framework developed by Prof Oguz A. Acar of King's College London aims to provide a balanced approach to integrating AI in learning. The framework aligns with key stages of the SDL process: identifying and articulating the learning challenge, critically selecting appropriate AI tools, actively engaging with these tools to develop and refine solutions and finally reflecting on the outcomes to enhance future learning strategies.

To evaluate the effectiveness of the PAIR framework, a study was conducted with Year 2 students from the Diploma in Information Technology programme at Ngee Ann Polytechnic, who were enrolled in the Mobile Application Development (MAD) module. In this module, students worked in teams to design and build real-world mobile applications.

This paper presents finding that examine how the PAIR framework, when combined with GenAI tools, can address common SDL challenges and foster more effective, independent learning in a tertiary education setting.

Research Design and Methodology

This study was conducted as part of the MAD module, a project-based module offered to 91 Year 2 students in the Diploma in Information Technology programme at Ngee Ann Polytechnic.

The MAD curriculum requires students to understand key Android development concepts. However, many students encountered challenges such as generating viable app ideas, navigating the Android development environment, debugging complex code, and managing version control using GitHub. To address these challenges and foster SDL, GenAI tools were integrated into the assignment through the PAIR framework, which provided a structured approach to guide meaningful AI engagement during scoping, implementation, debugging, and reflection.

The PAIR framework comprising four stages: Problem Formulation, AI Tool Selection, Interaction, and Reflection as depicted in Figure 1 was deliberately embedded into key phases of the assignment to scaffold SDL. Students were introduced to GenAI tools such as ChatGPT and Microsoft Copilot and were guided on their purposeful use at each stage. During the Problem Formulation stage, students used GenAI to brainstorm and refine app ideas, define user needs, and articulate functional requirements. In the AI Tool Selection stage, they evaluated suitable tools for tasks such as code generation, UI prototyping, and logic implementation. The Interaction stage involved hands-on use of GenAI to implement features, debug issues, and iterate on their designs. Finally, the Reflection stage encouraged students to critically assess their learning strategies, tool usage, and team dynamics. The PAIR framework aligns with Garrison's (1997) three dimensions of SDL by fostering: 1) self-management through structured planning where learners set learning goals, 2) self-monitoring through iterative problem-solving where learners actively track their progress, and 3) motivation through purposeful resource selection and reflective evaluation of learning outcomes.

Over the course of an 18-week semester, students worked in teams of four to design, develop, and deliver a fully functional Android mobile application. The objectives of the assignment were to: 1) demonstrate the ability to implement a mobile application; 2) encourage thoughtful and practical app design; 3) support students in identifying their individual learning needs based on selected app features; 4) promote active engagement in the development process through the iterative design and implementation of app features; and 5) to prepare students for possible app deployment on the Google Play Store.

This paper focuses on Stage 1 of the assignment, a critical 7-week phase that accounted for 30% of the overall module grade. This phase emphasized early-stage project planning, including problem formulation, feature scoping, and prototyping, making it well suited to examine how GenAI-supported SDL practices influenced student engagement and learning strategies.

As part of Stage 1, teams selected an app category from a predefined list as shown in Figure 2, which included domains such as Education, Health & Fitness, Travel & Local, Tools, Lifestyle, and Communication. Based on the selected category, students conceptualised and implemented the core functionality of their mobile application. Each team was required to integrate at least three technical features, such as: responsive layouts, multimedia components (images, video, audio), RecyclerView, or data persistence using SQLite, or SharedPreferences.

To support both collaboration and SDL, each team maintained a GitHub repository to manage source control, track progress, assign roles, and document their development progress. They also submitted a project proposal outlining the app concept, team structure, and planned features.

The deliverables for Stage 1 included: 1) a working prototype incorporating the required features; 2) a GitHub repository with documentation of the app concept, features, task allocation, and development timeline; 3) a team presentation covering the app's purpose, technical decisions, and overall development workflow; and 4) an individual reflection describing how GenAI tools supported their learning across the four phases of the PAIR framework.

Data Collection

To evaluate the effectiveness of GenAI-supported SDL within the context of the PAIR framework, data was collected through an individual reflection survey administered at the end of Stage 1 of the MAD assignment. The survey aimed to capture students' experiences with GenAI tools, structured around the four PAIR phases: Problem Formulation, AI Tool Selection, Interaction, and Reflection.

The reflection survey was conducted online using Microsoft Forms. It comprised open-ended questions aligned with each PAIR phase to gather qualitative insights on how students engaged with GenAI tools

The survey questions were categorized into the four PAIR phases as follows:

In the Problem Formulation phase, students were asked to describe the key challenges encountered during their assignment, such as difficulties with ideation, layout design, coding logic, or debugging. This question assessed their ability to independently identify and articulate problems.
Q1. What is/are the problem(s) you encountered in your Assignment 1?

For the AI Tool Selection phase, students reflected on how they selected and evaluated GenAI tools, considering factors such as relevance, ease of use, and familiarity. This phase focuses on understanding their decision-making process when choosing tools to address specific challenges.
Q2. What were the considerations did you have in selecting the GenAI tool to assist you in resolving the problem(s)?
Q3. Please indicate the GenAI tool(s) you used for the assignment.

In the Interaction phase, students explained how they used the selected GenAI tools, the usefulness of the generated outputs, and how these were integrated into their project work. This phase explored how students engaged with GenAI to support their problem-solving process.
Q4. How useful were the solutions provided by the GenAI tool. Please share your experience.
Q5. How were these solutions used in your assignment? Please elaborate in detail.

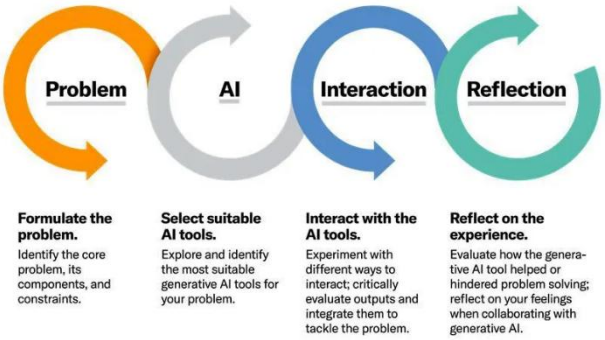


Figure 1 PAIR Framework

Daydream	Health & Fitness	Shopping
Beauty	House & Home	Social
Business	Libraries & Demo	Sports
Comics	Travel & Local	Tools
Communication	Video Players & Editors	Weather
Dating	Wear OS by Google	Lifestyle
Education	Map & Navigation	Medical
Entertainment	Music & Audio	Parenting
Events	Books & Reference	Personalization
Finance	Art & Design	Photography
Editors	Auto & Vehicles	Productivity
Food & Drink	News & Magazines	

Figure 2 App Category

Finally, in the Reflection phase, students assessed the overall impact of GenAI on their learning, highlighting both benefits and limitations. This phase encouraged metacognitive reflection on the value of AI-assisted learning.
Q6. Reflect on your experience in using GenAI tools for your assignment - did GenAI provide you with more/less help to resolve the problem? Please share your thoughts.

The responses gathered from the reflection survey served as the primary dataset for evaluating how the structured use of GenAI tools, scaffolded by the PAIR framework, influenced students' SDL experiences. The qualitative data was then analysed to identify patterns related to confidence in problem-solving, tool effectiveness, decision-making strategies, and reflective learning behaviours.

Results and Discussion

A total of 91 students responded to the reflection survey. In Q1, students were asked to describe the problems they encountered during Assignment 1. Figure 3 illustrates the six main categories of challenges students faced, with debugging and technical implementation as the most significant barriers.

Debugging challenges were the most prevalent, with 68.1% of students reporting difficulties in resolving code errors. This highlights the critical need for timely and accessible support, especially in project-based learning environments where immediate problem-solving is crucial. Technical implementation was the second most cited issues (58.2%), with students struggling to integrate core Android components such as Firebase, RecyclerView, and custom user interfaces. These results point to a broader difficulty in translating conceptual ideas into functioning features.

Other challenges included data persistence (26.4%), particularly in managing SQLite databases or using SharedPreferences. Ideation and concept design (19.8%), where students found it difficult to define app idea and project scope. Navigation and user interface (UI) logic (17.6%), including issues with screen transitions and button interactions. The least reported challenge was multimedia integration (5.5%), involving difficulties with embedding audio, video or images.

These findings reveal that students' primary challenges lay in the implementation phase rather than idea generation, it also reflecting the real-world complexity of mobile app development. The variety of challenges reported highlights the importance of targeted scaffolding. Integrating GenAI tools within the PAIR framework, particularly during Problem Formulation, enabled students to better scope, prioritize, and deconstruct development tasks. This approach reinforced SDL outcomes by empowering students to tackle technical barriers early in the project.

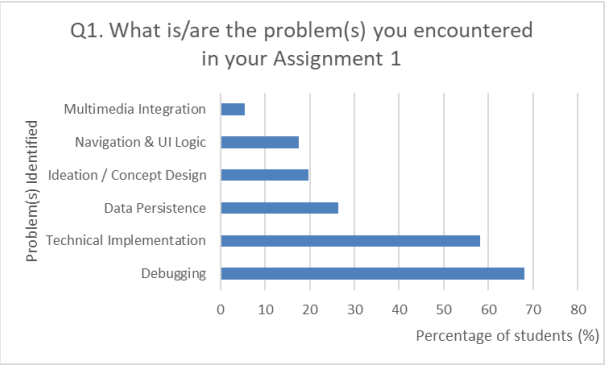


Figure 3 Problem formulation findings

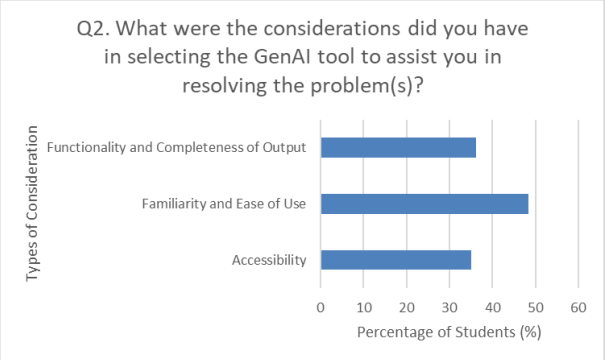


Figure 4 Considerations for selecting GenAI tools

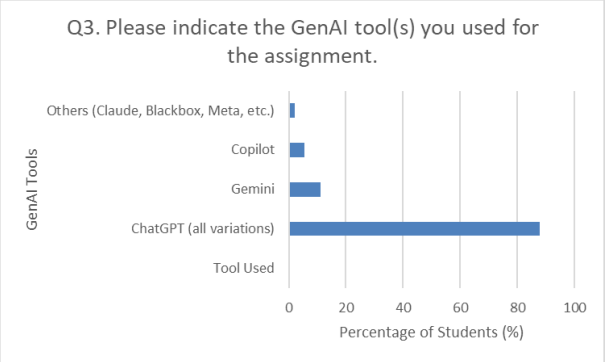


Figure 5 GenAI tools used by students

Figure 4 shows the results from Q2, which explored students' consideration when selecting GenAI tools for their assignment. Students primarily based their choices on three key factors: familiarity, accessibility, and practical utility. Nearly half of the respondents (48.4%) preferred tools they found intuitive or had prior experience with 35.2% selected tools that were freely accessible, while 36.3% valued tools that produced complete and usable outputs, allowing for immediate application to their technical tasks.

Figure 5 shows 88% of students identified Chat GPT as their GenAI Tool of choice in Q3. Its popularity can be attributed to its accessibility, familiarity, and broad applicability across wide range of development challenges. In contrast, approximately 11% of students reported using Google Gemini, likely due to its

integration with Google services or preference for its alternative response styles. A smaller proportion explored other tools, such as Microsoft Copilot (5%) and specialised platforms such as Claude and Blackbox AI (2%).

The combined results from Q2 and Q3 reveal students' developing digital literacy and their growing ability to strategically select appropriate learning resources, a key competency in SDL. Their ability to evaluation tools based on reliability, usability, and alignment with their learning goals demonstrates engagement with the AI Tool Selection phase of the PAIR framework. Notably, some students also explored lesser-known tools, indicating a willingness to evaluate options beyond familiarity, which is a sign of maturing SDL where learners adapt tool use to specific task demands.

Q4 and Q5 focused on how students interacted with GenAI tools and their perceived usefulness. Figure 6 shows more than half of the students (57.1%) rated GenAI tools as highly useful, particularly for debugging, generating code snippets, and clarifying Android specific concepts. These students reported that GenAI tools accelerated their progress and provided on-demand support that was often not available through traditional learning resources. 23% of respondents found the tools as moderately useful, noting AI-generated content often required additional refinement. Approximately 8.8% of students found the tools as minimally useful, citing challenges such as irrelevant or unclear output responses. The remaining about 9.9% of responses lack sufficient detail for classification.

Figure 7 illustrates how students applied AI-generated solutions in their development work. The most common use case was code debugging (69.2%), followed by code generation (57.1%), demonstrating students leaned on GenAI for technical execution. Many used ChatGPT to correct syntax errors, refine logical flaws, or generate code snippets aligned to their assignment requirements. About 33% of students used GenAI to assist in UI design and layout, especially for refining XML and achieving responsive interfaces. A smaller group (16.5%) used GenAI to strengthen conceptual understanding, such as clarifying Android lifecycle methods or Firebase integration.

These findings show that students engaged with GenAI purposefully, tailoring their use based on individual learning goals. Rather than relying on GenAI for rote answers, most students applied the outputs contextually and critically. This behaviour aligns with the Interaction phase of the PAIR framework, where learners experiment, learn through iteration, and adapt their solutions through feedback which is the core habits of effective SDL.

Q6 captured students' reflection on their overall experience with GenAI. As illustrated in Figure 8, 53.8% reported positive experiences, stating that GenAI enhanced their problem-solving efficiency and helped

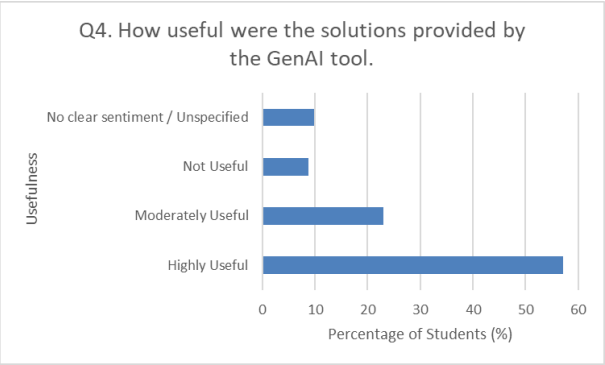


Figure 6 Perceived usefulness of GenAI tools

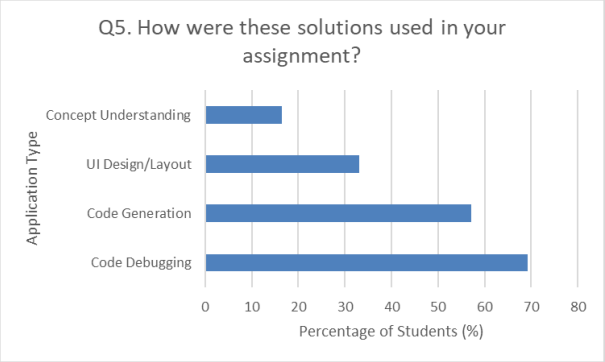


Figure 7 Interaction with GenAI solutions

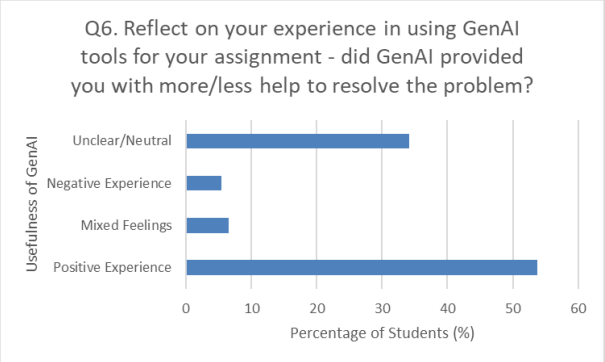


Figure 8 Students refection on GenAI learning support

them manage unfamiliar technical challenges. About 40.7% of students shared neutral or mixed reflections with limitations such as inaccurate or overly generic responses. A small group (5.5%) reported negative experiences, citing confusing or unhelpful outputs that hindered their learning.

These reflections show that while students generally valued GenAI support, many also demonstrated awareness of its limitations. Their ability to critically assess the strength and shortcomings of AI-generated assistance indicates developing metacognitive awareness, a key element of SDL. This aligns with the Reflection phase of the PAIR framework, where learners evaluate not just outcomes but also the tools and strategies used contributed to their learning process, ultimately fostering more intentional and deeper learning over time.

While these findings are exploratory and rely on students' self-reported perceptions, they provide initial evidence that PAIR-guided GenAI integration can meaningfully support the development of SDL competencies in project-based learning.

Conclusions

This study investigated how GenAI tools enhance SDL in a project-based MAD module, guided by the PAIR framework's four phases: Problem Formulation, AI Tool Selection, Interaction, and Reflection. Analysis of 91 student responses revealed that GenAI tools in particular ChatGPT served as effective learning companions when used purposefully. Students reported substantial benefits in multiple areas such as problem scoping, code generation, debugging, and conceptual understanding, with over half indicating the tools were highly useful in supporting their learning process. The structured integration of GenAI through the PAIR framework successfully scaffolded key SDL practices such as goal setting, resource evaluation, experimentation, and reflection.

The results also highlighted important variations in students' perception and utilisation of GenAI. While many demonstrated confidences in applying AI tools effectively, others offered mixed or ambiguous reflections, indicating varying levels of digital literacy and metacognitive awareness. These insights underscore the need for continued scaffolding to promote ethical, critical, and purposeful use of AI in education contexts.

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References

Acar, O. A. (2023). Are your students ready for AI? A 4-step framework to prepare learners for a ChatGPT world. Harvard Business Publishing, Education. Retrieved from https://hbsp.harvard.edu/inspiring-minds/are-your-students-ready-for-ai

Brandt, W. C. (2020). Measuring Student Success Skills: A Review of the Literature on Self-Directed Learning. 21st Century Success Skills. National Center for the Improvement of Educational Assessment. Retrieved from https://files.eric.ed.gov/fulltext/ED607782.pdf

Candy, P. C. (2004). Linking thinking: Self-directed learning in the digital age. Canberra, Australia: Department of Education, Science and Training. Retrieved from https://www.voced.edu.au/content/ngv%3A31516

Chou, P. N., & Chen, W. F. (2008). Exploratory study of the relationship between self-directed learning and academic performance in a web-based learning environment. Online Journal of Distance Learning Administration, 11(1). Retrieved from https://eric.ed.gov/?id=EJ1065497

Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. Adult Education Quarterly, 48(1), 18–33. Retrieved from https://doi.org/10.1177/074171369704800103

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235–266. Retrieved from https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Stadler, M., Weller, J., Kuhn, J., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences, 103, 102274. Retrieved from https://doi.org/10.1016/j.lindif.2023.102274

Knowles, M. S. (1975). Self-directed learning: A guide for learners and teachers. Retrieved from https://doi.org/10.1177/105960117700200220

Loeng, S. (2020). Self-directed learning: A core concept in adult education. Education Research International. Retrieved from https://doi.org/10.1155/2020/3816132

Ministry of Education, Singapore (2023). Transforming Education through Technology Masterplan 2030. Retrieved from https://www.moe.gov.sg/education-in-sg/educational-technology-journey/edtech-masterplan

Tan, L., & Koh, J. H. (2014). Self-Directed Learning: Learning in the 21st Century. Singapore: Ministry of Education. Retrieved from https://www.researchgate.net/publication/285591239_Self-Directed_Learning_Learning_in_the_21st_Century

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. Theory Into Practice, 41(2), 64–70. Retrieved from https://doi.org/10.1207/s15430421tip4102_2

IMPLEMENTING AI TRAFFIC LIGHTS FOR TEACHING AND LEARNING – CASE TURKU UAS

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One of the greatest challenges and opportunities for higher education is the development of Artificial Intelligence. It affects higher education institutes at the organizational level, impacts the work of teachers and challenges students' learning process and activities. The Rectors Council of Universities of Applied Sciences in Finland recognized the importance of structured approach to integrate AI in higher education institutes to ensure responsible and effective use of AI. As a result of a working group, the Council published recommendations for AI utilization at organizational, teacher, and student levels. The objective of the recommendation was to provide guidelines that promote ethical, transparent, and competent use of AI, enhancing educational and professional competencies. The recommendations are categorized into three main areas: organizational level, teachers' role, and students' role. Each category addresses specific aspects of AI use, including ethical principles, responsibility, data protection, and competence.

At the organizational level, the recommendations emphasize the importance of ensuring staff and students can use AI responsibly, promoting fairness, equality, and respect, using AI to enhance learning and working life skills, safeguarding privacy and data protection, providing training on AI tools, and making AI operations and decisions clear. For teachers, the focus is on understanding how AI can support teaching and learning, using AI to promote student development, maintaining fairness and respect, following data protection practices, and being aware of AI limitations. For students, the recommendations highlight the need to recognize AI's potential in studies, develop AI literacy and critically assess AI outputs, understand AI limitations, and follow ethical guidelines. The recommendations aim to ensure responsible and effective use of AI in universities of applied sciences, enhancing both educational and professional competencies. An essential part of the recommendations is the AI traffic lights that describe the use of AI in learning tasks.

At Turku University of Applied Sciences, a process to promote and implement the recommendations was started in early 2025. The aim is that the AI traffic lights will be in use on all programs and courses from the beginning of 2026. In this paper, the recommendations and their implications are presented and discussed along with our own process and experiences.

Keywords: *Artificial Intelligence, Recommendations, AI strategies, AI Traffic lights*

Introduction

One of the greatest challenges and opportunities for higher education is the development of Artificial Intelligence. It affects higher education institutes at the organizational level, impacts the work of teachers and challenges students' learning process and activities. There are several aspects to consider like OECD (2025b) report describes: *First, there is a focus on how to use AI to improve teaching, learning and assessment. Second, a related focus is on identifying and preventing risks of AI usage, such as AI bias, data protection and students using AI to cheat on tests. Third, there is increasing emphasis on adapting curricula to incorporate AI literacy – this is, educating about how AI works and how to use it. These are obviously important questions. However, they also overlook some significant social implications of AI's transformative potential and its subsequent effects on education. In particular, the fact that if AI and robots were to significantly reshape how humans carry out work and life tasks, the knowledge, skills, and attitudes promoted through education might need to change.* The World Economic Forum discussed in 2024 that almost 40 percent of global employment is exposed to AI, with advanced economies at greater risk but also better poised to exploit AI benefits than emerging market and developing economies (Cazzaniga, 2024). These changes further challenge teaching and learning and there is truly a need for all citizens to be AI literate to benefit from AI. Consequently, there are several concerns about the use of AI in teaching and learning such as the originality of student's work for assessment and grading (Luo, 2024).

OECD's "Trends Shaping Education 2025" report encourages policymakers and educators to use futures thinking to anticipate how AI and other technologies might disrupt or enhance education. (OECD, 2025a)

There's a strong focus on preparing students for a world where AI is ubiquitous including fostering digital literacy, critical thinking, and ethical reasoning. UNESCO has published AI competence frameworks for students and teachers(UNESCO, 2024a, 2024b). Furthermore, UNESCO calls for national AI strategies to include higher education explicitly and stresses the need to train university faculty and researchers in GenAI use, including prompt engineering, ethical considerations, and pedagogical integration (UNESCO, 2023). Actually, the precondition for the responsible use of AI in education is the enforcement of regulations to ensure the trustworthiness of AI tools and to safeguard learners and teachers (UNESCO, 2024b). In the next section, we look at a number of countries and their policies related to AI in higher education. After that the paper focuses on the framework and recommendations on AI from the Rectors' Council of Universities of Applied Sciences in Finland before moving to the case study of Turku UAS and discussion and conclusions.

AI strategies in education

This section looks at some potential countries and their AI policy and recommendations. The focus on the review is on the connection with higher education and teaching and learning. There are six short reviews from UK, France, Germany, Singapore, Japan, Australia, Finland and European Union.

The UK Government's AI Opportunities Action Plan outlines an ambitious vision for harnessing artificial intelligence across society – with higher education playing a central role. The plan includes clear recommendations that could inspire similar initiatives in other countries. The UK aims to train tens of thousands of new AI professionals by 2030. This requires the creation of new degree programs, close collaboration with industry, and the integration of AI into non-technical fields such as healthcare and public administration. The UK plans to establish AI Research Resource (AIRR) clusters that combine cutting-edge research, computing power, and data resources. Universities are encouraged to embrace open data practices and collaborate with government and industry to accelerate innovation. To summarize, AI is not just a technological shift – it's a pedagogical and societal transformation. The UK's strategy offers concrete steps that higher education institutions worldwide can adapt to prepare for an AI-driven future. (Department for Science, 2025)

Singapore has National AI Strategy 2.0 that outlines a forward-thinking framework that highlights the role of artificial intelligence in transforming education. The strategy provides a clear direction for higher education institutions to adopt AI in a responsible and impactful way. 1. Curriculum Transformation: AI literacy and technical skills are being integrated across various disciplines. The goal is to ensure that students from all fields understand the fundamentals and applications of AI. 2. Upskilling Educators and Students: The strategy supports training educators to effectively use AI in teaching, while also preparing students for a future where AI skills are essential in the workforce. 3. Research and Innovation: Universities serve as key hubs for AI research. They participate in national and international projects that develop AI solutions for sectors like healthcare and sustainability. 4. Ethics and Responsibility: Higher education institutions are involved in shaping ethical and legal frameworks for AI. The aim is to ensure that AI is used safely and in ways that are socially acceptable.

As part of the France 2030 initiative, the strategy "Make France an AI Powerhouse" places higher education at the heart of national efforts to advance artificial intelligence. The government outlines several targeted actions to strengthen universities' role in AI development such as Expanding AI education across all levels, Funding new academic programs via the Skills and Future Professions initiative, enabling institutions to design curricula aligned with emerging AI competencies and Providing access to advanced computing infrastructure for universities, enabling hands-on, research-driven AI education. (Gouvernement de la République Française, 2025)

Germany's AI strategy includes a dedicated initiative for higher education, focusing on digital transformation, AI literacy, and intelligent learning environments. The "AI Campus" platform provides open educational resources for students and educators. Universities are supported in developing AI-based teaching tools and research projects. The Federal Government and the Länder intend to jointly anchor AI across the German higher education system. Funded projects are aimed at making better use of AI in teaching and equipping the professionals of tomorrow with relevant skills and competences. A total of 81 universities have received funding under the umbrella of the initiative. The goal is to enhance educational quality and equip students with future-relevant skills. (Bundesministerium für Bildung und Forschung, 2023; Bundesministerium für Forsnung, 2025)

Japan's Ministry of Education (MEXT) has issued guidelines for the ethical and pedagogical use of generative AI in higher education. Universities are encouraged to develop institutional policies for AI use in teaching and research. The strategy also supports AI R&D and the development of domain-specific foundation models.(Ministry of Education, 2024)

Australia's AI framework, originally designed for schools, has been extended to include higher education. The 2024 review emphasizes responsible use, data privacy, and teacher support. Universities are encouraged to adopt AI tools that enhance learning while safeguarding student rights and academic integrity. (Department of Education Australian Government, 2025)

The EU Data Act, which entered into force in January 2024 and becomes applicable in September 2025, is a cornerstone of Europe's digital strategy. While it is not sector-specific, it has important implications for higher education institutions, especially in terms of data access, sharing, and governance. There's also a growing need for data literacy among staff and students. Universities must ensure that staff and students are trained to comply with the Data Act's provisions, especially when handling

shared or sensitive data. This may involve workshops, online modules, or new course offerings focused on data rights and responsibilities. (European Commission, 2024b). The European Commission has published ethical guidelines on AI and data usage in teaching and learning are designed to help educators understand the potential that the applications of AI and data usage can have in education and to raise awareness of the possible risks (Commission, Directorate-General for Education, & Culture, 2022). The follow-up regulation is The EU Artificial Intelligence Act (AI Act) is the first comprehensive legal framework for AI regulation globally (European commission, 2024a). For universities and research institutions, the Act introduces both challenges and opportunities. It classifies AI systems on different risk levels, and it prompts universities to address the ethical use of AI by students, especially in learning and assessment. Institutions are encouraged to establish governance frameworks and promote AI literacy to ensure responsible adoption.

In Finland, the integration of artificial intelligence into higher education is guided by a combination of ethical, pedagogical, and strategic principles. The Finnish National Agency for Education emphasizes AI literacy for both students and educators, advocating for its responsible use in teaching, assessment, and learning personalization. Institutions are encouraged to develop clear policies and ensure equitable access to AI tools, while educators are supported in building competencies through professional development. Complementing this, the Ministry of Education and Culture promotes interdisciplinary AI research, alignment with EU regulations, and the use of AI to enhance accessibility and innovation across all fields of study. Together, these recommendations aim to position Finnish higher education as both ethically grounded and technologically forward-looking. (Ministry of Education and Culture, 2024)

AI guidelines of Finnish Universities of Applied Sciences

The Rectors Council of Universities of Applied Sciences in Finland recognized the importance of structured approach to integrate AI in higher education institutes to ensure responsible and effective use of AI. As a result of a working group, the Council published recommendations for AI utilization at organizational, teacher, and student levels. Each university of applied sciences will prepare their own guidelines and procedures independently. The objective of the recommendation was to provide guidelines that promote ethical, transparent, and competent use of AI, enhancing educational and professional competencies. The recommendations operate at two different levels(ARENE, 2023):

- the organisational level: universities of applied sciences are encouraged to ensure the capability of the staff and students to use artificial intelligence responsibly
- the level of teaching: teachers are encouraged to ensure that AI is used in accordance with its purpose and in an ethical manner.

At the organizational level, universities of applied sciences are urged to proactively enable the responsible use of artificial intelligence (AI) across their communities. This involves providing access to AI tools and clear instructions for their use, ensuring that both staff and students are equipped with the necessary competencies through training and guidance. Ethical principles such as fairness, equality, and respect must underpin all AI-related activities, and institutions must safeguard data protection and privacy. Universities are encouraged to promote transparency by sharing information about AI capabilities and limitations, and to monitor usage through feedback mechanisms. Furthermore, they should continuously assess and update their ethical and operational guidelines in response to technological developments and actively participate in national discussions and initiatives to shape responsible AI practices. By fostering a culture of informed and ethical AI use, universities can support learning, enhance working life skills, and contribute to the broader societal discourse on artificial intelligence.

At the level of teaching, Teachers are encouraged to integrate AI thoughtfully into their teaching practices, ensuring that its use enhances learning rather than replaces critical thinking or pedagogical engagement. They should familiarize themselves with available AI tools and understand their limitations, biases, and ethical implications. Teachers are expected to guide students in responsible AI use, model ethical behavior, and foster discussions around digital literacy and data privacy. Continuous professional development is essential to keep pace with evolving technologies, and collaboration with colleagues is recommended to share best practices and develop consistent approaches across disciplines. Students, on the other hand, are advised to use AI tools as supportive resources in their learning journey, not as shortcuts or substitutes for original thinking. They should be aware of the ethical boundaries, including issues of plagiarism, data privacy, and the reliability of AI-generated content. Students are expected to follow institutional guidelines, seek clarification when unsure about appropriate use, and develop critical skills to evaluate AI outputs. By engaging responsibly with AI, students can enhance their learning outcomes and prepare for future professional environments where AI is increasingly prevalent.

As a very concrete tool for universities of applied sciences the recommendations provide a enlarged traffic light model to be used in learning tasks (ARENE, 2024). The basic idea is to communicate it clearly when and how use of AI tools relates to the course assignments.

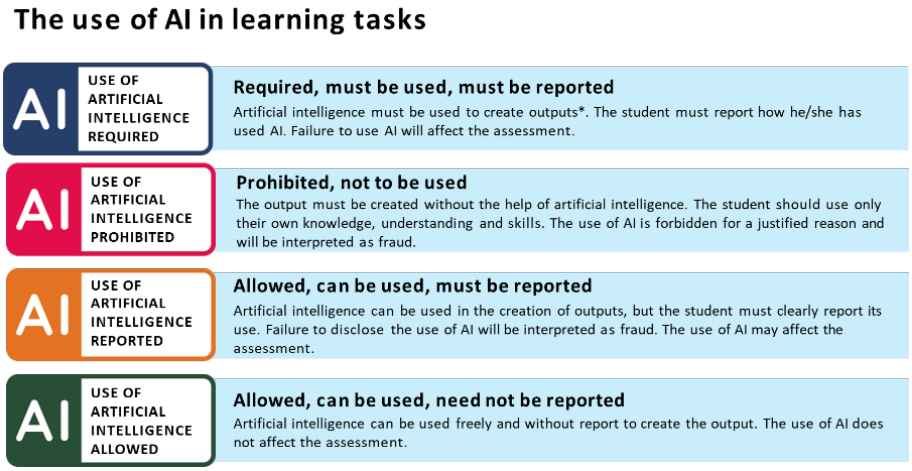


Figure 1. Traffic light model.

The Table 1 below summarizes the different levels and their key characteristics. The blue category is particularly useful for piloting new AI tools or approaches in teaching and learning, where the boundaries are still evolving and thoughtful experimentation is encouraged.

Traffic Light	Key Elements
USE OF ARTIFICIAL INTELLIGENCE REQUIRED	Artificial intelligence must be used to create outputs. The student must report how he/she has used AI. Failure to use AI will affect the assessment.
USE OF ARTIFICIAL INTELLIGENCE PROHIBITED	The output must be created without the help of artificial intelligence. The student should use only their own knowledge, understanding and skills. The use of AI is forbidden for a justified reason and will be interpreted as fraud.
USE OF ARTIFICIAL INTELLIGENCE REPORTED	Artificial intelligence can be used in the creation of outputs, but the student must clearly report its use. Failure to disclose the use of AI will be interpreted as fraud. The use of AI may affect the assessment.
USE OF ARTIFICIAL INTELLIGENCE ALLOWED	Artificial intelligence can be used freely and without report to create the output. The use of AI does not affect the assessment.

Table 1. Key elements of the traffic lights.

Case Turku UAS

At Turku University of Applied Sciences, a process to promote and implement the ARENE's recommendations was started in early 2025. The aim is that the AI traffic lights will be in use on all programs and courses from the beginning of 2026. The implementation of the traffic lights model is part of overall process of promoting and activating the use of AI in teaching and learning and strengthening AI literacy for all personnel and students. There was a pilot course testing the traffic lights early 2025 and in the feedback 54% of the course students said that the use of traffic lights clarified the usage of AI tools.

The enablement of the traffic lights requires updating of guidelines and tools for both teachers and students. We have updated our intranet regarding use of AI in teaching and learning, we have added element in our learning management systems (ItsLearning) and we have provided information on the process and schedules. At the same time a working group identified possibilities of AI to support and make things easier for teachers. These plans are not introduced on this paper, but they are partly covered on the workshops described below.

The implementation of the traffic lights requires guidance and support at the faculties, schools and teams. Basic process is that in each implementation plan of courses the connection with AI will be explained. Furthermore, in course assignments the corresponding traffic light will be presented. At the beginning of the course the implementation plan of the course will be introduced together with the AI guidelines. To support the smooth implementation, we will organize workshops the learn and discuss AI topics. The goal of these workshops is to

- To develop teachers' AI literacy and understanding of the possibilities of AI, especially as a streamlining of teaching and supporting the teacher team.
- To offer tips and examples of the possibilities of artificial intelligence in lightening the teacher's work and to activate individual and team reflections

The workshops will focus on the following themes:

- Artificial intelligence to support teaching and learning
- Using AI in Learning Assignments
- Artificial intelligence to support assessment.

Furthermore, we will discuss AI bots as co-teachers and teachers' teammates, creating summaries and notes with AI tools, and promoting accessibility and clarifying assignments. The workshops will focus on using Microsoft Copilot as our staff and students have access to enterprise-grade security.

The implementation of traffic lights on all our courses is a huge effort. We will collect feedback both from students and teachers in late spring 2026 and based on that modify our guidelines and procedures and continue the development.

Discussion

Artificial intelligence has already affected and will have effects on higher education in the future too. It is not a question that we can bypass rather is actively present and our task is to live with the AI revolution. The key question is not how the block AI tools and how to limit usage of AI. The key question is how we maintain our education meaningfull and relevant. With the introduction of traffic lights we try to have better control on the learning process. We define how and when AI is used, we balance the use of AI with other learning activities. Maybe we actually are bying some time for ourselves as changing curricula and courses does not happen overnight rather, they are processes that require time. However, that is something that higher education needs to do. Take some time and rethink their education. The Unesco's competence frameworks for teachers and students suggest that we need careful considerations on the role of teaching and learning. The same framework for teachers is intended to support the development of AI

Aspects	Progression		
	Acquire	Deepen	Create
1. Human-centred mindset	Human agency	Human accountability	Social responsibility
2. Ethics of AI	Ethical principles	Safe and responsible use	Co-creating ethical rules
3. AI foundations and applications	Basic AI techniques and applications	Application skills	Creating with AI
4. AI pedagogy	AI-assisted teaching	AI–pedagogy integration	AI-enhanced pedagogical transformation
5. AI for professional development	AI enabling lifelong professional learning	AI to enhance organizational learning	AI to support professional transformation

Figure 2. The AI competency framework high-level structure: aspects and progression levels.

competencies among teachers to empower them to use these technological tools in their teaching practices in a safe, effective and ethical manner. It provides tools for higher education institutes to reflect their staff competences using the competence framework shown in the figure 2. This is also something that we in Turku intend to introduce and reflect on in the future.

The implementation of the traffic lights is much more than just adding them to the course descriptions and course implementation plans. They initiate questions that make the teacher really reflect the course and the way course is implemented. There are questions such as

- What things in the learning process can be implemented or produced with the help of artificial intelligence?
- How should assignments and assessment methods be modified so that the use of artificial intelligence is possible, but not the only way to demonstrate competence?
- What things do students need to know without aids?
- How will the development of basic professional skills be ensured?
- How can you utilise artificial intelligence in the planning or implementation of course content, materials or learning assignments?

Conclusions

This paper provided a review of different policies on AI and higher education. It showed that there are generic challenges that are considered all over the world. Interestingly it also showed that you can see some national flavors in the policies. The presented Finnish UAS approach provided a very simple and clear way on looking AI in course level. It brings AI to spotlight of every teacher and student in higher education. The process is in progress and we could not provide concrete results and implications at this point. However, we have already seen that the implementation of traffic lights and implementation process itselt supports the build-up of AI literacy competences. Furthermore, we recognize that the UNESCO competences framework could offer additional tools for higher education institutes.

References

ARENE. (2023). *Arene's recommendations on the use of artificial intelligence for universities of applied sciences*. Retrieved from https://arene.fi/wp-content/uploads/PDF/2023/AI-Arene-suositukset_EN.pdf?_t=1686641192

ARENE. (2024). Arene's recommendations on the use of artificial intelligence for universities of applied sciences – The Traffic Light Model. Retrieved from https://arene.fi/wp-content/uploads/PDF/2024/Teko%C3%A4lysuositukset/ARENE%20AI%20english.pdf?_t=1731419903

Bundesministerium für Bildung und Forschung. (2023). *Federal Government Report on the High-Tech Strategy 2025*. Retrieved from https://www.bmftr.bund.de/SharedDocs/Publikationen/DE/FS/657232_Bericht_zur_Hightech-Strategie_2025_en.pdf?__blob=publicationFile&v=4

Bundesministerium für Forsnung, T. u. R. (2025). Digitale Zukunft - Lernen, Forschen, Wissen. Retrieved from https://www.bildung-forschung.digital/digitalezukunft/de/home/home_node.html

Cazzaniga, M. (2024). Gen-AI. *Staff Discussion Notes, 2024*(001), 1. doi:10.5089/9798400262548.006

Commission, E., Directorate-General for Education, Y., Sport, & Culture. (2022). *Ethical guidelines on the use of artificial intelligence (AI) and data in teaching and learning for educators*: Publications Office of the European Union.

Department for Science, I. a. T. (2025). AI Opportunities Action Plan (CP 1241). Presented to Parliament by the Secretary of State for Science, Innovation and Technology by Command of His Majesty. . Retrieved from https://www.gov.uk/government/publications/ai-opportunities-action-plan/ai-opportunities-action-plan

Department of Education Australian Government. (2025). *2024 Review of the Australian Framework for Generative Artificial Intelligence in Schools*. Retrieved from https://www.education.gov.au/schooling/resources/australian-framework-generative-artificial-intelligence-ai-schools

European commission. (2024a). AI Act. Retrieved from https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

European Commission. (2024b). Data Act. Retrieved from https://digital-strategy.ec.europa.eu/en/policies/data-act

Gouvernement de la République Française. (2025). *Make France an AI Powerhouse*. Retrieved from https://www.elysee.fr/admin/upload/default/0001/17/d9c1462e7337d353f918aac7d654b896b77c5349.pdf

Luo, J. (2024). A critical review of GenAI policies in higher education assessment: a call to reconsider the "originality" of students' work. *Assessment & Evaluation in Higher Education, 49*(5), 651-664. doi:10.1080/02602938.2024.2309963

Ministry of Education and Culture. (2024). Recommendations for artificial intelligence. Retrieved from https://okm.fi/en/project?tunnus=OKM021:00/2024

Ministry of Education, C., Sports, Science and Technology (MEXT),. (2024). White Paper on Science, Technology, and Innovation 2024. Retrieved from https://www.mext.go.jp/en/publication/whitepaper/title03/detail03/mext_00007.html

OECD. (2025a). *Trends Shaping Education 2025*. Retrieved from Paris:

OECD. (2025b). What should teachers teach and students learn in a future of powerful AI? *OECD Education Spotligths, No. 20*. doi:https://doi.org/10.1787/ca56c7d6-en

UNESCO. (2023). *Guidance for Generative AI in Education and Research*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000386693

UNESCO. (2024a). *AI Competence framework for students*(pp. 52). doi:https://doi.org/10.54675/JKJB9835

UNESCO. (2024b). *AI Competence framework for teachers*(pp. 52). doi:https://doi.org/10.54675/ZJTE2084

A PLAIN JAPANESE TRANSLATION APP USING OCR TO BOOST READING COMPREHENSION SKILLS

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Comprehension is an important aspect of reading. One effective method to improve reading comprehension skills is reading plain language text. Plain language writing produces documents that are clear, concise, and easy to understand. Language learners can boost their reading comprehension skills, including vocabulary and grammar, by reading documents that have been translated into plain language from complex text. We develop a web application for plain Japanese language translation using OCR for input text. OCR converts images of text into computer-encoded text. The proposed application allows learners to easily obtain plain Japanese text, simply by taking a photo of original text. In the evaluation, we conduct a reading comprehension test using the Japanese Language Proficiency Test with six international students. Participants complete test set using three different methods: the proposed application, the existing system that requires manual input, and without using any assistance. The results indicate that the proposed application helps students improve their comprehension of evaluation tests.

Keywords: *reading comprehension skills, plain Japanese language, OCR, web application*

Introduction

Comprehension is an important aspect of reading. People read to understand and extract meaning, gaining better awareness of what a document conveys (Herrity (2025)). One effective method to improve reading comprehension skills is reading plain language text. Plain language writing produces documents that are clear, concise, and easy to understand (Bricks Co., Ltd. (2020)). Language learners can boost their reading comprehension skills, including vocabulary and grammar, by reading documents that have been translated into plain language from complex text.

Japanese language is one of the most complex languages in the world. Reading and writing pose a significant challenge for non-native learners because Japanese uses three types of characters -*hiragana*, *katakana*, and *kanji*- with *kanji* alone comprising over 2,000 characters. Although some plain Japanese translation systems have been developed in recent years to be available improving reading comprehension skills, these systems still need better usability, as they require users to manually input complex Japanese text.

We develop a web application for plain Japanese language translation using OCR, which means “optical character recognition” technology, for input text. OCR converts images of text into computer-encoded text from a photo of a document. The proposed application allows learners to easily obtain plain Japanese text to boost their reading comprehension skills, simply by taking a photo of original text, without the need to manually input complex characters.

Materials and Methods

We describe the application design based on the following implementation functions:

- Optical Character Recognition
- Plain Japanese Translation
- Application Design

Optical Character Recognition

We compare three implementation approaches to consider the use of OCR. The first is “Tesseract”, an open-source library that is compatible with multiple operating systems. The second is “EasyOCR”, a Python-based library. The third is “Vision AI”, a web API service provided by Google.

We prepare an image containing Japanese text to compare the performance of each OCR tool. Each tool processes the image and output the text data. As a practical use case, we take a photo of the document using a smartphone; the captured image is shown in Figure 1. The image is in JPG format, with a resolution of 2419x3225 pixels and a file size of 1.6MB. The output results from each OCR tool are indicated in Table 1.

Vision AI indicate the highest accuracy among the OCR tools, followed by Easy OCR and Tesseract, as indicated in Table 1. Additionally, Vision AI successfully recognizes and outputs nearly all the characters in the image. Therefore, we adopt Vision AI as the implementation tool.

Plain Japanese Translation

We use the ChatGPT API provided by OpenAI for translating into plain Japanese text. ChatGPT is a service that generates natural language based on a given text.

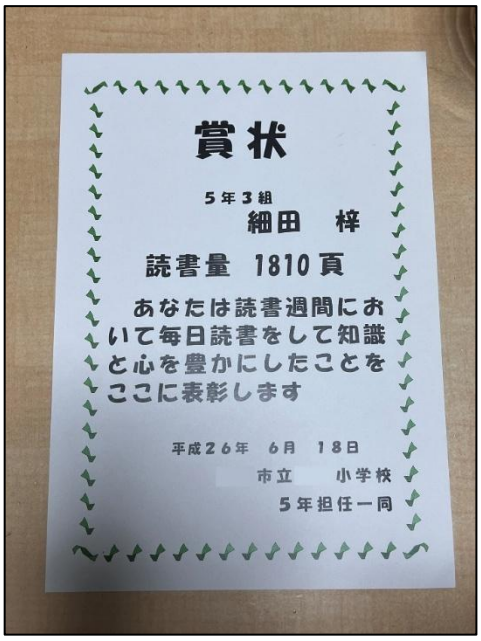


Figure 1. An image to compare OCR performance.

Table 1. Output from OCR of the image in Figure 1.

library	Output
Tesseract	引いプ NN へへへへへへへへ YY へ>。軸較納着 3| いいんき/Ne 開寺杖」記 2 に ANN1 昌間|有馬き人 Ss 95 年 3 組」し。さか）も|和んど 1 細田害 8] 和を 0 読書量 1810 具 8 -、、貞人 KK ロ 2C で 5. 三き「毎日読書をして知識>還|ん(1 て写日読書 Bk| |てとを豊かにしたことを較剛 WCS 用 LA でみ Sa| 上蘭間いこごごに表彰します>国(知っかーデシ旦をず 2 も替わり NG を。[続い 5 玉成 26 年 6 月 18 日ひみ 2 市立由学検の隊、年担任一同生還/ ままままままる 4 机| 上 Mg
easyOCR	賞状 5 年宮組細田梓読書量 1810 肩|ョ三西成口島年 6 月 7 昌日市立小学校 5 年担任一同う
Vision AI	**^^^^^^^^^^^^ 賞状 5 年 3 組細田梓読書量 1810 頁あなたは読書週間において毎日読書をして知識と心を豊かにしたことをここに表彰します平成 26 年 6 月 18 日市立| 小学校 5 年担任一同

Table 2. ChatGPT plain Japanese translation examples.

Original	ただ、所々丹塗の剥げた、大きな円柱に、蟋蟀が一匹とまっている。
Plain	しかし、大きな丸い柱の一部分の赤い塗りがはがれているところに、コオロギが 1 匹とまっています。
Original	必ず、かの邪智暴虐の王を除かなければならぬと決意した。
Plain	あの悪い王を絶対に取り除かなければならないと決めた。
Original	吾輩は猫である。名前はまだ無い。
Plain	私は猫だよ。まだ名前はないんだ。

We will continue to improve the application usability based on user feedback. We can easily adjust the level of plain text by providing prompts such as “Translate into plain Japanese that elementary school students can understand” because of high scalability of ChatGPT.

We first assess the ChatGPT’s capability to translate text into plain Japanese, specifically using the GPT-4 model. We refer to the passages as examples of complex text from following Japanese literature:

- *Rashomon* by Ryunosuke Akutagawa
- *Run, Melos!* by Osamu Dazai
- *I Am a Cat* by Soseki Natsume

We input each passage into ChatGPT with the prompt “Please rewrite the following text in plain Japanese”. The outputs are indicated in Table 2. we confirmed that the sentences were successfully translated into plain text however the outputs include a mix honorific and colloquial expressions.

Application Design

Users take a photo of a Japanese text to be translated into plain language using the device’s camera. Then the application displays both the original text and translation results on the screen. We show the display design in Figure 2. We describe the data flow between the application device and cloud-based services such as Vision AI API and ChatGPT API in Figure 3. Additionally, we indicate the process flow below.

1. Activate the camera.
2. Call Vision AI API with a captured image.
3. Receive the original text from Vision AI API.
4. Display the original text.
5. Call ChatGPT API with the original text.
6. Receive the plain text from ChatGPT API.
7. Display the plain text.

We use a Python-based web application framework to develop the plain Japanese translation system, as both the Vision AI and ChatGPT API are compatible with the Python language. Although Django and Flask are

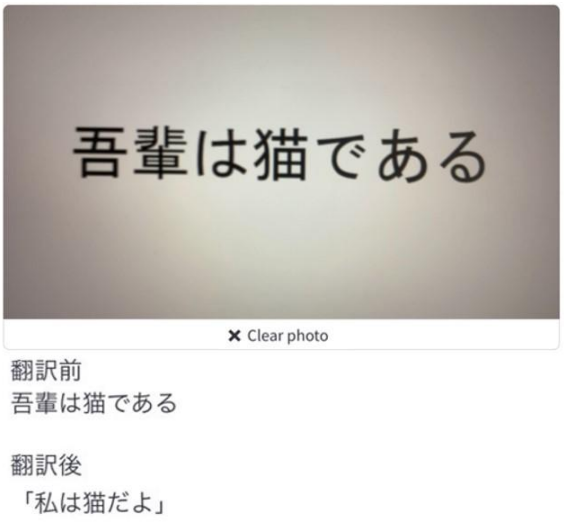


Figure 2. Web application execution screen.

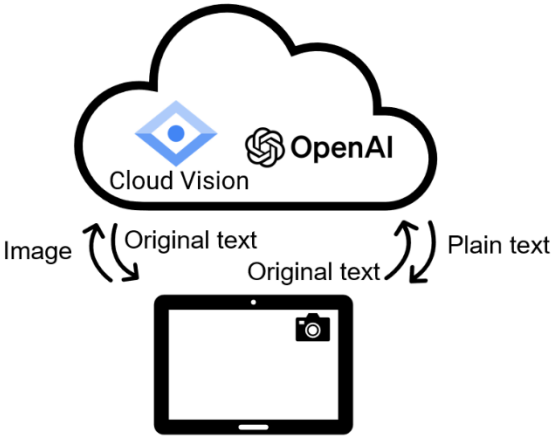
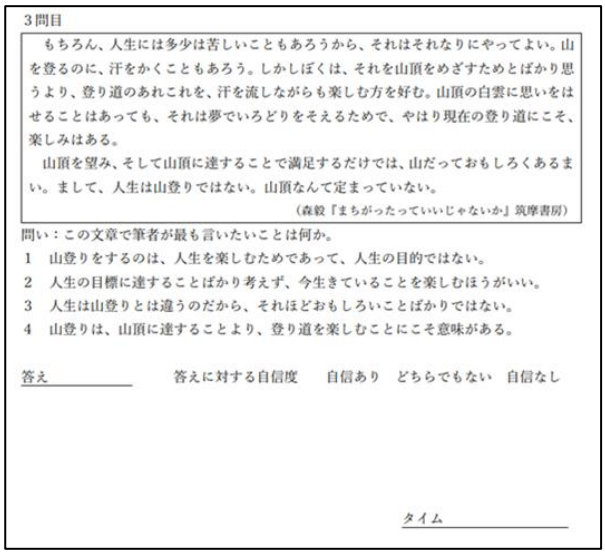


Figure 3. Data flow between the device and the web services.


3問目

もちろん、人生には多少は苦しいこともあろうから、それはそれなりにやってよい。山を登るのに、汗をかくこともあろう。しかしぼくは、それを山頂をめざすためとばかり思うより、登り道のあれこれを、汗を流しながらも楽しむ方を好む。山頂の白雲に思いをはせることはあっても、それは夢でいろどりをそえるためで、やはり現在の登り道にこそ、楽しみはある。

山頂を望み、そして山頂に達することで満足するだけでは、山だっておもしろくあるまい。まして、人生は山登りではない。山頂なんて定まっていない。

（森毅『まちがったっていいじゃないか』筑摩書房）

問い：この文章で筆者が最も言いたいことは何か。

1 山登りをするのは、人生を楽しむためであって、人生の目的ではない。
2 人生の目標に達することばかり考えず、今生きていることを楽しむほうがいい。
3 人生は山登りとは違うのだから、それほどおもしろいことばかりではない。
4 山登りは、山頂に達することより、登り道を楽しむことにこそ意味がある。

答え＿＿＿＿　答えに対する自信度　自信あり　どちらでもない　自信なし

タイム＿＿＿＿

Figure 4. An example of a reading comprehension test at the N1 level.

popular Python frameworks, they require the use of OpenCV to implement camera functionality, which can be cumbersome. Therefore, we adopt Streamlit as the framework. Streamlit is a framework for developing web applications in Python and is widely used in the fields of machine learning and data science. It allows easy integration of camera functionality within a web application.

Results and Discussion

Evaluation Design

We conduct reading comprehension tests (Method1 to Method3) based on the Japanese Language Proficiency Test (JLPT) with six international students at National Institute of Technology (KOSEN), Toyota College.

In Method1, the participants answer a reading comprehension test without any support tools. In Method2, participants manually input a part of Japanese text into their smartphones to translate it into plain language using the existing system provided by Alfasado Inc. (2025). In Method3, participants use the proposed application to take a photo of the Japanese text with a smartphone camera and translate it into plain language.

A reading comprehension test consists of three questions, each corresponding to the difficulty levels of N3, N2, and N1 of the JLPT. Participants complete one test for each method: Method1, Method2, and Method3. An example of a reading comprehension question at the N1 level is shown in Figure 4. We collect additional information from participants, including confidence in each answer, the response time, and feedback on their experience.

Results and Discussion

We indicate the overall results in Table 3. We indicate JLPT level and years of Japanese learning for each participant A to F. The results of the reading comprehension tests are indicated as True (1) or False (0). The participants' confidence levels in each answer are also indicated as High (1), Middle (0), or Low (-1). Additionally, the response time for completing the three questions in each test is also indicated.

We indicate the average correct answer rates for each method and each question in Table 4. The correct answer rates decrease as the difficulty level increases from Q1(N3) to Q3(N1). The proposed method (Method3) achieved a correct answer rate of 0.67, which was lower than that of the method without any support tools (Method1).

We indicate the average confidence levels for each method and each question in Table 5. Similar to the correct answer rates, the confidence levels also decrease as the difficulty increases. However, the proposed method (Method3) achieved the highest confidence level, at 0.56, when compared to the other methods. These results suggest that the proposed method contributed to helping participants' answering with greater confidence.

There is a possibility that participants may answer correctly by coincidence since the reading comprehension test in the JLPT is multiple-choice questions. Therefore, we indicate the correct answer rates based only on the questions where participants understood the content and answered with confidence.

Table 3. The overall results of evaluation.

Participant			A	B	C	D	E	F
JLPT level			N1	None	N2	N4	N1	N1
Years of learning			5 – 6	1 – 2	3 – 4	3 – 4	longer 7	3 – 4
Method1	Q1 (N3)	Correctness	True (1)	True (1)	True (1)	True (1)	True (1)	True (1)
		Confidence	High (1)	High (1)	High (1)	High (1)	High (1)	High (1)
	Q2 (N2)	Correctness	True (1)	False (0)	False (0)	True (1)	True (1)	True (1)
		Confidence	Middle (0)	Middle (0)	High (1)	Low (-1)	Middle (0)	High (1)
	Q3 (N1)	Correctness	True (1)	False (0)	True (1)	True (1)	True (1)	False (0)
		Confidence	Middle (0)	Middle (0)	High (1)	Low (-1)	Low (-1)	Middle (0)
	Time (second)		241	382	622	333	278	228
Method2	Q1 (N3)	Correctness	True (1)	False (0)	True (1)	True (1)	True (1)	True (1)
		Confidence	High (1)	High (1)	High (1)	Middle (0)	High (1)	High (1)
	Q2 (N2)	Correctness	False (0)	False (0)	False (0)	True (1)	True (1)	True (1)
		Confidence	Middle (0)	Middle (0)	High (1)	Low (-1)	High (1)	Middle (0)
	Q3 (N1)	Correctness	False (0)	False (0)	True (1)	True (1)	True (1)	False (0)
		Confidence	Low (-1)	Middle (0)	High (1)	Low (-1)	High (1)	Low (-1)
	Time (second)		580	576	653	387	217	322
Method3	Q1 (N3)	Correctness	True (1)	True (1)	True (1)	True (1)	True (1)	True (1)
		Confidence	High (1)	High (1)	High (1)	High (1)	High (1)	High (1)
	Q2 (N2)	Correctness	False (0)	False (0)	True (1)	True (1)	True (1)	True (1)
		Confidence	Middle (0)	Middle (0)	High (1)	Middle (0)	High (1)	Middle (0)
	Q3 (N1)	Correctness	True (1)	False (0)	False (0)	False (0)	True (1)	False (0)
		Confidence	High (1)	Middle (0)	High (1)	Middle (0)	High (1)	Low (-1)
	Time (second)		450	529	424	586	279	391

Table 4. Average of correctness.

Correctness		Ave.	Ave.
Method1	Q1 (N3)	1.00	0.78
	Q2 (N2)	0.67	
	Q3 (N1)	0.67	
Method2	Q1 (N3)	0.83	0.61
	Q2 (N2)	0.50	
	Q3 (N1)	0.50	
Method3	Q1 (N3)	1.00	0.67
	Q2 (N2)	0.67	
	Q3 (N1)	0.33	

Table 5. Average of confidence.

Confidence		Ave.	Ave.
Method1	Q1 (N3)	1.00	0.33
	Q2 (N2)	0.17	
	Q3 (N1)	-0.17	
Method2	Q1 (N3)	0.83	0.28
	Q2 (N2)	0.17	
	Q3 (N1)	-0.17	
Method3	Q1 (N3)	1.00	0.56
	Q2 (N2)	0.33	
	Q3 (N1)	0.33	

Table 6. Average of correctness when confidence is middle or higher.

Corr. with Conf. (Middle or High)		Ave.	Ave.
Method1	Q1 (N3)	1.00	0.61
	Q2 (N2)	0.50	
	Q3 (N1)	0.33	
Method2	Q1 (N3)	0.83	0.50
	Q2 (N2)	0.33	
	Q3 (N1)	0.33	
Method3	Q1 (N3)	1.00	0.67
	Q2 (N2)	0.67	
	Q3 (N1)	0.33	

Table 7. Average of correctness when confidence is high.

Corr. with Conf. (High)		Ave.	Ave.
Method1	Q1 (N3)	1.00	0.44
	Q2 (N2)	0.17	
	Q3 (N1)	0.17	
Method2	Q1 (N3)	0.67	0.39
	Q2 (N2)	0.17	
	Q3 (N1)	0.33	
Method3	Q1 (N3)	1.00	0.56
	Q2 (N2)	0.33	
	Q3 (N1)	0.33	

We indicate the correct answer rates for responses with confidence levels of "Middle" or "High" in Table 6, and those for responses with a "High" confidence level in Table 7. In both cases, the proposed method (Method3) achieved the highest correct answer rates. These results suggest that the proposed method supported participants' understanding of the question text and helped them to answer with greater confidence.

We indicate the average and standard deviation of the response time for answering the questions for each method in Table 8. The average time for the proposed method (Method3) was 443.17 seconds, which was longer than that of Method1 (no support tools), but shorter than that of Method2 (manual text input). Moreover, the standard deviation for the proposed method was 98.20, the smallest among all methods. These results suggested that the proposed method contributed to reducing the influence of differences in Japanese comprehension skills and Japanese text input abilities on the response time.

On the other hand, three participants (D, E, and F) took more response time to answer using Method3 than Method2 as shown in Table 3. This result can be attributed to two main reasons. First, the proposed method (Method3) requires approximately 20 seconds to complete the translation process after taking a photo. As a result, participants had to wait for the plain Japanese text to be displayed before answering. Second, participants entered varying amounts of difficult Japanese text in Method2. Some participants input only specific difficult words rather than the entire sentence, which shortened the input time.

Finally, we indicate the participants' feedback on using the proposed application in Table 9. Overall, the feedback was generally positive; however, there were some suggestions, such as a request for a "adding *furigana* to *kanji*" and a "selecting the area of text in the image".

Table 8. Average and Standard of Time.

Time (second)	Ave.	Std.
Method1	347.33	133.67
Method2	455.83	157.28
Method3	443.17	98.20

Table 9. Results of the survey on participant's feedback.

Feedback on usage
The text was made very easy to understand, which was very helpful when answering the questions.
It didn't take much time, and I could include all the text, so I found it easy to use.
It was helpful. The sentences became somewhat simpler.
It made the text much easier to understand.
I think it became significantly easier to understand compared to the original text.
It was very convenient to be able to use the camera. I appreciated that it simplified difficult N1-level sentences.
Requested features
There were still some difficult *kanji* even in the simplified text, so I think it would be helpful if the readings (*furigana*) were also provided.
I think it would be good if users could select the area of the text to be captured.
It would be helpful if there were a function to select a range and automatically copy and paste the selected text into the translation input field.
Even after translation, there were still some difficult *kanji*, so I think it would be better to either add *furigana* or replace them with simpler words.

Conclusions

We developed a plain Japanese translation system that uses OCR to extract text from images and translates difficult Japanese language into more understandable Japanese. The system employed ChatGPT API provided by OpenAI and Vision AI API provided by Google. We developed the system as a web application to ensure compatibility with various devices.

We conducted an evaluation using reading comprehension tests from the JLPT. The proposed application helps participants better understand difficult text and answer with greater confidence. Furthermore, we indicated that the proposed application reduces the response time to answer compared to the existing system that require manual input.

These results indicate that the proposed application helps participants improve their comprehension of evaluation tests. We need to enhance the application's usability and conduct a long-term evaluation to assess its effectiveness in improving reading comprehension skills.

Acknowledgements

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References

Jennifer Herrity (2025). "7 Simple Strategies to Improve Reading Comprehension". Retrieved from https://www.indeed.com/career-advice/career-development/reading-comprehension-improvement-strategies .

Bricks Co., Ltd. (2020). "多言語翻訳サービス利用における「やさしい日本語」の活用に関する調査研究報告書" in Japanese title. "A Research Report on the Use of Plain Japanese in Multilingual Translation Services" in English title.

Alfasado Inc. (2025). "伝えるウェブ" in Japanese title. "Information-Friendly Web" in English title. Retrieved from https://tsutaeru.cloud .

ACCESSING CLASS MATERIALS FROM LINE: AN AI CHATBOT APPROACH FOR STUDENTS

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We present the development and implementation of an AI chatbot integrated with the LINE messaging application to facilitate student access to class materials, syllabi, and academic resources. Leveraging Google's Dialogflow, an online natural language understanding platform, the proposed chatbot aims to address the limitations of traditional information retrieval methods based on physical printouts and online repositories. A key focus of this research is the chatbot's ease of use to both teachers and students.

By utilizing LINE, a familiar and widely adopted messaging platform in Japan, students can intuitively interact with the chatbot using natural language. This eliminates the need for complex navigation through menus and printouts, simplifying the process of accessing vital course information. Dialogflow's machine learning algorithms allow the chatbot to continuously improve its understanding of student needs and refine its responses over time.

To setup the chatbot, teachers don't require AI knowledge and just need to upload their existing class materials (printouts, presentations, etc.) to Dialogflow's platform and provide a set of possible message interactions with the students and their desired outcome. The chatbot's core functionality relies on the robust capabilities of Google's Dialogflow. This platform is available 24/7 and enables the chatbot to understand and interpret student queries at their convenience, even with variations in phrasing and syntax, look for material that matches the query request and show such materials to the student on its entirety or in the way of a chat answer. This paper details the development process, including the design of the conversational flow and the integration of Dialogflow with the LINE messaging API. We also present preliminary findings from a pilot study, evaluating student perceptions of the chatbot's usability and effectiveness. We conclude by discussing the potential for future enhancements and broader applications of AI chatbots in education, particularly in leveraging messaging platforms to broaden access to academic resources.

Keywords: *AI, chatbot, dialogflow, accessibility*

Introduction

The way students interact with classes and the materials provided in them is changing rapidly as technological developments allows a smoother integration of digitalization and accessibility both during classes and after them (Labadze, L. et al., 2023)

One example of this is the rapid spread of online class platforms such as Microsoft Teams and Google Classroom. Platforms such as these allow students to access class materials and information outside of school at the time they find it convenient. This is also beneficial to teachers, as they can rapidly communicate class updates to students, create assignments and evaluate their results, give feedback, etc. However, as more and more classes make use of online platforms, the negative aspects of having to navigate many online repositories to find class materials has begun to become a burden on the academic experiences of students.

When students want to, for example, check the syllabus for a specific class online, they can access the syllabus system, which in its current form doesn't have a smartphone-oriented website and thus provides a suboptimal browsing experience.

Another possible option to access the syllabus might be available if the teacher in charge of a class has uploaded the syllabus to the class platform. In this case, the students need to access the corresponding app or website, go to the page of the class, go through some menus, find the syllabus and either visualize it there or download it. This example illustrates a single case of material searching for a single class, but students constantly need to access and go through multiple classes and their related materials on a daily basis, so having to go through such process to access very simple but necessary and relevant information can become a significant detriment in their academic experience.

To address this issue, we implemented a chatbot powered by Dialogflow, a natural language understanding platform based on large language models, on the messaging application LINE that can provide information from the syllabus and other materials by naturally interacting with its users. The chatbot presented here does not require any level of understanding of AI for its implementation, as all processes involving AI are

already setup and automatically managed on the Google's server side.

In the following sections, we present the steps to necessary to implement the chatbot, from creating a business LINE account, to the process of feeding information to the chatbot platform and the results from a very simple survey with potential end-users.

Creating and linking necessary accounts

To implement the chatbot we propose, a Google account to access the service called Dialogflow ES (Google's Dialogflow ES access, 2025) and a LINE business account are required.

(1) The Google account can be the one provided by the school or any other. Dialogflow ES is free to use at the time of writing of this work and there's a paid version with more features and better understanding capabilities called Dialogflow CX. It should be noted that the free version of Dialogflow used for this work limits the number of queries that can be done per minute, day, week and month as stated in the Dialogflow documentation. All conclusions, comments and descriptions provided in this work are made under the current environment of Dialogflow ES.

(2) A LINE business ID must be created and access to the LINE developers console and LINE official Account Manager must be confirmed with this account. In the LINE developer console home, create a provider first, access it, and create a channel of the "Messaging API" type. Access the created channel and look for the Webhook Settings (which are found under the Messaging API tab at the time of writing) and make sure the option to use webhook is on.

(3) In Dialogflow, create an agent and name it. After that, on the menu to the left, go to "Integrations" and search for LINE under the "Text based" category. After clicking it, you will be prompted with a floating window as the one seen in Figure 1. Following the instructions provided should be enough to get the following information from the channel created in (2) of this section: Channel ID, Channel secret (both of these were found in the basic settings) and Channel Access Token (found in the Messaging API tab and has to be issued).

Copy and paste these three pieces of information into their respective fields in the floating window. Then, copy the webhook URL provided in the floating window and paste it in the Webhook URL field found in the Messaging API tab of the channel created in your business LINE account (the same one from which the channel ID, channel secret and channel access token were taken from) by clicking "Edit". Once pasted, click "Verify" to see a message displaying "Success". If any error is displayed instead, even though the process was followed correctly, try refreshing the page for the floating window where the Webhook URL is provided in Dialogflow, then repeat the verification process.

By completing these three tasks, the core integration of Dialogflow and the LINE account is completed. Although it is not necessary for continuing, I recommend to access the LINE official account manager and turn off chats and auto-response messages to make sure that all interactions with the chatbot are solely determined by the Dialogflow service.

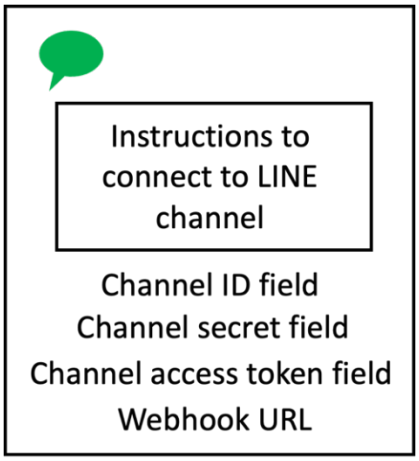


Figure 1. Representation of the floating window where the information to link the LINE channel and the Dailogflow agent is shown.

Chatbot training and testing conditions

The most direct way to train the chatbot is through the creation of Intents, which are interactions that the chatbot manager expects to occur between the chatbot and the end-users.

To create an Intent, we access them from the "Intents" option on the main Dialogflow menu (to the left on the Dialogflow console at the time of writing) and then click the "CREATE INTENT" button.

In the created Intent, two main drop menus of interest are found: "Training phrases" and "Responses". Training phrases are suggestions of the possible inquiries the chatbot will get from the end-users and must be written by the chatbot manager. The chatbot will learn from these phrases and will be able to understand the intent of the end-users' request if the phrase received is of the same nature are the ones used for training without necessarily being the same phrase. After receiving an inquiry and understanding its intent as one it has been trained to recognize, the chatbot will then respond by using one of the options given to it in the "Responses" drop-down menu. The responses can be simple text messages or more complex application-oriented cards with options (visible after clicking the + button next to DEFAULT responses).

A single Intent should define a single type of interaction. For example, if the students are expected to inquire about the syllabus and also about school rules, an Intent that manages each of those topics should be created for easier management of the chatbot.

Another option to train the chatbot is by providing documentation with the information the chatbot can learn to interact with the end-user without creating specific intent scenarios. This can be done over the "Knowledge" option (to the left on the Dialogflow console at the time of writing). If this feature is in beta, it won't be accessible until turned on using the agent's settings and selecting the "Enable beta features and API's" option. After creating and naming a "KNOWLEDGE BASE", a message stating that no Knowledge has been created will be seen,

followed by a highlighted text to create the first one as seen in Figure 2. To create the first instance of Knowledge the chatbot manager needs to prepare a document based on the archetypes: FAQ or Extractive Question Answering. FAQ is a document formatted so a series of questions and answers are presented one after the other, while Extractive Question Answering can analyze text written without particular structure and extract information for its answers from what it understands of it. As a beta feature, this approach has a lot of limitations, for example, the formatting of the documents, which at the time of writing doesn't allow for tables or lists being used in the documents used to generate Knowledge.



Figure 2. Example of the message seen when no Knowledge has been created and the underlined option to be clicked to create one.

For this project, an intent that prompts a card when asked about the syllabus was created and the training phrases used for this are summarized in Table 1. The response when this intent is recognized is to ask the student who is the professor in charge of the class they are taking by means of an option card shown in the LINE chat. Additionally, we created Knowledge for a class called Network Basics and the information included is: class objective, grading method and overall description of its topics and scope. The document containing the class information was formatted to fit the Extractive Question Answering type, meaning it doesn't have any tables or lists, but it is not formatted as a series of questions and answers. The overall structure of the document can be seen in Figure 3.

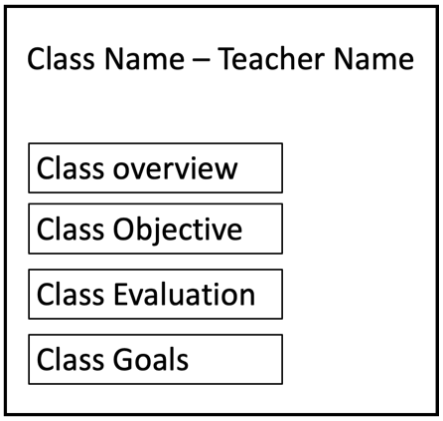


Figure 3. Overall structure of the document used for knowledge generation.

Default responses for the chatbot can be tested in the built-in cat box on the right of the Dialogflow window, which as the time of writing is signalled by a "Try it now" message. Writing in this text box will prompt the chatbot to write a reply from all of its currently created Intents and knowledge. This option only works for responses that are not app-dependant, so any response that uses cards within an app or more complex responses can't be verified using this tool.

Table 1. Training phrases and responses used in the created Intent.

Training phrases	Syllabus, list of syllabi, please show me the syllabus, class syllabus
Responses	Card response with syllabi available and links to them

To fully test our chatbot, we need to add it as a Friend on LINE and interact with it. The QR code to befriend the chatbot can be found in the LINE developer console under "Messaging API" settings.

Ten students added the chat as a friend and were asked to interact with the chatbot in no particular way to get the following information: name of the teacher in charge of the class, evaluation method and description of the class.

Results and Discussion

Opening a chat dialog with the chatbot prompts an automatic welcome response that can be configured in the "Greeting message" option found in the LINE Official Account Manager. A series of control inquiries were made regarding the class to be answered by plain text messages. This is only to establish that the chatbot is working properly when the inquiry specifically targets information found in the document used for Knowledge generation.

After that, the chatbot was asked about the syllabus and the expected answers was to be in the form of a card with 2 options, one for each of the teachers in charge of the subject. However, the first answer was of text type, as shown in Figure 4(b), and contained information from the Knowledge base, which was not the intention. To solve this, the Knowledge Results Preference was adjusted in the Dialogflow console from 1 to -0.7, which prompted the expected response, as shown in Figure 4(c). When the user taps the option corresponding to their teacher, it gets directed to the syllabus website.

To further test the chatbot, 10 students from the 5th grade of the electrical department were asked to use the chatbot freely for no more than 3 minutes to retrieve information for a class and fill out a survey based on their experience (see Table 2).

All of the students succeeded in retrieving the information by performing very different inquiries. While some asked with more formal sentences such as "Who teaches this class?", others simply asked "Teacher?", with both cases ending in the same answer. Although the desired information itself was received, some students felt that the information was accompanied by unnecessary details. When asking for the name of the teacher, they would additionally receive a brief description of the class contained in the course "Class

Table 2. Survey results for the 10 students that tested the chatbot. 1 is for strongly disagree, 2 for disagree, 3 for agree, and 4 for strongly agree.

	Level of agreement			
	1	2	3	4
1 Writing to the chatbot was easy and felt natural	0	0	1	9
2 The results from the queries were satisfactory	0	0	2	8
3 Wider implementation of the chatbot could improve the academic experience	0	0	0	10

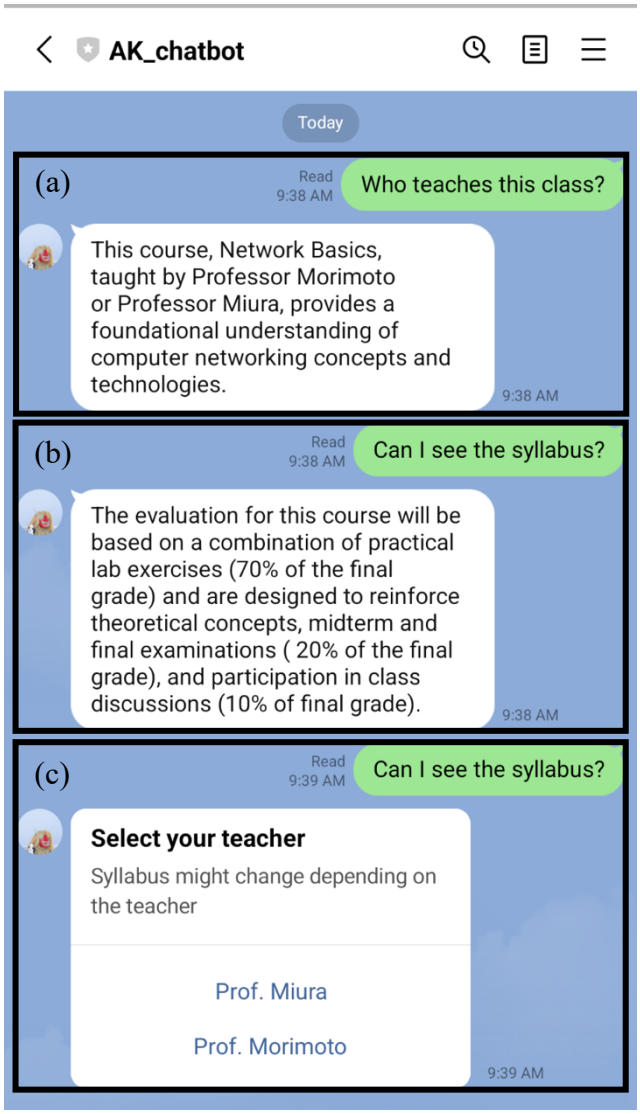


Figure 4. Chatbot responding to queries using Knowledge in (a) and (b), and using Intent (c) to prompt card style response.

overview block" of the document used for Knowledge generation (see Figure 3). On the other side, students were satisfied with the speed of the response and the ability of the chatbot to understand what they wanted to know without having to use specific phrases or writing style.

Conclusions and future work

The work presented here goes through the creation and linking of the accounts and services needed to implement a chatbot in LINE powered by the Dialogflow platform. In our testing of the chatbot, students successfully retrieved specific information from it without receiving any kind of training. Furthermore, the students had overall a good experience interacting with the chatbot, and thought of it as a convenient way to get school information.

The chatbot implemented here runs on the free version of Dialogflow and has limited query quotas (Dialogflow documentation, 2025), which would impact the school-wide application and testing of the instance of the chatbot presented in this work. Opting for a paid Dialogflow service would allow not only for more students to access the chatbot, but also the access to more advance tools for training the chatbot that are not available in the free version.

Overall, we found that the proposed chatbot approach was promising for facilitating class materials and information. However, further testing is required to elucidate whether Dialogflow fits the needs of the KOSEN system on a broader scale. Furthermore, issues regarding privacy and the use of personal information have to be carefully considered, as in its current state, the chatbot can be befriended by any person with a LINE account and access to the friend QR code.

Going forward, we will provide the chatbot with Knowledge and Intents to cover more aspects of a class and test it real scenario to address how efficient this approach is in real life and assess the costs that deploying this model school-wide would incur. Additionally, alternative options to Dialogflow will be considered, with Microsoft Azure AI Bot being considered due to the possibility of using it with LINE in a similar way to the one presented in this work (Azure AI bot for LINE, 2025), as well as within Microsoft Teams, a service that has been widely adopted by the KOSEN system.

References

Labadze, L., Grigolia, M. & Machaidze, L. Role of AI chatbots in education: systematic literature review. Int J Educ Technol High Educ 20, 56 (2023).

Dialogflow SE access. Retrieved on May 13, 2025 from https://dialogflow.cloud.google.com/

Dialogflow documentation. Retrieved on May 13, 2025 from https://cloud.google.com/dialogflow/

Azure AI Bot for LINE. Retrieved on June 13, 2025 from https://learn.microsoft.com/en-us/azure/bot-service/bot-service-channel-connect-line?view=azure-bot-service-4.0

FULL PAPERS FOR SUBTHEME 4

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STRENGTHENING COLLABORATION WITH THE ITOIGAWA UNESCO GLOBAL GEOPARK THROUGH STUDENT SDGS PROMOTERS AND VR EDUCATIONAL MATERIAL DEVELOPMENT

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Nagaoka University of Technology (NUT) established programs for the GIGAKU SDG Institute (UNESCO Chair) and GIGAKU SDG Network (UNITWIN Network) and has been promoting collaboration with UNESCO. The ongoing Science Working Group of the Youth Committee of the Japanese National Commission for UNESCO aims to strengthen collaboration with the Itoigawa UNESCO Global Geopark. In line with this initiative, students and faculty members from NUT, primarily from the student organization SDGs Promoters, including members of the Youth Committee of the Japanese National Commission for UNESCO, conducted research and hands-on activities in Itoigawa, Niigata Prefecture.

As part of the program, the group visited the Fossa Magna Museum, which offers an accessible and engaging exhibition on the formation of the Earth and the Japanese archipelago. They attended a lecture by a curator on the origins of the Fossa Magna, then explored the museum to learn about the region's rich geological history, including jade and the Itoigawa-Shizuoka Tectonic Line. In addition, they visited Benten Rock, a pyroclastic deposit from a submarine volcano about one million years ago. At Jade Beach, where a variety of stones can be found, they searched for jade stones that had washed down from the Kotakigawa Jade Gorge.

Following these activities, a survey was conducted among the student participants to explore effective ways to enhance collaboration with the Itoigawa UNESCO Global Geopark. The results indicated that many participants found the jade-searching experience particularly memorable, while others were impressed by the large-screen visualization of the formation of the Japanese archipelago.

Subsequently, students engaged in a group discussion to brainstorm strategies for attracting more visitors to the Itoigawa Geopark. Through this discussion, they proposed ideas such as a virtual jade-searching experience accessible from anywhere in the world and a visual representation of the formation of the Japanese archipelago and the Fossa Magna (a geological rift) as effective ways to promote the Geopark.

Based on these ideas, the group decided to develop multilingual VR educational materials to share the appeal of jade-searching and provide knowledge about the Fossa Magna to a wider audience. The VR content is planned to recreate the jade-searching experience and incorporate an interactive quiz feature related to the Geopark.

Keywords: *Engineering education, Geopark, SDGs, VR educational material*

Introduction

Nagaoka University of Technology (NUT) has been proactively promoting engineering education programs that incorporate the perspective of the Sustainable Development Goals (SDGs), adopted by the United Nations. In parallel, the university has also been engaged in various activities to raise awareness and deepen understanding of the SDGs in the local community.

To advance these efforts, NUT established the GIGAKU SDG Institute, which integrates SDG perspectives into its pioneering engineering education (GIGAKU: Science of Technology) programs. In 2018, the university became the first engineering institution in Japan to be designated as the UNESCO Chair programme, "UNESCO Chair on Engineering Education for Sustainable Development." Furthermore, in collaboration with nine institutions from six countries that share the same credos, NUT launched the GIGAKU SDG Network. In 2023, this initiative was officially recognized by UNESCO as the "UNITWIN Network for Engineering Education towards Sustainable Pathways," making it the third such network in Japan.

In 2020, NUT established the student organization "SDGs Promoters," which currently comprises 40 active members (10 Japanese and 30 international students as of

2025). Among them, two students who demonstrated outstanding commitment and achievements were recommended by NUT and, through the selection process of the Japanese National Commission for UNESCO, were appointed as members of its Youth Committee. Both students belong to the Science Working Group and, although there is no formal agreement between NUT and the Geopark administration, they have been actively contributing to UNESCO's mission through support activities for the Itoigawa UNESCO Global Geopark, based on mutual interests in youth engagement and UNESCO-related goals.

Itoigawa City, on the other hand, was the first location in Japan to be designated as a UNESCO Global Geopark in 2009. The city has utilized its rich geological assets, including the Itoigawa-Shizuoka Tectonic Line, which divides the Japanese archipelago, and jade, which is recognized as Japan's national stone, for regional revitalization. It is also known for its comprehensive educational approach that incorporates Geopark-based learning into local education for children from ages 0 to 18. However, due to the absence of a university or other higher education institutions in the city, engagement with young people aged 18 to 29 remains limited after they graduate from high school. While elementary, junior high, and high schools actively participate in Geopark-related learning through extracurricular activities and school programs, university-level involvement tends to rely on personal relationships, for example, with students studying geology or geomorphology in specialized laboratories elsewhere. This lack of structured collaboration with universities results in missed opportunities to involve non-local university students, who could otherwise bring fresh perspectives and interdisciplinary approaches. The project, therefore, focuses on reconnecting such youth with the Geopark through meaningful engagement opportunities.

To address this situation, the project aims to build a foundation for sustainable regional education that supports the protection and preservation of cultural and natural heritage from a scientific and engineering perspective, in alignment with SDG 11: Sustainable Cities and Communities. It also seeks to convey the value of the Geopark to young people and promote their participation in related activities. In addition, to expand learning opportunities beyond site visits, the project is developing VR educational materials designed to make the Geopark's appeal more accessible to a wider audience. This approach is expected to enhance the relevance and inclusivity of the content, particularly for diverse learners. The development of VR materials is considered essential not only for overcoming geographical constraints but also for offering flexible and engaging educational experiences tailored to the needs and preferences of the younger generation.

To implement specific initiatives such as the development of VR educational materials, this project was made possible with support from the National University Reform Enhancement Project.

Objectives

This project is structured around three primary objectives, each of which addresses a specific aspect of the overall aim to strengthen collaboration with the Itoigawa UNESCO Global Geopark and enhance sustainable regional education through student participation.

The first objective is to foster university students' development through practical inquiry-based learning. The primary target group is the SDGs Promoters at NUT, comprising both Japanese and international students. The goal is to cultivate their ability to identify and analyse regional issues from scientific and engineering perspectives. Through field visits, brainstorming sessions, and co-creation activities with Geopark experts and local stakeholders, students are encouraged to apply academic knowledge to real-world challenges and gain transferable problem-solving skills. This approach helps students become proactive contributors to sustainable development initiatives both locally and globally.

The second objective is to create opportunities for youth engagement in Geopark activities. Here, "youth" specifically refers to university students, particularly those from outside the Itoigawa region who would otherwise have no access to the Geopark through any formal educational program. While local children (ages 0 - 18) participate in structured learning through schools, this project fills a significant gap by involving university students in the planning and promotion of Geopark-based education. Students contribute not only as learners but also as facilitators, developing educational content and outreach strategies aimed at engaging peers. This is expected to strengthen long-term ties between young people and the Geopark, fostering sustainable community engagement.

The third objective focuses on the development and utilization of multilingual VR educational materials (VREM). This objective builds upon the student-led research and brainstorming activities. Students' diverse insights and ideas are incorporated into prototype content, which is iteratively refined. VR technology allows learners, particularly those who cannot physically access the Geopark, including international students and remote users, to explore its geological and cultural features in a highly engaging and realistic way. By providing content in multiple languages, starting with Japanese and English, the project promotes inclusive, global access. The final materials will be shared as open-access resources, expanding their educational value beyond the immediate project scope.

Materials and Methods

The first phase of this project was conducted from January 2024 to March 2025. During this period, a cumulative total of 40 student SDGs Promoters from Nagaoka University of Technology (NUT) participated in structured activities designed to support the objectives of the Science Working Group of the Youth Committee of the Japanese National Commission for UNESCO, with a specific focus on strengthening collaboration with the

Itoigawa UNESCO Global Geopark. A mixed-method approach was employed, combining field-based experiential learning, qualitative data collection through open-ended questionnaires, and participatory content design through brainstorming workshops. These methods encouraged learner autonomy and ensured relevance by engaging students in addressing real-world regional challenges.

The project commenced with a courtesy visit and information exchange meeting with Geopark officials. This was followed by an on-site field trip, where students attended a lecture by a curator at the Fossa Magna Museum and explored its exhibits. They also visited Benten Rock, formed by pyroclastic flows from a submarine volcano approximately one million years ago, and participated in hands-on jade searching at Jade Beach.

To capture initial impressions and inform future collaboration strategies, an open-ended online questionnaire (via Webform) was administered immediately after the field trip. Students were asked to reflect on their most memorable learning experiences and propose ideas for improving youth engagement with the Geopark.

Following this, two online brainstorming sessions were held using synchronous Zoom meetings and asynchronous discussions on Slack (Fig. 1). These sessions were designed to leverage diverse student perspectives and generate innovative outreach ideas. The decision to use brainstorming was guided by participatory co-creation methods commonly used in educational design. Proposals included gamifying the jade-searching experience, adapting the existing Geopark quiz provided by the Fossa Magna Museum, creating non-social-media-based digital outreach tools, and developing interactive content to visually explain the formation of the Japanese archipelago and the Fossa Magna.



Fig.1 Screenshot of the first online brainstorming session conducted via Zoom. Students from various disciplines shared ideas to promote the Itoigawa UNESCO Global Geopark, with a focus on accessibility, multilingual outreach, and interactive experiences.

During a second site visit to deepen understanding, students moved into the content development phase. They began designing and testing prototype elements of the VR materials, including gamified jade-searching experiences and quiz-based educational activities. Content development was conducted in multiple languages, reflecting the diverse cultural perspectives of the participating students. Given the project's limited budget and timeframe, development focused on creating a modular and scalable framework that could serve as the foundation for future expansion. The selection of activities, tools, and topics was informed by the students' reflections, input from Geopark experts, and alignment with SDG 11 goals.

Results

Between January 2024 and March 2025, a total of 40 students from the NUT SDGs Promoters participated in this project. The program was structured in four phases, which included on-site fieldwork, a questionnaire survey, online discussions, and the design of VREM. The students' experiences and proposals were documented, analysed, and reflected upon throughout the process.

In the questionnaire conducted after the field visit, the most memorable experiences cited by students included the jade-searching activity, the large-screen visualization of the formation of the Japanese archipelago, and on-site observation around Benten Rock, a geological formation created by a submarine volcanic eruption related to the Fossa Magna. On the other hand, when asked for suggestions to improve the Geopark and increase the number of museum visitors, students proposed a variety of creative ideas.

Many students suggested ways to further enhance the existing efforts by integrating experiential tourism and nature-based activities. In addition to current initiatives, they proposed ideas such as snorkelling and underwater observation around Benten Rock, developing tour packages that combine camping and hiking with visits to Geopark sites, and organizing seasonal nature programs for children during summer and winter.

To support and expand outreach to families and younger audiences, students proposed hands-on workshops such as fossil excavation and basic geology experiments, as well as kid-friendly exhibit spaces with simplified visual explanations. They also suggested incorporating gamified elements like stamp rallies or bingo to further enrich educational engagement.

Several responses emphasized the value of strengthening outreach and promotional strategies already in place. Suggestions included placing brochures and advertisements at major train stations in Niigata Prefecture, collaborating with railway companies to develop travel packages, and producing promotional content such as videos, posters, and blogs. Students also noted the potential benefit of diversifying communication platforms beyond social media and enhancing multilingual accessibility.

With regard to broader improvements to the Geopark, proposals focused on building upon existing strengths. These included developing model courses that incorporate surrounding areas such as Jade Beach, expanding souvenir and dining options, and improving infrastructure to offer more diverse visitor experiences.

Among the various ideas proposed, many students emphasized the importance of direct explanations from experts and curators, noting that such interactions not only deepen visitors' understanding but also add a sense of uniqueness to the experience. They highlighted that building opportunities for interaction with specialists would be crucial for enhancing the appeal of the Geopark.

Building on the questionnaire results, students participated in online brainstorming sessions and explored the future direction of VREM, inspired by NUT's ongoing work in metaverse applications. Ideas discussed included gamifying the jade-searching experience, utilizing existing quiz content provided by the museum, and creating visual content that explains geological phenomena such as the Fossa Magna and plate tectonics.

Figure 2 shows one of the collaborative brainstorming sessions, where students used a shared PowerPoint slide to visualize and organize ideas for the educational content. During the session, students emphasized the importance of incorporating game-like elements to maintain engagement, such as designing a "Quest" format in which users search for jade as items to progress through stages.

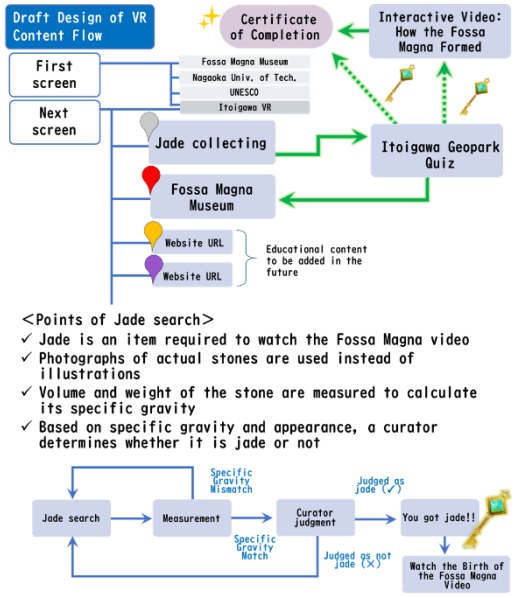


Fig. 2 Visualization of the second brainstorming session using a shared PowerPoint slide. Students categorized and refined their ideas into themes such as gamification, field experience, and cultural relevance, leading to the initial design of the VR educational materials. This figure is a reconstructed schematic based on students' original hand-drawn ideas.

They also expressed a strong preference for using real images of jade rather than illustrations to enhance authenticity and realism. These ideas were integrated into the planning of the VR materials.

As an initial step, the VREM was designed to include three main components. One is an explanation by curators, one is a jade-searching with educational elements activity, and the other is a Geopark quiz. These were developed as web-based educational resources accessible from anywhere in the world. The current framework was intentionally designed to allow for future scalability. To inform its design, an open-ended questionnaire was conducted to gather student reflections after the field visit, which contributed to shaping the subsequent development. Additional VREM content will be incorporated in stages, based on the characteristics and needs of each Geopark.

The current version of VREM includes multilingual audio guidance produced using text-to-speech technology based on written scripts, along with background music, to enhance user immersion through both visual and auditory channels. In the first stage, the jade-searching activity presents several stones on screen, from which users select the one they believe to be jade. They then conduct a simulated measurement of volume and weight to calculate its specific gravity. Based on the calculated value and the visual appearance of the stone, the curator avatar determines whether it can be identified as jade. Users who successfully identify jade can proceed to the next stage. The feeling of receiving a direct explanation from experts and curators is one of the key features.

In the following stage, users take part in the "Geopark Quiz Challenge," which consists of ten multiple-choice questions covering topics such as geology, landforms, and cultural features. Those who answer at least eight questions correctly are awarded a certification badge, providing a sense of accomplishment.

These ideas have been incorporated into the current design of VREM (Fig. 3). Through this project, students were given the opportunity to engage with regional issues from multiple perspectives and to translate their ideas, grounded in both academic knowledge and social relevance, into visible and practical proposals.

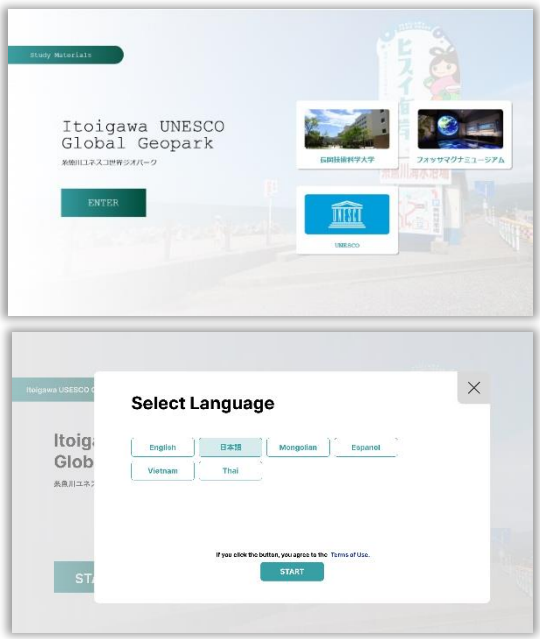




Fig. 3 shows screenshots of the VR Educational Material (VREM) prototype developed based on student input. The main features, jade-searching using visual characteristics and specific gravity, a curator avatar providing guided explanations, and a quiz challenge, were selected based on student proposals and implemented as core components of the prototype. These features reflect the ideas discussed and organized during the earlier brainstorming sessions.

Discussion

This project aimed to foster student growth, promote youth engagement in local activities, and develop VR educational materials that incorporate student ideas, accessible from anywhere in the world.

This comprehensive approach not only increased awareness of the Geopark but also suggested new pathways for reconnecting youth with regional heritage and sustainability issues.

Furthermore, the project emphasized the development of multilingual VREM. By leveraging the outcomes of fieldwork and collaborative learning, students created VREM that caters to diverse audiences, including non-Japanese speakers. Incorporating students' perspectives added authenticity and relevance to the materials, demonstrating the potential of student-led content creation to generate impactful and scalable educational resources. These resources may also be adapted for use by various institutions and regions.

The implementation of the metaverse elements posed financial challenges, which prevented the visual representation of the formation of the Japanese archipelago and the Fossa Magna. However, the current VREM framework is designed to accommodate future expansions. Once funding is secured, additional visual content will be incorporated to enhance the learning experience.

Conclusions

This project aimed to enhance collaboration with the Itoigawa UNESCO Global Geopark through field-based activities involving youth and to promote understanding of the Geopark's value from scientific and engineering perspectives. Through practical inquiry-based learning, students not only deepened their understanding of geological heritage but also proposed strategies to improve outreach and increase visitor engagement, such as gamified jade-searching activities, quiz-based learning modules, and multilingual visual explanations of geological phenomena. These strategies were developed through field observations, brainstorming sessions, and questionnaire feedback, and were partially implemented in the prototype of the VR educational materials.

The project led to concrete outcomes, including the development of ideas such as gamified jade-searching with educational elements, quiz-based learning, and visual explanations of the Fossa Magna and tectonic formation of the Japanese archipelago. These ideas were integrated into the design of multilingual VREM, and a prototype website featuring interactive content is currently under development.

This initiative suggests that, through their engineering perspective, university students can serve as effective mediators connecting the Geopark, scientific knowledge, and public audiences. Especially in regions where youth engagement opportunities are limited, such a role may prove to be significant. By combining hands-on experience with digital content creation, the project contributes to sustainable regional education and may serve as a model case for promoting youth participation. Further development, including expansion into languages other than Japanese and English, as well as more sophisticated content, is planned in collaboration with students and local stakeholders.

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References

Catherine Attard, Nathan Berger and Erin Mackenzie (2021). The Positive Influence of Inquiry-Based Learning Teacher Professional Learning and Industry

Partnerships on Student Engagement With STEM, *Front. Educ., Sec. STEM Education, Vol 6*

Xinli Zhang, Yuchen Chen, Lailin Hu, Youmei Wang (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics, *Front. Psychol., Sec. Educational Psychology, Vol. 13*

Mami Katsumi, Osamu Takahashi (2022). Engineering Education for Sustainable Development as UNAI Hub for SDG9, *15th International Symposium on Advances in Technology Education*

Mami Katsumi, Tomoko Ohta, Makoto Nanko (2023). The Role of Student SDGs Promoter and Its Impact on Both Inside and Outside of the University, *16th International Symposium on Advances in Technology Education*

Robby Hilmi Rachmadian, Alfyananda Kurnia Putra, Sumarmi Sumarmi and Heni Masruroh (2024). Developing interactive virtual reality as a tech-based learning media to improve students' geoheritage comprehension, *Published Online: November 5, 2024pp 332-351* https://doi.org/10.1504/IJLT.2024.142510

Koriyama, S. et.al. (2025). Development of Experiential Exhibits at the Itoigawa Fossa Magna Museum: A Case Study of the Special Exhibition Commemorating the 30th Anniversary of the Museum, *Proceedings of the 32nd Annual Meeting of the Japanese Council of Science Museums*
https://jcsm.jp/.wps/wp-content/uploads/2025/02/32th-Poster1-3.pdf

Yukari Kimura (2025). Project-Based Learning to Promote a Geopark by University EFL Learners Practical, Proactive, and Collaborative Learning through Industry-Academia-Government-Private Cooperation at the Hakusan Tedorigawa UNESCO Global Geopark, https://www.researchgate.net/publication/390039005

UNESCO Chairs and UNITWIN Networks
https://www.unesco.org/en/education/unitwin

Fossa Magna Museum
https://fmm.geo-itoigawa.com/en/

Youth Committee of the Japanese National Commission
https://www.mext.go.jp/unesco/006/index_00002.htm
Enhancing the Value of the Research and Education System and Expanding the Financial Base by Utilizing the Metaverse and Resource Management at the University of Technology
https://tech-meta.nagaokaut.ac.jp/

EFFECT OF TEAM TEACHING AS A BRIDGE TO TAKE MORE ADVANCED CLASSES

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The purpose of this research is to present how beneficial team teaching is, where a Japanese teacher of English and an assistant language teacher work together in English classes aimed at developing global citizenship and encouraging students to learn different languages. Hiring an international teacher is highly recommended in KOSENs. However, conducting English classes without any use of the mother tongue seems to have for almost all students aged 15 to 18 a long way to go, with the exception of those who have experience studying abroad. Since the Japan Exchange and Teaching Programme was installed in Japan in 1987, Japanese teachers of English have experienced a joint teaching style called team teaching. Therefore, it is now common for students to have an international teacher in their language classes, who gives students more incentive to learn English. However, it has not yet been thoroughly discussed how Japanese teachers and assistant language teachers should cooperate to achieve a certain goal within the classroom, even much less in higher education institutions such as KOSENs and universities where team teaching is hardly employed. The research question was to investigate how students experienced team teaching and the effect of team teaching aimed at making the classes a bridge to take more advanced classes conducted entirely in English. Team teaching was carried out in five classes of 215 third-year students in general education English language classes whose objectives were developing their communication skills in English and international competence, such as collaboration and diversity awareness. Students engaged in group work to learn SDGs-related subjects and present their ideas. The survey results showed that many students appreciated support from the assistant language teacher to encourage them to communicate in English. However, they preferred the current class model with a Japanese teacher and an assistant language teacher in future classes. In this paper, we will describe how we organized the classes and analyze what kind of support was helpful for students. The research also indicated that collaboration among Japanese teachers and an assistant teacher is crucial to conduct team teaching classes and create a better environment where students can feel supported and engage in language learning.

Keywords: *TT (team teaching), collaboration, CLIL, English learning*

Introduction

The joint teaching style in English classes, called TT (team teaching), has been common since JET Programme (The Japan Exchange and Teaching Programme) was installed in Japanese educational settings from elementary to high schools in 1987. It aims to improve English language education and promote international exchange at the community level (CLAIR, 2015). Now there are 5,861 participants from 51 countries (as of 2024), and they are deployed in more than 1,000 cities across the country and mainly engaged in education as ALTs (assistant language teachers). In TT, a Japanese teacher of English and an ALT, who is a native speaker of English, work together in class to promote learners' communication in English. ALTs usually come to the school once or twice a week and join several classes accordingly, which means that students do not always have an ALT in English class. They appreciate having an international teacher who can give them more incentive to communicate in English and create an enjoyable atmosphere.

On the other hand, TT is not adopted in higher education institutions like KOSEN or a university. KOSEN strongly promotes hiring international teachers to proceed with internationalizing on-campus activities. Toyota KOSEN implemented a year-long science class for third-year students taught by a native speaker of English from the academic year of 2020 to 2023 to increase their input as a part of the first Global Engineering Project. However, participating in the course conducted in English without any use of the mother tongue was quite challenging for almost all students aged 17 to 18, except for those who have experience studying abroad.

Hence, we decided to redesign the subject where TT was adopted when the second project started, aiming that the course would be a bridge to the advanced classes conducted in English that students might take in the future. It employed CLIL (Content and Language Integrated Learning) approach, whose purpose was that

students would develop their communication skills and global citizenship.

In the research, we will describe how we organized the course and analyze what kind of support can be helpful for students. The research aimed to explore the following questions:

1. How did students experience TT?
2. Did TT become a bridge to take a class conducted entirely in English?

With the support of an ALT, students are expected to have more opportunities for English communication, which enables them to acquire appropriate English expressions and experience the different cultures that the ALT can bring. Therefore, the significance of this research is to explore the benefits of TT, where each teacher plays a role in scaffolding, serving as a bridge to a class fully conducted in English in the future.

Materials and Methods

The participants of this research comprised five different classes of 215 third-year students (equivalent to the third-year students of high school) at National Institute of Technology, Toyota College, who were enrolled in the compulsory subject of Science Basic English I. Their English proficiency ranged from beginner level to intermediate level (CEFR A1 to B1).

Two Japanese teachers and one ALT were involved with the course. The purpose of the course and its teaching style were explained to students. The classes were basically conducted in English to increase their exposure to the target language. The course also featured project-based learning to cultivate generic skills such as problem-solving and collaboration, based on the topics from the textbook (*CLIL Primary SDGs*). Students used data and materials to grasp facts related to global issues, examined opinions from multiple perspectives, and learned basic discussion skills in English. At the end of the project, students performed a group presentation. Table 1 shows the products of the project-based learning. In the process of creating their products in a group, students discussed in Japanese. They were required to present the products in English.

Table 1. Products of the course

First term	Second term
Teacher A	
Drama-making activity -how to wear clothes Discussion -palm oil	Decision-making meeting -facilitation -pros and cons of Rally Japan
Teacher B	
Group presentation (Fact and Solution) -food problem Group presentation (Fact and Solution) -plastic problem	Group presentation (Fact and Solution) -energy issues Group presentation (Fact and Solution) -labor issues

After implementing TT in June 2024, the ALT participated in all classes with Japanese teachers, 10 times in the first term and 15 times in the second term. The Japanese teachers and the ALT discussed what topic students would cover and how the project should be organized to achieve the goals beforehand. They reviewed the class to improve as well. The main job of ALT during the class is to encourage students to communicate in English, as shown below:

- showing a role model of the presentation or conversation that students are going to learn
- checking the progress by asking some questions while students are working on the task
- evaluating the performance and giving feedback

Along with these, the ALT spontaneously gave some more instructions and explanations to develop students' understanding of linguistic knowledge and different cultures. The Japanese teachers also paraphrased the words that seemed to be difficult for students into easier ones. They occasionally had to explain in Japanese when the topic was too complicated to understand.

In this way, placing two teachers in a class increased the opportunities for students to communicate in English. Students also experienced a different culture and way of thinking, which was brought by the ALT.

At the end of the course, a survey was conducted to measure how students thought of TT and how beneficial TT was as a bridge to take a more advanced course. Students were informed that their responses would have no influence on course grades. It was also assured that the privacy of students' personal information and responses would be confidential, with identifiers removed and data securely stored.

There were six multiple-choice questions and two open-ended questions to answer on Microsoft Forms. There were 177 responses, including 36 students who had experienced studying abroad for nine months before joining the course.

Table 2. Items of the questionnaire

Multiple-choice questions
Compared to the beginning of the course 1. can understand spoken English 2. can speak English better 3. can speak more often to the ALT 4. accustomed to present in English 5. get more interested in other countries 6. Which type of classes do you want to join if you participate in CLIL class in the future?
Open-ended questions
7. What impressed you about your interactions with the ALT and the support you received? 8. If you take a class conducted in English, what kind of support or activities would be useful?

Table 2 presents the survey questions. For multiple-choice questions 1 to 5, students selected one of five options: "Strongly agree", "Agree", "Not sure",

"Disagree", and "Strongly disagree", to reflect their self-perception after participating in the course. They responded to multiple-choice question 6 using three options: "Completely conducted in English", "Current style", and "Japanese teacher of English", to assess whether the course encouraged them to pursue a more advanced English class. For the open-ended questions, students were required to answer question 7, while we gathered 40 responses voluntarily for question 8.

Results

Results revealed that many students felt they had improved their listening comprehension and presented themselves better compared to the beginning of the course (Figure 1). The positive responses of "Strongly agree" and "Agree" to questions 1 and 2 accounted for 75% in both cases. The positive responses to question 5 accounted for 70%, indicating that the course made students more interested in overseas. The responses to questions 2 and 3 were slightly less positive than the other questions, but still accounted for 53% and 52% of the total responses, respectively. Compared to other items, it cannot be said that students feel they have become able to speak English through lessons or that this has led to them talking to the ALT.

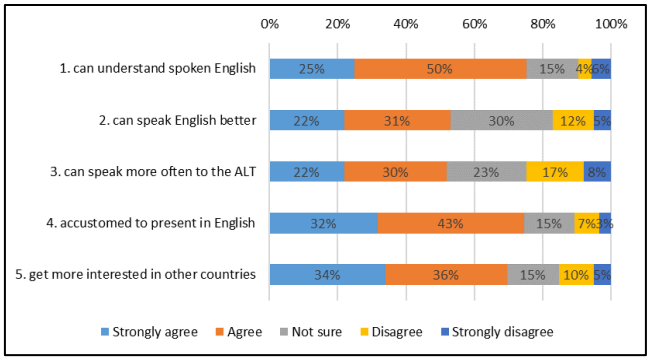


Figure 1. Results of multiple-choice questions

As mentioned above, the ALT played a significant role in encouraging students to communicate in English. The qualitative data regarding open-ended question 7 was collected to identify what support students appreciated and found helpful. In the analysis, the comments from students were categorized according to their experiences: "Language Experiences," "Language Support," "Supportive Prompting," "Advice on Discussion," and "Cultural Experience." The categories of "Language Support" and "Supportive Prompting" include subcategories as Description, which illustrate more specific supports that students received. Table 3 also provides representative comments from each category.

Qualitative findings derived from the results with students provide valuable insights into their perceptions of TT and its impact on learning experiences. Students appreciated regularly having an ALT in class and gained experience in listening to and speaking English, which most of them do not usually encounter in their daily lives. They noted two types of support: "Language Support" and "Supportive Prompting." The former included two subcategories: first, the ALT paraphrased expressions into simpler forms to enhance student understanding, and second, they (as singular they) facilitated their attempts to express themselves in English. The latter comprised three subcategories, wherein the ALT actively engaged with students, gently prompting and striving to comprehend their English. The frequency of these comments within this category was the highest, indicating that students valued their approach to communication and encouragement over the technical support provided, such as aiding their language production. This suggests that emotional support is crucial for students to feel engaged in English communication. Many students remarked: "I was happy that the ALT spoke to me," "They frequently spoke to us," "I was happy to have some help communicating in English," and "It was nice of them to listen to my English and try to understand what I wanted to say."

Students also appreciated that the ALT gave useful advice during group activities to promote their discussion. One student remarked: "When the group discussion was stuck, the ALT summarized the discussion and presented a new perspective." Students enjoyed that the ALT shared their experiences related to the topic they were learning.

Table 3. Counts per category and example (originally written in Japanese)

Category	Description	Count	Example
Language Experience	Listening and speaking English	31	"It was good to actually be able to speak English." "I didn't have many opportunities to speak with foreigners, so it was a good learning experience."
Language Support	Paraphraising	27	"When I couldn't understand English, the ALT repeated it in simpler English." "The ALT tried to explain things in the simplest English possible, so I learned the expressions and used them myself."
	Helping speaking English	18	"When I didn't know how to express my opinion in English during class, the ALT helped me." "When I couldn't express myself well in English, the ALT supported me kindly."
Supportive Prompting	Speaking to students	34	"The ALT actively talked to me." "I don't usually speak up on my own, but the ALT approached me, giving me opportunities to speak English."
	Gentle and kind	14	"The ALT responded thoughtfully to each and every opinion." "The ALT responded with a smile and kindness, which made me happy."
	Understanding	9	"The ALT made an effort to fully understand what I was trying to convey, which was heartwarming." "Even when I spoke broken English, the ALT responded with a smile, making it easy to feel at ease."
Advice on Discussion	Giving advice on group work	14	"During group activities, the ALT asked questions that helped facilitate more active discussions." "When group discussions were not progressing smoothly, the ALT stepped in to support us, making the discussion flow more easily."
Cultural Experience	ALT's life story	9	"The ALT shared stories about the home country."

Although the number was very small, there were comments that even when the ALT spoke to them, they could not understand at all. It seems that they exaggerated it. However, it must have been challenging for those students to participate in the class, which was mostly conducted in English.

There were comments that did not mention support from the ALT, such as "They noticed I dyed my hair," or

"They like playing games." Those were excluded from the analysis. Still, it shows that the ALT had a lot of interactions with students.

The result of multiple-choice question 6 showed that most of the students still want to participate in English class with the current style in the future (Figure 2). There were 33 students who wanted to join a class completely conducted in English, and 20 of them had studied abroad. The number of students wanting to join the class of a Japanese teacher of English was only 15 (8%).

We found that they desire more personal support and language assistance in Japanese if they enroll in a class conducted in English, as indicated by the responses to an optional question 8: "If you take a class conducted in English, what kind of support or activities would be useful?" There were 39 responses, and nine of them mentioned needing some more Japanese to understand the class. Very few, but some other responses indicated they wanted to practice English more: "I want to have more opportunities for presentation," and "I want to discuss in English." The proficiency in English varies among students. Therefore, it is challenging for teachers to find a balance in how to conduct the class in English.

Discussion

The qualitative findings are associated with the ATL's perspectives on the course. They sincerely tried to create an atmosphere where students could talk at ease, which they found was most important when they interacted. They mentioned:

> They started to speak more freely and without worrying too much about whether their English would be grammatically correct or not. I feel that creating this safe space where mistakes are okay is an essential basis for language acquisition.

This aligns with previous research on the relationships between student-centered approach and speaking skills, which shows that it is imperative to establish a supportive atmosphere (Larasati, 2018). The ALT worked incredibly hard to encourage students to speak English and feel emotionally supported, even when they had trouble expressing their thoughts, as shown in the results. In this regard, TT has been successful in motivating students to communicate in English, which owes a lot to the ALT.

As mentioned above, Toyota KOSEN placed a science teacher who was a native speaker of English in the first Global Engineering Project. For many students, attending a class conducted entirely in English was too demanding. One major reason was that students felt unsupported both in terms of language and emotionally, which demotivated them from engaging with the class, except for those who were highly motivated or had studied abroad. Although the current students began learning English in elementary school, the results revealed that they still needed language support in Japanese and, more importantly, emotional support to become more confident in speaking English.

Another contribution to the success is attributed to the collaboration between the Japanese teachers and the ALT, as the previous research described (Carless & Walker, 2006; Tajino & Smith, 2015). It is often pointed out that many challenges exist in ensuring effective collaboration. Since the teachers are too busy to develop the team teaching partnership, they do not fully realize the advantages that TT is expected to bring, as MEXT (the Ministry of Education, Culture, Sports, Science and Technology in Japan) and many other educators hope (Miyazato, 2009). Therefore, we set up the time to discuss the course or lessons beforehand, as working hours for the ALT aside from the periods of classes, which brought us more understanding and trust of each other. The ALT noted:

> I perceive the two Japanese teachers as very experienced and professional. The students seem to enjoy their classes and the topics they chose for them to discuss. I personally appreciate working together with them because of the smooth workflow and well-prepared, as well as well-structured classes. Both are extraordinarily reliable, and either of them takes their work with a high level of responsibility, which I find highly inspiring. Working together with them taught me a lot about the teacher-student connection and how to make enjoyable classes with a high educational value.

Collaboration among teachers is implicit in students' learning during class. However, teachers' interpersonal communication is crucial for the successful implementation of TT, which will create a more favorable environment where students can feel more motivated and supported.

While teachers have been able to create an environment where students can relax and enjoy classes, it is necessary to examine how this has contributed to the improvement of communication skills and global mindsets. According to the survey, many students perceived TT as beneficial, acknowledging their improvements in listening and speaking skills in English. We also found that they developed an interest in other countries. With a lot of help from the ALT, students engaged in presentations.

However, it remains unclear whether these improvements and developments served as prompts to participate in a course entirely conducted in English, as many students want to join the class in its current style in the future. Even high-achieving students in academic grades desire emotional support from an ALT and language assistance in Japanese from a Japanese teacher to ensure their understanding of what they hear or want to express in English is accurate.

This indicates that the most important aspect for students, particularly when focusing on developing their productive skills in a language class, is to accumulate successful experiences and build confidence. In this respect, TT was effective, but not sufficient to the point where students are motivated to take a more advanced course.

It is extremely difficult to make every student feel confident enough to take on more challenges. The results also showed that students wanted more personal assistance when communicating in English, which is not easy to realize because of a large class size of 40 students or more. As the ALT mentioned:

> It is very difficult to find things to improve when the classes already run so smoothly. The teacher and ALT teamwork was very good, and the classes were always well prepared and thoroughly thought through. I think distributing my time more efficiently between more students by asking questions which are more likely to be answered with ease, would be a feasible option. The best but probably not possible to change is the size of the classes. 40 students is a large number and if I could distribute my time perfectly by giving every student 2 minutes of speaking practice with me, 80 minutes of a 90 minutes class would be necessary.

Class size and time constraints do not lead us to an ideal setting; however, we should pursue a more optimal environment where more students can engage and feel more confident. These practical adjustments can contribute to a more positive and productive experience with classes, thereby benefiting students' English learning.

Conclusions

The purpose of this study is to investigate how students evaluate TT and to explore the advantages of TT based on the survey. The research revealed that students appreciate TT since they have experienced interactions in English. The findings suggest they become more confident when they have linguistic and emotional support, which motivates them to communicate in English. KOSEN students who experienced TT were in the same age group as high school, they needed language and emotional support as scaffolding.

While MEXT (2022) provides online content describing how to collaborate during class and what to expect from their assistance, it is evident that interpersonal communication outside the classroom is more crucial to enhance collaboration inside the classroom. We strongly suggest that Japanese teachers and an ALT be guaranteed time to discuss how they organize their classes. The two Japanese teachers in the research acknowledged it all too well since they had experienced TT in their former workplaces in junior and senior high schools.

There are two potential limitations that could be addressed in future research. First, the research focused on how students perceived TT, it needs to be associated with their academic grades or linguistic proficiency to measure the extent to which their communication skills have developed. Second, the research does not address how they should be fostered to participate in a more advanced course conducted in English. It is apparent that encouragement is insufficient in language learning. Nevertheless, what scaffolding is necessary for students to become autonomous learners should be discussed.

Acknowledgements

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References

Carless, D. & Walker, E. (2006). Effective team teaching between local and native-speaking English teachers. *Language and Education, 20*(6), 463–477.

Larasati, F. (2018). Student-centered learning: An approach to developing speaking skills in the EFL classroom. *English Community Journal, 2*(1), 153–157.

Miyazato, K. (2009). Power-sharing between NS and NNS teachers: Linguistically
powerful AETs vs. culturally powerful JTEs. JALT Journal, 31(1), 35–62. Retrieved
Beyond team teaching 27
from www.jalt-publications.org/jj/articles/271-power-sharing-between-ns-and-nnsteachers-
linguistically-powerful-aets-vs-culturally

Ministry of Education, Culture, Sports, Science and Technology. (2022, June). *Online Contents for ALTs*. Retrieved from: https://www.mext.go.jp/en/policy/
education/elsec/1373870.htm

The Council of Local Authorities for International Relations (CLAIR). (2015). *JET Programme*. Retrieved from: https://jetprogramme.org/

Case Study of Multi-Institutional Collaboration for Final-Year Project with Mongol Koosen College of Technology

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In the field of civil engineering and infrastructure, a commonly encountered problem is aging infrastructure. According to a report by the Japan International Cooperation Agency, most road bridges in Mongolia were constructed post 1960, with assistance from China or the former Soviet Union. Notably, 49% of the 70 existing bridges in Ulaanbaatar are older than 30 years. As Ulaanbaatar has been rapidly growing, with a population of 1.67 million as of 2023, the city is suffering from severe traffic congestion. The bridges are aging, with many in need of rehabilitation, reinforcement, or replacement work. However, the simultaneous repair of numerous bridges can be prohibitively expensive. Proactive maintenance is a more cost-effective approach than reactive maintenance, allowing for the identification and repair of minor damages before they escalate, thereby reducing the overall repair costs. In FY2024, we conducted research on bridge maintenance as the final-year project for the students of Mongol Koosen College of Technology (hereafter Mongol Koosen). The National Institute of Technology (KOSEN) Tomakomai College has supported the education and research at the Mongol Koosen College of Technology since its inception in 2014, building friendly relationships on the way. Five students and one teacher from Mongol Koosen, two mentors from NIT Tomakomai, and an engineer from a civil engineering consulting firm worked on this project. After following initial online lectures regarding basic knowledge of bridges and bridge maintenance, including bridge inspection, the students researched and summarised the bridge maintenance methods used in other countries. Subsequently, we visually inspected two bridges in Ulaanbaatar city, Mongolia, researched the factors contributing to the damages, and classified them based on Mongolian standards. Finally, the students analysed the main factors contributing to bridge damage in Mongolia using data from bridge inspections. Through this final-year project, students learnt bridge inspection methods, the causes of serious bridge damage, and the importance of bridge inspection and maintenance.

Keywords: *Final-year project, bridge inspection, bridge maintenance, Mongol Koosen College of Technology*

Introduction

Since its establishment in 2014, Mongol Koosen College of Technology has received ongoing support from National Institute of Technology (KOSEN), Tomakomai College (hereafter referred to as Tomakomai Kosen) in the areas of education and research. This support has included the sharing of experience, including technical expertise and methodologies for teaching, experiments, and practical training. Consequently, a strong and collaborative relationship has been cultivated between the two institutions.

Notably, Mongolia is increasingly facing the issue of aging infrastructure, particularly bridges. Bridge deterioration in developing countries is primarily driven by two factors. The first involves early stage defects resulting from poor-quality materials and inadequate construction techniques. The second involves aging-related defects stemming from insufficient maintenance and management practices. According to Matsuo (2019), in developing countries, there is a significant shortage of well-trained bridge engineers possessing the expertise to conduct inspections and determine appropriate repair methods.

To address this challenge, bridge engineering, particularly bridge maintenance, must be incorporated into the curricula of higher education institutions. In this study, we aim to enhance bridge engineering education in Mongolia by focusing on bridge maintenance and management in the final-year project at the Mongol Koosen College of Technology (hereafter referred to as Mongol Koosen).

This paper presents a case study of a multi-institutional collaboration in a final-year project. In FY2024, a joint research project on bridge maintenance was conducted by the students of Mongol Koosen as their final-year project. The project involved five students and one faculty member from Mongol Koosen, two mentors from Tomakomai Kosen, and an engineer from a civil engineering consulting firm.

In this project, we conducted a bridge inspection with Mongol Koosen students in Ulaanbaatar, identified various defects, and analysed their causes. This project provided students with foundational knowledge on bridge maintenance and heightened their awareness of the importance of sustaining public infrastructures.

Final-Year Project 2024 (Mongol Koosen)

According to a report by the Japan International Cooperation Agency (JICA), road bridges in Mongolia are deteriorating, facing issues akin to those experienced in Japan. Therefore, to address the problem of aging bridges, a growing need is to shift the maintenance from breakdown to preventive. More than 45% of the bridges managed by the Ulaanbaatar Government were constructed between 1960 and 1991. Thus, concepts and skills related to preventive maintenance are becoming increasingly important. With this in mind, we selected '*bridge maintenance*' as the final year project theme for Mongol Koosen. The structure of this project is illustrated in Figure 1. Mentorship was provided by a teacher from Tomakomai Kosen and an engineer from Tanaka Consultant Co. Ltd. In addition, one local teacher and a Japanese civil engineering teacher, temporarily working at Mongol Koosen, provided one-on-one support to the five participating students at Mongol Koosen. The Japanese teacher was also Professor Emeritus at Tomakomai Kosen. The project aimed to inspect bridges, identify the causes of damage, evaluate and categorise damage conditions, and summarise the results.

Pre-learning Bridge Maintenance

Figure 2 illustrates the bridge maintenance cycle. In preventive maintenance, bridge inspection plays a crucial role in identifying the damage at an early stage. We visited Mongol Koosen on December 5 and 6, 2023, as Japanese mentors (from Tomakomai Kosen and Tanaka Consultant Co., Ltd.) to teach bridge inspection methods, including how to design repairs and plans for the bridge maintenance cycle. Prior to the visit, the students selected several bridges located near the Mongol Koosen campus for this study.

The students had not studied bridge engineering; therefore, prior to the field bridge inspection, we provided online and face-to-face lectures on the fundamental concepts of bridge structures and maintenance practices.

Bridge Inspection Activities

Bridge inspections were conducted on the Gurvaljin Bridge and Bridge 32, as shown in Figures 3 and 7, respectively. Both bridges were made of prestressed concrete. The Gurvaljin Bridge and Bridge 32 span approximately 108 m and 49 m, respectively. According to publicly available sources, the Gurvaljin Bridge was constructed in 1989 and repaired in 2010. During the inspections, students were instructed on practical techniques such as crack marking and hammering tests,

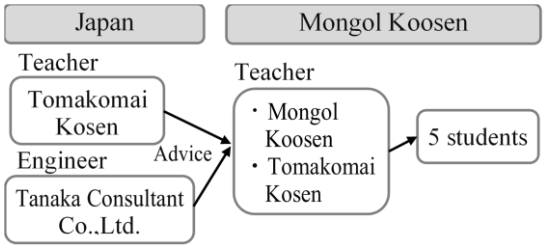


Figure 1 Project structure

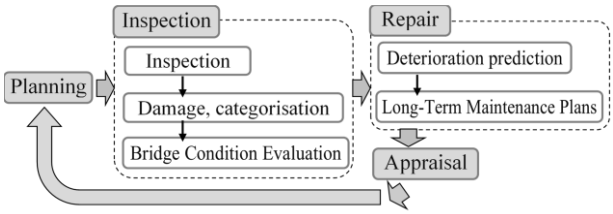


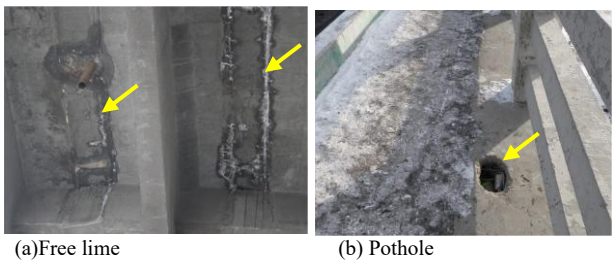
Figure 2 Bridge maintenance cycle



Figure 3 Gurvaljin Bridge (L = 108 m)



Figure 4 Bridge inspection



(a)Free lime (b) Pothole

Figure 5 Slab from Gurvaljin Bridge

as illustrated in Figure 4. Following bridge inspection, the students independently revisited both bridges approximately five times to inspect them in more detail.

On the Gurvaljin Bridge, free lime deposits and a pothole were observed on the sidewalk, as shown in Figure 5. The presence of free lime was attributed to



Figure 6 Uncovered pier

water leakage, whereas the potholes were likely caused by poor construction quality, possibly because of insufficient concrete filling. Furthermore, as shown in Figure 6, the piers were exposed above the ground level, suggesting that sediment runoff from the foundation may have occurred because of rainwater erosion.

Bridge 32 exhibited more extensive free lime deposits along the entire girder, as shown in Figure 8. Figure 9 shows the damage caused by the freeze-thaw cycles. The exposed steel reinforcement in Figure 9(a) arises when the water within the concrete freezes and expands, leading to surface cracking. Figure 9(b) depicts the deterioration of the concrete abutment caused by repeated freeze-thaw cycles; the concrete has disintegrated and resembles soil. Figure 10 shows the damage around the bearing area. The first observation involved spalling at the edge of the girder with a section of concrete measuring over 40 mm in length and 4 mm in depth. The second is a misalignment of the base plate, which has shifted from its intended position relative to the edge plate of the girder. Additionally, concrete delamination along the edge of the girder was confirmed through hammering tests, indicating that the steel reinforcement was rusting and expanding.

Classification and Characteristics of Bridge Damages

Table 1 presents the classification of concrete damage based on the Mongolian Bridge Code (refer to S. Hasnavch, *Use of Reinforced Concrete Bridges*, 2019). The code categorises damage into five levels ranging



Figure 7 Bridge 32 (L = 49 m)

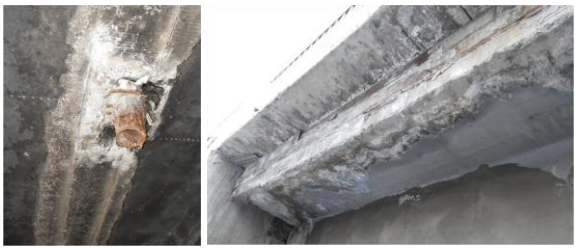


Figure 8 Free lime



(a) Exposed steel bars (b) Concreate deterioration

Figure 9 Freeze-thaw damage

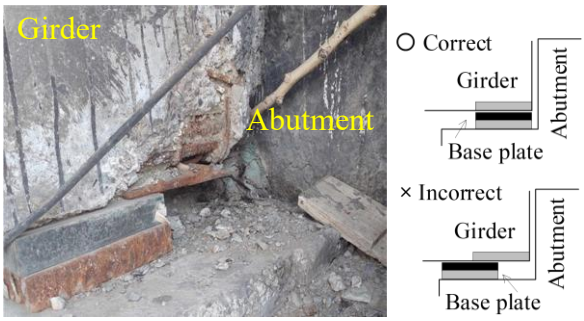


Figure 10 Deteriorations around the bearing

Table 1 Classification of concrete damage

Degree of damage	Description of the degree of damage
0: No damage at all	The size and growth of cracks are within the allowed standard. For example: The size of the crack opening and growth of damage in reinforced concrete structures is within 0.2 mm. No special measures are required to correct this.
1: Low-impact damage	Damages exceed the limits permitted by the standards. These damages need to be repaired because although they do not affect the basic transport and operational characteristics of the bridge, they may gradually affect it.
2: Influential damage	Damages adversely affect the basic transport and operational characteristics of the bridge structure. This does not pose a direct threat to the operation of the structure. Repairs to such damage are conducted in a planned sequence.
3: Dangerous but repairable damage	Damage in this category significantly reduces the basic transport and operational performance of the bridge structure but is not catastrophic.
4: Irreparable damage	This category includes damage that threatens structural collapse, compromises the load-bearing capacity of the components, or makes the bridge unusable without strict restrictions, such as closing lanes to traffic, restricting truck traffic, or preventing any operation.

from 0 (no damage) to 4 (irreparable damage). Students were provided with reference materials on general bridge inspection practices, and they independently researched documents relevant to the Mongolian standard that appeared to align with the principles of preventive maintenance. Based on this classification, the students evaluated both Gurvaljin Bridge and Bridge 32 as falling under Category 2, indicating 'influential damage'. In addition, the students analysed the characteristic damage patterns observed in Mongolian bridges.

Common types of damage include deterioration caused by water infiltration, such as free lime deposits, corrosion of steel reinforcement, and freeze-thaw cycles. These types of damage are typically associated with surface cracks, often resulting from poor material quality or substandard construction practices. Other frequently observed issues include defects caused by construction deficiencies such as potholes (Figure 5(b)) and misalignment of the base plate. This analysis provided the students with a clear understanding of the importance of ensuring construction quality in maintaining long-term durability and serviceability of bridges.

Questionnaire for Participating Students

After completion of the final year of the project, a questionnaire was administered to gather feedback on the project theme. Questions were prepared in advance, and a local teacher facilitated discussions with the students based on these questions. The questionnaire results are presented in Table 2. The response to Question 2 in Table 2 indicates that the students recognised the role of poor construction quality in causing bridge damage. Question 3 reflected the growing awareness of the importance of bridge maintenance. Students appeared to understand the critical role of regular inspections in identifying damages at an early stage. Question 4 explored how the students' perceptions of bridges changed as a result of the research. All the students reported a shift in their thinking about bridges. Their responses suggest that they are now more interested in bridges and understand the importance of addressing damage in the early stages to reduce repair costs and promote sustainability. Their awareness of bridge maintenance also increased.

Such awareness is essential for future infrastructure development in Mongolia and highlights the importance of fostering engineers who understand and value preventive maintenance.

Table 2 Questionnaire for participating students

Q1. What first got you interested in this theme of the final-year project?
・ *We are studying civil or structural engineering, and we found it interesting to explore other areas of construction.*
Q2. What impressed you while inspecting the bridge?
・ *In our country, bridges are often damaged due to mistakes made during construction—for example, when they are not built according to quality requirements and standards, or when construction is careless. After several years of use, these mistakes can eventually lead to bridge collapse.*
Q3. What do you think should be done to maintain Mongolia's bridges in the future?
・ *It is necessary to make regular inspection a routine practice and then take appropriate maintenance and repair measures. This will help prevent major risks and losses in the future. I think it is important for experts to be more careful in conducting inspections regularly.*
Q4. How has your thinking about bridges changed as a result of this research?
・ *Before conducting bridge research, I would just walk across a bridge without thinking. Through this research, I learnt what causes bridges to fail, why they deteriorate, how much damage can occur, and when repairs are no longer possible.* ・ *I used to think monitoring a bridge was simple, but now I understand that it involves identifying the causes and severity of damage more deeply.* ・ *In the past, I crossed bridges without giving it much thought. Now, I am more conscious of their condition. I realised that if a bridge collapses, it can have a huge impact on human lives and the economy. I have even started to subconsciously look for signs of damage.* ・ *I learnt the names of bridge components and causes of collapse. I also learnt that if damage is not repaired while it is still minor, it can worsen and become more expensive to fix.*

Conclusions and Future Prospects

This paper presents a case study on a multi-institutional collaboration in a final-year student project. The project served as a source of motivation and inspiration for the participating students. Student engagement with real-world infrastructures in the field is crucial because such experiences enhance the understanding of practical engineering challenges. The project significantly increased students' awareness of construction quality and the importance of maintenance. Furthermore, it provided insights into the common types of bridge damage, enabling students to estimate the progress of deterioration and to develop strategies for preventing similar failures. As many countries are currently facing the challenge of aging infrastructure, engineers who recognise the importance of long-term infrastructure sustainability are required. Educating students in acquiring the knowledge and experience required to address these challenges is a vital responsibility of academic institutions.

However, we were unable to obtain official specifications for road bridges in Mongolia. One possible reason for this is Mongolia's historical background as a former satellite state of the Soviet Union, which likely influenced the adoption of Soviet-based bridge standards. Consequently, students were required to refer to specifications from other countries in the absence of localised guidelines. In addition, there are significant climatic differences between Mongolia and Japan. For

example, Japan has a humid climate that makes steel corrosion a critical concern for infrastructure maintenance. In contrast, Mongolia has low precipitation and an extremely dry climate. Therefore, the extent to which Mongolian conditions cause corrosion problems remains unclear, as data on this issue are limited. Overall, because of differences in national standards, languages, and context, there were aspects of the project where we, as mentors, faced challenges in providing adequate support. Regarding future prospects, long-term exposure data on structures in Mongolia should be collected to better understand infrastructure deterioration under Mongolian conditions. In addition, we would like to involve a Mongolian consulting firm to discuss the specifications.

Acknowledgements

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References

Y. Matsuo, T. Wada & T. Obata (2019). Proposal of international technical cooperation for bridge maintenance and management of developing countries, *Proceedings of Construction Steel*, Vol. 27, Japanese Society of Steel Construction

S. Hasnavch (2019). *Use of reinforced concrete bridges.* Hasnavch, Sambuu. ISBN9789919222826

JICA and Goverment of Mongolia (2015), *Manual for Bridge Inspection (Mongolia Bridge Repair and Maintenance Capacity Development Project).*

JICA (2015), *Final Report of Mongolia Bridge Repair and Maintenance Capacity Development Project.*

Project-Problem Based Learning and Internship in Mechatronics Department of KOSEN – KMITL

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KOSEN – KMITL was established with the aim of developing engineers who will be active mainly in Japanese companies that will be attracted to the Eastern Economic Corridor under the Thailand 4.0 policy. The KOSEN education system is characterized by a 5-year integrated education from the age of 15 to 20, a wedge-shaped education combining general and specialized subjects, and a combination of classroom lectures and experiments (we call it Lab work). By receiving specialized education centering on experiments and practical subjects from a young age, the human resources produced by KOSEN have the ability to think flexibly and absorb new knowledge even after graduation. Furthermore, KOSEN graduates have received a high reputation in the industrial sector over the 60-year history. We are transferring the KOSEN education system to Thailand. We are undertaking new challenges to develop a more advanced education system, including Project-Problem Based Learning (PBL) and collaboration with companies. PBL is conducted in the 3rd and 4th year, with the 3rd year students aiming to satisfy the given specifications, and the 4th year students starting from the procedure of problem identification. In addition, the internship is introduced as a compulsory subject. It is designed to recognize the relationship between the content of study and industrial application and simultaneously discover themes for graduation research. From the above background, the purpose of this paper is to report on the PBL and internship programs conducted last year for future education.

Keywords: *Industrial Collaboration, Internship, KOSEN Education System, Project-Problem Based Learning, Thailand 4.0*

Introduction

KOSEN – KMITL (King Mongkut's Institute of Technology Ladkrabang) was established in 2019 under the Human Resources Development Project in Engineering, Technology, and Innovation. This project aligns with the Thailand 4.0 policy, which supports investment and enhances the capabilities of the industrial sector in the country and region, especially in the Eastern Economic Corridor (EEC). It also focuses on developing human resources who are key in promoting targeted industries. In our institute, KOSEN – KMITL, the KOSEN education system, which involves the method combining lectures in the classroom and practices in the laboratory (it's called Lab work in the following), is being transferred from the Japanese KOSEN to educate practical engineers who will be able to contribute to the Thailand 4.0 policy. Mechatronics department was also established with the institute's opening; the first batch of students graduated in March 2024. Generally, the KOSEN students begin taking Lab work from the lower year to transform their lecture-based knowledge into practical skills effectively. In addition to Lab work, which lets students follow the instructed procedure, they take courses of Project-Problem Based Learning (PBL) 1 to 4 provided for 3rd and 4th year students. Unlike Lab work, the students need to consider a method and decide directions to solve assigned tasks by applying skills developed with past subjects in PBL 1 and PBL 2. This year, students made the equipment to satisfy the required specification in the topic that feeds balls into boxes. Here, there were balls with two materials and boxes with three sizes. Therefore, they must apply their skill of actuators, sensors, and controllers learned in Lab work to achieve the given goal. The experience through PBL 1 and PBL 2 makes their skill more practical, effectively solving actual social problems. Moreover, as the next step, the students are requested to find actual problems by themselves in PBL 3 and 4 to nurture their problem identification skills. Developing the original technology in industries highlighted by the Thailand 4.0 policy is essential. We collaborate with the company to conduct PBL 3 and 4 to let students know social problems. Also, an Internship is introduced to our curriculum for career education and to develop their skills. This paper will introduce unique educational concepts in the Mechatronics department at KOSEN – KMITL.

Curriculum Overview

Mechatronics department of KOSEN – KMITL has the curriculum to educate engineers who can develop robotic/mechatronic systems by applying their abilities in mechanical, electrical, and electronic, software, and network engineering. We have installed a "wedge-shaped curriculum" as shown in Figure 1 for the achievement of this objective (Aburatani, 2017) and are brushing up on the implemented educational system right now. The term "wedge-shaped education" has two meanings, one of which is the collaboration between general and engineering subjects, and the other is the collaboration between lecture and practical-based education. The former is effective for students who need to apply knowledge of a general subject (for example, mathematics, physics, and chemistry) to engineering subjects like dynamics in mechanical engineering and electrical circuits in electrical and electronic engineering. The latter can transform the knowledge of students into practical skills. This process is essential for a student who want to be an engineer and will be more important for current students who can learn knowledge by using web-based material and AI technology because practical subjects can help students to understand key concepts of engineering subjects and to achieve "symbol grounding" that can't realize with AI in current technology. Since Japanese KOSEN students acquire enough engineering skills through classes included in the curriculum, the KOSEN education system has received a great evaluation from industry for over 60 years.

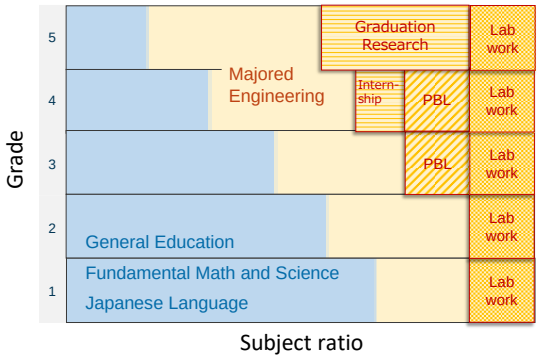


Figure 1 The curriculum structure of KOSEN – KMITL.

Figure 1 shows the allocation of Lab work, PBL, Internship, and Final Year Project with the school year. One of the new challenges in KOSEN – KMITL is to develop subjects of PBL that function to foster students' engineering skills, making them more useful for solving social problems, as discussed in our previous work on PBL implementation at KOSEN – KMITL (Luckanawat, 2024). Also, this education procedure enhances students' cognitive and research skills and cultivates critical soft skills such as teamwork, communication, and adaptability (Markham, 2011). This subject is designed to make KOSEN – KMITL distinctive compared to Japanese KOSEN. Beforehand, we need to mention the difference in employee hiring systems between Thailand and Japan. In short, Thai companies tend to expect students to have skills, while it seems Japanese companies emphasize high potential. Moreover, most Thai universities don't provide a supporting system for job-hunting. On the other hand, 100% of graduates who want to find a job from Japanese KOSEN can get it, and we have to build the same system in Thailand. To keep providing this system, we need to let students learn skills that make our graduates attractive to companies.

Subjects of PBL are conducted for 3rd and 4th year students. Then, they must take an internship course to recognize the application of engineering skills for industry between the 1st and 2nd semesters of the 4th year. This is another main topic of this paper.

After that, 5th year students tackle the Final Year Project with companies that accepted them for an Internship. Therefore, we summarize that the biggest feature of KOSEN – KMITL is strong collaboration with companies. The Details of the Final Year Projects conducted in cooperation with companies have been reported in our previous study (Sakonkanapong, 2024).

Project-Problem Based Learning (PBL) in 3rd Year

Project-Problem Based Learning (PBL) is implemented to the curriculum for 3rd and 4th year students of the Mechatronics department to transform their engineering skills, which have been acquired in lectures and Lab work. The 3rd year students take PBL 1 and 2 in each semester, then, 4th year students take PBL 3 and 4 in each semester. Each PBL has 100 minutes per week for 15 weeks. The purpose of PBL for 3rd-year students is to be more familiar with mechatronics engineering. In general, mechatronics engineering involves the five elements of sensor, actuator, controller, power source, and mechanism. Students are requested to fabricate the equipment by applying their fundamental skill of the five elements learned before taking PBL. In Lab work, they just need to follow the instructions to conduct it, but they are forced to consider and select components that can achieve specific performance in PBL. We consider that this is the largest difference between Lab work and PBL.

In Academic Year (AY) 2024, 3rd year students were divided into 8 groups (each group has 5 members), then, they were assigned to develop the equipment for sorting balls. The required specification is following.

- Metal and glass balls of 12 mm of diameter must be sorted.
- The size of box (50 mm, 40 mm, and wrong size cubic) must be detected.
- The system size must be within 800 mm × 500 mm × 500 mm.
- Only one Arduino Mega is available as a microcontroller.
- Only one power supply with 12 V and 5 A is available.
- The budget must be lower than the upper limit.

This was the second year for the same topics, but the specifications provided for students were sophisticated with the experience of AY2023. In detail, we focused on only one specification to properly guide students,

accelerate progress, and increase completion (in the last year, 8 groups were further divided into four groups each. Each of the four groups was assigned a different specification). Also, the product of the microcontroller and the power supply were designed to be ordered easily. In addition, they were instructed how to craft the flame by using aluminum profiles. These modifications were effective in improving the degree of perfection.

The rough schedule of PBL 1 and 2 is shown in Figure 2. The goal of PBL 1 in the 1st semester is to determine the concept by drawing the 3D CAD model to satisfy the specification. 3D CAD models of the two groups are shown in Figure 3. Before that, students learned methods for brainstorming to discuss the concept with group members. Then, at the beginning of several weeks of PBL 2 in the 2nd semester, they were asked to submit a Gantt chart of their project and a BOM (Bill of Materials) to clarify the progress.

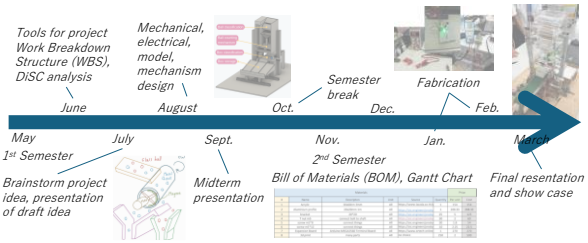
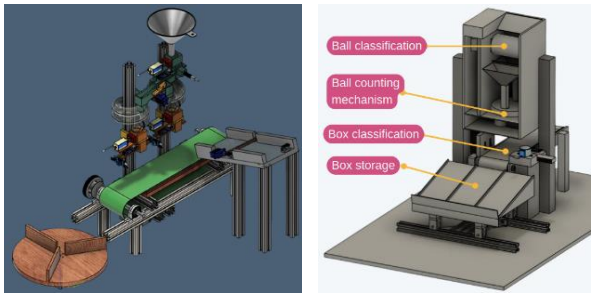


Figure 2 The annual schedule of PBL 1 and 2.



(a) Example 1 (b) Example 2

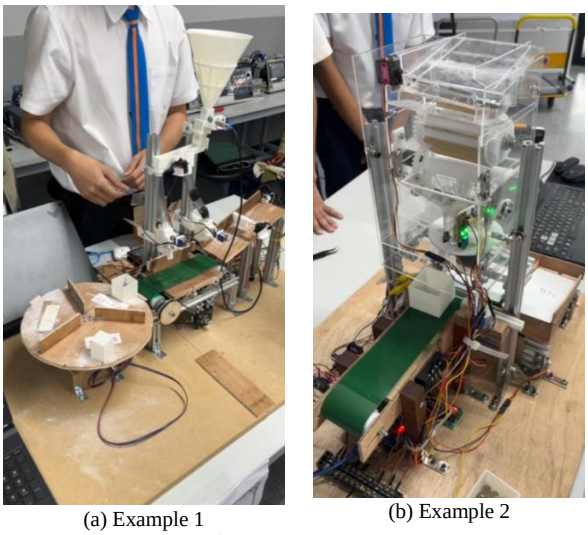
Figure 3 Examples of designs in PBL 1 and 2.

Photos of representative fabricated equipment with two groups are shown in Figure 4. These groups succeeded in manufacturing equipment that can complete all assigned tasks. Regardless, the procedure of tasks wasn't specified by teachers, but most groups adopted the following procedure.

a) The operator sets the balls and the box in the initial place.
b) Balls are sorted by materials (metal and glass).
c) The size of the box is detected to determine the number of balls that must be filled (This number was designated).
d) A box is moved to the filling location with a conveyor belt.
e) The designated number of balls of each material is filled into a box.
f) A box is transported to a place for each size.

The significant difference among groups was seen in the mechanism for detecting and sorting balls. The group with Figure 4(a) utilized a proximity sensor to detect the coming of a ball and its material. Then, a servo motor regulates opening and closing the gate for changing routes. After feeding balls to pipes, the designated number of balls are put into a box with a solenoid valve. More than half of the group applied a proximity sensor to detect the material of balls.

The machine in Figure 4(b) has a unique mechanism to sort balls. The cylinder with brown parts is located at the top of equipment. This cylinder has an embedded magnet inside. Therefore, glass balls fall in the front while attracted metal balls fall in the back.



(a) Example 1 (b) Example 2

Figure 4 Examples of fabricated equipment in PBL 1 and 2.

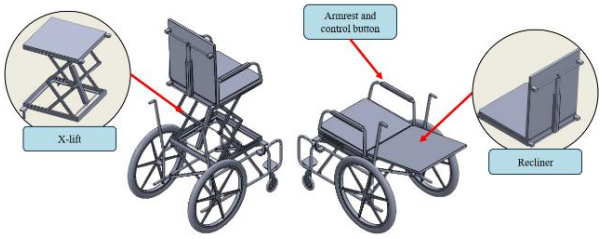
As shown in these figures, students utilized many kinds of sensors (IR sensors, proximity sensors), actuators (DC motor, servo motor, stepper motor, solenoid valve), jigs fabricated with a 3D printer, a wooden board, an aluminum profile, and a microcontroller. Also, they needed to write a 3D model with 3D CAD. Every group decided a person in charge of subdivisional works, for example, making the frame, electrical wiring, programming of the controller, and so on.

Project-Problem Based Learning (PBL) in 4th Year

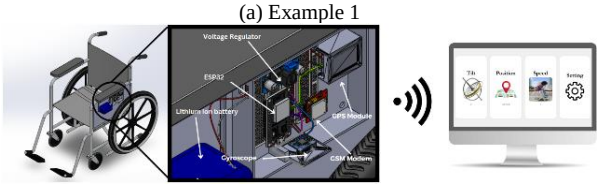
Courses of PBL 3 and 4 are offered 4th year students in the 1st and 2nd semesters respectively. In these courses, students collaborate with companies to solve more practical social issues based on the experience gained from the projects conducted in their third year. Furthermore, while specific specifications were provided in the 3rd year, the 4th year begins with the discovery of issues. In this way, in addition to the problem-solving skills acquired in the third year, problem-finding skills are also developed. These abilities seem to be essential to survive for humans after implementing AI technologies to industries.

Last two years (AY2023 and AY2024), we collaborated with MATSUNAGA, the company that holds the largest market share of wheelchairs in Japan, to develop a smart wheelchair. For considering the innovative idea, students engaged in group work to find problems with existing wheelchairs through

brainstorming in the first half of the 1st semester. Then, they spent the remaining period of the semester to make their project concrete by making a BOM, a Gantt chart, and a model of 3D CAD similar to PBL 1. In the 2nd semester, they began to fabricate the prototype after modifying the model of 3D CAD and receiving ordered materials and components. Models of 3D CAD with two groups are shown in Figure 5. We can roughly categorize them into groups that focus on customization with software and hardware aspects, so representative groups for each are chosen as examples.



(a) Example 1



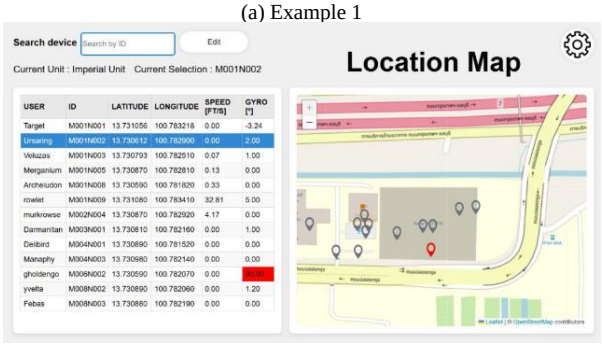
(b) Example 2

Figure 5 Examples of designs in PBL 3 and 4.

The group which built a wheelchair with Figure 5(a) and Figure 6(a) proposed improvements focusing on addressing the convenience when a caregiver provides support, situations where the user takes an object from a high place, and comfort when the user is seated. The X-lift is used as the mechanism, which is based on the mechanism made in the first semester of the third year in machinery practice.



(a) Example 1



(b) Example 2

Figure 6 Examples of fabricated equipment in PBL 3 and 4.

In contrast, the group that fabricated the wheelchair of Figure 5(b) and Figure 6(b) focused on the advanced function with software technology. Their wheelchair is equipped with a GPS module and a Gyroscope mainly to detect when the wheelchair is falling. This function enables the caregiver to check the location and the condition of the user remotely. Therefore, the developed system has the potential to solve the problem of the caregiver shortage in the welfare industry.

Internship

The 4th year students in KOSEN – KMITL must participate in the internship during the semester break between the 1st and 2nd semester in October. It differs from the Japanese KOSEN in duration and type, compulsory or elective. The duration of the internship in KOSEN – KMITL is longer than that of Japanese KOSEN (one or two weeks is common). However, it is shorter than the normal one for students at universities in Thailand, which is generally 3 or 4 months. To compensate for the shortage of time, 5th year students in KOSEN – KMITL conduct final year projects, such as graduation research, in Japanese KOSEN. In a Final Year Project, a student or a group of students carry on research with a company that accepted those students to solve a problem that the company is facing. Therefore, 4th-year students need to discuss with the company's engineers to decide the project's direction in the 2nd semester. This structure has been adopted to educate students as practical engineers. Also, we think that it is a valuable method for enhancing the effectiveness of education at KOSEN that prioritizes hands-on skills.

Table 1 shows the companies that accepted students for internships in 2024. Topics of internship are widely spread, such as mechanics, electrical and electronic, and information engineering. Since our internship is to be followed by a Final Year Project, the topic should be matched to the expertise of an advisor of KOSEN to properly guide students and enhance project outcomes. Therefore, sufficient discussion with companies is necessary before assigning students to enrich the achievement of faculty members. We have an Industrial Linkage Team that is a unique team to enhance the collaboration between companies and KOSEN – KMITL. It is imperative to accumulate experience and build a better structure for this educational scheme.

Table 1 The list of collaborated companies in the internship.

A.I. TECHNOLOGY COMPANY LIMITED
AppliCAD PLC
DENSO Innovative Manufacturing Solution Asia Co., Ltd.
DMG MORI
Fujikura Electronic Components (Thailand) Ltd.
Hitachi Astemo Korat Brake System Ltd.
Honda R&D Southeast Asia Co., Ltd.
ISUZU ENGINE MANUFACTURING CO.,(THAILAND)LTD.
Kanemitsu Pulley Co., Ltd.
Mitutoyo (Thailand) Co., Ltd.
Okuma Techno (Thailand) Ltd.
OS Design
Runexy(Thailand) Co.,Ltd.
SIAM KUBOTA Corporation Co., Ltd.
Thai Kikuwa Industries Co.,Ltd.
Thaioil Energy Service.Co.Ltd
Toyota Tsusho NEXTY Electronics (Thailand) Co., Ltd.
YASKAWA ELECTRIC THAILAND CO. LTD.

Conclusions

This paper has described PBL and internship in KOSEN-KMITL, which are implemented to make students' engineering skills more practical. The students' productions showed their ability and potential. Installing those subjects effectively raised not only engineering skills but also skills of time management and team building for students. This effective education method should be reintroduced to Japanese KOSEN. However, we couldn't ensure enough fabrication time for both PBLs due to the allocation of the budget schedule for the last academic year. The early budget allocation is essential to improve the quality of products and to release them from the excess anxiety with deadlines in those practical subjects.

On the other hand, KOSEN has the feature that 100% of students who want to find a job will find a job position before graduation. For the achievement of this goal, we need to promote the KOSEN educational system for industrial companies to ensure enough job positions, regardless of its short history and the cultural gap. Additionally, companies in Thailand have a skill-based hiring style, so the concrete development of students' practical skills is more important than Japanese KOSEN. From this viewpoint, we can say the installation of these kinds of subjects is a valuable trial in KOSEN-KMITL.

Acknowledgements

Many companies have participated in our internships in cooperative education. We would like to express our gratitude to them.

References

Aburatani, H., Kano, S., Teawchim, S., et al. (2020). Implementation of Introductory Engineering Education at KOSEN–KMITL in Thailand. *Proc. Ann. Conf. Japanese Society for Eng. Education*. Paper No.2C07.

Luckanawat T., Teewchim S., Sakonkanapong A., et al. (2024). PBL Courses to Develop Project Implementation Ability. *Proc. ISATE 2024*. Paper No. ST4-59.

Markham, T. (2011). Project-Based Learning. Teacher Librarian, 39(2), 38-42.

Sakonkanapong A., Luckanawat T., Teewchim S., et al. (2024). Collaborative Learning with Companies in KOSEN–KMITL. *Proc. ISATE 2024*. Paper No. ST4-17.

QUALITATIVE STUDY OF JAPANESE STUDENTS' ENGAGEMENT IN THE CARDBOARD EVACUATION SHELTER PROJECT WITH THAI STUDENTS
- Case Study: KOSEN KMUTT Engineering Program Enhancement -

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This study attempts to examine Japanese students' learner engagement in the Cardboard Evacuation Shelter Project with Thai students, and to explore perspectives for improving the one-month engineering program for KOSEN KMUTT in 2025. The objectives of our one-month engineering program for KOSEN KMUTT are 1) (for Thai students) to gain practical skills and experience in mechanical, electrical, and information engineering; 2) (for Thai students) to increase their confidence in becoming competent automation engineers through various activities with Japanese students and staff; and 3) (for Japanese students and staff) to interact with Thai students and staff and to develop communication, multilingual, and intercultural skills of Japanese students and staff.
Cardboard Evacuation Shelter Project was one of the six courses offered to KOSEN KMUTT students and was the only project-based learning (PBL) course that involved collaborative work with Japanese students. Thirty-three Japanese students worked with twenty-four Thai students in eight groups to create a carboard evacuation shelter to provide comfort for affected Thais living in a tropical monsoon climate. The engagement of both the Japanese and Thai students was critical to increase the project's learning outcomes, and this study focuses on the engagement of the Japanese students. The high response values of Japanese students to the learner engagement survey indicate the high educational impact of the project, with two less engaged students having low responses. We examine the engagement of these two less engaged students (Student A and Student B) qualitatively through their responses to the interview survey.
The results are as follows: 1) Both Student A and Student B were less engaged because they could not make use of their area of expertise, information engineering, in the project, but they tried to collaborate in their own group; 2) Introducing the roles in collaborative work (leader, facilitator, operator, etc.) and the skills required for these roles could encourage Student A and Student B to value their participation highly and to fulfil their individual accountabilities; and 3) Reviewing vocabulary and expressions related to basic engineering English, such as numbers, calculations, and figures, at the beginning of the project could help students to actively participate in the group discussion.

Keywords: *qualitative study, learner engagement, collaborative work, project-based learning*

Introduction

Our school accepted twenty-four students in 2024 and will accept twenty-two students in 2025 from KOSEN KMUTT, established in 2020. The objectives of our one-month engineering program for KOSEN KMUTT are 1) (for Thai students) to gain practical skills and experience in mechanical, electrical, and information engineering; 2) (for Thai students) to increase their confidence in becoming competent automation engineers through various activities with Japanese students and staff; and 3) (for Japanese students and staff) to interact with Thai students and staff and to develop communication, multilingual, and intercultural skills of Japanese students and staff. Cardboard Evacuation Shelter Project (Figure 1 shows its final presentation) was one of the six courses offered to KOSEN KMUTT students and was the only project-based learning (PBL) course that involved collaborative work with Japanese students. The engagement of both the Japanese and Thai students is critical to increase the project's learning outcomes, and this study focuses on the engagement of the Japanese students. We attempt to examine Japanese students' learner engagement to increase the educational outcomes of the engineering program for KOSEN KMUTT in 2025.



Figure 1: Final presentation of Carboard Evacuation Shelter Project

Carboard Evacuation Shelter Project is one of the four collaborative studies in System Technology Experiments, required four-session (90min. x 4) first-year course of NIT, Matsue college advanced engineering faculty. Table 1 shows the course allocation for 2024, and Figure 2-4, the group discussions. The course consists of four collaborative PBL projects and one individual PBL project. The subject matters of these five projects are not disclosed to the students prior to each day of the project. The students must work and solve the problem in a limited amount of time. The students are organized into groups consisting of four or five members, with each group including individuals with different engineering expertise. These groups collaborate on four projects, with the groups being reorganized for each project.

Table 1: Allocation for System Technology Experiment

Week	Date of 2024	Content (Percentage of Grades)
1	April 10th	Group Project 1 (7%)
2	April 17th	Group Project 2 (7%)
3	April 24th	Group Project 3 (7%)
4	May 8th	Individual Project (58%)
5	May 15th	
6	May 22nd	
7	May 29th	
8	June 5th	
9	June 12th	Group Project 4 (21%) with Thai students in 2024 & 2025
10	June 19th	
11	June 26th	
12	July 3rd	
13	July 10th	
14	July 17th	
15	Aug. 7th	

Note: Group Project 4 is scheduled to coincide with the visit of the Thai students. In previous years, this project took place from week 12 to 15.



Figure 2: The group discussion of June 12th, 2024



Figure 3: The group discussion of June 19th, 2024

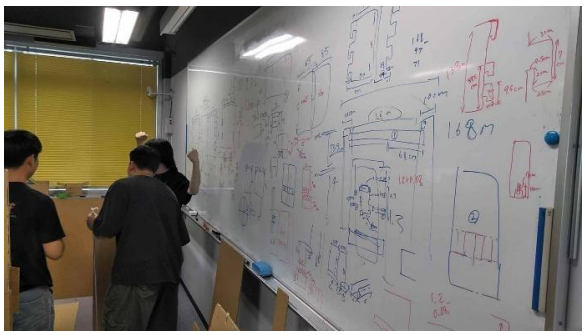


Figure 4: The group discussion of June 26th, 2024

Previous Research

Learner engagement is one of the areas of focus in the field of educational psychology. Mercer & Dornier (2020, p.2) define it as "active participation and involvement in certain behaviours." Engaged learning improves learning outcomes, academic performance, and motivation for lifelong learning (Hiromori, 2024). Learner engagement measures a person's motivation to learn through four aspects of engagement: emotional, cognitive, behavioural, and social. Sakurai (2020) states that learner engagement needs to be measured by five factors (the four aspects above plus self-efficacy) with nine key points, which are summarized in Table 2.

Table 2: Learner Engagement Metrics (Sakurai, 2020) and Specifics in Carboard Evacuation Shelter Project

5 factors of Engagement	9 key points of Engagement	Specifics in this program
(1) Emotional engagement	(a) Interests	I worked on this project with sustained interest and concern.
	(b) Enjoyment	I enjoyed working on this project
(2) Cognitive engagement	(c) Goals and Motivation	I was goal oriented and motivated.
	(d) Self-regulated learning	To achieve the goal, I tried various intellectual challenges.
(3) Behavioral engagement	(e) Effort	I focused on this project and worked hard to achieve its goal.
	(f) Persistence (Durability)	I never gave up, even when things didn't work out.
(4) Self-efficacy	(g) Self-efficacy	I approached this project with a sense of self-efficacy.
(5) Social engagement	(h) Mutual aid	I helped and was helped by others in my group.
	(i) Cooperation	I worked cooperatively with my group members and instructors.

Note: Sakurai (2020, pp.82-83), excerpted by the authors, with the authors' description of the specifics in this project.

Subjects and Methods

We conducted a learner engagement survey with all the thirty-three advanced engineering faculty first-year students involved in the project on Aug. 5th-9th, 2024. Table 3 shows the survey questions, which coincide with the specifics in this program (Table 2). Japanese students' high response values indicate the high educational impact of our project, with two less engaged students (Student A and B) having low responses (Table 4). Student A and B's backgrounds are shown in Table 5. Both are Information Engineering majors; A is reserved, polite, diligent, and not highly active, but able to respond appropriately to questions or requests for help; and Student B is even active in international exchange activities, but B tends to skip things that B is not interested in. We examine the engagement of these two students qualitatively through their responses to the interview survey.

Table 3: Survey questions for 33 Japanese students

Please indicate your level of engagement in the Cardboard Evacuation Shelter Project.

	Not applicable				Very applicable
Q1.I worked on this project with sustained interest and concern.	1	2	3	4	5
Q2.I enjoyed working on this project	1	2	3	4	5
Q3.I was goal oriented and motivated.	1	2	3	4	5
Q4.To achieve the goal, I tried various intellectual challenges.	1	2	3	4	5
Q5.I focused on this project and worked hard to achieve its goal.	1	2	3	4	5
Q6.I never gave up, even when things didn't work out.	1	2	3	4	5
Q7.I approached this project with a sense of self-efficacy.	1	2	3	4	5
Q8.I helped and was helped by others in my group.	1	2	3	4	5
Q9.I worked cooperatively with my group members and instructors.	1	2	3	4	5
Q10. Please describe freely what you noticed or thought about through this project learning.					

Note: See Appendix 1 for Q10 comments

Table 4: Responses to the survey

Survey Questions (Specifics in this program)	Student (Subject)		33 Japanese students	
	A	B	AVE	SD
Q1.I worked on this project with sustained interest and concern.	2	2	4.3	0.91
Q2.I enjoyed working on this project	2	2	4.4	0.86
Q3.I was goal oriented and motivated.	2	2	4.2	0.9
Q4.To achieve the goal, I tried various intellectual challenges.	4	3	4.5	0.62
Q5.I focused on this project and worked hard to achieve its goal.	3	2	4.4	0.76
Q6.I never gave up, even when things didn't work out.	2	3	4.4	0.83
Q7.I approached this project with a sense of self-efficacy.	3	2	4.4	0.78
Q8.I helped and was helped by others in my group.	4	2	4.5	0.71
Q9.I worked cooperatively with my group members and instructors.	4	4 / 3	4.7	0.54

Table 5: Two subjects' background

	Major TOEIC	Academic advisor's view
A	Information Engineering 450 (May 18th, 2023)	A is soft-spoken, reserved, polite, diligent, and not highly active, but able to respond appropriately to questions or requests for help.
B	Information Engineering 495 (Jan.12th, 2023)	B is active, has experience as a tutor for international students, and has attended an international conference in Taiwan. B tends to skip things that B is not interested in.

Student A's Results and Discussion

Table 6 shows Student A's responses to the interviews.

Table 6: Student A's responses to the interviews

Interview Question: Can you talk about your survey responses?		
Q1	2	My answer was low because I am a graduate of the Dept.of Information Engineering, and there was nothing I could do that would allow me to use what I had learned there.
Q2	2	Of course, I enjoyed the interaction with the Thai students, but I felt that I could not do much work or contribute much to the actual creation of the house, so it was difficult for me to enjoy the experience.
Q3	2	I chose a 2 because I found it difficult to be enthusiastic about the project.
Q4	4	It was difficult, but I thought I was able to review and make adjustments in cooperation with my group members;
Q5	3	I worked hard, but I did not feel 100% motivated and I answered a 3.
Q6	2	I did not actively work on the design of the cardboard shelter, which I thought I should have worked on with persistence.
Q7	3	I wasn't sure at the beginning if we could get what we originally designed, and I didn't think we could if we tried that hard, but after working with the group I thought we ended up with something much better, even if it wasn't perfect in terms of what we designed.
Q8	4	I struggled to explain what I didn't understand in simple English, but I managed to illustrate and talk about it, and foreign students also drew pictures to explain it to me.
Q9	4	I thought the interaction was solid when working together to figure out or teach something I didn't understand.

Overall comments
The cardboard shelter was something that most of the students had probably never used before, so it was difficult for us to work on it. I would like to see a subject that is easier to visualize and that any engineering majors can use what we have learned. For example, the civil engineering majors could make a model, and the electrical and electronics engineering majors could make something like a monorail or robot, which could be programmed and controlled by the information engeering majors. This time, the shelter was destroyed as soon as it was built, so I thought it would be better if it was something that the international students could take home with them if possible.

Note: underlined parts, cited in the body text in italics

Student A's emotional engagement (Table 2-(1)) was low because the subject matter was not familiar to A, as it says *there was nothing I could do that would allow me to use what I had learned* and *I could not do much work or contribute much to the actual creation of the house*. Solving problems from multiple engineering perspectives is one of the course goals, and Student A, outside of mechanical or civil engineering, must struggle with this project. Introducing the roles of cooperative learning (such as leader, follower, facilitator, manager, and operator) and the competences needed to fulfill these roles could help Student A to be more confident about its contribution to the group (Hattori, 2024; see Appendix 2), and could improve its emotional engagement. Student A *found it difficult to be enthusiastic about the project* at the beginning, but A's group members helped A to make several attempts, and A's cognitive engagement (Table 2-(2)) gradually improved. Student A was not persistent and was not behaviourally engaged (Table 2-(3)). This is because, although A worked hard, A *did not feel 100% motivated* and *did not actively work on the design of the cardboard shelter.* Meanwhile, Student A felt self-efficacy (Table 2-(4)) with the help of A's group members, as A says *after working with the group I think they ended up with something much better*. Student A's social engagement (Table 2-(5)) was relatively higher than other factors of engagement, as it says *I managed to illustrate and talk about it, and foreign students also drew pictures to explain it to me* and *I thought the interaction was solid when working together to figure out or teach something I didn't understand*. This indicates successful interaction and cooperative learning among A's group. In overall comments, Student A wishes to see *a subject that any engineering majors can use what we have learned*, which is already realized in System Technology Experiment course (Table 1) because Group Project 1-3 require the skills of electrical, electronics, and information engineering, and Group Project 4, Carboard Evacuation Shelter Project, requires the skills of mechanical and civil engineering. Student A thinks it is a pity that *the shelter was destroyed as soon as it was built,* but at the same time this is a practice of SDG 12: Responsible Consumption and Production. Making the shelter glue-free is also in line with SDG 12.

Student B's Results and Discussion

Table 7 shows Student B's responses to the interviews.

Table 7: Student B's responses to the interviews

Interview Question: Can you talk about your survey responses?		
Q1	2	It was a good opportunity for me to use my English, but it was too hard for me to work with the Thai students on the cardboard shelter from designing to building in a limited time. It was difficult for me to use construction-related vocabulary (simple words like "structure" are fine, but difficult words were not), and my motivation dropped.
Q2	2	
Q3	2	Thai students only understand English, so it was difficult to have a clear goal within the group. There was one Japanese student in the group who could speak English very well, and he tried to lead the whole group, but he and a few others were the only ones who knew the goals. We felt like we were on a lower level, and we often wondered what they were doing, and it was hard for me to be aware of our goal.
Q4	3	It was difficult to communicate with the Thai students in English, which made it challenging to review and make changes. However, I believe I should have been more proactive.
Q5	2	I didn't know why I came to the department of Electronics and Information Systems Engineering to work on a cardboard shelter, and I wasn't excited about the project.
Q6	3	It was difficult to communicate with Thai students in English.
Q7	2	My answer was a little too low, but I chose a 2 because it was too hard to exchange opinions because of the language barrier.
Q8	2	Teaching something in a foreign language is a high level of communication. For example, I was asked to explain a structure, but the words were difficult, there were calculations, and I could not explain the complex structure in English.
Q9	4 or3	The answer to Q9 could be a 4 or a 3. I did cooperate.
Overall comments		
I think that working on a project with Thai students is a good opportunity to communicate with them and improve my English, and I would like to see the number of such projects increase, but the subject matter, from designing to manufacturing cardboard shelters, was difficult. I would like to see more projects that are easier to work on. The pressure to finish it by the deadline was too much. I wish it had been something I could do without feeling pressured. Well, pressure is what makes us want to do what we have to do.		

Note: underlined parts, cited in the body text in italics

Student B appreciates the opportunity to work with Thai students, saying *I would like to see the number of such projects increase* in overall comments, but B had lost interest in the project and its emotional engagement (Table 2-(1)) was low. B attributes its low motivation in the project to the subject matter, lack of time, and communication difficulties; *it was too hard for me to work with the Thai students on the cardboard shelter from designing to building in a limited time* and *It was difficult for me to use construction-related vocabulary*. Student B's cognitive engagement (Table 2-(2)) was low, though B believes that *I should have been more proactive*. There was a leader in B's group, but that student did not seem to be doing an adequate job of fulfilling its role, as B says *he and a few others were the only ones who knew the goals. We felt like we were on a lower level, and we often wondered what they were doing, and it was hard for me to be aware of our goal*. Again, introducing the roles of cooperative learning (leader, facilitator, operator, etc.) and the skills needed to fulfill these roles could help the group members to demonstrate their abilities and take the initiative (Hattori, 2024). Role awareness will create awareness of the group's purpose and facilitates collaboration. The Japanese student playing the role of leader could have taken the initiative and share their goal with the group.

Student B's behavioural engagement (Table 2-(3)) was low, reflecting B's emotional engagement and cognitive engagement. Student B *didn't know why I came to the department to work on a cardboard shelter*, and had alomost skipped this project because B was not interested in it (Table 5). Student B had been active and good at international exchange activities, but it didn't work in this project. B found *it was too hard to exchange opinions because of the language barrier,* and B lost its self-efficacy (Table 2-(4)) in this project. The social engagement (Table 2-(5)) of Student B was relatively higher than other factors of engagement, but B repeated the difficulty of the subject matter and vocabularies needed, as *I was asked to explain a structure, but the words were difficult, there were calculations, and I could not explain the complex structure in English*. Reviewing vocabulary and expressions related to basic engineering English that they had previously learned, such as numbers, calculations, and figures, at the beginning of the project could have helped students like B to actively participate in the group discussion and feel self-efficacy.

Conclusions

This study attempted to examine Japanese students' learner engagement in the Cardboard Evacuation Shelter Project with Thai students, and to explore perspectives for improving the one-month engineering program for KOSEN KMUTT in 2025. Our discussion can be summarized in the following three points.

The first point is that both Student A and Student B were less engaged because they could not make use of their area of expertise, information engineering, in the project, but they tried to cooperate in their own groups. Solving problems from multiple engineering perspectives is one of the course goals. Students need to remember this, and the students outside of the engineering department involved will have to struggle. This following second point may help those struggling.

The second point is role awareness. Introducing roles in collaborative work (leader, facilitator, operator, etc.) and the skills required for these roles could encourage all the students to demonstrate their abilities and take the initiative. Role awareness could create awareness of the group's purpose and facilitates collaboration.

The third point is that reviewing vocabulary and expressions related to basic engineering English, such as numbers, calculations, and figures, at the beginning of the project, could help students to actively participate in the group discussion and feel self-efficacy.

This conclusion is based on a qualitative study of only two students with low engagement and therefore does not represent a comprehensive assessment of the educational program. Nevertheless, the reflections of students with low engagement levels can offer substantial and insightful recommendations for the enhancement of educational programs.

We welcomed twenty-four students from KOSEN KMUTT in 2024 and will welcome twenty-two students in 2025. Modifying our project with the three points mentioned above could improve the learning outcomes and academic performance of the students involved in this course.

Acknowledgements

We would like to express our profound gratitude to the faculty and staff of the NIT, Matsue College for their invaluable cooperation in the one-month engineering program for KOSEN KMUTT in 2024.

References

Hattori, M. (2024). Qualitative Study of Learners' Individual Accountability in Group Presentation -A Case Study for Enhancing Cooperative Learning-, *Journal of the Council of College English Teachers*, 43, 11-20.

Hiromori, T. (2024). 3 things to know about learner engagement. *The English Teachers' Magazine*, Vol.73 No.3, 36-37.

Mercer, S., & Dorney, Z. (2020). *Engaging Language Learners in Contemporary Classrooms*. Cambridge University Press.

Sakurai, S. (2020). *"Engagement" in learning -Assess and encourage a proactive attitude toward learning-*, Tokyo: Toshobunkasha.

Appendix

Appendix 1: Table 3-Q10 comments from 33 Japanese students

Positive comments
・I thought the planning was really good. I figured that even though we speak different languages, we can still make the project a success, exciting, and fun. ・The Thai students were very active in the project, and we ended up with a pretty decent shelter. ・I was surprised by how much better the Thai students were at English compared to us. I had a good experience with my own design. ・I realized that even though we speak different languages, we can still create something together. ・I realized that even my English will help us communicate, if we make an effort. ・It was a bit of a challenge at first, talking to someone who spoke a different language, but as the number of conversations increased, it got easier. I realized the importance of output. ・I had a lot of chances to speak English, so it was good practice for using English every day. I'm not sure about the "cardboard shelter" project, but if you look at it as "international exchange," it was good. ・I realized that even if I didn't understand English, I could still communicate better than expected. ・I'm looking to keep improving my English skills and expertise by participating in international exchanges. ・The chatting time was exciting and fun. When we played picture shiritori in both Thai and Japanese, it was difficult to find each other's language from the pictures, but it was fun. ・Communication was a challenge, but I did my best. ・My English isn't the best, but I've found that I can get by with a little momentum and a smile. Listening was a bit of a challenge, so I'm hoping to work on that. ・I realized how difficult it is to communicate in English.
Negative Comments
・If we do this again next year, we need to clarify the rules. ・The schedule was too tight, so we need to review it. The presentation venue was too hot and dangerous.

Appendix 2: Roles of cooperative learning

Roles	Competencies required for the role
Leader	The ability to express one's will, influence and move others
Follower	The ability to understand, believe, cooperate and synchronize with their leader and others
Facilitator	The ability to build relationships that maximize the strengths of each member
Manager	The ability to create a safe and secure environment for members (time, records, etc.)
Operator	The ability to faithfully carry out what has been decided

Note: extracted from Hattori (2024)

COMPARATIVE ANALYSIS OF PROGRAM LEARNING OUTCOMES: THE CASE OF TECHNOLOGICAL AND POLYTECHNIC COLLEGES IN MONGOLIA

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The quality of education in technological and polytechnic colleges plays an important role in ensuring sustainable economic development in Mongolia. The Mongolian higher education system is divided into four types: universities, institutes, colleges, and KOSEN technology colleges. Over the past ten years, the Government of Mongolia has been exploring the possibility of introducing the KOSEN-model engineering program—currently being successfully implemented in Kosen-model Technology Colleges—into Polytechnic Colleges. Colleges of Technology, which provide undergraduate and graduate vocational training, and polytechnic colleges, implement programs based on the concept of Education–Research–Production, to determine the results of the program. This study compared the learning outcomes of the "Mechanical Engineering" program of the Polytechnic and the Japanese KOSEN Model College of Technology, measured by performance-based, criteria-based indicators with the participation of stakeholders, and compared the results. This study included programs from 2 polytechnic colleges and 2 KOSEN-model technology colleges that offer similar mechanical engineering curricula. The research was conducted using structural equation modeling, and the SPSS and SmartPLS software were employed for analysis.

The results revealed that the selected factors have a strong influence on the learning outcomes of the mechanical engineering programs. When comparing the learning outcomes of the two types of colleges included in the study, noticeable differences were found between the polytechnic colleges and the Kosen-model technology colleges.

To further improve the learning outcomes of these programs, it is crucial to clearly define expected learning achievements in measurable terms, assess the outcomes at each stage of the training process, and implement continuous improvement mechanisms. These steps are essential to enhancing the competencies of students enrolled in these programs.

Keywords: *Japanese KOSEN-model Curriculum, Engineering Education, Program Learning Outcomes, Polytechnic College / Technical Education, Mechanical Engineering*

1. Introduction

Due to the rapid pace of technological advancement and the impacts of the Fourth Industrial Revolution (Industry 4.0), the global labor market is facing significant challenges, requiring educational systems to respond more effectively and flexibly (Government of Mongolia, 2020). Education plays a crucial role in meeting the demands of the labor market for engineers and technology professionals. In Mongolia's education system, institutions such as universities, institutes, colleges, Kosen-model technology colleges, and polytechnic colleges are engaged in training human resources in engineering and technical fields. The 'National Regional Development Program 2022–2030', approved by the State Great Khural (Parliament) of Mongolia, includes goals to improve the system of vocational and technical education. Furthermore, the Government's Action Plan for 2024–2028 outlines the objective to introduce a '5-year Kosen-model training program based in colleges' in alignment with the priority development directions of regions and local areas, and to prepare graduates with knowledge and skills recognized by the labor market. For example, during the first semester of the 2022–2023 academic year, a total of 38,034 students were studying in 79 vocational and technical education institutions, including 33 polytechnic colleges and 43 vocational training and production centers, across 187 specialties in 16 sectors. However, according to labor market surveys and employer feedback, 36.3% of workers do not meet the required educational qualifications, 32.2% lack the appropriate skills or specialization, and 22.1% lack sufficient work experience.

While graduates of Technical and Vocational Education and Training (TVET) institutions and polytechnic colleges were somewhat recognized for their practical skills, they were noted to be weak in theoretical knowledge, problem-solving abilities, and professional

experience. In addition, after being employed, many were found to lack motivation and professional drive, often failing to stay in the same job for long and showing a tendency to leave their positions easily. Therefore, there is a clear need to reform the system of vocational and technical education and develop curricula based on outcome-based approaches (Ministry of Education and Science, 2022). The unique feature of Japan's KOSEN (high-level, advanced) model Technology Colleges is that their curricula are integrated, with knowledge being delivered through practical applications, validated by experiments, and structured to include industry-specific training and internships. In 2014, three KOSEN-model Technology Colleges were established in Mongolia, and over the past 11 years, they have successfully graduated 673 students. More than 80% of graduates from these colleges are directly employed, with employers highlighting their superior knowledge and skills in the workplace.

In the context of implementing Mongolia's development policies, several critical questions emerge: What should be prioritized in the continued development of polytechnic and Kosen-model colleges? What is the current quality of their respective curricula? How do stakeholders evaluate the learning outcomes of these programs? And which competencies will be increasingly important in the future?

To address these questions, this study aims to assess the learning outcomes of Mechanical Engineering programs offered at technological and polytechnic colleges in Mongolia using a stakeholder-inclusive evaluation approach. In the Mongolian context, few studies have employed participatory methods to evaluate program-level learning outcomes. Therefore, this research offers a novel perspective and contributes to a more comprehensive understanding of the challenges and opportunities in engineering education reform.

A comparative analysis of program learning outcomes refers to the assessment of the extent to which students have attained the intended knowledge, skills, and attitudes (learning outcomes) as outlined in the curriculum. This analysis also involves benchmarking those outcomes against similar programs or past performance data. Engaging key stakeholders—such as employers and graduates—in the evaluation process ensures a more realistic and practice-oriented assessment of learning outcomes. Moreover, their feedback plays a crucial role in identifying gaps, resolving challenges, and ultimately contributing to program improvement and relevance in the labor market.

2. Literature review

In recent years, many researchers have demonstrated the importance of implementing outcome-based education (OBE) in engineering education [1,2]. Since 2014, Mongolia has been applying the CDIO (Conceive–Design–Implement–Operate) framework in its engineering education to support the development of outcome-based programs.

Outcome-Based Education (OBE) is an educational approach that aims to achieve clearly defined learning outcomes by actively involving students in the learning process. It encourages learners to take greater responsibility and make more independent decisions regarding the content and direction of their learning [3].

Vocational and technical education institutions play a critical role in preparing the skilled human resources necessary for implementing development policies and programs, while also contributing to economic growth and the sustainability of employment in a country [4-6].

3. Materials and Methods or Pedagogy

This study used two types of research methods: documentary and questionnaire. First, in the documentary research, the main program planning documents of the two colleges were evaluated according to a total of 9 criteria in accordance with the common requirements issued by the Ministry of Education. Second, a comparative study was conducted on the learning outcomes of the programs. The evaluation of the learning outcomes of the training programs and their current performance was conducted with the participation of stakeholders. The evaluation was conducted in two main stages. These are:

a) Outcome-based performance, documentary evaluation (Content analysis)

b). Stakeholder evaluation: student, alumni, and employer evaluation

Comparative research: Although Polytechnic Colleges and Kosen Technology Colleges are two different types of educational institutions, they both provide training in technical and engineering fields. When comparing these two colleges, first, it is possible to compare them using general statistical indicators. Second, with the help of stakeholders, it is possible to evaluate the quality and effectiveness of the programs they offer in similar specialties.

In examining the current state of Polytechnic and Kosen Technology Colleges, we compared the concepts and forms of their educational systems. These institutions are developing in two different directions within Mongolia's education system.

Polytechnic Colleges focus on providing vocational education and skills in specific fields, with training activities centered around science, engineering, and technology. Kosen Technology Colleges, on the other hand, prepare technical and engineering specialists through a system modeled after Japan's education system [7-9]. This study compares the learning outcomes of the Mechanical Engineering Program offered at both types of institutions. This section presents a comparison of the

programs offered by the Polytechnic and the Kosen Model College (see Table 1).

The Mechanical Engineering program at the Polytechnic College aims to quickly equip students with technical skills and practical knowledge, enabling graduates to work as technicians in the domestic industrial sector.

Table1.Differences Between Polytechnic and KOSEN-Model College Programs

Metric	Polytechnic College (Mechanical Engineering)	KOSEN Technology College (Mechanical Engineering)
Age of admission	The entrance age for the Polytechnic College is 15.	The average age of admission at Kosen College is 15.
Program duration	2.5 to 3 years.	5 years.
Educational Characteristics	Provides skills training with a focus on practical experience and hands-on practice.	A five-year program designed to train professionals in engineering and technology.
Focus of Training	Technical Skills, Practical Knowledge	In-depth Engineering Knowledge, Research, Projects
Professional Field	Technician, Engineering Assistant, Equipment	Mechanical Engineer, Technology Manager, Researcher
Curriculum Content	Basic Technical Skills, Mechanical Equipment Repair, Manufacturing Process	Mechanical Systems, Robotics, Automation, Component Modeling
Practical and Project Work	Industrial Internship, Working with Mechanical Equipment	Project Management, In-depth Research, Engineering Projects
Graduation Age	17.5 and 20.	around 20.
Professional Degree	Secondary Education Certificate, Professional Diploma	Associate degree in Engineering
Opportunities for Graduates	Working in the Technical Field, Mid-Level Engineering Roles	Senior-Level Engineering Roles, Research, Development

In contrast, the Mechanical Engineering program at the Kosen Technology College focuses on providing deeper and more specialized engineering knowledge, as well as skills in research, analysis, and working in the global market. Graduates are capable of performing high-level engineering work and have opportunities to work for international companies.

Information about Evaluation Participants: The evaluation was conducted over a one-month period beginning on March 15, 2025, in accordance with the proposed methodology. Details of the participants involved in the evaluation are presented in Table 2.

Table 2. Participants in the Evaluation

Constructs	Type	Frequency	Percent
Age	18-24	3	11.5
	25-34	3	11.5
	35-44	9	34.6
	45<	11	42.3
	total	26	100
Colleges	Construction Poly. College	1	3.8
	MONGOL KOSEN	2	7.7
	MUST-KOSEN	5	19.2
	Polytechnic of MUST	18	69.2
	Total	26	100
Organization type	Public	14	53.8
	Non-government	12	46.2
	Total	26	100
Employee Satisfaction	1-Very Poor	1	3.8
	2-Poor	1	3.8
	3-Average	3	11.5
	4-Good	16	61.5
	5-Excellent	5	19.2
	Total	26	100

The study employed a stratified sampling method targeting three key stakeholder groups involved in mechanical engineering programs: current students, graduates, and employers of graduates. A total of 107 student representatives, 81 graduates, and 26 representatives from employer organizations affiliated with the programs participated in the study.

To evaluate the knowledge, skills, and attitudes acquired by students and graduates—aligned with the intended learning outcomes of the Mechanical Engineering program—data were collected through structured questionnaires. A total of 131 items were administered to current students, 102 items to graduates, and 103 items to employers.

Research Methodology: This study aims to systematically analyze the Program Learning Outcomes (PLOs) of the Mechanical Engineering program, considering international trends, national policies, and differences in educational environments. The research is grounded in several theoretical frameworks, including Outcomes-Based Education (OBE), Comparative Program Evaluation, Bloom's Revised Taxonomy, the CDIO Syllabus 2.0, Japan's Mechanical Engineering Model Core Curriculum (MCC, 2023), and the graduate competency standards of the Washington Accord [10-12]. The study involves two polytechnic colleges and two technological (Kosen model) colleges in Mongolia that offer mechanical engineering programs. It evaluates and compares the learning outcomes of these programs using both quantitative and qualitative data.

The study employed a mixed-methods approach, incorporating document analysis, a questionnaire survey, and structural equation modeling (PLS-SEM). A stratified purposive sampling method was used to select participants based on the type of educational institution (technological or polytechnic), the level of students (graduate level), and stakeholder role (graduate or employer). The survey included an average of 103 items

measured on a 5-point Likert scale. Learning outcomes were categorized and evaluated across three domains: cognitive, affective, and psychomotor.

Descriptive statistics, independent samples t-tests, ANOVA, and correlation analyses were conducted using SPSS version 26.0 to analyze the survey data. Additionally, SmartPLS version 4.0 was utilized to perform Partial Least Squares Structural Equation Modeling (PLS-SEM) in order to assess the influence of knowledge, skills, and attitudes on learning outcomes. The measurement and structural models were evaluated using key indicators such as path coefficients, Composite Reliability (CR), Average Variance Extracted (AVE), and R^2 values.

In accordance with research ethics, informed consent was obtained from all participants, confidentiality was strictly maintained, and the reliability of the questionnaire was verified through a pilot test.

4. Results and Discussion

The evaluation was conducted over a one-month period beginning on March 15, 2025, in accordance with the proposed methodology. A total of 107 students, 81 graduates, and 26 employer representatives from the Mechanical Engineering program in Mongolia participated in the survey. Among the student participants, 93.5% were male and 6.5% female; among graduates, 97.5% were male and 2.5% female; and among employer representatives, 84.6% were male and 15.4% female.

Regarding employer feedback, 80.7% rated their experience and satisfaction with hiring program graduates as "Good" or "Excellent." Additionally, 53.8% of the employer representatives were affiliated with government agencies. Survey participants assessed the implementation level of the Program Learning Outcomes (PLOs) using a five-point Likert scale, ranging from 1 (Very Poor) to 5 (Very Good).

Evaluation of Program Learning Outcomes

A total of 214 participants took part in the study, with up to 103 questionnaire items rated on a 5-point Likert scale. The average rating given by students was 3.20 (standard deviation = 0.952), slightly higher than the graduates' average rating of 2.60 (standard deviation = 0.817), and close to the employers' average rating of 3.30 (standard deviation = 0.850). The highest-rated learning outcomes included engineering problem-solving skills (mean = 4.01), technical drawing processing (3.89), teamwork skills (3.78), and analysis of measurement and experimental results (3.76). These outcomes align closely with the core competencies outlined in prominent international curricula, such as the Mechanical Engineering Model Core Curriculum (MCC, JABEE, 2023), ABET (2022), and CDIO (Crawley et al., 2014).

Conversely, the lowest-rated competencies were professional information processing skills in English (2.71), innovative proposal and design skills (2.93), and systems thinking (3.10), suggesting that current program policies and teaching methodologies may be insufficient to adequately develop these skills.

Comparative Analysis of Program Learning Outcomes in Polytechnic and KOSEN Colleges

A comparative analysis of the average Program Learning Outcomes (PLOs) between the Polytechnic and Technology (KOSEN) colleges revealed that the average score for students at the Polytechnic College was 3.49, whereas students at the Technology College (KOSEN) achieved a higher average score of 3.91. An independent sample t-test indicated that this difference was statistically significant ($p < 0.05$).

These results suggest that the KOSEN model—with its emphasis on a stepwise, hands-on approach and the cultivation of an engineering mindset—is more effective in fostering systems thinking and creativity. Conversely, students from the Polytechnic College demonstrated stronger performance in areas related to technical operations and practical work experience, likely reflecting their training in real equipment and production environments.

Results of Structural Equation Modeling (PLS-SEM)

Structural equation modeling (PLS-SEM) was conducted using SmartPLS software to identify the relationships between key factors influencing learning outcomes.

Table 3. Average of program learning outcomes/1-5/

Stakeholders	Number of participants	Average of program learning outcomes/1-5/		
		Knowledge	skills	attitude
Employer	26	3.53	3.24	3.35
Alumni	81	3.17	2.80	3.47
Student	107	3.48	3.69	3.49
Total	214	3.39	3.24	3.44

The results of the study showed that the program stakeholders rated the PLOs of the Mechanical Engineering program as 3.39 for knowledge, 3.24 for skills, and 3.44 for personal soft skills(see table 3).

Alumni Feedback on the Mechanical Engineering Program

A structural equation model (SEM) was employed to estimate the impact of general engineering knowledge, engineering software usage, graphic design skills, coding, application software usage, and soft skills on the learning outcomes of graduates from the Mechanical Engineering program (see Figure 1).

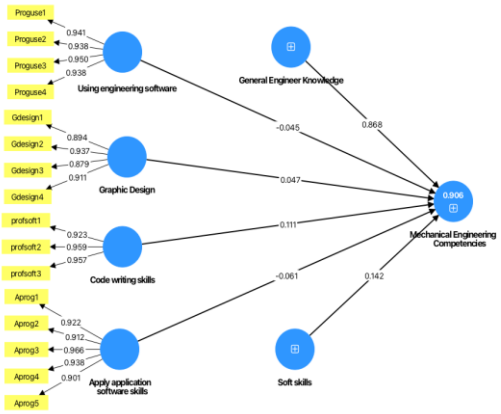


Figure 1. Structural Equation Model (SEM) Path Diagram of Competency Factors Influencing Learning Outcomes in Mechanical Engineering

The metrological evaluation of the measurement instruments used in the study exceeded the recommended thresholds for reliability and validity. Specifically, Cronbach's Alpha values ranged from 0.927 to 0.978, Composite Reliability (rho_a) ranged from 0.927 to 0.988, and the Average Variance Extracted (AVE) ranged between 0.699 and 0.887, confirming acceptable reliability and convergent validity of the constructs (see Table 4).

Table 4. Construct reliability and validity

PLOs	Cronbach's alpha	CR (rho_a)	CR (rho_c)	AVE
Apply application software skills	0.961	0.984	0.969	0.861
Code writing skills	0.942	0.953	0.962	0.895
General Engineer Knowledge	0.978	0.980	0.980	0.699
Graphic Design	0.927	0.927	0.948	0.820
Mechanical Engineering _ Competencies	0.977	0.979	0.979	0.701
Soft skills	0.981	0.988	0.983	0.750
Using engineering software	0.958	0.966	0.969	0.887

Path analysis results revealed that general engineering knowledge ($t = 19.81$, $p < 0.001$), coding skills ($t = 2.43$, $p = 0.032$), and soft skills ($t = 2.90$, $p < 0.001$) had statistically significant positive effects on learning outcomes. In contrast, application software usage, graphic design skills, and proficiency in engineering-specific software did not demonstrate statistically significant impacts. This lack of significance may be due to insufficient instruction in these areas or the possibility that some students had not yet completed relevant coursework.

Student Evaluation Results

A structural model for the evaluation of student program learning outcomes was developed and the factors influencing program outcomes, namely general engineering knowledge, mathematics, natural sciences, humanities, and personal development knowledge and skills, were statistically significantly correlated through regression analysis (Table 5).

Table 5. Regression analysis

Variable	Coefficient	Results
GENG	**0.359**	Positive, strong influence
MATH	**0.246**	Positive, moderate influence
NAT	**0.113**	Positive, weak influence
NUM	**–0.023**	Negative, negligible influence
SOFT	**0.303**	Positive, moderately strong influence

Note: **GENG**- General engineer knowledge; **MATH-Mathematic**; **NAT**- natural science; **NUM**-Humanities; **SOFT**-Soft skills

The results of the analysis confirmed that these factors selected for the study have a strong impact on the learning outcomes of the mechanical engineering program, and the explanatory power (R^2) of the model is 0.775.

Employer Evaluation Results

Based on the evaluations provided by employers, the highest-rated competencies among graduates were "ability to adapt to the workplace" (4.10), "ability to learn independently" (3.95), and "ability to understand and model engineering problems" (3.90). The lowest-rated competencies were "understanding of laws and ethics" (3.02) and "use of English language" (2.76).

These results indicate that certain competencies emphasized in the MCC framework, such as "social understanding" and "communication skills," have not yet been fully developed in the Mongolian educational context. While employers expressed satisfaction with graduates' ability to analyze problems, work in teams, and engage in creative design, they also emphasized the need to improve foreign language skills, particularly for international communication.

Conclusions

This study compared and evaluated the learning outcomes (Program Learning Outcomes – PLOs) of mechanical engineering programs in polytechnic and KOSEN model technical colleges in Mongolia, aligning them with international educational quality standards to determine the implementation and impact of the programs. The research employed a mixed-methods approach, utilizing evaluations from students, graduates, and employers, document analysis, and structural equation modeling (PLS-SEM) to establish the causal relationships affecting learning outcomes in quantitative terms.

Firstly, the results of the study indicate that mechanical engineering programs successfully impart core engineering skills such as problem-solving, technical drawing, measurement and testing, and teamwork. However, higher-level skills such as the use

of English, systems thinking, and the ability to propose innovative ideas received lower evaluations. This is linked to factors such as the content of the curriculum, teaching methods, and the level of support from the learning environment.

Secondly, graduates of the Kosen model colleges performed better in terms of learning outcomes compared to students from polytechnic colleges. This indicates that the Kosen program's structured framework and its systematic approach to providing foundational engineering education are more effective. On the other hand, polytechnic colleges have an advantage in their close alignment with industrial environments, focusing on technical utilization and performance through practical training, as confirmed by employers' evaluations.

Thirdly, the results from the structural equation modeling (PLS-SEM) indicated that four key factors—program content alignment, instructor competency, learning environment, and student attitude—significantly influence learning outcomes. Among these, program structure and instructor skills had the highest impact, showing that these factors are crucial for improving the quality of engineering programs.

Fourth, employers rated the graduates' ability to solve engineering problems, learn independently, and adapt to the work environment highly, while skills in ethics, English language, and international communication were rated lower. This highlights the need for engineering education to focus not only on technical skills but also on developing social and communication skills[13].

Fifth, the findings from the research demonstrate the importance of clearly defining learning outcomes, aligning them with the curriculum content and evaluation system, continuously improving the evaluation process, and incorporating feedback from stakeholders to revise programs. Additionally, the Kosen model's structured approach, systematic learning, and real-world practice demonstrate a successful model that can be implemented in Mongolia's educational system.

Acknowledgements

I would like to express my deepest gratitude to all those who dedicated their time, effort, and intellectual support throughout the course of this research.

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References

1. Spady, W. (1993). *Outcomes-based education.* Notes provided for an Australian Curriculum Studies Association workshop, Workshop Report No. 5.
2. Willis, S. & Kissane, B., (1995). Outcome-based education: A review of the literature. Education Department of Western Australia. https://digitised-collections.unimelb.edu.au/bitstream/handle/11343/115681/scpp-00829-wa-1993.pdf?sequence=1
3. Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking Engineering Education: The CDIO Approach* (2nd ed.). Springer.
4. UNESCO (2015). *Unleashing the Potential: Transforming Technical and Vocational Education and Training (TVET).*
5. Asian Development Bank (ADB) (2020). *Technical and Vocational Education and Training Sector Development Program: Mongolia.*
6. Ministry of Labor and Social Protection Research Institute. (2023). *Labor Demand and Supply Survey 2023*. Ulaanbaatar: MLSPRI.
7. KMTL & KOSEN Thailand. (2016). *Implementation of Introductory Engineering Education at KOSEN-KMTL in Thailand.*
8. National Institute of Technology. (2023). *QA for the MCC in National Institute of Technology – Education Activities*.
9. JICA & MCC. (2023). *MCC in KOSEN and Quality Assurance by Outcomes Based Learning*.
10. ABET. (2022). *Criteria for Accrediting Engineering Programs, 2022–2023*. Accreditation Board for Engineering and Technology. https://www.abet.org
11. Japan Accreditation Board for Engineering Education (JABEE). (2023). *Model Core Curriculum for Mechanical Engineering*. https://jabee.org
12. Washington Accord. (2021). *Graduate Attributes and Professional Competencies (Version 3)*. International Engineering Alliance. https://www.ieagreements.org
13. Mongolian University of Science and Technology. (2020). *CDIO Proceedings*. https://www.cdio.org

INTEGRATING ART AND MATHEMATICS IN STEAM EDUCATION: A CASE STUDY ON TILING FOR FEMALE STUDENTS

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In the era of Society 5.0—a future societal vision proposed by the Japanese government—there is an increasing demand for STEAM (Science, Technology, Engineering, Arts, and Mathematics) professionals capable of approaching problems from diverse perspectives and solving them creatively. Society 5.0 envisions the National Institute of Technology (KOSEN) as a hub for STEAM education for elementary and junior high school students, contributing to the development of a comprehensive educational framework.

Since 2019, we have incorporated STEAM education into the "Liberal Arts Seminar," a course for fourth-year students in the main academic program. In these seminars, faculty members from the humanities introduce topics such as mathematics, debate, and economics based on their areas of expertise. This interdisciplinary approach fosters collaborative learning among students from different departments, promoting the integration of knowledge and creativity. However, opportunities for students to apply their mathematical knowledge in real-world, socially meaningful contexts remain limited.

To address this gap, we developed teaching materials that integrate art and mathematics, aiming to promote early STEAM education and encourage students' societal engagement. These materials were implemented in a 2024 open course specifically designed for female junior high and high school students. The teaching assistants (TAs), all female students who had previously studied the relationship between art and mathematics in the Liberal Arts Seminar, played a vital role in facilitating the course.

The course targeted female students due to the low enrollment of women in science and engineering fields in Japan. By fostering interest in these subjects through art-integrated mathematical activities, we hope to encourage more female students to pursue STEM pathways.

The initiative received positive feedback from participants. Moreover, female TAs gained valuable experience applying their academic knowledge in educational settings. Since 2023, the course has explored the tiling of a plane using nets of regular polygons and polyhedra. In 2024, we enhanced the curriculum by incorporating more design elements, such as Escher's artworks and Penrose tilings, to emphasize the fusion of art and mathematics within a STEAM framework.

This paper presents the development and implementation of these teaching materials and evaluates their educational effectiveness through exercise results and pre- and post-course questionnaires.

Keywords: STEAM Education, Art and Mathematics, Tiling, Female Students, Teaching Assistants

Introduction

STEAM education, introduced by G. Yakman, is a pedagogical approach that uses Science, Technology, Engineering, Arts, and Mathematics as interdisciplinary entry points to guide students' inquiry, dialogue, and critical thinking for solving real-world problems.

We have explored mathematics education from a STEAM perspective and implemented it in various settings (e.g., Sakai & Tanaka, 2014; Kawashima, Sakai & Matsuda, 2021). In particular, we have conducted multiple open courses for junior high school students focused on mathematical concepts (e.g., Sakai & Miyaji, 2013; Sakai, Miyaji & Nakabo, 2013; Kawashima et al., 2018; Sakai, Nakamura & Miki, 2024).

Tiling has been a mathematical interest since ancient Greek times and can be observed in everyday settings such as floor tiles and wallpaper. The works of M.C. Escher, who illustrated human and animal figures in tessellated patterns, make tiling a highly visual and engaging subject. For this reason, it is particularly well-suited for STEAM education, as it bridges abstract mathematical theory with artistic creativity.

In 2023, we developed an open class that examined plane tiling and extended the discussion to spherical tiling. To engage female students, we created educational materials that emphasized symmetry, inspired by Escher's works.

The purpose of this study is to promote early STEAM education through the development and implementation of tiling-related teaching materials, and to empower students from the Liberal Arts Seminar to serve as TAs in junior high school courses.

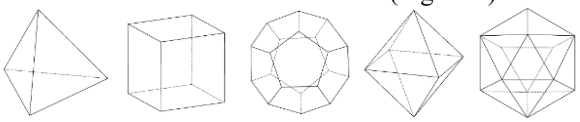
This paper is structured as follows: First, we define key concepts and theorems related to regular polyhedra, their net developments, and tilings. Next, we describe the

structure and implementation of the open course, followed by an analysis of questionnaire results. Finally, we discuss the effectiveness of the course and outline directions for future research.

Regular polyhedrons and tiling

First, we define the regular polyhedra and provide some examples.

Definition 1. Being a regular polyhedron implies that the faces are congruent regular polygons, and the same number of faces meet at each vertex (Figure 1).



[Figure 1: Examples of regular polyhedra]

Then, the regular polyhedra are known to have the following property.

Theorem 1. Only five regular polyhedral are present: tetrahedron, hexahedron, octahedron, dodecahedron, and icosahedron, as shown in Figure 1.

The all polyhedra are known to have the following property.

Theorem 2 (Euler's polyhedron theorem). Let v, e, f be the vertices, edges, and faces of the polyhedron, respectively. Then $v - e + f = 2$ holds.

Next, we define the tiling of a plane and provide some examples.

Definition 2. When a plane is filled with the same figure without gaps or overlaps, the result is called the tiling of the plane (Figure 2).



[Figure 2: examples of tiling of a plane]

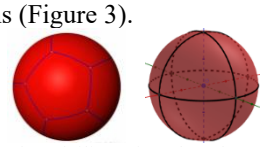
The tiling problem has been known since ancient Greek times, and it is called the "*tiling problem.*"
The tiling problem. Laying out a plane with no gaps or overlaps using several different figures is called the tiling problem.

Then, the tiling of a plane is known to have the following properties.

Theorem 3. Regular polygons that tile planes are only triangles, quadrilaterals, and hexagons.
The tiling of a sphere can be defined in the same way as tiling of a plane as follows.
Definition 3. When a sphere is filled with the same (curved) figure without gaps or overlaps, the result is called the tiling of a sphere.

The tiling of a sphere is known to have the following property.

Theorem 4. A sphere can be tiled using curved regular polygons made from each face of a regular polyhedron, namely, a sphere has five types of tiling with curved regular polygons (Figure 3).



[Figure 3: examples of tiling of a sphere by 12 curved regular pentagons and 8 curved regular triangles]

Construction of open course

In this class, we set up tiling as a theme for STEAM education that integrates art and mathematics. Through activities in which participants think about the tiling of a plane and a sphere with the support of a teacher and TAs, we aim to encourage TAs to improve their teaching skills and deepen their understanding, stimulate participants' interest in mathematics, and provide them with clues to have multifaceted ideas. The purpose of the TAs is to give back to society through the acquired mathematics ability and improve teaching skills and deepen their understanding of mathematics. The remainder of this paper is organized as follows. First, as an introduction to tiling, we introduce tiling and its history through Escher's works. After defining regular polygons, we explained what kind of regular polygons can tile a plane through exercises. Finally, after defining regular polyhedra, the tiling of a sphere using curved regular polygons made from each face of a regular polyhedron will be explained through exercises.

A questionnaire was administered before and after the class to investigate changes in participants' awareness. The flow of this class is as follows:

(Pre-questionnaire)
(1) Definition and history of tiling
(2) Tiling of a plane using regular polygon
(3) Problem exercises
(4) Tiling of a sphere using curved regular polygon
(5) Problem exercises
(6) Tiling and Symmetry
(7) Problem exercises
(Questionnaire administered afterwards)

Content of our practice

In this class, we set the tiling of a plane or a sphere using (curved) regular polygon as the theme for early STEAM education and provided an opportunity for students who have studied tiling at Liberal Arts Seminar to teach them as TAs, aiming not only to arouse participants' interest in mathematics but also to provide them with clues to have multiple perspectives. This class is organized as follows:
(a) Learning contents
Tiling of a plane or a sphere using (curved) regular polygon, and Symmetry.
(b) Construction

Date: December 7, 2024
Participants: 21 elementary school students
Leaders: Two teachers and three TAs studied tiling at a Liberal Arts Seminar.
Time: 150 (90+60) minutes

At the start of the session, a questionnaire was distributed, based on the competency framework proposed by the National Institute of Technology (KOSEN) STEAM Project Working Group. The items evaluated the following competencies:

(Problem-Solving Skills)
- When you didn't understand something, did you try to look it up by yourself?
- When you faced a problem, did you try to solve it on your own?

(Critical Thinking)
- When you encountered something you didn't understand or found strange, did you think, "Why is that?"
- When listening to your friends or teachers, did you ever think, "Why do they think that way?"

(Creativity)
- Did you enjoy coming up with fun ideas or thinking of something new?
- When doing something, did you try to add your own creative twist or personal touch?

(Flexibility)
- When plans or situations changed suddenly, were you able to stay calm and respond appropriately?
- When things didn't go as expected, did you try various approaches to solve the problem?

(Perspective-Taking)
- When a problem occurred, did you try to consider the cause and solution from a broad point of view?

(Execution Ability)
- Did you follow through with the plans you made?
- Even when things didn't go well, did you make efforts to complete the task to the end?

Through the lesson, we showed slides to the participants and provided explanations, as well as hints to help them solve the exercises. Participants took notes on their answer sheets before solving the problems while the TAs walked around and answered their questions. Through these activities, the TAs developed their abilities to teach others (Figure 4).



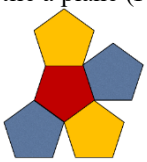
[Figure 4: the scene of open course]

In the beginning of the class, we introduced Escher's artwork and asked the participants to think about what type of figures are hidden in the paint (Figure 5).



[Figure 5: Regular Division of Plane III and IV by Escher]

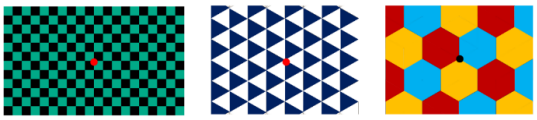
Next, we provided the definition of the tiling of a plane and its problem and property (Definition 1, tiling problem, and Theorem 2). After asking the participants if they could tile a plane with figures other than regular triangles, squares, and hexagons, we provided them an example of failure to tile a plane (Figure 6).



[Figure 6: An example of failure to tile a plane]

As one of the preparations for discussing the difference between being able to tile a plane and not, we described a pair of shapes around a vertex and their number of pieces (Figure 7).

Preparation 1. Let us consider the tiling by the following regular polygons as below. Since there are four squares around each vertex in the left figure, we denote them as (4,4). Similarly, there are six regular triangles and three regular hexagon around each vertex in the middle and the right figure, we denote them as (3,6) and (6,3), respectively (Figure 7).

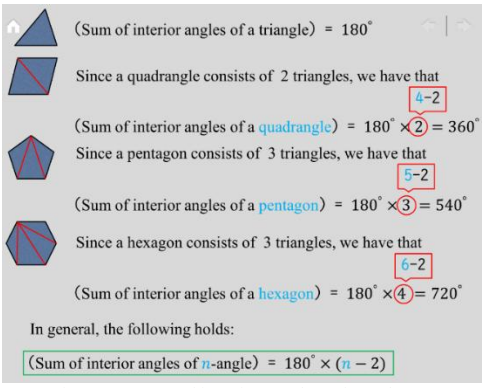


(4, 4) (3, 6) (6, 3)

[Figure 7: Examples of a pair of shapes around a vertex and their number of pieces]

In addition, as another preparation, we explained the sum of the interior angles of a polygon using the following slide (Figure 8):

Preparation 2.



[Figure 8: Sum of interior angles of a polygon]

After these preparations, we tasked the participants with the following exercises. In particular, Exercise 2 leads to the properties of regular polygons that can tile a plane.

Exercise 1. Fill in the underlined blanks below.
The sum of the interior angles of an n-angle is ___. Since all the interior angles of a regular n-angle are equal in size, the size of one interior angle is ___. Suppose that we have a plane tiled with regular n-angles. If there are p n-angles around each vertex, i.e., (n, p)-type tiling, then we have $\frac{n-2}{n} \times 180° \times p =$ ___. Dividing both of these sides by 180°, we get $\frac{n-2}{n} \times p = 2$.

Exercise 2. Fill in the underlined blanks below.
Dividing both sides of $\frac{n-2}{n} \times p = 2$ by p, we have $\frac{n-2}{n} = \frac{2}{p}$. Since left-hand side can be transformed to $\frac{n-2}{n} = \frac{n}{n} - \frac{2}{n} =$ ___, we have $1 - \frac{2}{n} = \frac{2}{p}$. This equation is transformed to obtain $1 = \frac{2}{n} + \frac{2}{p}$. Dividing both of these sides by 2, we have ___.

Exercises 2 and 3 can be summarized as follows:

Theorem 5. Suppose there is a plane tiled by regular n-angles. Let p be the number of regular n-angles around each vertex of a regular n-angle, then the equality: $\frac{1}{n} + \frac{1}{p} = \frac{1}{2}$ holds.

In Exercise 3, participants were asked to verify that tiling of a plane by squares, triangles, and hexagons satisfies the condition that obtained in Exercise 2. Moreover, they were also asked to verify that a regular pentagon does not satisfy this equality (Table 1).

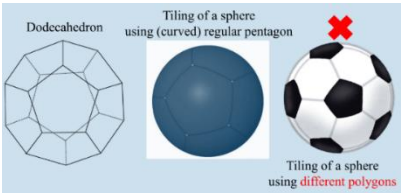
Exercise 3. Answer the following questions.
(1) Perform the calculation $\frac{1}{n} + \frac{1}{p}$ using the following table: for a regular square, a regular triangle, and a regular hexagon, where n is the number of sides of the regular polygon and p is the number of figures around the regular polygon.
(2) Consider the reason why regular pentagonal tiling is not possible.

[Table 1: Calculation of p and $\frac{1}{n} + \frac{1}{p}$]

n	p	$\frac{1}{n} + \frac{1}{p}$
3		
4		
5		
6		

Remark 1. Suppose that there is a plane tiled by regular pentagons, then the equality: $\frac{1}{5} + \frac{1}{p} = \frac{1}{2}$, namely, $p = \frac{3}{10}$ holds by Theorem 4. This is inconsistent with p being a natural number. When n is 7 or more regular polygons, substituting condition $\frac{1}{n} + \frac{1}{p} = \frac{1}{2}$, we see that the same contradiction occurs as when $n = 5$. Thus, we have Theorem 1.

Next, we explained the tiling of a sphere using the following slide as follows: If you think of a dodecahedron made of rubber, and fill it with air like a balloon, it becomes a tiling of sphere by curved regular pentagon. The soccer ball is an example of sphere tiling, but since it uses different polygons, we will not consider it in this class.



[Figure 9: Examples of tiling of a sphere and tiling of a sphere not covered in this class]

After explaining the tiling of a sphere, we asked whether there are any regular polygons, other than the (curved) regular pentagon, that can tile a sphere. Then, we introduced the regular polyhedrons called Platonic Polyhedrons and helped the participants understand that, just like in the case of the regular dodecahedron, if these polyhedrons are transformed to a sphere, each of their regular polygonal (curved) faces makes a tile of a sphere (Figure 10).

	tetrahedron	hexahedron	octahedron	dodecahedron	icosahedron
Platonic Polyhedrons					
Face of them	Regular tringle	Square	Regular tringle	Regular pentagon	Regular triangle

[Figure 10: Platonic polyhedrons and their faces]

To experience a property of polyhedrons called Euler's Polyhedron Theorem, we asked participants to calculate the number of vertices, number of edges, and number of faces of each of the following five polyhedrons, and to confirm that the alternating sum is all 2 (Figure 11).

	regular tetrahedron	Regular hexahedron	regular octahedron	regular dodecahedron	icosahedron
Regular polyhedron					
(1) Number of vertices					
(2) Number of edges					
(3) Number of edges					
(1)-(2)+(3)	2	2	2	2	2

For any polyhedron (not just regular polyhedrons), the following equality holds:
(number of vertices) - (number of edges) + (number of faces) = 2.
This is called Euler's polyhedron theorem.

[Figure 11: Euler's polyhedron theorem]

Next, the following problem was assigned to find general expressions for the number of vertices, edges, and faces of all Platonic polyhedrons.

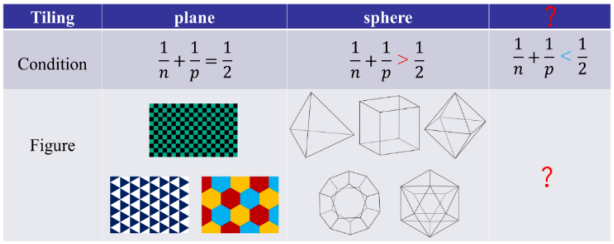
Exercise 4. Let k, n and p present the number of faces of a regular polyhedron, the number of sides of each face, and the number of faces around each vertex, respectively. Then, answer the following questions.
(1) Find n and p for all platonic polyhedrons.

(2) Represent the number of vertices and edges of all platonic polyhedrons by k, n and p, respectively.

By using Exercise 3 and Euler's polyhedron theorem, we can see that the following theorem holds.

Theorem 6. The condition for laying out a sphere with one type of (curved) regular polygon is $\frac{1}{n}+\frac{1}{p}>\frac{1}{2}$.

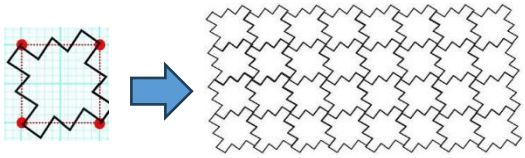
After Exercise 4, we introduced that there are only five pairs of natural numbers (n, p) satisfying $\frac{1}{n}+\frac{1}{p}>\frac{1}{2}$: (3,3), (4,3), (3,4), (5,3), (3,5). In addition, we gave the participants a summary of the class and presented one of the future tasks. In particular, I asked them what figure satisfies condition $\frac{1}{n}+\frac{1}{p}<\frac{1}{2}$, and gave them an opportunity to study tiling in the future (Figure 12).



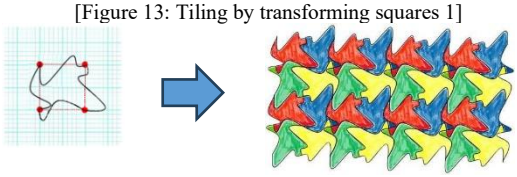
[Figure 12: Summary and future tasks]

Tiling and symmetry

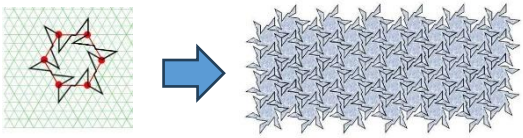
In the latter part of the class, the participants challenged themselves to tile the plane by transforming equilateral triangle, square and regular hexagon according to a certain rule (Figure 13-16).



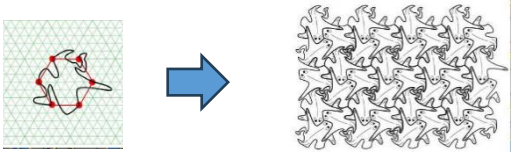
[Figure 13: Tiling by transforming squares 1]



[Figure 14: Tiling by transforming squares 2]



[Figure 15: Tiling by transforming regular hexagons 1]



[Figure 16: Tiling by transforming regular hexagons 2]

Considerations from the questionnaire results

The primary aim of this course was to deepen TAs' teaching abilities and mathematical understanding by involving them in the instruction of tiling using polyhedral developments. Simultaneously, the course aimed to cultivate participants' interest in mathematics and foster the development of multifaceted thinking.

To evaluate the effectiveness of the course, we analyzed both the accuracy of exercise responses and the results of pre- and post-course questionnaires. Each questionnaire item was scored on a 4-point Likert scale:

- **4**: Agree
- **3**: Somewhat agree
- **2**: Somewhat disagree
- **1**: Disagree

The mean scores for each competency category were calculated and compared, as shown in Table 2.

[Table 2: Average score for question item choices]

Competency	Question items	Before	After	Increase
Problem-Solving Skills	When you didn't understand something, did you try to look it up by yourself?	3.38	3.79	0.40
	When you faced a problem, did you try to solve it on your own?	3.24	3.64	0.40
Critical Thinking	When you encountered something you didn't understand or found strange, did you think, "Why is that?"	3.57	3.86	0.29
	When listening to your friends or teachers, did you ever think, "Why do they think that way?"	3.48	3.79	0.31
Creativity	Did you enjoy coming up with fun ideas or thinking of something new?	3.67	3.86	0.19
	When doing something, did you try to add your own creative twist or personal touch?	3.24	3.64	0.40
Flexibility	When plans or situations changed suddenly, were you able to stay calm and respond appropriately?	3.05	3.36	0.31
	When things didn't go as expected, did you try various approaches to solve the problem?	3.19	3.57	0.38
Perspective-Taking	When a problem occurred, did you try to consider the cause and solution from a broad point of view?	2.95	3.50	0.55
Execution Ability	Did you follow through with the plans you made?	3.05	3.43	0.38
	Even when things didn't go well, did you make efforts to complete the task to the end?	3.38	3.71	0.33

The analysis results for each competency are as follows. Problem-Solving Ability improved steadily, indicating that students became more proactive in tackling challenges independently. The activities encouraged initiative and persistence. Critical Thinking Ability showed moderate improvement. Students were already relatively strong in this area, and the workshop helped them deepen their habit of asking "why" and considering different perspectives. Creativity also saw a moderate increase. Participants enjoyed coming up with ideas and applying their own twists, showing that the environment supported imaginative thinking, though there may be room to further boost divergent thinking. Flexibility improved as students became better at adapting to unexpected changes and trying alternative approaches. The hands-on, problem-based format likely fostered this growth in resilience. Perspective-Taking showed the most significant improvement. Students learned to consider broader contexts and analyze problems from multiple viewpoints. This indicates a meaningful shift toward holistic and metacognitive thinking. Execution Ability improved as students demonstrated stronger follow-through and problem-solving persistence. They were better able to execute plans and adjust when things didn't go as expected.

The overall insights are as follows.

- The biggest growth was in *systems thinking*, suggesting that the workshop was particularly effective in helping students see the bigger picture.
- Improvements in *problem-solving* and *implementation* show strengthened self-direction and perseverance.
- While *critical thinking* and *creativity* were already relatively high, the workshop helped sustain and slightly enhance these competencies.
- The growth in *flexibility* reflects a positive impact on emotional regulation and strategic adaptability.

This competency growth profile suggests that the STEAM workshop offered a well-rounded, effective learning experience that helped students develop both cognitive and practical 21st-century skills.

Next, participants' comments were listed as evidence to verify the achievement of the objectives. The results of the comments for the participants are as follows.

- "I'm glad I was able to help and cooperate with the participants sitting nearby".
- "I found it interesting to learn why regular pentagons cannot be used for planar tiling".
- "I didn't know there was mathematics in art, so it was very intriguing".
- "It seemed simple at first, but it was actually deep, and it broadened my view of mathematics. It was a very meaningful time".
- "I was able to understand various shapes used in tiling, and regular tiling of the plane was interesting."
- "I'm glad I got to learn the characteristics of different shapes. It was the first time I realized that the planar compositions I learned in art are connected to science and mathematics".

The comments and their analyses indicate that the course has achieved some degree of success in arousing interest in mathematics. In addition, we observed the activities of the TAs and participants in class. During the exercise-solving time, we observed participants eagerly solving exercises and TAs actively approaching them and answering questions.

Conclusion of this effort and a future subject

Our goal is to "provide our students with the opportunity to teach what they have learned about tiling," and to "spark participants' interest in mathematics and give them the opportunity to gain multiple perspectives" through this course.

Comments with participants, survey responses, and observations indicated that the course is somewhat effective for learners and has potential as a STEAM resource. However, we found that the participants did not fully understand the relevance of mathematics to other fields or acquired multiple perspectives. Moreover, because the participants were interested in science, technology, and mathematics, the survey was not sufficient to determine changes in their attitudes.

In this class, we focused on tiling of a plane, but in the next class, we would like to prepare materials for proofs of tiling of a sphere and for tiling figures that satisfy condition $\frac{1}{n}+\frac{1}{p}<\frac{1}{2}$, called hyperbolic planes, which we left to the participants as a future task. The hyperbolic plane, which appeared as a plane to develop "non-Euclidean geometry," can be drawn using software called GeoGebra, and is suitable not only as a mathematics teaching material but also as a learning material for junior high school students using ICT.

Acknowledgements

The authors would like to express their gratitude to the following teaching assistants: Kokoro Kawaida, Funa Miyake and Mizuki Yoshida for their excellent contributions.

References

J. W. Collins (2003). *The Greenwood Dictionary of Education*, Greenwood Publishing Group.

K. Kawashima, M. Sakai & Y. Matsuda (2022). A practice of deep learning by geometry, *Proceedings of ISATE 2021, The 14th International Symposium on Advances in Technology Education*, 124-128.

K. Kawashima, M. Sakai & T. Tanaka (2014). An effort of mathematics teaching materials for secondary education using matrix and knot theory (in Japanese). *Gifu Educational Studies in Mathematics*, Vol. 13, 1-11.

K. Kawashima, M. Sakai, T. Tanaka & Y. Matsuda (2015). A practice of deep learning about mathematics using knot theory, *Proceedings of the 9th International Symposium on Advances in Technology Education,* 377-382.

M. Sakai, T. Miyaji & S. Nakabo (2013). A report on a mathematics open class for junior high school students at Kurume National College of Technology. *Proceedings of 7th International Symposium on Advances in Technology Education*, 241-244.

M. Sakai, S. Nakamura, H. Miki (2024). Early STEAM Education Practice: Application of Graph Theory through Teaching Assistants. *Athens Journal of Technology & Engineering 11(2),* 145-166.

M. Sakai, T. Tanaka (2025). Development and practice of mathematics teaching materials for early STEAM education of junior high school students using tiling. *Proceedings of 17th International Symposium on Advances in Technology Education*, 34-38.

G. Yakman (2008). STEAM education: An overview of creating a model of integrative education, in *Pupils' Attitudes Towards Technology (PATT-19) Conference: Research on Technology, Innovation, Design and Engineering Teaching* (Salt Lake City, UT).

STUDY OF SPACE EDUCATION ACTIVITIES AND EDUCATIONAL EVALUATION METHODS USING INTERNATIONAL COLLABORATIVE STRATOSPHERIC BALLOON EXPERIMENTS

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Mongolia spans a vast east–west distance, with its eastern regions characterized by flat terrain and sparse population. These geographical features make it particularly suitable for stratospheric balloon experiments. In addition, radio communication for academic purposes is permitted, the Mongolian aviation authorities are supportive of such activities, and the general public maintains a favorable disposition toward Japan. Leveraging these advantages, we have conducted stratospheric balloon experiments in Mongolia since 2016, in collaboration with the Institute of Engineering and Technology (IET), Mongol Koosen College of Technology (MKCT), and the Mongolian University of Science and Technology (MUST).

Building upon these efforts, we are developing space education programs in both Japan and Mongolia that incorporate stratospheric balloon experiments as core instructional tools. While multiple definitions of space education exist, we define it in this context as educational activities conducted under the theme of space exploration and technology.

In Japan, two initiatives have been jointly implemented in Ehime Prefecture since September 2022: a stratospheric balloon experiment program for university students and the "Stratospheric Balloon Koshien" competition for high school and technical college students. Furthermore, since 2023, a joint international project involving university and college of technology students from Japan and three Mongolian KOSENs—MKCT, New Mongol College of Technology (NMCT), and MUST-Kosen College of Technology (MUST-KCT)—has been in operation.

The stratosphere, the operational domain of these balloons, presents extreme environmental conditions, with atmospheric pressure reduced to approximately 0.5% of sea-level values and temperatures reaching −50°C. Designing mission equipment capable of functioning under such conditions, managing multidisciplinary project teams, and executing flight operations to successful completion parallels the challenges encountered in actual spacecraft development. As such, stratospheric balloon experiments provide significant educational value within the context of space education.

This paper presents the potential of stratospheric balloon experiments as a sustainable and scalable space education platform through international collaboration[1][2]. It also explores an approach for educational assessment using rubric-based evaluation methods.

Keywords: *Stratospheric Balloon, Space Education, Engineering Education, International Cooperation, PBL*

Introduction

When a helium-filled rubber balloon is released, it ascends continuously due to buoyant force. As it rises, the atmospheric pressure decreases, causing the balloon to expand. At an altitude of approximately 30 km, the balloon bursts due to overexpansion. The payload then descends gradually using a parachute and eventually lands on the ground. Throughout the flight, onboard cameras and electronic instruments conduct observations and experiments. This process is referred to as a stratospheric balloon experiment.

Since 2016, we have been conducting stratospheric balloon experiments in collaboration with the Mongolian University of Science and Technology and the Mongolian National College of Technology. A total of 40 experiments have been completed, all of which successfully recovered the onboard equipment. In 2019, permission was obtained from the Mongolian Civil Aviation Authority to regularly submit NOTAMs and utilize a portion of the airspace above Ulaanbaatar for balloon launches. As part of public outreach, a commemorative experiment was organized in 2019, in which three balloons were launched sequentially from Sukhbaatar Square to celebrate the 380th anniversary of Ulaanbaatar. Technical support was provided to ensure

the safe and reliable execution and retrieval of the balloons.



Figure 1. Stratospheric balloon experiment in Mongolia

Materials and Methods

Building on these achievements, we investigated the application of stratospheric balloon experiments in space education. Space education broadly encompasses two categories: one involves using knowledge, technology, and data obtained from actual space missions; the other aims to foster human resource development through simulated space experiences. This study focuses on the latter. Hybrid rockets and CanSats are frequently utilized in such educational contexts. Hybrid rockets are student-built and launched to altitudes of several kilometers, while CanSats emulate satellite behavior by collecting and processing data via sensors and controllers. These hands-on projects are designed to enhance student engagement and foster non-cognitive skills such as problem-solving, project management, and teamwork.

In Japan, student-led stratospheric balloon experiments have been conducted since approximately 2013. With the advancement and miniaturization of electronic components, such experiments have become increasingly accessible. Additionally, public interest has grown due to media exposure, encouraging student participation. However, challenges remain, including the need to navigate regulatory procedures and the absence of a shared technical knowledge base.

Japan's geographic characteristics, such as limited landmass and surrounding oceans, pose additional difficulties in recovering balloon payloads. When equipment is lost at sea, valuable data and imagery cannot be retrieved, compromising the educational value of the simulated space experience. To address this issue, we aimed to establish a structured educational framework enabling students to successfully recover payloads based on our experimental success in Mongolia.

Technical guidance was provided to students to ensure accurate prediction and retrieval of balloon payloads. We employed the Cambridge University Spaceflight Landing Predictor[3], which requires parameters such as launch coordinates, altitude, date and time, ascent rate, burst altitude, and descent speed. Balloon ascent rate, a key input, is influenced by the amount of helium injected and the payload mass. Helium volume was calculated using spreadsheets developed during previous experiments in Mongolia. As upper-atmospheric wind conditions are unpredictable beyond 180 hours in advance, trajectory predictions are subject to periodic revision based on weather updates.

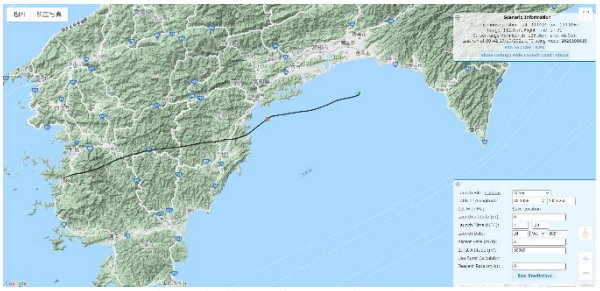


Figure 2. Stratospheric balloon flight path simulation

Reliable communication systems are essential for payload tracking and recovery. GPS devices onboard collect positional data, which is transmitted via communication modules. Past failures in student projects were often due to communication malfunctions. To mitigate this risk, students were instructed to install redundant communication systems and perform environmental and performance tests, including low-temperature, long-range, and endurance tests on the ground.

Following technical instruction, three stratospheric balloon experiments were conducted in Japan in 2021: in Kuroshio Town (Kochi Prefecture), Itoshima City (Fukuoka Prefecture), and Uwajima City (Ehime Prefecture). All payloads were successfully recovered. For the Fukuoka mission, the balloon was launched 10 km offshore from Itoshima City based on trajectory predictions to capture stratospheric images.

To facilitate ongoing experimentation, a permanent balloon environment was established near Uwajima City and Ainan Town. Beginning in 2022, two educational initiatives are held annually: the Stratospheric Balloon Joint Experiments for university students and Stratospheric Balloon Koshien for high school and technical college students. These initiatives enable participants to engage in comprehensive or introductory-level balloon activities, respectively.

Joint experiments are a collaborative model used in other space education contexts. They allow teams with limited resources to conduct experiments in cooperation with other organizations. This model helps students develop essential collaborative skills such as coordination, negotiation, and project management. In the joint stratospheric balloon experiment, university students are responsible for all aspects, including equipment development, gas injection, flight operations, tracking, recovery, and coordination with authorities and local communities.

Balloon Koshien provides an introductory experience with minimal restrictions, encouraging creativity in payload design. Participants are only required to develop their observation equipment. After the experiment, each participant evaluates and reports on their mission, with assessments conducted by an external jury.



Figure 3. Stratospheric balloon experiment at sea in Itoshima City, Fukuoka Prefecture

To ensure experiment safety, a panel of experts was established, including engineers from JAXA and private balloon companies. Participating teams must undergo a third-party safety review before conducting experiments. The review process includes ICAO-compliant airspace regulations[4], parachute drop tests, buoyancy checks, communication and long-run tests, and confirmation of the actual flight hardware at the site. This framework mirrors that of hybrid rocket launch safety reviews.

Based on the results from Japan, a joint project was launched involving Japanese and Mongolian students. Participants included teams from Japanese universities and Mongolian KOSENs such as Mongol Koosen College of Technology (MKCT), New Mongol College of Technology (NMCT), and MUST-Kosen College of Technology (MUST-KCT). Annual joint experiments have been held since 2023, following preparatory lectures delivered at each Mongolian KOSENs. After the project team was established, students in Japan and Mongolia shared information using online tools and held regular online meetings to prepare for the experiments.



Figure 4. Preparation work for stratospheric balloon experiment in Mongolia

Japanese university students led the overall project, including equipment development and flight path prediction. Technical college students from both countries contributed to payload development. Assigning clear roles within international project teams helped facilitate successful implementation and enhanced educational impact.

Post-experiment debriefings were held in Ulaanbaatar, where teams presented their findings and engaged in discussions. These sessions were conducted as part of the International Space Balloon Summit[6] organized by MARSA[5] and were attended by students, industry stakeholders, and government representatives, including officials from the Mongolian Civil Aviation Authority.



Figure 4. Japan-Mongolia Stratospheric Balloon Joint Experiment



Figure 5. Japan-Mongolia Stratospheric Balloon Joint Experiment Results Debriefing

To evaluate the educational methodology based on a series of stratospheric balloon experiments, we conducted a structured analysis of the competencies that students are expected to acquire through participation in such projects. Five core competency domains were defined as the learning objectives of the program. For each domain, detailed evaluation criteria were established as follows:

A) Ability to independently design a mission utilizing a stratospheric balloon
1. Setting and defining mission objectives
2. Identifying technical or societal challenges
3. Formulating specific mission goals and deliverables
4. Assessing feasibility in terms of technical, financial, and temporal constraints

B) Ability to explain the processes and requirements necessary for conducting a stratospheric balloon experiment
1. Understanding and articulating the experimental workflow
2. Identifying required resources, equipment, and personnel
3. Developing an appropriate schedule for implementation

C) Ability to solve complex problems through project management in stratospheric balloon experiments
1. Monitoring project progress and making necessary adjustments
2. Prioritizing tasks and allocating resources accordingly

D) Ability to work collaboratively and harmoniously with diverse individuals through international and domestic project participation
1. Understanding and adapting to different cultures
2. Building constructive relationships with team members

E) Ability to transfer knowledge and lessons learned from the stratospheric balloon experiment to future generations
1. Organizing and reproducing knowledge for dissemination
2. Providing constructive feedback and proposing areas for improvement

In addition, a rubric was created for the achievement level of each detailed evaluation item with a 5-point scale (5 being the highest and 1 being the lowest), and the students were asked to self-evaluate before and after the experiment was conducted.

Results and Discussion

A rubric evaluation was conducted on a trial basis during the Japan-Mongolia stratospheric balloon joint experiment in March 2025. The results are shown below.

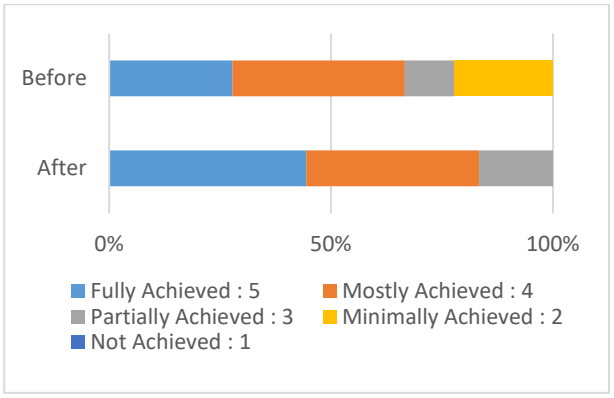


Figure 6. Pre-post evaluation of rubric assessment item A)-1

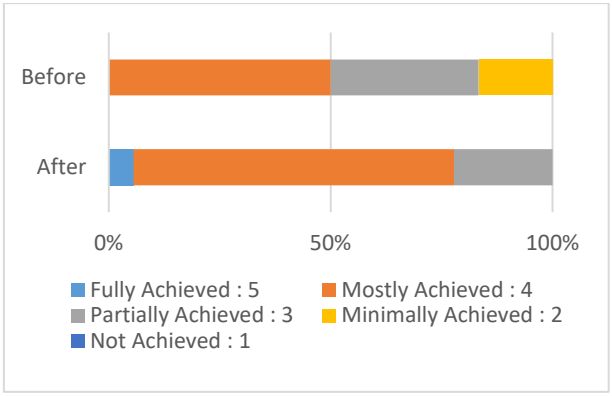


Figure 7. Pre-post evaluation of rubric assessment item A)-2

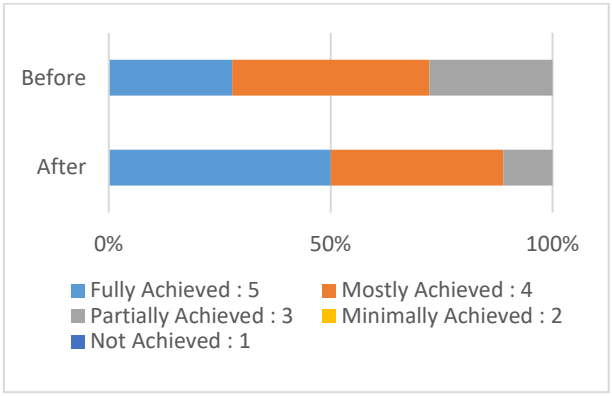


Figure 8. Pre-post evaluation of rubric assessment item A)-3

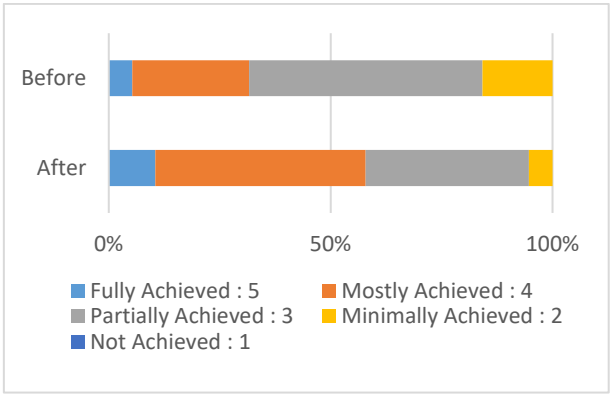


Figure 9. Pre-post evaluation of rubric assessment item A)-4

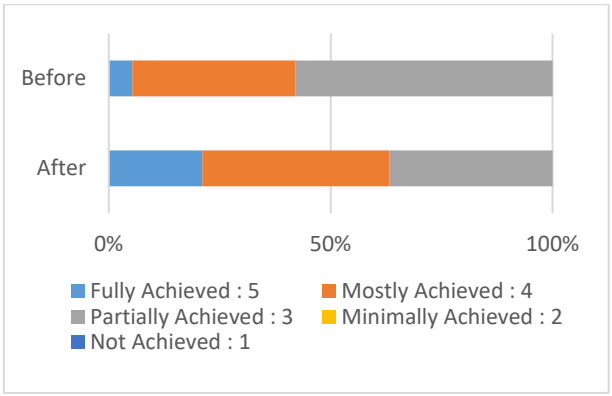


Figure 10. Pre-post evaluation of rubric assessment item B)-1

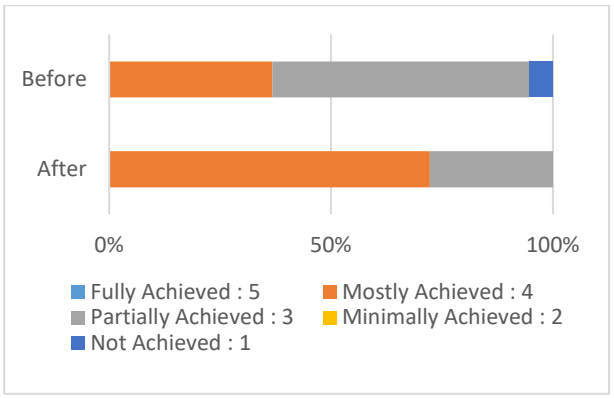


Figure 11. Pre-post evaluation of rubric assessment item B)-2

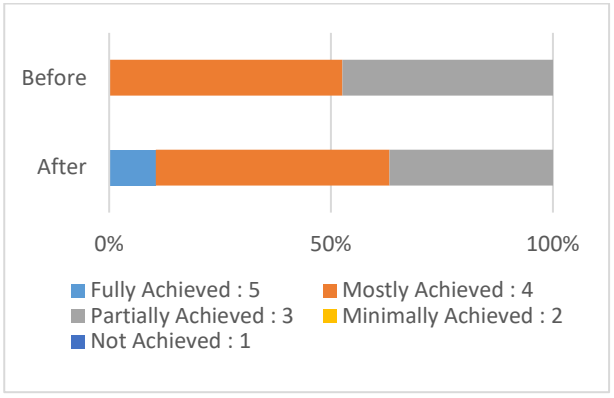


Figure 12. Pre-post evaluation of rubric assessment item B)-3

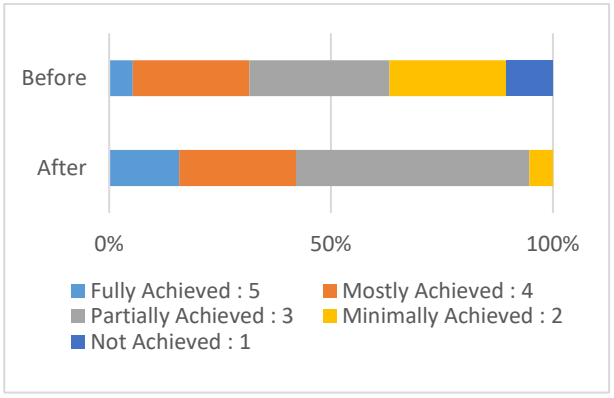


Figure 13. Pre-post evaluation of rubric assessment item C)-1

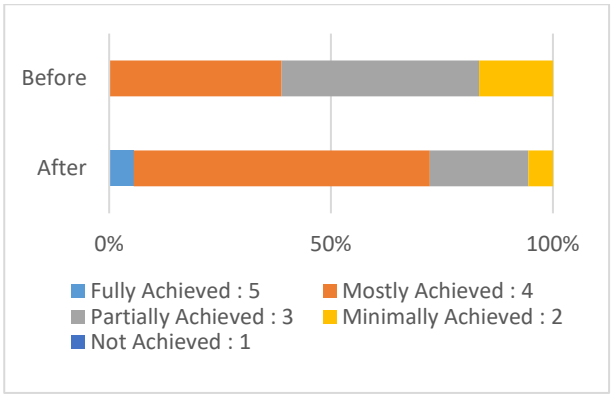


Figure 14. Pre-post evaluation of rubric assessment item C)-2

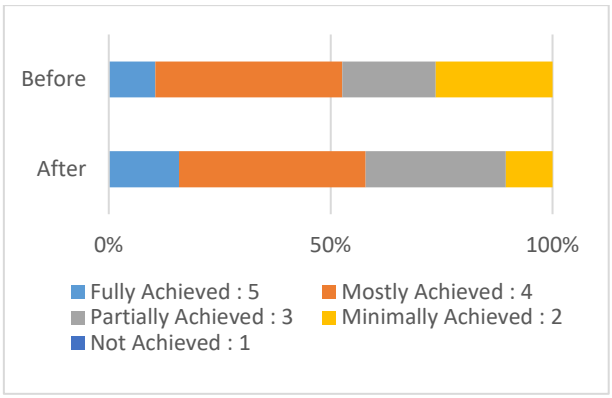


Figure 15. Pre-post evaluation of rubric assessment item D)-1

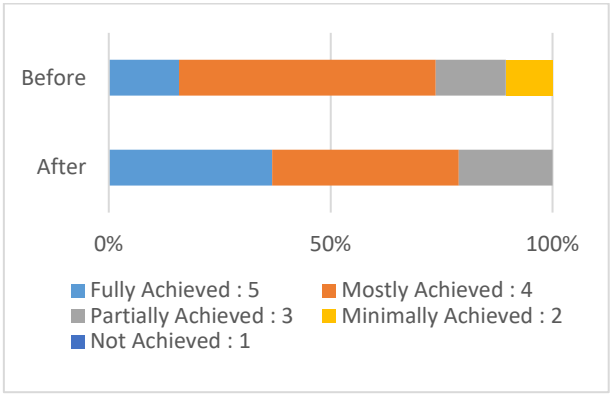


Figure 16. Pre-post evaluation of rubric assessment item D)-2

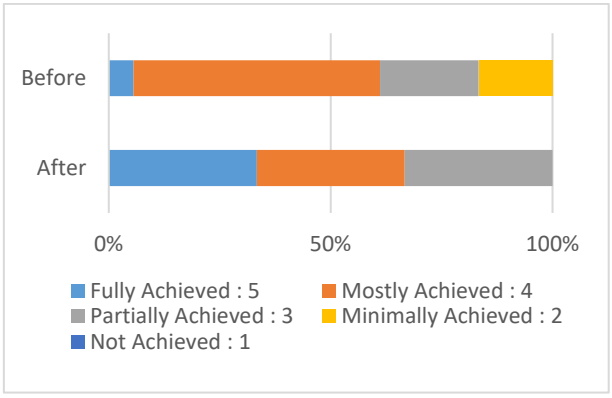


Figure 17. Pre-post evaluation of rubric assessment item E)-1

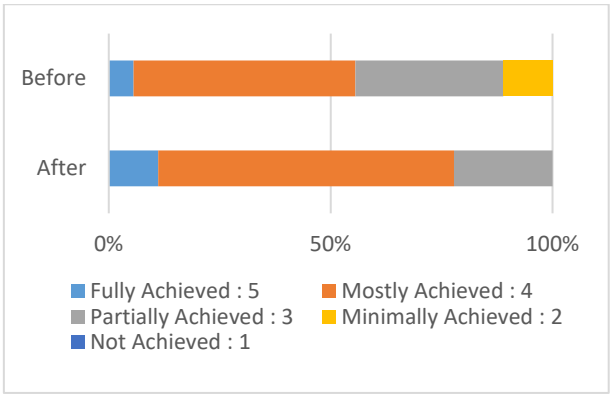


Figure 18. Pre-post evaluation of rubric assessment item E)-2

The following table shows the change in average scores and the difference in each detailed evaluation item assessed before and after the experiment. There were 18 participants in this project. Furthermore, a t-test was conducted with a significance level of 0.05, and it was confirmed that all items showed significant differences. Additionally, the results of the effect size calculation using Hedges' g are also included.

Table 1. Changes in mean scores in rubric evaluation before and after stratospheric balloon experiment

Item	Before / After	Avg.	Diff.	p-value	g
A)-1	Before	3.72	0.56	<0.05	0.67
	After	4.28			
A)-2	Before	3.33	0.50	<0.05	0.67
	After	3.83			
A)-3	Before	4.00	0.39	<0.05	0.74
	After	4.39			
A)-4	Before	3.17	0.50	<0.05	**0.92**
	After	3.67			
B)-1	Before	3.50	0.33	<0.05	0.65
	After	3.83			
B)-2	Before	3.17	0.56	<0.05	**1.03**
	After	3.72			
B)-3	Before	3.44	0.39	<0.05	0.74
	After	3.83			
C)-1	Before	2.94	0.61	<0.05	**0.96**
	After	3.56			
C)-2	Before	3.22	0.50	<0.05	0.67
	After	3.72			
D)-1	Before	3.33	0.44	<0.05	**0.83**
	After	3.78			
D)-2	Before	3.89	0.33	<0.05	0.65
	After	4.22			
E)-1	Before	3.50	0.50	<0.05	**0.92**
	After	4.00			
E)-2	Before	3.50	0.39	<0.05	0.61
	After	3.89			

Conclusions

Based on t-tests of the rubric evaluation, we conclude that the program is effectively meeting our expectations. Additionally, we assessed the effect sizes using Hedges' g and identified several items with 'large effects' ($g \geq 0.8$). The educational effects of the program on five items, A)-4, B)-2, C)-1, D)-1, and E)-1, are significant. In particular, “C)-1: Monitoring project progress and making necessary adjustments” is a skill that can only be developed through such project activities. “E)-1: Understanding and adapting to different cultures” is an ability that could only have been developed through this project, which was conducted jointly by Japanese and Mongolian students. These are the educational effects we expected. In the future, we would like to continuously measure the educational effects by further subdividing the evaluation items of this rubric and scrutinizing them.

On the other hand, there are several problems with this initiative. The transfer of skills and know-how among the participating students of different ages is often not smooth. This is a problem unique to student project activities in which the students' grades increase as they get older. It is necessary to take countermeasures such as consolidating technology and know-how across participating organizations, handing over the technology and know-how among the different age groups, and holding regular technical seminars.

Regarding experiments in Mongolia, the “language barrier” between Japanese and Mongolian students hinders smooth communication. Both students often communicate in English, which is not their native language, but they are often unable to understand each other in terms of detailed differences in nuances. This may cause serious accidents in emergency situations during experiments, and immediate action is needed. It is necessary to prepare manuals in Japanese, English, and Mongolian on how to operate equipment, procedures, emergency response methods, evacuation routes, etc., during experiments, to ensure a common understanding.

While solving these issues, we would like to continue space education activities using stratospheric balloon experiments in Japan and Mongolia, and evaluate the effectiveness of the education using rubric evaluation.

Acknowledgements

We would like to thank Ehime Prefecture, Ainan Town, Uwajima City, and all the people involved for supporting stratospheric balloon experiments in Japan.

We thank Mongol Koosen College of Technology (MKCT), New Mongol College of Technology (NMCT), and MUST-Kosen College of Technology (MUST-KCT), Mongolian Government, Mongolian Civil Aviation Authority, MARSA and all the people concerned for supporting the stratospheric balloon experiment in Mongolia.

References

[1] K. Maeda, H. Akiyama, Y. Murakami and O. Okudaira (2024) Space education activities using stratospheric balloon experiments in Japan and Mongolia, *The 68th Space Sciences and Technology Conference*

[2] K. Maeda, H. Akiyama, O. Okudaira, Y. Murakami and M. Wakabayashi (2023) Space education activities using stratospheric balloon experiments in Japan and Mongolia, *Balloon Symposium: 2023 JAXA/ISAS*

[3] CUSF Landing Predictor 2.5
http://predict.habhub.org/

[4] ICAO Rules of the Air
https://www.icao.int/Meetings/anconf12/Document%20Archive/an02_cons%5B1%5D.pdf

[5] MARSA https://www.mars-v.com/

[6] International Space Balloon Summit 2024
https://www.facebook.com/events/437247935496014

KOSEN Global Camp: Opportunities and Challenges for Global Education

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Japan's National Institute of Technology (KOSEN) has recently emphasized the development of global engineers capable of competing in the modern era. The KOSEN global camp was introduced as a key short-term program to promote the exchange of knowledge and skills with international counterparts. This study presents the outcomes of the current format, with a particular focus on the 2025-Tomakomai KOSEN Global Camp. The evaluated learning components include: English proficiency; teamwork; leadership; and cultural mindset. Evaluation was conducted through self-evaluation questionnaires administered before and after the camp.

Keywords: *KOSEN, Global Camp, English, Learning tool*

Introduction

Global education has emerged as critical path for preparing individuals to compete and collaborate in an increasingly interconnected and diverse world. It encompasses the development and application of knowledge, skills, attitudes, and values that empower learners to understand and propose solutions to global issues, and act responsibly as global citizens.[1]

Global competency can be defined as a set of abilities that includes at least three key components: 1. A positive disposition toward cultural difference; 2. The ability to speak another language; and 3. Deep knowledge and understanding of global issues.[2] A positive disposition involves an appreciation of cultural diversity and a commitment to act with fairness and respect for human rights. The ability to speak, think, and communicate in a language other than the dominant language of one's home country can expand one's global perspective. Furthermore, deep knowledge of subjects such as world history and economics enhances critical thinking and helps individuals better understand current global challenges.

Japan's National Institute of Technology (KOSEN) launched a new program in 2023 aiming to bring internationalization to the students from the 51 KOSEN colleges nationwide at their Campus. KOSEN Global Camp is a short period, usually over a week, English taught program hosted at one of the Kosen schools. This program aims to provide the students an opportunity for working together with international students in a group to become highly skilled engineers. Since its introduction on 2023, the program has been conducted at different KOSEN campuses with a variety of topics and different guest counterpart countries. Although the outcomes have been annually evaluated, the outcomes mostly remain for internal revision.

In this study, I have conducted an evaluation of the current stage, outcomes, and points that require attention for further improvement of the program. The results are taken from the 2025-Tomakomai KOSEN global camp, conducted on February-March 2025 at Tomakomai College. This study mainly focuses on the evaluation of participant's improvement on the following components: English proficiency, teamwork, leadership, and cultural mindset (Figure 1). The evaluation format was through self-evaluation questionnaires conducted at the beginning and at the end of the program.

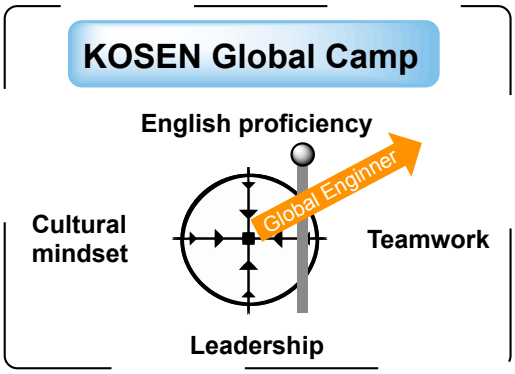


Figure 1: Evaluated components from the 2025-Tomakomai KOSEN global camp.

Program Description

The 2025-Tomakomai KOSEN global camp adopted the following title for the program: "Learning Manufacturing and Management with a Multinational Team of Kosen students from Mongolia, Thailand, and Japan". The program comprised two primary projects:

Manufacturing practice and Management practice (Figure 2).

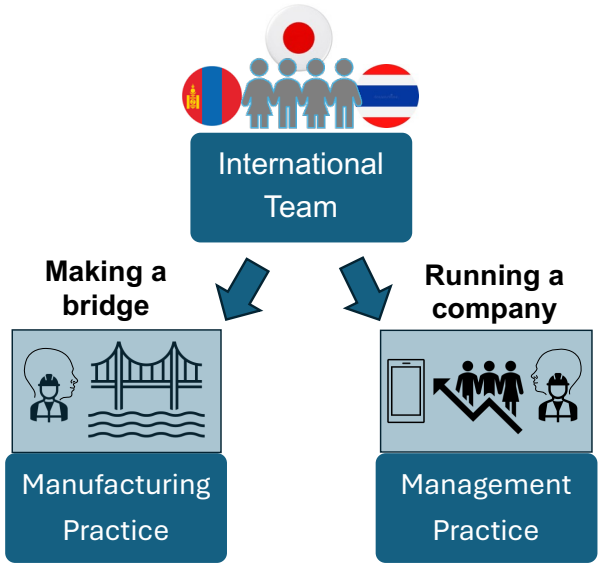
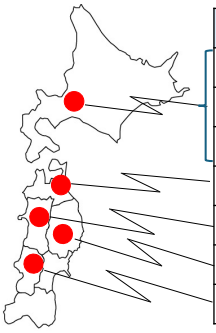


Figure 2: The 2025-Tomakomai KOSEN global camp project.

Participants. The selection of Japanese participants was limited to Kosen students from the Hokkaido-Tohoku region, Block 1 (Figure 3). A total of 11 students -7 males and 4 females- were selected through a lottery system. Participants were enrolled in the regular KOSEN program, ranging from first- to fifth-year students. Despite the proximity of dates with other Kosen Global programs scheduled in February-March 2025, Tomakomai Kosen received a high number of applications, with some applicants ultimately not selected. International participants from Thailand Kosen and Mongolia Kosen were nominated by their respective school administrators. There were 5 students from Mongolia and 6 from Thailand, making a total of 11 international students.



Kosen	Students	Grade
Tomakomai	5 (1)	1-2
Asahikawa	1 (1)	2
Hakodate	1 (1)	2
Hachinohe	1 (0)	3
Akita	1 (0)	4
Ichinoseki	1 (1)	5
Tsurugaoka	1 (0)	3

Figure 3: Number and affiliation of Japanese participants. Parenthesis numbers are for female students.

Program. An integral and well-rounded 8-days program was organized to provide both Japanese and international students the opportunity to develop technical and entrepreneur skills while learning about culture and traditions from all the participants. All the event was conducted in English as the common language. Detailed description of the contents is provided on Table 1. The participants were conveniently accommodated at the same hotel in downtown Tomakomai, and a shuttle bus was provided to transport them between the hotel, the campus, and other destinations.

Table 1: Program details.

Date	Activity	Place
Day 0. Feb. 4	Pre-camp guidance	Online
Day 1. Feb. 22	Overseas-Tomakomai travel	
Day 2. Feb. 23	AM: Orientation PM: Visit to ESCON Field	Campus Kitahiroshima
Day 3. Feb. 24	AM: Manufacturing practice PM: Innovation base (iBase)	Campus Campus
Day 4. Feb. 25	AM: Manufacturing practice PM: Management practice	Campus Campus
Day 5. Feb. 26	AM: Visit Toyota Motor PM: Visit Upopoy	Tomakomai Shiraoi
Day 6. Feb. 27	Management practice	Campus
Day 7. Feb. 28	AM: Results presentation (poster) PM: Closing event & Farewell Party	Campus
Day 8. Mar. 1	Departure from Tomakomai	

Methods

Questionnaire. The evaluation methodology was based on the application of a questionnaire at the beginning and at the end of the camp. Questions were carefully designed to quantitively or quasi-quantitively reveal the learning improvement. The evaluation was conducted electronically (survey platform), and it was done by a self-evaluation format. Multiple-choice questions with five rating options, were divided into four main different subjects: English proficiency, Teamwork ability, Leadership ability, and Cultural mindset (Table 2). To assess improvement in English ability, the questionnaire included items on reading, listening, and speaking skills. The average of these components was combined into a single overall score.

Table 2: Utilized questions in the survey.

Subject	Questions
English ability	1. How would you rate your reading ability of basic sentences in English? 2. How would you rate your ability in conversations about daily things in English? 3. How would you rate your listening ability in a conversation with a friend in English? 4. How would you rate your skills in presentations in English (ppt or poster)?
Team-work ability	How would you rate your team-work ability?
Leadership ability	As a leader, how would you rate yourself on a scale 6-10?
Cultural mindset	Awareness about cultural mindset

Results and Discussion

The results from the questionnaires showed an intriguing improvement in all the four subjects evaluated for both Japanese and international students. For Japanese students, there was a notably improvement delivering a combined 10% increase value. Among those subjects, teamwork (increase 10.8), leadership (increase 10.5), and English proficiency (increase 10.4) showed the highest improvement. Japanese students were making use of English language to help coordinating activities and explaining details from the assigned activities, hence somehow forcing the Japanese students to make use of their skills (Figure 4, top). Leadership improvement was particularly remarkable, especially considering that Japanese students are generally known to take a passive role in learning and team-based activities. I believe that the success in enhancing leadership skills may be attributed to the thoughtful arrangement of the program components. The program was structured progressively, starting with cultural exchange, followed by manufacturing practice and management activities, and concluding with a poster presentation session. Japanese students became increasingly comfortable after guiding international students at local facilities. Steady improvement was observed throughout the 7-day period.

International students, on the other hand, showed a slightly improvement with a combined 3.5% increase value. Teamwork (increase 4.5) ranked highest, while cultural mindset (increase 1.1) was the subject with lowest improvement (Figure 4, bottom). Thailand and Mongolian are geographically, and historically, more exposed to cultural exchange, therefore participating in the global camp showed little improvement in this subject.

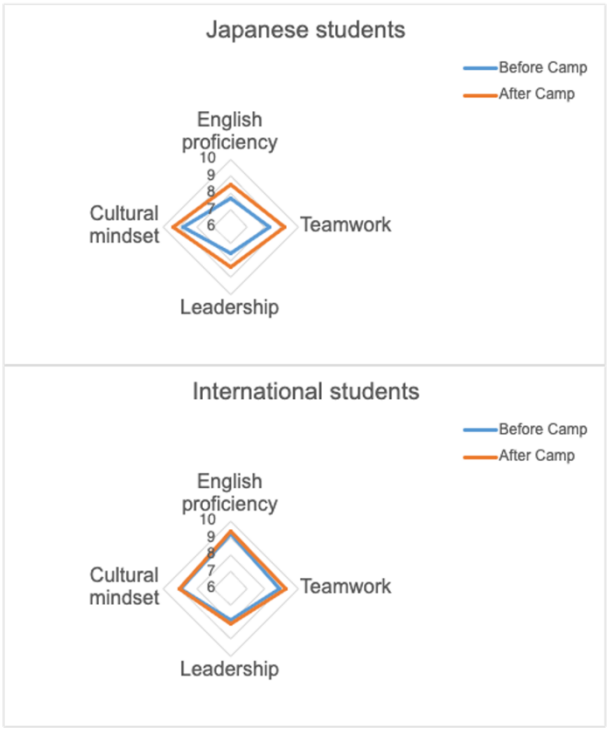


Figure 4: Comparative improvement performance between Japanese students (top) and international students (bottom).

Results from the current format of the program showed indeed a very positive impact on improvement of the participants. However, there are still some aspects that require attention to further optimize the program. Enlisted below are some points I have encountered relevant.

- Japanese students low English proficiency
- Tight schedule
- Poor understanding of entrepreneurial practices

Japanese students were committed to the entire program; however, there were clear limitations in their communication with international students. At Tomakomai College, we are currently considering incorporating English practice into a pre-camp course. Programs such as DMM English conversation platform are being considered as potential options for this purpose.

We also conducted a post-camp questionnaire to evaluate the overall program. While the feedback was generally positive, some participants suggested that although they enjoyed the program, they felt somewhat exhausted and wished for a designated “free time” section on the program.

A particular observation from the Tomakomai Global camp was the difficulty participants faced in following the section of entrepreneurial practices, which is not a common topic for all the Kosen students. It is therefore recommended to offer a pre-camp training on this subject to support better understanding.

Conclusions

The KOSEN global Camp has established a distinctive platform that facilitates the development of student's technical expertise, the enhancement of global competencies, and the formation of international academic and professional networks. The program provides participants with a valuable opportunity to engage in short-term collaborative projects and intercultural exchange. Findings from this study indicate a marked improvement among Japanese students, particularly in areas such as English communication profieciency, leadership, teamwork, and intercultural awareness, competencies that are essential for enginners in an increasingly globalized professional landscape.

The current format of the program provides Japanese students with valuable exposure to international experiences. However, limited English proficiency remains a significant barrier. Integrating the KOSEN Global Camp with a pre-camp English conversation course could help further enhance the program's effectiveness.

Acknowledgements

I would like to express my deep gratitude to the colleagues and administrative staff who collaborate during the program, including all the preparations for the event.

References

1. Reimers, F. M. (2020). *Educating Students to Improve the World.* Springer Briefs in Education.
2. Reimers, F. M. (2010). *Educating for Global Competency.* In Cohen, J. E., & Malin, M. B. (Eds), International Perspectives on the Goals of Universal Basic and Secondary Education. New York: Routledge.

Attempt to establish a credit transfer system between Turku University of Applied Sciences and National Institute of Technology (KOSEN), Nagaoka College.

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Based on the agreement established in 2020 between the National Institute of Technology, Nagaoka College (Nagaoka KOSEN), and Turku University of Applied Sciences (TUAS), a collaborative program began in 2023 after a delay caused by the global COVID-19 pandemic. This program, aimed at enhancing the advanced courses of Nagaoka KOSEN, allows KOSEN students to earn a degree from TUAS, while TUAS students can complete 60 ECTS credits at KOSEN. Three students from TUAS were taken the classes of our Nagaoka Kosen and did research work in laboratories during the stay in Nagaoka Kosen. TUAS students also took regular examinations of Nagaoka Kosen and got the Kosen credits. To transfer the Japanese Kosen credits to European ECTS credits, we have used the idea how many hours students must study for one ECTS and how many hours students must study for one credit of Nagaoka Kosen. Students from TUAS have also done research as well as the group work project together with our Kosen students. Such collaborative group works as well as research projects have promoted the global minds toward our students of Nagaoka Kosen.

In September 2024, two students from Nagaoka Kosen started the degree program of TUAS. Students of Nagaoka Kosen mainly study the subjects about business, marketing and the basics of the finance. Nagaoka students debate with TUAS students in the class. By experiencing and studying these subjects in TUAS, they will cultivate entrepreneurship and the skill of debating using English. The present attempts to establish a credit transfer system between TUAS and Nagaoka Kosen are our first attempts to exchange the credits to the partner institute abroad. We will discuss on the educational benefits and some issues to be solved for the present program.

Keywords: *credit transfer, student exchange program, degree, business and marketing, entrepreneurship*

Introduction

Recently, Japanese universities and colleges are focusing and developing on the student exchange program abroad. Some of the Kosens also developed the student exchange programs between the institutes abroad. [1), 2)] Our Kosen, Nagaoka College, has also made efforts to increase the number of the partner institutions abroad to promote the student exchange programs.[3)] However, the main program of these student exchange programs are mainly joint collaborations of the group works such as the building the circuits, programming and debating with the recent international topics between the students of partner institutions. Some of the Kosens reached the agreement of the student exchange program with research collaborations. Further advanced attempts are now underway for developing the content of the student exchange program of Kosen.

Dual degree, joint degree and double degree program became popular between universities. Double degree program between European and Japanese universities have been also reported.[4)] Since degree of Kosen is conferred by the National Institute of Academic Degrees and Quality Enhancement of Higher Education, such degree program between universities abroad is difficult. However, if Japanese Kosen students can experience and attend the classes of the partner institutions of Kosens abroad, it will be good program for our Nagaoka Kosen students. For such motivation, we have established the Kosen version agreement of “double degree program” between Turk University of Applied Sciences (TUAS) and Nagaoka College (Nagaoka Kosen) in 2020.[5)] The present paper is the series of the reports on the establishment of the collaborative credit transfer system between Turk University of Applies Science and Nagaoka Kosen. We will report our attempts and the recent progresses on the achievements for the credit transfer system between the international partners of Nagaoka Kosen abroad.

Acceptance of TUAS Students in Nagaoka Kosen

To transfer the credits from our Kosen to TUAS, we should first understand the different credit system between Japanese Kosen and European university. In Europe, ECTS (European Credit Transfer and Accumulation System) is commonly used since 1990 to increase student exchange between European countries. 1 ECTS is based on the 27 hours' study. On the other hand, credit system of Kosen is a mixture of two different credit systems ("Risyu Credit System, which is nearly equivalent to the high school credit": 1 credit = 30 hours' study, and "Gakusyu Credit System, which is equivalent to the university credit": 1 credit = 45 hours' study). We have used these hours of study for the basis of transferring the Japanese Kosen credits such as "Risyu" credits and "Gakusyu" credits to the TUAS credit (ECTS). We have also incorporated the basic subjects of Nagaoka Kosen to the credits of TUAS. For such incorporations of the subjects taken in Nagaoka Kosen, students of TUAS who stayed one year at Nagaoka Kosen from autumn semester of 2023 to spring semester of 2024 can earn 60 ECTS toward the degree after they go back to TUAS. Table 1 is an example of the timetable TUAS students during the stay in Nagaoka Kosen.

Table 1. Example of the timetable of TUAS student.

開講学期 Semester	曜日・時限 Day and Period(s)	授業科目 Subject	ECTS	単位 Credits	担当教員 Instructor
2023 3rd and 4th	Tuesday 12:50-14:20	Electronic Devices（電子デバイス）	3	2	Prof. Shimamune
2023 3rd and 4th	Tuesday 14:30-16:00	Study of Self-Development Subject（自己啓発型課題学修）	1.05	1	Prof.Iyama, Prof. Toyama
2023 3rd and 4th	Friday 14:30-16:00	English IV （英語IV）	3	2	Prof. Tania, Prof. Thanet
2023 4th	Monday 12:50-16:00	Global debate （グローバルディベート）	3	2	Prof. Toyama, Prof. Narata, Prof.Tania
2023 4th	Tuesday 8:40-10:10 Thursday 8:40-10:10	Physical properties of electronic materials(電子物性工学)	3	2	Prof. Shimamune
2023 3rd and 4th		Thesis work Ⅰ（電子機械システム工学特別研究Ⅰ）	6	4	Prof. Ikeda
2023 3rd and 4th		Thesis work Ⅱ（電子機械システム工学特別研究Ⅱ）	15	10	Prof. Ikeda
2024 1st and 2nd	火1・2限	Electrical materials Ⅰ（電気電子材料Ⅰ）	3	2	Prof. Shimamune
2024 1st and 2nd	木3・4限	Information processing Ⅱ（情報処理Ⅱ (C15)）	3	2	Prof. Yamamoto
2024 1st and 2nd	火3・4限	Mechanical Design and Engineering（機械設計学）	3	2	Prof. Kaneko
2024 1st and 2nd	水1・2限	English VC（英語VC）	3	2	Prof. Ichimura
2024 2nd	月5～8限、水5～8限	Advanced Seminars（専攻科ゼミナール）	3	2	Prof. Ikeda
2024 1st and 2nd	火7・8限	Health, Physical Education（保健・体育）	1.05	1	Prof. Eda, Prof. Ichikawa, Prof. Kiryu

Students of TUAS attended the classes of Nagaoka Kosen during the program. Although students of TUAS attended the class of Nagaoka Kosen had difficulties in listening the class and reading Japanese textbooks, students of TUAS had finally passed the exams by the helps of the translation of the class materials to English or black board writing in English by the teachers. For the class of the collaborative group work, there were fewer problems. Students from TUAS were joined to the group of the Kosen students and made discussions about the project.



Figure 1. Example of the class (collaborative group work)

Figure 1 is one of the pictures that the three TUAS students collaborated with Kosen Students together. The TUAS students have also performed the research work by belonging one of the laboratories of Nagaoka Kosen. They wrote the thesis for the research work done in Nagaoka Kosen and the presentation of the research work was also performed in front of the Japanese Kosen students in English. This might be good experiences for the students at Nagaoka Kosen to be exposed in debates on the research work in English between TUAS student and teachers in Nagaoka Kosen.



Figure 2. Presentation of the research work in front of Kosen students.

For the life in the laboratory, they spend the time with the students in the laboratory of Nagaoka Kosen. One of the TUAS students went to the Japanese conference for the discussion of the research work together with our students. Figure 3 is the picture of the farewell parties for TUAS students. They finally got the credits of Nagaoka Kosen. TUAS students has gone back to TUAS and with our credits of Nagaoka Kosen in 2024, they will be awarded the degree of TUAS for the first time.

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Figure 3. Picture of the farewell party for TUAS students with students of the laboratory members of Nagaoka Kosen.

Sending of Nagaoka Students to TUAS

In recent years, the importance of entrepreneurial education in higher educational institution is growing. Since the Turk University of applied science is known as one of the advanced institutes that educate both of the technology and entrepreneurship together.[6] For the

students of Nagaoka Kosen, it is the very good opportunities to study in the class of TUAS using the present credit transfer systems. For such purposes, our Nagaoka students went to TUAS in autumn 2024 and now they are studying at the faculty of Industrial Management and Engineering to get the bachelor's degree of TUAS. To get the degree, they have to accomplish one-year (2 semesters) classes from the autumn 2024 to spring 2025. The credit transfer from Nagaoka Kosen ("Risyu" high-school credit and "Gakusyu" university credits) to TUAS (European Credit Transfer and Accumulation System (ECTS) credits) will be also carried out for our Nagaoka students to get the degree of TUAS. The credits of thesis research work of Nagaoka Kosen are also be transferred to those of TUAS project work, which is included in the agreements for the double-degree program between Nagaoka students and TUAS students. Since 240 ECTS in total is the requirement of the degree in TUAS, credit transfer from Nagaoka Kosen to TUAS was included in the agreement. Below are the details of the agreements for our Nagaoka Kosen students to take a degree of TUAS.

Degree and degree Programme at TUAS:
Bachelor of Engineering in Industrial Management and Engineering.

The students must have completed 240 ECTS in total to be eligible for the degree, which consists of

1) Minimum 135 ECTS credits at Nagaoka KOSEN
2) Minimum 60 ECTS credits at TUAS courses
3) 30 ECTS practical training
4) 15 ECTS Thesis final project at Nagaoka KOSEN and a written summary in English to TUAS. Supervisors will be from both institutes.

Figure 4 is the class of TUAS that teaches the business communications. The student from Nagaoka Kosen learn how to communicate to the customers with practical training. Students who attend this class is planned to participate in a business contest in Finland.

Figure 5 is the picture of the class of TUAS, which debates about the differences of the environmental issues between Japan and Germany. Students of Nagaoka Kosen learned the differences of the environmental problems between Japan and Germany in the class.



Figure 4. Example of the class (business



Figure 5. Example of the class (Environment and business).

Figure 6 is the picture of the class, which teaches about the business based on the theories. The teacher in Figure 6 had the experiences at the company and he talks about his experiences about the business at the company.



Figure 6. Example of the class (Business).

The students who now study TUAS will be back in the spring 2025 and start the final thesis works at Nagaoka Kosen again and the credits of the final thesis in Nagaoka Kosen will be transferred to TUAS and use as the ECTS credits of TUAS for the bachelor's degree of TUAS. Therefore, the bachelor's degree of TUAS will be awarded to the Nagaoka student after he was completed and awarded the advanced course programs of Nagaoka Kosen. The dispatched period of the program with the bachelor's degree of TUAS and the advanced course of Nagaoka Kosen is shown in the Figure 7. Because the advanced course of Nagaoka Kosen introduced the quarter system, Nagaoka students can choose the period when to go to TUAS. To get the bachelor's degree of TUAS, both for the 1st and 2nd grades of the advanced course is now available and if they decided, they will be in TUAS from the autumn semester to the spring semester of TUAS for one year.

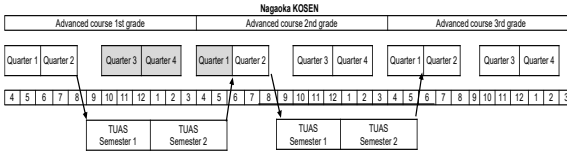


Figure 7. Dispatched period of the bachelor's degree program of TUAS for Nagaoka students.

Results of questionnaires to the Nagaoka students and teachers.

To share our educational effects on the present degree program, questionnaires to the Nagaoka students who went to study in TUAS for the bachelor's degree and to the teachers who had the class to the TUAS students who had stayed to study in TUAS in 2024 have been performed.

Students:
(Q1) Why do you want to decide to go to TUAS for the bachelor's degree?

I was interested in studying abroad. I wanted to study not only engineering at a technical college but also engineering management in Finland.

I thought that the present program would help my professions that utilized the specialized knowledge in science and engineering as well as language skills.

If I can achieve it, it will be the first example.

I wanted to build new relationships during the advanced course at Nagaoka Kosen. There are three universities in Turku, and the students at these universities come from all around the world. I think this is an attractive aspect of the present program.

(Q2) How difficult was it to listen and to discuss using English in the classes of TUAS?

Very difficult: Difficult

(Q3) What do you think the class of TUAS will be useful in your future after you come back Japan?

Very Useful

It depends on the person. Most of the Kosen students will work for engineering, there may not be many situations where business skills can directly apply to our Kosen students.

Teachers:
(Q4) How were the influences on the Kosen students to have a class with TUAS students?

Class materials were translated to English and these materials influenced to the Kosen students from abroad as well as the Japanese Kosen students.
Students were forced to use English in their everyday conversations in the lab and also the discussions at research meetings. It is believed that students' reading and speaking skills have improved.

Conclusions

The present attempts to have the student exchange program with the credit transfer systems between two institutes of Nagaoka and TUAS are now underway, and here the progress of the present program was reported. New types of student exchange programs between Kosen partners abroad have to be developed in future. In that sense, the present challenge will be an example for our future collaboration between Kosens and the Kosen partner institutions abroad.

Acknowledgements

We would like to thank Dr. Motomu Takeshige, the previous president of Nagaoka Kosen. We are also grateful to the staffs of TUAS, especially the former dean of TUAS, Dr. Juha Kontio, who concerned this double degree agreement. We would also thank all the members who had devoted many efforts on implementation and management of the double degree program for both TUAS and Nagaoka Kosen.

References

1) Sugawara, T, (2015) *International exchanging section at ANCT and sone activities on student abroad.* Kiyou of Akita Kosen, vol.51, pp.31-p.36.

2) Hanai et al., (2008) D*evelopment of International Education at Suzuka National College of Technology.* Kougaku Kyoiku (J. of JSEE) 56-3.

3) Nakamura, S. (2016) *Global Education in National Insititute of Technology, Nagaoka College: Networking with Mexican Technical College.* web magazine "Ryugakusei Kouryuu" vol.61 pp.8 - 15.

4) Takagi, H. (2016) *Significances and Issues of Double-degree Programmes Developed between Japanese and European Universities: From the Perspective of Postgraduates' Experiences.* web magazine "Ryugakusei Kouryuu" vol.67 pp.12 - 24.

5) Urabe, S., (2021) *The Path to a Double degree Program Agreement between Nagaoka Kosen and TUAS -from the perspective of Nagaoka Kosen- (*14th International Symposium on Advances of Technology Education. 17 – 20.

6) Kontio, J., (2010) *inspiring the inner entrepreneur in students – a case study of entrepreneurship studires in TUAS.* Proceedings of the 6th international conference, Ecole Polytechnique.

COMPETENCY IMPROVEMENT THROUGH STUDENTS' INDEPENDENT ACTIVITIES AT THE DEPARTMENT OF ELECTRICAL ENGINEERING, UBE KOSEN

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A group called as E-project has been supporting students working proactively in Ube KOSEN. The E-project has prepared 14 themes related to electrical engineering and applied the philosophy of servant leadership to the organization. In 2024, about a half of students, 97 members, in the Department of electrical engineering belonged to the E-project and strengthened electrical engineering knowledge as well as competency such as communication, and teamwork skills so on. Participating students themselves actively worked on themes of their own interest. Throughout the year's activities, they were successfully developed and improved various competency skills. In particular, about 60% of participants realized the developments of communication skills irrespective of years. It was also found that the skills developed was different in the themes each due to different policy and actual activities.

Keywords: *Entrepreneurial mindset, Electrical engineering, Contribution for neighbouring community, Competency*

Introduction

National Colleges of Technology are in need of proactive electrical engineers with an entrepreneurial mindset who can find new solutions to problems. In a course of the Department of Electrical Engineering (DEE) in Ube KOSEN, students are supported to proactively working as a member of the group of the E-project, which is launched in 2021. The purpose of the E-project is to strengthen not only electrical engineering knowledge but also competency such as communication skills, and teamwork skills by challenge ourselves to contests and by convention of fun learning an electrical engineering toward elementary and junior high school students. Through the activities, it is expected to be increase the number of applicants to the department of electrical engineering. Entrepreneurial mindset training was also started in 2023 with the E-project. This paper reports the recent activities undertaken as the E-Project and the effects of the competency improvement of the participating students in this project.

Table 1: History of E-project.

Year	Remarks	Number of theme
2018	PE-girls (only female) launched,.	4
2021	Male students begin to participate and E-Project is launched.	5
2022	Activities centered on female students.	5
2023	The number of participants has increased rapidly and the scale has expanded.	7
2024	Further expansion and improvement is planned.	14

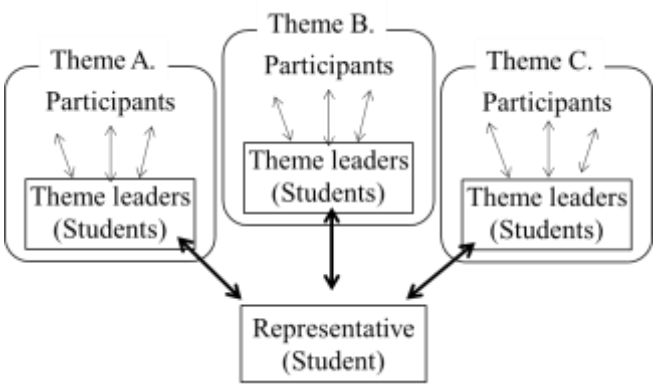


Figure 1: Management organization in E-Project.

Materials and Methods or Pedagogy

Transition or history on the E-project is summarised in table 1. The E-Project was launched by some students belong to DEE in Ube KOSEN, based on P.E.girls, in which was launched by female in DEE to improve the number of female's applicants to the DEE. The activities in the E-project continued every year and the number of the participants increased gradually, number of themes also increased. Figure 1 shows a schematic view of management organization in the E-project. The E-project is composed of some theme as for the electrical engineering, their leaders and a representative. Each theme is organized by the student's theme leaders. Based on the main purpose of the E-project, the theme leaders share the opinions of their member and decide on a policy

of each theme for a year. The E-project applies the philosophy of servant leadership, which prioritizes serving others, to the organization. The servant representative, which the student also becomes to, shares the needs of the theme leaders first, and helps them to develop and perform as highly as possible. Since some of the participates belong to different theme at the same time, the servant representative accommodates schedules of the theme activities sometimes.

All participants selected and declared skills that they wanted to develop, to consider their intention to work in the E-project before the activities. In order to evaluate effects for E-project, we compared with skills to felt to develop through the activities.

Results and Discussion

Table 2 shows lists of the participants in 2024. One-second of students in the DEE, where 40 people in each year belong, participated active across all years and genders. A main member including the theme leader was students in 3rd year. The past representatives were also student in 3rd year actually. The 4th and 5th year participants supported the 1st ~ 3rd year students in terms of competency as well as electrical engineering knowledge. In 2024, about half of participants actively repeated and worked as shown in figure 2. These participants who gained experience in the E-project in last year remains to improve further skills and help new participants to strength skills through the activities. These alignments and connections between the participants are an advantage for helps of successive activities in E-project.

Table 3 shows theme lists and its participants in 2024. As for the electrical engineering, these themes were categorized to five; power electronics, device, control, information network and spread of fun learning electrical engineering. In the theme of video production, videos that were easy to understand about power electronics and to interest it for common people was planned to be produced. In the railway research, materials were produced to convey the appeal of power electronics and electrical engineering that can be learned from railways. The theme of EV miniature car improved a EV miniature car and challenge to a race competition. The theme of Robot for decommissioning manufactured for a robot competition. The theme of BSO counter produced a new BSO counter, which was used in baseball games. The theme of a sea turtle-shaped robot for cleaning beaches manufactured an auto robot that cleaned beaches polluted by microplastic materials. The theme of pitching machine manufactured a pitching machine to use practice of batting in baseball. The theme of illumination exhibits produced the illumination exhibits for TOKIWA fantasia festival, which was held in Ube city in winter season. The theme of application development for electrical engineering proposed education systems to help students to learn the electronic engineering. The theme of virtual reality created school buildings of Ube KOSEN in virtual reality by using Blender and Unity applications. The theme of craft class planned classes as the electric engineering for elementary and junior high school students. The theme of development of teaching materials developed and proposed teaching materials to learn electric engineering. The theme of business plan proposed plans to solve social problems and produced systems and/or products, and entered it into various business plan competitions. The theme of public relations appealed our activities and DEE by using SNS, so on. All participants selected themselves to actively work on themes of their own interest. Here is an introduction describing typical activities of VR, craft class, TOKIWA fantasia festival and EV miniature car on E-project, firstly. Next, we summarized survey results for developments and improvements of the various skills after the activities and discussed them.

In the theme of VR, it was considered to check present skills of the members to create the school building of Ube KOSEN in VR. Then, the theme leaders

Table 2: Composition of the member in 2024.

Year	Number of member	Participation rate [%]
1st	20	48.7
2nd	24	55.6
3rd	23	57.5
4th	20	45.5
5th	10	25.6
total	97	

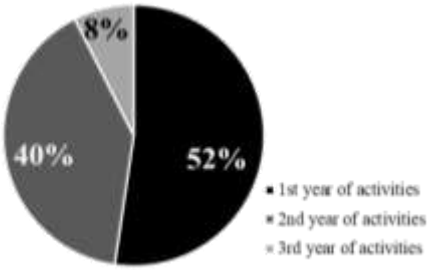


Figure 2: Number of years of activities in E-Project.

Table 3: Theme lists and its participants in 2024.

Category	Name of theme	Participants	Since
Power electronics	Video production	17	2021
	Railway research	8	2021
	EV miniature car	24	2024
	Decommissioning	7	2024
Device	BSO counter	13	2024
Control	Cleaning on beaches	23	2023
	Pitching machines	16	2024
	TOKIWA fantasia festival	18	2024
Information network	Applications	15	2024
	Virtual Reality (VR)	28	2024
Spread of fun learning electrical engineering	Craft class	19	2021
	Teaching Materials	12	2021
	Business Plan	9	2023
	Public relations (PR)	4	2023



Figure 3: Seminar held by VR theme.

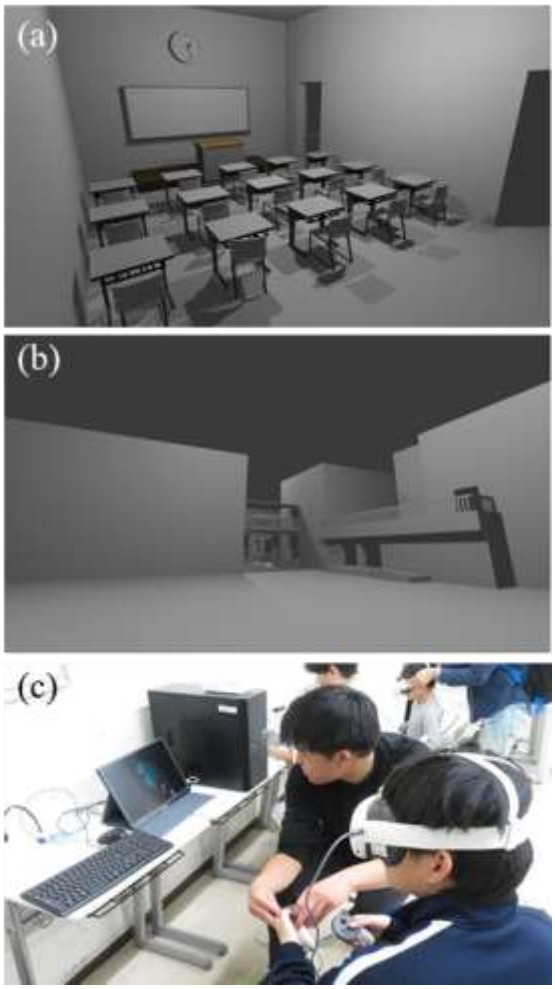


Figure 4: (a) Creation of classroom inside building, (b) appearances of the building in VR Ube KOSEN by using Blender application, and (c) experiences in 61st Kosen-sai festival in 2024. [1]

surveyed the skills and experiences to use Blender application, which is one of tools of modelling of the materials. As a result, it was found that 90% of participants was no experience to use the applications. So, the leaders planed and held on seminars how to use the Blender applications as shown in figure 3. At the same time, they required the member to submit reports about items, which was installed in the school, modelling by the application. The member actually modelled some items; pencils, clock, white board, chair, desks and storage case,

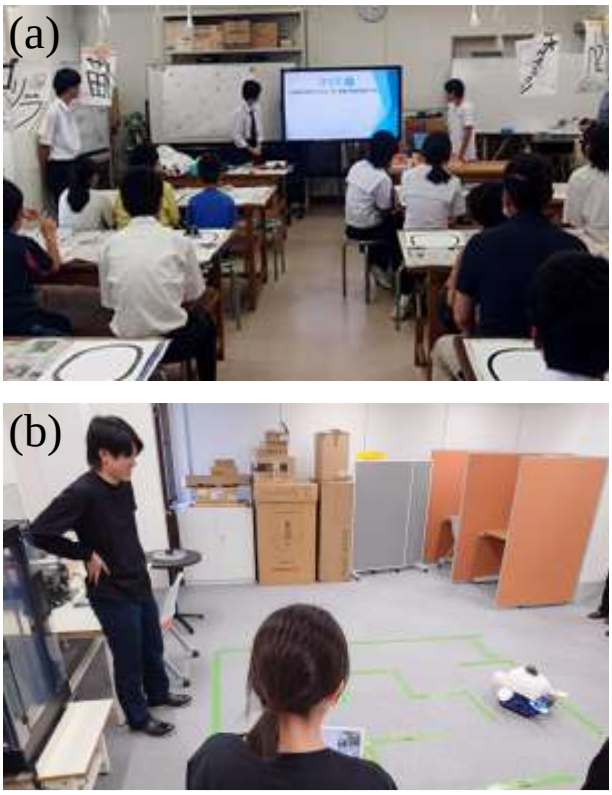


Figure 5: Craft class planned for 2024; (a) line tracer mobile, (b) experience of control of a turtle shaped-robot for clean beaches.

so on. Figure 4 shows the views of (a) a typical classroom and (b) a school building in Ube KOSEN modeled by the members. Most of the items in the classroom were modeled by members who attended the seminars. Ube KOSEN created by VR was experienced in 61st Kosen-sai festival in 2024 by its visitors as shown in figure 4 (c). Details were referred as ref. 1.

In the theme of craft class, classes to get students interested in electric engineering was planned by themselves. The theme leader shared the interests in the members and decided first subject the line trace mobiles for 40 minutes' class. To understand how to move the mobiles and to get interested the electricity, class managements and slides were improved by members. Advertisements of the craft class were also prepared themselves. 20 elementary and junior high school students were totally attended in the craft class for the line trace mobiles in summer as shown in figure 5 (a). With a support of the member, the students attended successfully learned principle of movements of its mobiles while actually moving. According to questionnaire after the class, all students answered that it was enjoyed during the class, and interested not only the electricity but also education in DEE of Ube KOSEN. In recent march, another craft class of robot control and lecture of environment on microplastic trash was held as shown in figure 5 (b).

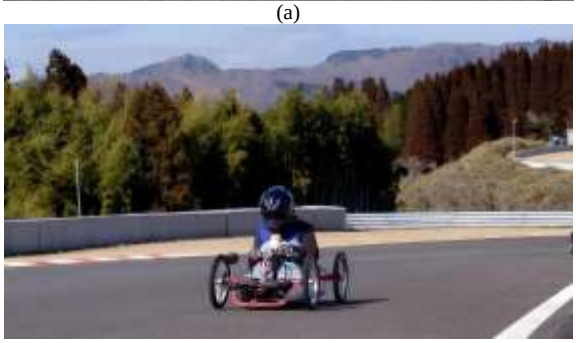
In the theme of TOKIWA fantasia festival, the illumination exhibit for TOKIWA fantasia festival, which was held in Ube city, was manufactured. Figure 6 shows a photo of the exhibit, which was a bench created



Figure 6: Illumination exhibit for TOKIWA fantasia festival 2024 in Ube city by the theme of TOKIWA fantasia festival. [2]



(a)



(b)

Figure 7: Photos of (a) coordinating their machine and (b) running in EV miniature car race competitions by the theme of EV miniature car.

by combining dynamic illumination using matrixLEDs and static illumination using ribbonLEDs [2]. Students worked on all ideas, design, purchase of goods, scheduling and production of the production. The exhibit was lit without problems throughout the festival, much to the delight of visitors.

Figure 7 shows photos of the activities in the theme of EV miniature car. In the theme, a single-seat miniature electric car equipped with an outer-rotor motor, batteries and an inverter was tuned for race competition, which was held at SPA Naonyu in Kyushu in march 2025, for the first time. The students proactively learned about the structure of motors and the basics of inverters, in addition to the content of the electrical engineering class. In the race competition, their EV ran trouble-free for 30 minutes and placed 7th out of 14 teams.

After the activity, a reflection was conducted. The skills of choice were typical competency items; “Initiative”, “Communication”, “Listen attentively”, “Teamwork”, “Team management”, “Flexibility”, “Self-management”, “Perseverance”, “Identifying problems”, “Planning solutions”, “Implementing solutions”, “Problem solving” and “Presentation”. In the reflection, participants selected about their skills before the activities, the skills they improved, and the skills they would like to develop in the future. The number of responses from each year was 14, 4, 4, 5, and 3 respectively. The total number of responses accounted for 30% of the 97 individuals. Figure 8 shows the response rates for skills by years. After the activities, the proportion of various skills has increased. Although many students with initiative and communication skills originally participated, they also felt their communication skills have improved more after the activities. In particular, approximately 60% of the 1st year students indicated that their communication skills had improved. This can be attributed mainly to the fact that they worked not only with their classmates but also with upperclassmen. Furthermore, many students answered a growth in their listening skills and teamwork abilities. Also, all 4th year students who responded felt a growth in their ability to identify problems. It could be inferred that they had many experiences discovering challenges towards achieving their goals while supporting the advancement of the themes.

Figure 9 shows the response rates for skills by theme, to compare the effectiveness of skill development in four typical themes. It was confirmed that communication skills could be cultivated in the four themes. More than half of the students who participated in illumination exhibit felt an improvement in their listening skills and flexibility. This was largely due to the sequential changes in direction made as the project progressed step by step from adjustments that were discovered during post-design production and on-site meetings at the venue. In the theme of EV miniature car, perseverance and presentation skills appeared to have improved. This can be attributed to the ability to coordinate their machines for the race competition, and to their experience in preparing presentation materials for their report on the theme of this year's activities. Many of the participants who participated in craft class mainly realized their

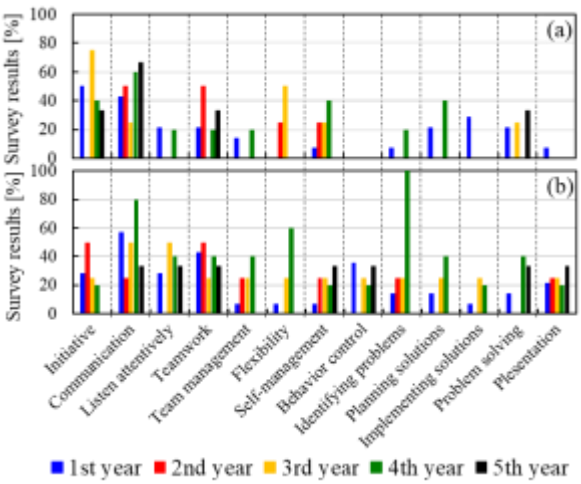


Figure 8: Survey results for each year, (a) before activities and (b) after activities.

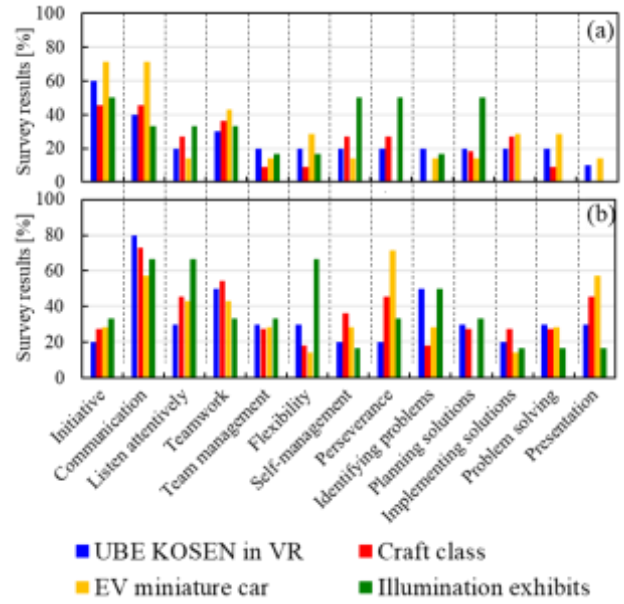


Figure 9: Survey results for typical theme, (a) before activities and (b) after activities.

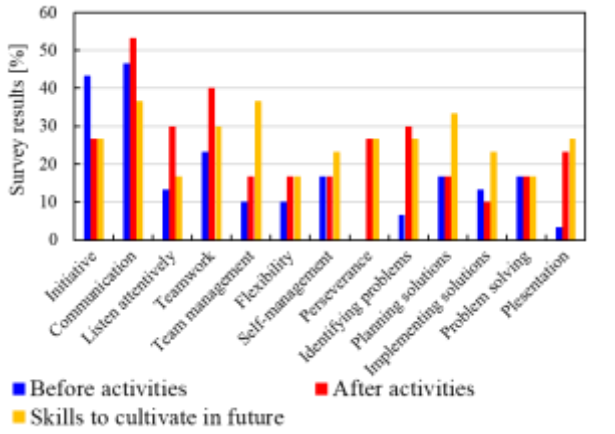


Figure 10: Summary of survey results for skills for participants answered.

teamwork, perseverance, and presentation skills. It is suggested that each skill have been cultivated as the members worked together to organize and plan the craft class and prepare class materials. From these results, it was found that skill improvement was expected to be effectively achieved by selecting a theme in the same electrical engineering field according to the skills that the students want to develop.

Figure 10 shows summary of survey results for skills for all participants answered. It was found that E-project activities are expected to greatly improve communication, listen attentively, and teamwork skills, as the participants work as a team regardless of years or genders. In addition, through team activities, it is also possible to develop new skills such as perseverance and presentation skills. In the future, we plan to introduce other-self evaluation to visualize the improvement of students' skills from multiple perspectives and to stimulate their activities. Through these activities, we would like to increase the number of students interested in electrical engineering.

Conclusions

In order to improve student's competency, their independent activities is supported at Ube KOSEN. In the department of electrical engineering in Ube KOSEN, E-project is launched in 2019. The number of participants has increased from the last year, and we have gotten many opportunities to collaborate between all years and genders. In 2024, by creating many ideas and starting new activities, the scope of their activities has expanded. It was found that the participating students improved various competency skills, in particular communication, listen attentively, and teamwork skills. In addition, student's skill improvement can be effectively achieved by selecting a theme according to the skills that they want to develop. In the future, we plan to introduce other-self evaluation to visualize the improvement of students' skills and to stimulate their activities. Finally, through various activities, we would like to increase the number of students who are interested in electrical engineering.

References

[1] Naoya, F. *at al*. (2025). Activities for the Modeling of UBE Kosen into VR in 2024. *Research report of Ube Technical College*, 71, 7-13.

[2] Hibiki, K. *at al*. (2025). The potential of matrixLEDs as an educational tool. *Research report of Ube Technical College*, 71, 1-6.

ENERGY GAP ESTIMATION OF SILICON SEMICONDUCTORS BY TEMPERATURE CONTROL USING PELTIER ELEMENTS

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The global semiconductor shortage has now extended to a shortage of skilled semiconductor engineers, placing increased pressure on higher education institutions to bridge this gap through specialized training programs. Simultaneously, abnormal weather patterns have intensified concerns related to heat and energy management. In this context, Peltier devices—which can either absorb or dissipate heat depending on the direction of current flow—offer promising applications.

This study investigates the unique thermal properties of Peltier devices through an experiment conducted by fourth-year students in the Department of Electronics and Information Engineering. Previously, a simple thermostatic chamber was constructed by wrapping nichrome wire around a test tube to study the voltage-current (V-I) characteristics of a Zener diode at elevated temperatures. These experiments yielded five V-I plots at temperatures above room temperature, including one at room temperature.

In the present study, a Peltier element was integrated to enable measurements at sub-room temperatures. Figure 1 shows the V-I characteristics of the Zener diode mounted on the surface of the Peltier element. As the temperature decreased, the current through the diode also diminished. From the processed data, the energy band gap of the silicon material was estimated to be approximately 1 eV.

The experiment demonstrated that diode temperature could be precisely controlled by adjusting the current supplied to the Peltier device. The underlying principle is explained in the section *Estimation of Energy Band Gap of Silicon Materials*, while *Temperature Characteristics of Peltier Element* discusses how the temperature depends on the current input. The *Temperature Characteristics of Diodes* section presents measured data and details the process of estimating the energy band gap using Peltier devices.

Finally, the *Conclusions* section reviews the experimental results and offers suggestions for further educational experiments involving Peltier elements. This study not only serves as an effective educational resource for students in semiconductor device engineering but also provides meaningful insights for those studying electrical, electronic, and information science. Moreover, the findings may be beneficial for mechanical systems courses, particularly in the field of thermoelectric conversion.

Keywords: *Constant temperature chamber, Peltier Elements, Silicon Energy Band Gap, Physics Experiment, Education Material*

Introduction

As the demand for semiconductors continues to rise, manufacturing plants are being constructed at a rapid pace, creating an urgent need for engineers to work on-site. However, the supply of qualified engineers is not keeping up with this growing demand. For this reason, educational institutions are expected to begin training students interested in the semiconductor field from an early stage.

As part of the student experiment curriculum in our Department of Electronics and Information Engineering, Yamada (2019) conducted experiments to estimate the energy band gap of silicon materials using the voltage-current (V-I) characteristics of diodes, with temperature as a variable. This is a physics-based experiment that provides valuable insight into semiconductor behavior in response to temperature changes. In previous experiments, the ambient temperature of the diode was increased using a thermostatic chamber constructed with a filament wound around the bottom of the test tube. The temperature was gradually raised from room temperature — approximately 25 ℃, which was the lowest temperature recorded in the data.

However, this approach posed two key limitations: the risk of overheating if the temperature was increased excessively, and the inability to collect measurements at temperatures below room temperature. To overcome these limitations, the current study focuses on obtaining data below room temperature by leveraging the Peltier effect—a unique thermoelectric phenomenon observed in semiconductors.

This experiment aims to stimulate student interest in semiconductors by introducing phenomena that are distinct to these materials. The Peltier structure consists of multiple p-type and n-type semiconductors bonded to metal and connected in series. The device features a heat-

absorbing (cooling) side and a heat-generating (heating) side. Temperature control is relatively simple, as the amount of heat transferred is proportional to the current flowing through the element.

Peltier elements are widely used for electronic cooling in semiconductor components such as charge-coupled devices (CCDs), laser diodes used in optical communication, and CPUs that require localized cooling. They are also applied in the temperature regulation of small biological samples.

In this study, we measured the V-I characteristics of a Zener diode using the temperature-controlling properties of a Peltier element and estimated the energy band gap of the silicon material. In addition, we discuss the potential application of Peltier devices as effective teaching tools for semiconductor device education.

Estimation of Energy Band Gap of Silicon Materials

Zener diodes were fabricated using a p-n junction structure with silicon as the base material. Figure 1 illustrates the general V-I characteristics of the diode under forward bias. This figure is adapted from a graph presented in the book by E.S. Yang (1981). Notably, in some cases, the slope of the curve differs between the low- and high-voltage regions.

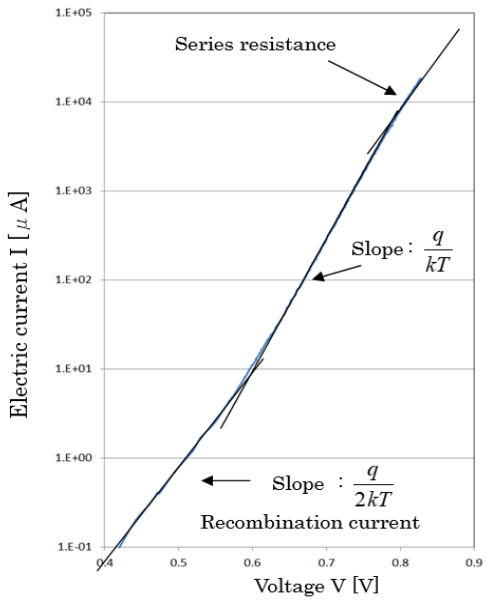


Figure 1 Voltage-current characteristics of p-n junction diodes under forward bias condition

Based on the result obtained, the diode current can be expressed using the ideal factor *n*, as shown in Eq. (1). In the relatively high-voltage region, the constant term "1" within the parentheses in Eq. (1) becomes negligible, allowing the expression to be approximated as Eq. (2), where I_0 denotes the reverse saturation current. As shown in Eq. (3), I_0 is proportional to the square of n_i, which is proportional to the product of temperature T^3 and $\exp(-E_g/k_BT)$ (Eq. (4)). As the change in $\exp(-E_g/k_BT)$ is larger than that in T^3, I_0 can be considered proportional to $\exp(-E_g/k_BT)$. With a proportionality factor of 1, Eg can be expressed as Eq. (5). In other words, if I_0 at each temperature is known with the temperature as a parameter, Eg can be calculated from the slope of the graph of I_0 against the reciprocal of the temperature.

$$I = I_0\left\{\exp\left(\frac{qV}{nk_BT}\right)-1\right\} \quad (1)$$

$$I \approx I_0 \exp\left(\frac{qV}{nk_BT}\right) \quad (2)$$

$$I_0 = qA\left(\frac{D_n}{L_n}n_{po}+\frac{D_P}{L_p}p_{no}\right) = qAn_i^2\left(\frac{D_n}{L_nN_a}+\frac{D_P}{L_pN_d}\right) \quad (3)$$

$$I_o \propto n_i^2 \propto T^3 \exp\left(-\frac{E_g}{k_BT}\right) \quad (4)$$

$$E_g = -k_B\frac{d(\ln I_0)}{d\left(\frac{1}{T}\right)} \quad (5)$$

Temperature Characteristics of Peltier Element

The temperature characteristics of a Peltier element (TES1-12739, 4.6A, 16V), 30 mm in length and width on low- and high-temperature surfaces are shown in Figure 2. The current values ranged from 0.5 A to 2.0 A. The temperature changed as soon as the current started to flow and became almost constant after 120 s.

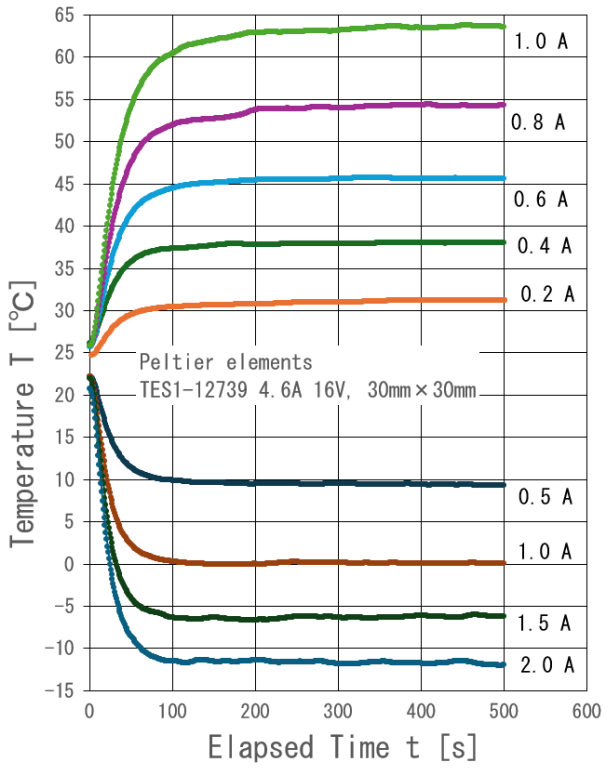


Figure 2 Temperature characteristics of Peltier elements

The average constant temperatures maintained during the experiment are listed in Table 1. These temperatures were measured using a commercially available IC

temperature sensor (–40 to 85 °C) and recorded on a PC. The results from Table 1 are plotted in Figure 3, along with the corresponding approximate equations. The slope on the high-temperature side was 40.65, while the slope on the low-temperature side was 14.04－a significantly smaller value. This reduced rate of temperature decrease is likely due to heat inflow from the surrounding environment, as the Peltier element was installed only on the heat sink. The data presented in Figure 3 can be conveniently used to set arbitrary target temperatures with ease.

Table1 Saturation temperature versus current value

Current value [A]	Temperature [℃]
1.0	63.7
0.8	54.3
0.6	45.6
0.4	38.0
0.2	31.2
-0.5	9.3
-1.0	0.1
-1.5	-6.2
-2.0	-12.0

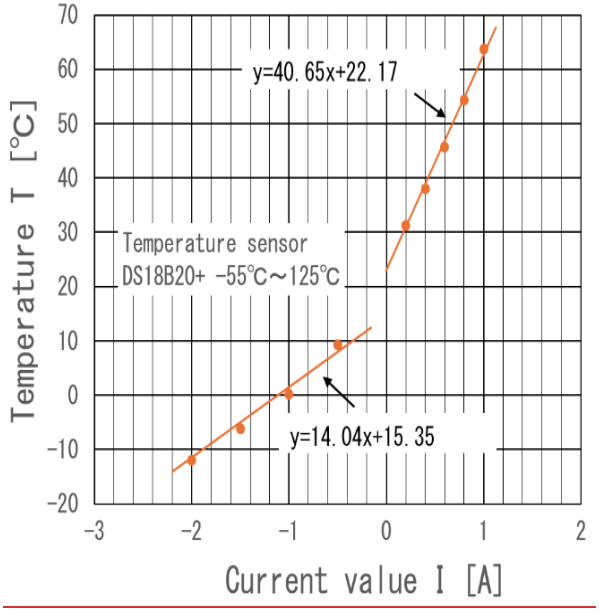


Figure 3 Saturation temperature variation with respect to the current value applied to the Peltier element and its approximate formula

For the low-temperature side of Figure 2, the 2.0 A graph shows a larger fluctuation than the 0.5 A graph. Figure 4 shows an enlarged graph used to estimate the extent of fluctuation, with the maximum variation observed being 0.55 eV. When measuring the voltage-current (V-I) characteristics with temperature as a parameter, it is essential to conduct measurements promptly once the temperature stabilizes. Any increase or decrease in temperature during measurement can affect the resulting graph. If the temperature remains constant at each measurement point, the resulting V-I curves will appear as straight, parallel lines, as shown in Figure 1. However, if the measurements are taken at fluctuating temperatures, these straight lines may intersect. To minimize such errors, it is recommended to maintain temperature fluctuations within Δ 1.0 °C. When this condition is met, the graph shown in section 2.0A remains reliable and does not significantly impact the measurement data.

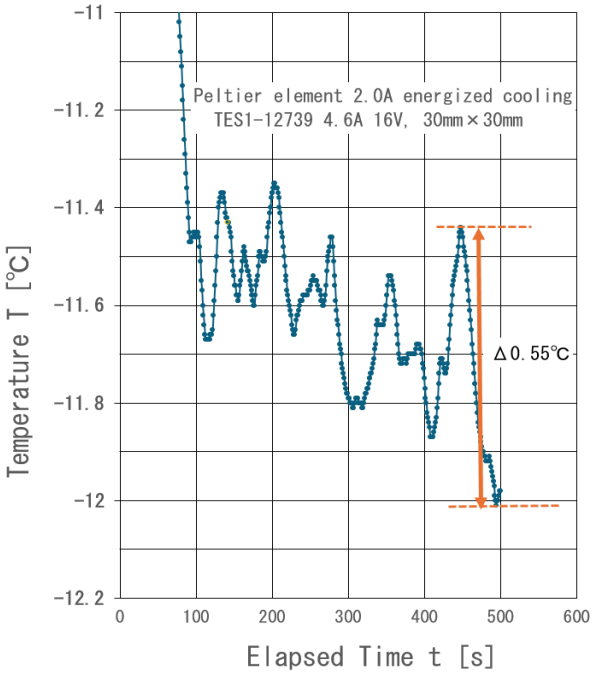


Figure 4 Fluctuations in the saturation temperature region of the Peltier element

Yamada (2024) previously used a thermostatic chamber with a filament to vary the ambient temperature of the diode. However, the use of a Peltier element has proven to be more effective, as it allows for more precise temperature control and enables measurements in the sub-room-temperature range. Moreover, since this course includes the study of low-temperature phenomena, exploring the functionality of the Peltier element itself can enhance student engagement and foster greater interest in semiconductor devices.

Additionally, by replacing diodes with transistors, temperature dependence can be explored in the context of transistor V-I characteristics. Because transistors, like diodes, are made of semiconductor materials and are highly sensitive to ambient temperature, amplifier circuits are typically designed to minimize the impact of thermal fluctuations. Using Peltier elements, students can easily conduct verification experiments that incorporate temperature variation into the analysis of transistor-based amplifier circuits. This provides a hands-on opportunity to understand and evaluate how temperature influences semiconductor device behavior in practical applications.

Experimental equipment

The experiments required three digital multimeters and two DC power supplies. Zener diodes, Peltier elements, and temperature sensors were also required electronic parts and devices. The DC power supply requirement for the Peltier element was 18 V at 2 A. The student laboratory was equipped with a DC power supply (with a maximum rating of several Amperes) so that it could also be used for motor experiments. Figure 5 shows a schematic of the circuit used for measuring the voltage-current characteristics of the diode with temperature as a parameter.

The electronic devices used in the experiment are readily available and inexpensive. Twenty-three sets will be prepared for groups, comprising two students each. These experiments will be conducted as a theme for fourth-year students in the Department of Electronics and Information Engineering. In two 90-min experiments, students will measure voltage-current characteristics and capacitance-voltage characteristics. In another two 90-min experiments, students will learn how to process data using a PC and analyze data using Excel. These experiments will be conducted during the winter season, close to December; by that time, students will have already learned about p-n junctions and energy gaps in the "Electronic Devices" course.

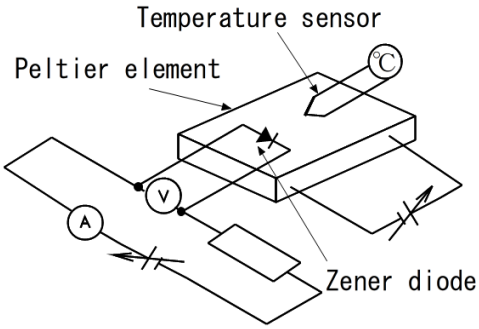


Figure 5 Schematic of Voltage-current characteristics measurement circuit

Temperature Characteristics of Diodes

The voltage-current (V-I) characteristics of the Zener diode were measured using temperature as a parameter (Figure 6). As the forward voltage applied to the diode increased, the current rose exponentially. When the vertical axis of the graph is plotted on a logarithmic scale, the curve transforms into a straight line—an effect that often captures students' interest. The graph is centered at 0.0 A and shifts upward to the left on the heat-generating side and downward to the right on the heat-absorbing side as the current increases. The linear portion of this graph was extracted and is shown in logarithmic form in Figure 7. The data exhibit a consistent shift to the upper left, from -12.0 °C to 63.7 °C. An approximate equation for the linear fit can be obtained using the "Add Trendline" function in Excel, highlighting the important of spreadsheet software in data processing.

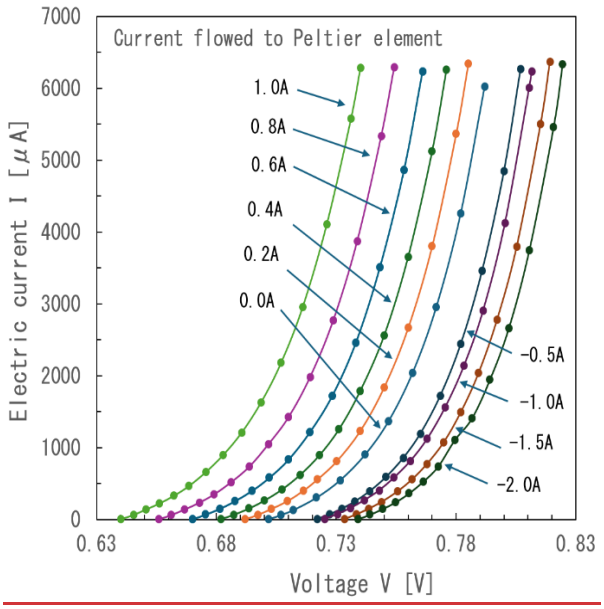


Figure 6 Voltage-current characteristics of Zener diodes with temperature as a parameter

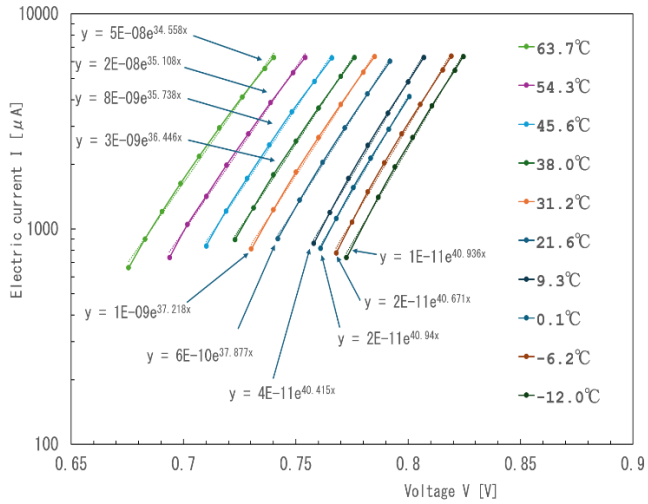


Figure 7 Logarithmic display of voltage-current characteristics

This exercise also reinforces students' understanding of how physical quantities can be derived from the slopes of linear graphs using mathematical techniques. As Yamada (2019) noted, this type of material serves as a valuable component of STEM education—integrating concepts from science, technology, engineering, and mathematics. For the graph at 21.6 °C, the inverse saturation current value is 6×10^{-16} A. The reciprocal values of the absolute temperatures used are listed in Table 2, and the corresponding results are plotted in Figure 8. The value of I_0 decreases in the lower-temperature range. The slope of the linear approximation in Figure 8 is approximately 1.025×10^4. When this value is multiplied by the Boltzmann constant k_B and converted into electron volts, the result is approximately 0.88 eV. Rounded to one

significant digit, this yields about 1 eV — closely matching the known energy band gap of silicon.

Table2 Reverse saturation current value for the reciprocal of absolute temperature

T [℃]	1/T [1/K]	I_0 [A]	LN I_0 [A]
63.7	0.00297	5.00×10^{-14}	−30.63
54.3	0.0030553	2.00×10^{-14}	−31.54
45.6	0.0031387	8.00×10^{-15}	−32.46
38.0	0.0032154	3.00×10^{-15}	−33.44
31.2	0.0032873	1.00×10^{-15}	−34.54
21.6	0.0033944	6.00×10^{-16}	−35.05
9.3	0.0035423	4.00×10^{-17}	−37.76
0.1	0.0036617	2.00×10^{-17}	−38.45
−6.2	0.0037481	2.00×10^{-17}	−38.45
12.0	0.0038314	1.00×10^{-17}	−39.14

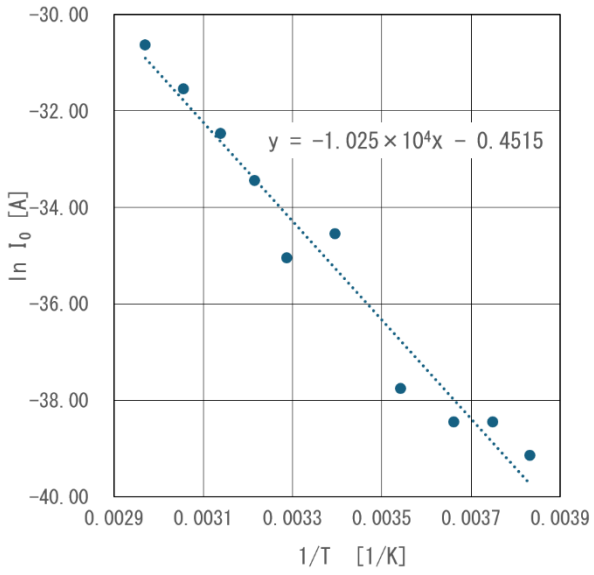


Figure 8 Reverse saturation current characteristic as a function of the reciprocal of absolute temperature

In semiconductor education, the energy band gap is a key material property that influences device performance, typically expressed in electron volts. However, estimating this value experimentally usually requires specialized equipment. This experiment is particularly meaningful because it enables students to directly apply concepts learned in lectures—such as energy expressed in electron volts—to real measurements using accessible tools.

Conclusions

As part of developing semiconductor experiments, we investigated the voltage-current characteristics of diodes using temperature as a variable. Until now, these experiments were conducted in thermostatic chambers with filaments wound around test tubes. In this study, we introduced a new approach by creating a temperature-controlled environment ranging from low to high temperatures using a Peltier element. This allowed us to estimate the energy band gap of silicon to be approximately 1 eV based on measured characteristics. Importantly, these experiments go beyond simple data collection—they aim to equip students with the skills to derive new physical quantities through data processing. The experiment integrates concepts from semiconductor physics, mathematics, and information processing, making it a valuable tool for comprehensive STEM education. Because Peltier elements are inexpensive and commercially available, this setup can be readily adopted by institutions of higher education.

The experiment is particularly significant as an applied physics exercise, utilizing temperature as a key parameter. Furthermore, it holds promise as effective teaching material for training future semiconductor engineers — an area of growing importance amid the global demand for skilled professionals in the semiconductor industry.

Acknowledgements

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References

Edward S. Yang, T. Goto, R. Nakata, K. Okamoto. (1981). Fundamentals of Semiconductor Devices. McGraw-Hil. P.107, Fig. 4-9.

K. Yamada. (2019). Development of STEM educational materials for semiconductor engineering. Memoirs of National Institute of Technology, Ishikawa College, 51, 15-18.

K. Yamada, (2024). International collaborative educational trial using experimental diode materials, Memoirs of National Institute of Technology, Ishikawa College, 56, 24-29.

A New Collaborative STEAM Education Initiative with a Local Plating Company

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This report describes a new collaborative STEAM education initiative conducted by Akita KOSEN in partnership with Azuma Denka Co., Ltd., a local plating company in Daisen city, Japan. The objective of this initiative is promotion of scientific curiosity among elementary school students and enhancement of awareness of local industries through a hands-on plating experiment. Numerous examples of school–industry collaborative STEAM education programs exist across Japan, but few involve local companies rooted in the community. This project is intended to fill that gap by engaging students with a real-world industrial application: electroless nickel plating.

Third-grade to sixth-grade students from Daisen city were invited to participate in the workshop held at Azuma Denka's facility. Using a simplified and age-appropriate instructional guide, students conducted electroless plating of *Enkianthus perulatus* leaves, a familiar natural material, under the guidance of Akita KOSEN students who served as Student Assistants. The experiment, using plating conditions at 30°C and 40°C for manageable durations, was designed based on preliminary trials to ensure safety and engagement. During the 30-min plating, the children toured the company's plating and analytical facilities, gaining further insight into the real-world application of scientific techniques.

Post-lecture questionnaires revealed that all participants enjoyed the experiment. Many were surprised by the transformation of green leaves into shiny, metallic ones. Most participants expressed increased interest in plating and science, a desire to learn more, and understanding of plating's role in high-tech applications. Furthermore, students recognized that electroless plating is applicable to various materials, indicating that using familiar, tangible objects facilitated knowledge acquisition.

This initiative demonstrated the effectiveness of a localized, school–industry collaborative STEAM program for promoting scientific engagement and understanding among young learners. It also provided valuable outreach experience for technical college students, helping bridge the gap separating education, community, and industry.

Keywords: *electroless plating, elementary school students, local plating company, STEAM education*

Introduction

In 2022, the National Institute of Technology, Akita College (Akita KOSEN) established the "Akita KOSEN Glocal Human Resource Development Council" to use global perspectives and experiences to foster "glocal" human resources capable of contributing to the regional community and economy. The council has launched initiatives such as the Career Plan Fes to promote local employment, along with industry research sessions and one-on-one meetings with companies for students, and internship programs for third-year students. Nevertheless, collaborative research with local companies remains limited. The number of students from Akita KOSEN gaining employment within Akita prefecture has not increased to any considerable degree, probably because of insufficient awareness of local companies among students and their guardians and a lack of knowledge of their strengths and appeal.

STEAM education is an integrated educational approach that encompasses five disciplines: Science, Technology, Engineering, Arts (including liberal arts), and Mathematics. Adding the "A" for Arts to traditional STEM education sets a goal of cultivating problem-solving skills that incorporate both logical thinking and creativity. A report from the Central Council for Education of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) emphasizes the importance of defining and promoting "Arts" broadly to include not only arts and culture, but also aspects of daily life, economics, law, politics, ethics, and other areas encompassed by liberal arts (Central Council for Education, 2021). Today, STEAM education is gaining attention in both school education and community collaboration as a method for nurturing talent that can respond to the rapid changes of contemporary society.

Nationwide, numerous examples can be found of STEAM education programs conducted through collaboration between schools and companies. For example, the "Modeling Education on 'Sleep × Technology'" class program was developed through

collaboration between Satoe Gakuen Elementary School, the NTT East, and sleep-related companies affiliated with the virtual community ZAKONE (NTT East Japan Saitama Branch et al., 2022). Another example is the STEAM education program “Let’s Brighten the Future!” conducted by Hitachi Systems, Ltd. for students ranging from elementary school to technical college level (Hitachi Systems, Ltd., 2024). Many examples of school-led STEAM education also exist, such as the work of Ueda and colleagues (Ueda et al., 2022). Nevertheless, no clear cases of STEAM education conducted through collaboration between schools and local companies rooted in the community have been identified.

In response, as part of Akita KOSEN’s collaborative STEAM education efforts, a public lecture for elementary school students was conducted in collaboration with Azuma Denka Co., Ltd., a local plating company based in Daisen city. The goals were to raise awareness and interest in local companies, products, and technologies among local elementary school students and their guardians, and to increase awareness among Akita KOSEN students themselves, using third-year students as Student Assistants (SAs), with the further aim of promoting future internship participation and local employment.

The lecture was designed to cultivate scientific interest among children through a hands-on experiment involving electroless nickel plating on leaves, a familiar natural object. Electroless plating is a technique that deposits metal evenly onto a substrate without the use of an external power source. It is useful not only for deepening students' understanding of chemical reactions, but also as an illustrative practical example of industrial technology. Particularly using leaves, a natural material familiar to children, the lecture was intended to help participants recognize the close connection between science and everyday life.

This report describes the outcomes of this collaborative STEAM education initiative.

Recruitment of Elementary School Students

Elementary school students of grades 3–6 living in Daisen city, where Azuma Denka Co., Ltd. is located, were invited to participate in the lecture. To raise awareness among local children, we requested and received the endorsement of the Daisen City Board of Education to distribute flyers. As a result, flyers were distributed to 1,583 students in grades 3–6 attending 22 elementary schools in Daisen city. Figure 1 shows the flyer. Although 17 students applied, because of limitations in the company’s laboratory and tour logistics, participation was limited to 10 students. Each student was allowed to bring one guardian. On the day of the event, three students were unable to attend, leading to final participation of seven students. The lecture was conducted inside the main building of Azuma Denka Co., Ltd. Figure 2 portrays the exterior of the company building. The company is a specialist in functional plating, particularly for electronic components, printed circuit boards, and ceramic substrates.



Figure 1: Flyer distributed to elementary school students in Daisen city.



Figure 2: Exterior view of the main building of Azuma Denka Co., Ltd.

Schedule and Experiment

The schedule for the elementary school students on the day of the lecture was the following.

1. Explanation of plating and company introduction by engineers
2. Experiment conducted by the students
3. Tour of the company’s plating facilities and analytical equipment
4. Packaging of the plated leaves
5. Summary and post-experiment questionnaire

The lecture was held during 10:00 AM – 12:00 PM, with care taken to ensure that the children remained engaged throughout.

Figure 3 shows the instructional handout used for the lecture. Because the lecture was designed for elementary school students, complex chemical names were omitted. Visual aids such as illustrations of the experiment apparatus were included for better understanding by all participants.

In preliminary experiments conducted at Akita KOSEN, conditions were studied to ensure that the electroless nickel plating of leaves could be done safely at lower temperatures and within a short time, to avoid burns and to maintain students’ concentration. Leaves of various types were tested. Those of *Enkianthus perulatus* produced the most silvery and glossy results. Results confirmed the safety of thermostatic baths at 30°C and 40°C, and showed that the plating process required approximately 15 min of hands-on activity and 30 min of unattended processing. To keep the students engaged, a company tour was conducted during the unattended time.



Figure 3: Instructional handout used during the lecture.

Preparations made at Akita KOSEN the day before the lecture were the following:

After *Enkianthus perulatus* leaves were collected from the school garden, they were soaked overnight in a 70% ethanol aqueous solution as pretreatment. Figure 4 shows an *Enkianthus perulatus* tree. Solutions of 0.1 M $CuSO_4$, 0.1 M dimethylamine-borane (DMAB), 0.1 M $NiSO_4$, and 1 M NaOH were prepared. For every 300 mL of 0.1 M $NiSO_4$ solution, 9.1 g of trisodium citrate dihydrate was added and dissolved thoroughly. The pH was adjusted to 9–10 using 1 M NaOH. These solutions were poured into bottles. The DMAB solution was stored in an ice-filled cooler. Other solutions were transported at room temperature to Azuma Denka Co., Ltd.



Figure 4: *Enkianthus perulatus* tree in the Akita KOSEN garden.

Preparations conducted at Azuma Denka Co., Ltd. on the day of the lecture were the following.

Thermostatic baths were set up in the company's laboratory at 30°C and 40°C. A 100 mL beaker containing $CuSO_4$ solution and another containing DMAB solution were prepared. The DMAB beaker was placed in the 30°C bath. A separate 100 mL beaker containing 50 mL of $NiSO_4$–citrate solution, adjusted to pH 9–10, was placed in the 40°C bath. Another beaker with 50 mL of DMAB solution was also placed in the 40°C bath.

The experiment procedures followed by the elementary school students are explained below.

First, the *Enkianthus perulatus* leaves were catalyzed with copper. Each student selected a pretreated leaf, clamped the base of the stem with unbroken disposable wooden chopsticks, and immersed the leaf in $CuSO_4$ solution for 3 min. The leaf was then rinsed lightly with water. Next, the leaf was immersed in 30°C DMAB solution for 3 min; it was again rinsed lightly. This $CuSO_4$–DMAB immersion process was repeated once for a total of two cycles. Figure 5 shows a photograph of *Enkianthus perulatus* leaves during the copper catalyzation process.

Next, electroless nickel plating was done. The $NiSO_4$–citrate and DMAB solutions, each preheated to 40°C, were mixed. The leaf, clamped in chopsticks, was immersed in the mixture and was left undisturbed for 30 min. Figure 6 depicts the process of electroless nickel plating on *Enkianthus perulatus* leaves.

After plating, the leaf was removed, rinsed with water, and placed on a paper towel to dry. Figure 5 shows the nickel-plated leaf. Finally, the leaf was placed in a petri dish lined with cotton, covered with a lid, and sealed with cellophane tape. Figure 7 presents images showing *Enkianthus perulatus* leaves before and after electroless nickel plating.

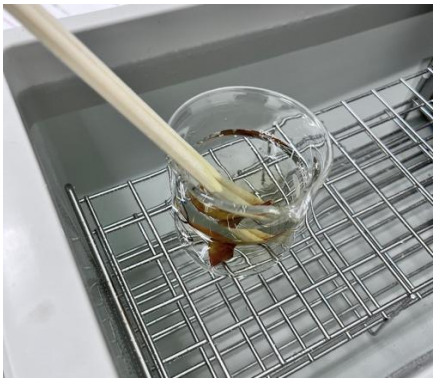


Figure 5: Applying a copper catalyst to *Enkianthus perulatus* leaves.

While waiting 30 min for the nickel plating process, children were given a tour of the company's plating site and analytical equipment. During the tour, the company's engineers explained the work processes and the function of each analytical instrument.

After the company tour and completion of the plating experiment, a summary session of the lecture was

conducted, followed by a questionnaire survey. Details of the questionnaire are described hereinafter.



Figure 6: *Enkianthus perulatus* leaves undergoing electroless nickel plating.

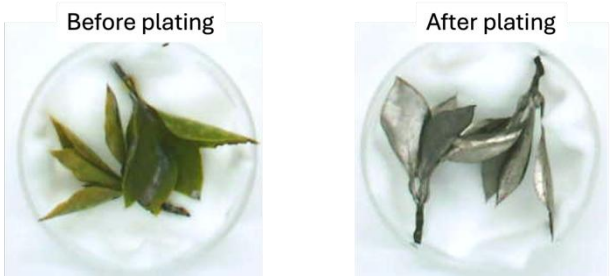


Figure 7: *Enkianthus perulatus* leaves before and after electroless nickel plating.

Responses to Questionnaires

Although no formal questionnaire survey was administered before the lecture, the SAs from Akita KOSEN casually asked the elementary school students some questions during ice-breaking conversations at the beginning of the lecture. Although the students had heard the word "plating," they were not familiar with its applications or effects.

Figure 8-13 shows the aggregated results of questions Q1–Q9 from the questionnaire survey conducted after the lecture.

Figures 8 and 9 show that all the elementary school students enjoyed the experiment, and that the electroless nickel-plated *Enkianthus perulatus* leaves evoked not so much a sense of accomplishment as a sense of surprise. This surprise likely derived from the unexpected result of placing the leaves into a green plating solution containing nickel ions, later to see them emerge with a silvery metallic luster.

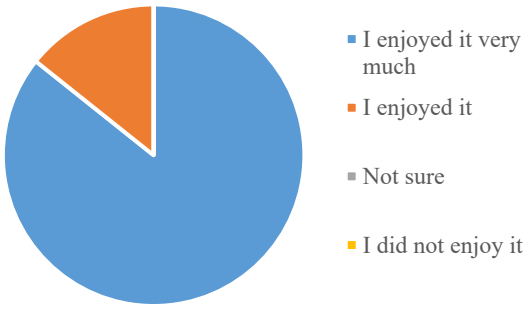


Figure 8: Responses to Q1: *Did you enjoy this event?*

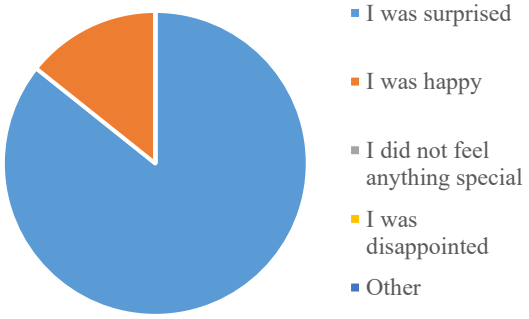


Figure 9: Responses to Q2: *How did you feel when you finished plating the leaves yourself?*

Figures 10–12 show that, as a result of the lecture, the elementary school students became more interested in plating and developed a desire to learn about it in greater depth. They also came to understand where plating is used and its expected effects.

Figure 13 shows that the elementary school students came to understand that plating is also used for high-tech materials. This knowledge is likely to have been intuitive because the lecture was held at Azuma Denka Co., Ltd., a company specializing in functional plating, which helped students recognize the close relation between functional plating and advanced materials.

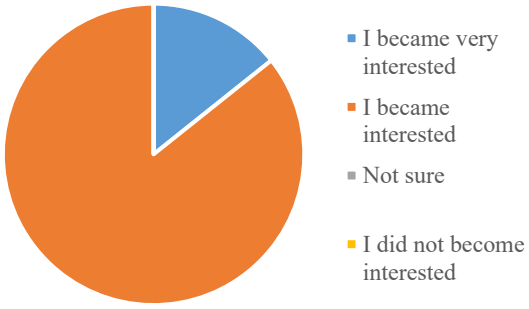


Figure 10: Responses to Q3: *Did this make you more interested in plating?*

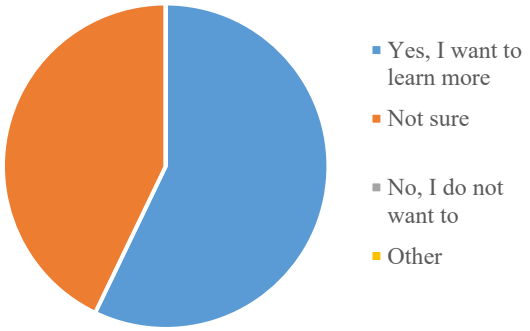


Figure 11: Responses to Q4: *Would you like to learn more about plating?*

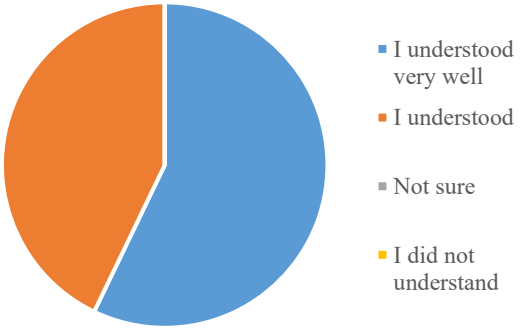


Figure 12: Responses to Q5: *Did you understand where plating is used?*

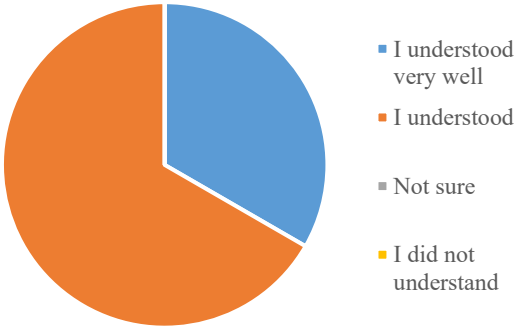


Figure 13: Responses to Q6: *Did you learn that plating is important for high-tech things?*

The results shown in Figure 14 indicate that the elementary school students recognized that electroless plating can be applied to various materials. This outcome is likely attributable to their hands-on experience with electroless plating using familiar and approachable materials, in this case leaves, as substrates for the experiment, which helped them accept new knowledge without resistance.

Results presented in Figure 15 were predictable at the time the students applied for the lecture. However, as Figure 16 shows, most participants expressed a desire to conduct additional experiments, which indicates that the collaborative STEAM education practiced with a local company clearly enhanced the elementary school students' interest in science.

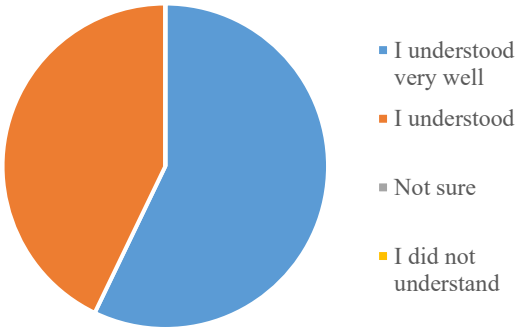


Figure 14: Responses to Q7: *Did you learn that plating can be done on many kinds of materials?*

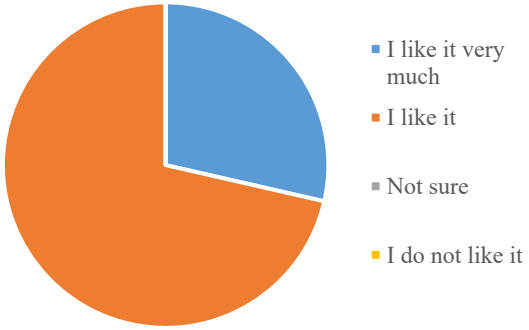


Figure 15: Responses to Q8 *Do you like science?*

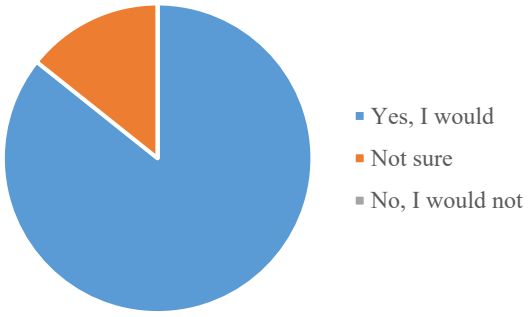


Figure 16: Responses to Q9: *Would you like to try other experiments?*

Conclusions

This collaborative STEAM education initiative, conducted in partnership with Azuma Denka Co., Ltd., ehnanced elementary school students' understanding and interest in science through a hands-on electroless nickel plating experiment. Students initially had limited knowledge about plating, but reported increased curiosity and comprehension related to its applications, including that for high-tech materials. Students engaged with complex scientific concepts in an accessible and

enjoyable manner because familiar natural objects, in this case leaves, were used as substrates for plating. Due to constraints of the venue provided by the company, it was not feasible to accommodate a large number of elementary school students in the STEAM education program. Moving forward, similar programs will continue to be implemented on a regular basis, and their educational effectiveness will be systematically evaluated.

Questionnaire results revealed that the lecture not only sparked interest in plating; it also encouraged students to learn more about science and to participate in additional experiments. The collaborative setting within a local company specializing in functional plating helped students to connect industrial technologies clearly to their everyday lives. This approach also provided Akita KOSEN students serving as Student Assistants with valuable teaching and leadership experience, further enhancing their understanding of community engagement and science communication.

Overall, this initiative demonstrated the effectiveness of school–industry collaboration in STEAM education and highlighted its potential for fostering scientific curiosity, community awareness, and future career interest among young learners.

Acknowledgments

We would like to express our deepest gratitude to Mr. Hiroaki Wakaizumi, President and Representative Director of Azuma Denka Co., Ltd., and Mr. Shigeyuki Sawaguchi, Managing Director, for kindly approving implementation of the lecture. We are also sincerely thankful to Mr. Tomohiro Sado and Ms. Hina Watanabe for their dedicated efforts in facilitating the experiments and company tour, and to all employees who assisted with transporting and setting up the equipment.

We also extend our heartfelt thanks to third-year students from the Department of Chemical and Biological Engineering at Akita KOSEN, and to Messrs. Hiroto Kudo and Kazuho Sato, Ms. Akane Haseyama, and Ms. Kayo Miura, who supported and guided the elementary school students as Student Assistants (SAs).

References

Central Council for Education. (2021). Toward the Construction of "Japanese-Style School Education in the Reiwa Era": Realization of Individually Optimized Learning and Collaborative Learning that Draws Out the Potential of All Children (Report). *Ministry of Education, Culture, Sports, Science and Technology (MEXT)*. https://www.mext.go.jp/content/20210126-mxt_syoto02-000012321_2-4.pdf

Hitachi Systems, Ltd. (2024). Contribution to Human Resource Development. *Hitachi Systems, Ltd. Official Website.* https://www.hitachi-systems.com/sustainability/social_report/action/education.html

NTT East Japan Saitama Branch, NTT DX Partner Inc., & Satoe Gakuen Elementary School, Satoe Educational Foundation. (2024). NTT Eastern Japan Group and Satoe Gakuen Elementary School Conduct a Class Aiming to Model "Sleep × Technology" Education. *NTT Eastern Japan Saitama Business Office.* https://www.ntt-east.co.jp/saitama/news/detail/pdf/hp20241025.pdf

Ueda, M., Sakaki, S., & Nishino, T. (2022). A solution for science phobia problem in Japan: A trial on cultivating interests in science experiments in junior high school students through distance education. *15th International Symposium on Advances in Technology Education*, 544–549.

VIII. SHORT PAPERS

INTRODUCTION OF SHORT PAPERS

In the ISATE 2025 Proceedings, two categories of contributions—Full Papers and Short Papers—are included, each serving a distinct purpose within the Symposium. Short Papers are clearly identified as non-peer-reviewed and were assessed solely on their relevance and alignment with the aims and scope of ISATE 2025. The purpose of this assessment was not to evaluate academic completeness or rigor, but to confirm that the content was consistent with the Symposium's theme and objectives.

The Short Paper category was introduced to encourage the sharing of a broad range of report-style and practice-oriented contributions, including educational activities and research initiatives at various stages of development. In particular, it was intended to provide presenters with opportunities to share ongoing, exploratory, or not-yet-completed educational and research work, thereby increasing discussion, feedback, and mutual learning among participants.

By clearly distinguishing between peer-reviewed Full Papers and non-peer-reviewed Short Papers, the ISATE 2025 Proceedings aim to ensure transparency regarding the academic status of each contribution, while fostering an inclusive and interactive forum for the exchange of ideas.



SHORT PAPERS

	ID	Corresponding Author	Title	Affiliation	Presen-tation	Page
1	02-43-ST2-4#JP_51	HATAMURA Manabu	Development of Experiential Chinese Language Learning Materials and Systems Utilizing VR	National Institute of Technology (Kosen), Ube College	Oral	S-ST2-p1
2	05-43-ST2-4#JP_46	TAKABAYASHI Susumu	Education Program of Radio-Frequency Impedance Matching for Kosen Grade System	National Institute of Technology (KOSEN), Ariake College	Oral	S-ST2-p4
3	PP-41-ST2-03#JP_10	TAKE Seisho	A New Approach to English Education for Technical College Students	National Institute of Technology (KOSEN), Oyama College	Poster	S-ST2-p10
4	PP-41-ST2-14#JP_50	ICHITSUBO Hikari	Comparative Analysis of Disability Support in Thailand and Japan: Legal Frameworks, Institutional Approaches, and the Current Status in KOSEN	Nagaoka University of Technology	Poster	S-ST2-p14
5	PP-41-ST2-15#JP_53	TOKAIRIN Tomoya	Development of a Scratch Extension to Use Python in the Scratch Editor	National Institute of Technology (KOSEN), Hakodate College	Poster	S-ST2-p18
6	PP-41-ST2-16#JP_57	HIGA Kiyoshi Marshall	Applying Optical Character Recognition and Deep Learning to a Web Application for Studying English Words in a Specialized Field of Study	Hiroshima University	Poster	S-ST2-p20
7	02-44-ST4-2#JP_26	SHIMOKAWA Rie	Local Industrial Collaboration Project at National Institute of Technology, Ichinoseki College: Local Storytelling, Kōdan, for Inbound Tourism	National Institute of Technology (KOSEN), Ichinoseki College	Oral	S-ST4-p1
8	PP-41-ST4-25#JP_59	KIKUCHI Takashi	Study on University Courses on Discharge, Plasma, and Pulsed Power for Transfer Students from KOSEN Education	Nagaoka University of Technology	Poster	S-ST4-p6

Development of experiential Chinese language learning materials and systems utilizing VR

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The purpose of this study is to develop and construct a new experiential Chinese language learning material and learning system utilizing VR (Virtual Reality). To achieve this goal, between April 2023 and March 2024, we addressed three tasks: (1) development of VR learning materials for beginner Chinese learners, (2) development of video materials using local resources from Taiwan, and (3) implementation of Chinese language classes in VR chat spaces. Especially with regard to issue (3), participants responded that "It was fresh and interesting" and "It was similar to reality" were received, confirming significant potential for this new method of remote teaching in the future.

Keywords:*Digital textbook1, Chinese Class2, VR3, VRChat-based metaverse classroom4*

Introduction

This paper introduces our research on an immersive Chinese language education system using VR technology, which began in 2022.The motivation for this research is threefold. First, although online classes became widespread before and during the pandemic, there remain limitations. Students have expressed concerns that online learning lacks realism and cannot fully substitute in-person instruction. As full-scale in-person classes may remain difficult in the future, educational institutions must explore alternative teaching methods.

Second, the rising cost of travel has made it increasingly difficult for students to participate in overseas programs. Promoting internationalization has become ever more important for educational institutions.

Third, VR technologies have rapidly evolved in recent years. Systems using VRChat for English, Korean, and Chinese language education have already shown promising results. As faculty members at national colleges of technology, we saw potential in applying such technologies to Chinese language education.

Fortunately, our team includes both language educators and information engineers. Since 2022, we have actively worked to develop this project.

A New Experiential Chinese Learning Platform Using Virtual Space

In this new experiential Chinese language learning sy stem utilizing virtual space, students and teachers in Tai wan and Japan can wear VR headsets to immerse thems elves in various Chinese learning experiences within a v irtual environment.

In the **Virtual Classroom**, Japanese students can attend live Chinese language lessons conducted by native Taiwanese teachers while remaining in Japan.

In the **Language Exchange Space**, both Taiwanese and Japanese students can participate together and freely engage in language learning—Chinese, Japanese, and English—through interactive games and quizzes installed in the space.

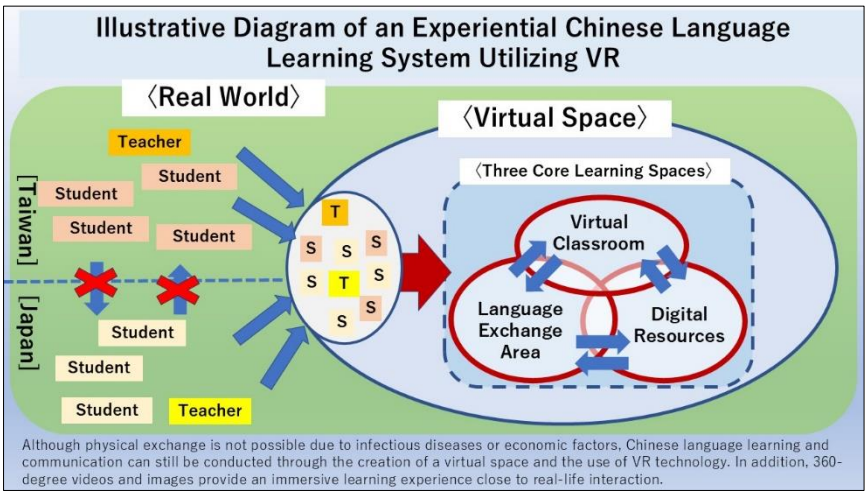


Figure 1 Illustrative Diagram of an Experiential Chinese Language Learning System Utilizing VR

In the **Digital Resources Area**, users can upload and explore videos and images captured with 360-degree cameras and Go Pros to visually experience and learn

about facilities and tourist attractions described in the textbook.

Figure 1 **Illustrative Diagram of an Experiential Chinese Language Learning System Utilizing VR**

Although these spaces are independent from each other, users can freely move between them at any time by entering the designed virtual world with their VR headsets.

The following outlines our research project that began in 2022. Aiming to develop an experiential Chinese language learning system using virtual space, we have been working on the following three themes since 2022:
(1) Development of VR teaching materials for beginner-level Chinese learners
(2) Creation of video-based learning materials utilizing local resources from Taiwan
(3) Implementation of Chinese language lessons in a VR chat environment

(1) Development of VR Teaching Materials

Taiwan Mandarin: Exploring Taiwan is a beginner-level Chinese textbook consisting of 19 lessons themed around travel, incorporating both grammar instruction and content related to tourism. Two students from the Department of Applied Chinese at Wenzao Ursuline University of Languages developed the textbook as part of their short-term internship from October 2023 to February 2024.

Some of the lessons have already been uploaded to the virtual classroom and have been used in two instructional sessions.





Figure 2 Digital Textbook *Taiwan Mandarin: Exploring Taiwan*

In addition, the team led by Professor Hashimoto constructed a virtual classroom themed around Taiwanese night markets using Unity. This environment allows learners to participate by wearing VR headsets, solve problems, and enjoy interactive educational games.

(2) Production of Video-Based Teaching Materials Utilizing Taiwanese Regional Resources

In March 2024, the lead author conducted a field study in Tainan, guiding students in recording locations such as Chihkan Tower (赤嵌樓), Anping Fort(安平古堡), and Shennong Street(神農街) using a RICOH THETA Z1 and an Insta360 Ace Pro. These recordings were used to create immersive video-based teaching materials that provide learners with a vivid and engaging educational experience.



Figure 3 Video available in the Digital Resources area (神農街)

(3) Implementation of Chinese Language Lessons in VRChat

The team led by Professor Hashimoto created a virtual classroom themed around Taiwanese temples using Unity and uploaded it to VRChat. Two instructional sessions were held in this virtual space, which included several panels displaying lesson content. The classes were conducted by a Taiwanese student instructor and attended by eight students from Ube College and Matsue College. Participants used avatars to take turns approaching the panels and engaging with the lesson.

A parallel lesson using the same content was also conducted via Microsoft Teams to compare learning effectiveness between the two formats.



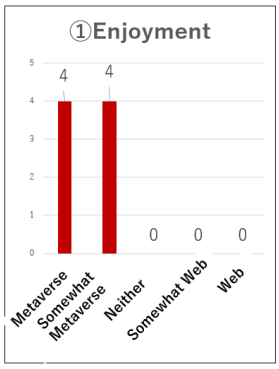
Figure 4 A class held in the VR classroom

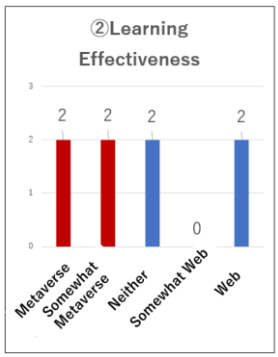


Figure 5 Taiwanese and Japanese students participating in a VR class while wearing VR headsets

Survey Results

After the courses, a survey was conducted with eight students from colleges of technology who participated in both the VR-based and conventional online classes. The survey focused on three aspects: (1) enjoyment of the classes, (2) perceived learning effectiveness, and (3) expectations for future implementation. The results are summarized in Table 1-3.





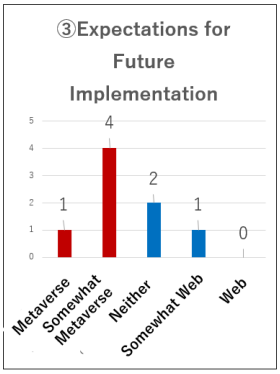


Table 1-3 Results of the Survey on Metaverse-based and Web-based Classe

(1) **Enjoyment**: All students reported that the VR-based class was more enjoyable. In the open-ended responses, comments such as “It was fresh and interesting” and “It felt like playing a game” were noted.

(2) **Learning Effectiveness**: Four students stated that the VR-based class was more effective, two preferred the online class, and the remaining two reported no preference.

Positive feedback for the VR class included comments such as, “The teacher could judge whether students were paying attention based on the orientation of their avatars, so we had to stay focused,” and “It felt like a face-to-face lesson, which was great.”

Negative feedback included remarks like, “It was hard to see because I usually wear glasses, and the VR headset affected my vision,” and “The avatars and panels overlapped, making the content difficult to view.”

(3) **Expectations for Future Implementation**: Five out of eight students expressed a desire to participate in future lessons conducted in the virtual classroom.

Conclusion

The achievements of this study to date are as follows:
(1) A digital Chinese language textbook titled *Taiwan Mandarin: Exploring Taiwan* was developed for use in VRChat.
(2) A virtual classroom and instructional slides were constructed within the VRChat environment.
(3) Taiwanese student interns conducted Chinese language lessons in the virtual classroom, and a comparative experiment was carried out with conventional online classes.

In 2025, we plan to develop a virtual environment equipped with three core functions—Virtual Classroom, Language Exchange Space, and Digital Materials Zone—as part of student research projects at colleges of technology. In addition, Taiwanese interns will continue to produce various types of instructional content as part of their internship projects, to be integrated into this virtual space.

References

宮本 真有. (2022). いつもの教室で「留学」体験！メタバースを活用した言語教育の試み —「バーチャル・キャンパスツアー」を通して—. *名古屋外国語大学論集*, 11, 177-193.

류선숙. (2022). 메타버스(Metaverse) 기반의 한국어 교과목 설계에 관한 가능성 탐색 연구. *韓国一般教育ジャーナル*, 16-2, 289-305.

李 相穆. (2022). メタバースを利用した外国語学習に関する研究. *九州大学大学院言語文化研究院言語研究*, 57, 55-60.

澤崎 敏文. (2023). メタバースを活用した多様な学習環境の構築と実践. *日本教育工学会研究報告集*, 2, 83-87.

Education Program of Radio-Frequency Impedance Matching for Kosen Grade System

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Impedance matching in electrical engineering is a very important concept for radio-frequency electrical circuit design. Electrical circuits without impedance matching are not power efficient and do not lead effective telecommunication. Incomplete impedance matching may cause breakdown or fire by power reflection. However, impedance matching is difficult to learn because it requires deep understanding of both the electrical circuit and electromagnetism. Here we present a step-by-step education program of impedance matching performed in National Institute of Technology, Ariake College (Ariake Kosen). This education program is ranged over three grades in the Kosen system so that students learn it without difficulty. The program comprises four practices. The education starts in the fourth grade from electromagnetism theory with Maxwell's equations including the skin effect and electromagnetic wave. Actual impedance matching of an audio circuit in the KHz region is performed in the next fifth grade. Finally, in the sixth grade (first grade of the advanced course), impedance matching of the circuit in the MHz region and that of a waveguide in the GHz region are experienced with the S-parameter analysis using a vector network analyzer (VNA). The VNA is one of the most expensive apparatuses in electrical engineering. Fortunately, a low-cost VNA such as NanoVNA is released recently. Through this program, Kosen students will be expected as radio-frequency electrical engineers.

Keywords: *Impedance matching, audio circuit, waveguide, S-parameters, vector network analyzer (VNA)*

Introduction

A voltage signal is a kind of electromagnetic wave. The wave is characterized by wavelength λ, expressed by $\lambda = {}^{c}/_{f}$ [m], where f is the frequency $[\mathrm{Hz} = {}^{1}/_{s}]$ and c is the speed of light, 299,792,458 ${}^{\mathrm{m}}/_{\mathrm{s}}$ in vacuum. The wavelengths of commercial 50/60 Hz voltages are calculated as approximately 6000/5000 km. In general, people do not feel the influence of the wavelengths of voltage signals on electrical circuits.

On the other hand, the characteristics of an electrical circuit working at a radio frequency depend on its size. The wavelength of a 2.45-GHz signal, a frequency for the wireless local area network (LAN) and microwave ovens, is calculated as only 122 mm that is comparable to the actual circuit size. Figure 1 shows variation of voltage signals that are expressed by $A = A_0 \exp(j\omega t)$, where ω is angular frequency, on a 30-mm distance line without any elements on the circuit. Signals of 50/60 Hz keep constant anywhere on the line. However, another signal at a frequency of 2.45 GHz varies. Even if 0 V at the point X, the maximum signal is observed at the point Y that is ${}^{1}/_{4}\,\lambda$ apart from X. An invisible passive element must be considered.

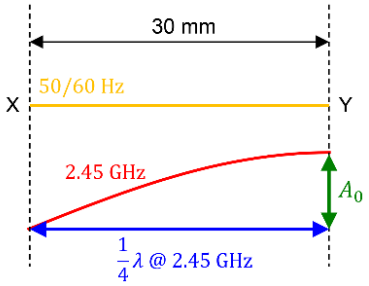


Figure 1. Voltage variation in a 30-mm distance line without any elements between X and Y. 50/60-Hz or low-frequency signals do not vary on the line; however, because the distance matches ${}^{1}/_{4}\,\lambda$ of a 2.45-GHz signal, the maximum value A_0 is observed at the point Y.

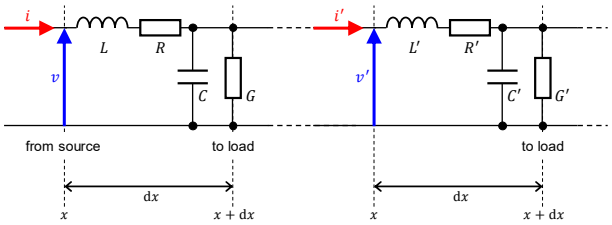


Figure 2. Sequential connection of DCCs.

When designing a radio-frequency circuit, the distributed constant circuit (DCC) analysis must be considered, instead of the lumped constant circuit (LCC) analysis that expresses a general electrical circuit. Figure 2 shows that a DCC is composed of a series of an inductor L, a resistor R, a parallel of a capacitor C, and another

resistor G. The voltage and current are both a function of distance x. An actual radio-frequency circuit is regarded as sequential connection of DCCs.

A DCC is analyzed by the following telegraph equations (Equations 1 and 2) on voltage v and current i,

$$\begin{cases} -\dfrac{\mathrm{d}v}{\mathrm{d}x} = (j\omega L + R)i = Zi, & (1) \\ -\dfrac{\mathrm{d}i}{\mathrm{d}x} = (j\omega C + G)v = Yv, & (2) \end{cases}$$

where $Z \equiv j\omega L + R$ and $Y \equiv j\omega C + G$. From these equations, we obtain the voltage and current results (Equations 3 and 4),

$$\therefore \begin{cases} v = \begin{Bmatrix} A\exp\left(-j\omega\sqrt{LC}x\right) \\ +B\exp\left(j\omega\sqrt{LC}x\right) \end{Bmatrix} \exp(j\omega t), & (3) \\ i = \begin{Bmatrix} A\sqrt{\dfrac{C}{L}}\exp\left(-j\omega\sqrt{LC}x\right) \\ -B\sqrt{\dfrac{C}{L}}\exp\left(j\omega\sqrt{LC}x\right) \end{Bmatrix} \exp(j\omega t), & (4) \end{cases}$$

where A and B are constants. We can easily understand that the voltage in a DCC is composed of two members: the first one expresses the travelling wave $V_\mathrm{f} = A\exp\left(-j\omega\sqrt{LC}x\right)\exp(j\omega t)$ that goes forward; the second one expresses the reflected wave $V_\mathrm{r} = B\exp\left(j\omega\sqrt{LC}x\right)\exp(j\omega t)$ that reflects back. The current is composed similarly. The reflected wave tells us that the input voltage is reflected and back to the source, resulting in $v \neq v'$ (see Fig. 2). It also means that the power/signal transfer is inefficient and the source may be destroyed.

Let us consider an actual DCC with the whole impedance Z_0, as shown in Figure 3. The whole length is ℓ. R and G are omitted for simplicity. The input connects with a power source having a voltage v_p and an input impedance Z_p. The output connects with a load having an impedance Z_ℓ. The voltage reflection coefficient Γ is expressed by

$$|\Gamma| \equiv \frac{V_\mathrm{r}}{V_\mathrm{f}} = \left|\frac{Z_\ell - Z_0}{Z_\ell + Z_0}\right|. \quad (5)$$

Equation 5 demonstrates that if the $|\Gamma|$ value becomes zero, no reflection is accomplished. In other words, every DCC impedance comprising a whole radio-frequency circuit must be the same. That is the *impedance matching*.

However, impedance matching is difficult to learn because it requires deep understanding of both electrical circuits and electromagnetism. Here we propose a step-by-step education program comprising four practices so that students learn it without difficulty. This program ranges over three grades in the Kosen system.

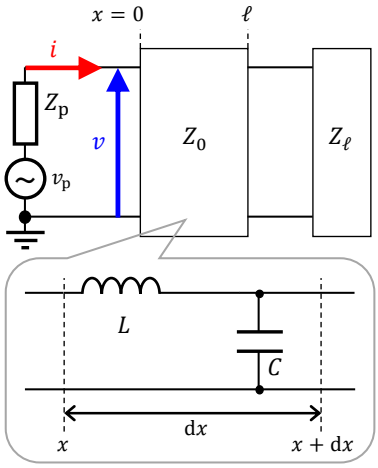


Figure 3. An actual DCC. The whole impedance Z_0, and the length is ℓ. R and G are omitted for simplicity. The input connects with a couple of power source with a voltage v_p and input impedance Z_p. The output connects with a load having an impedance Z_ℓ.

Practices 1&2: Electromagnetic Wave Theory and Audio Impedance Matching in KHz Region

First, in a half of the fourth grade, we educate students to electromagnetism with Maxwell's equations, which unifies electric, magnetic, and light. They learn the skin effect and electromagnetic waves. They learn that an AC voltage can be treated as a wave having a certain wavelength.

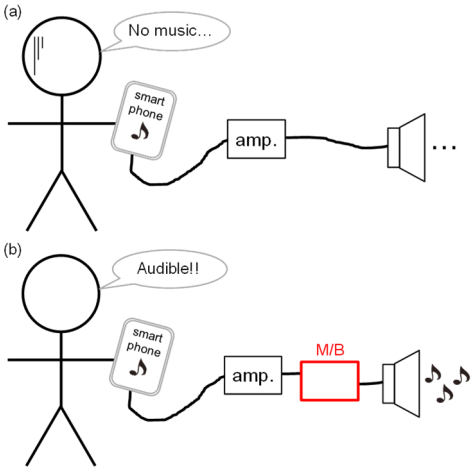


Figure 4. Music from a smart phone played through a speaker: (a) without and (b) with a M/B.

Based on this electromagnetism theory, in a quarter of the next fifth grade, we educate students to a familiar impedance matching example, an audio circuit. We can listen to any music from a smart phone. To open the music for everyone, we may connect an amplifier and a speaker to the smart phone; however, we hear the music very small or cannot as a result, as shown in Figure 4(a), because the output impedance of the smart phone or amplifier and that of the speaker are unmatched.

Thus, as shown in Figure 4(b), by inserting an impedance matching box (matching box, M/B) to the line, everyone can listen to the music. The M/B adjusts different impedances between connected components so

that the reflected wave set to zero, explained later. However, in actual audio systems, several transformers instead of a M/B are used. This is because the audible range is very wide from 20 to 20,000 Hz, in contrast, the M/B can adjust impedance at only one frequency. Small impedance mismatching with a transformer at some frequency is adjusted by an equalizer.

These phenomena are electrically explained how efficiently we transfer power. Figure 5 shows an electrical circuit with a power source with a voltage V_0 and an output impedance $Z_0 = R_0 + jX_0$ and a load with an impedance $Z' = R' + jX'$. We need to make the power for the load P' the maximum.

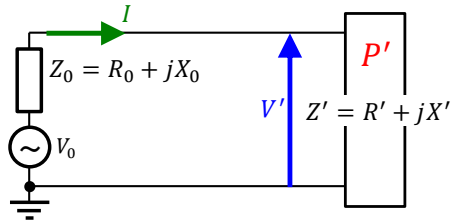


Figure 5. An electrical circuit to explain maximizing power supply to a load.

The complex power for the load P_c' is expressed by

$$P_c' = V'\bar{I} = \frac{Z'}{Z_0 + Z'}V_0 \cdot \frac{V_0}{\overline{Z_0 + Z'}}. \quad (6)$$

Thus, P' is obtained by

$$\therefore P' = \mathrm{Re}(P_c') = \frac{R'}{(R_0 + R')^2 + (X_0 + X')^2}{V_0}^2. \quad (7)$$

The P' takes the maximum when ${\partial P'}/{\partial R'} = {\partial P'}/{\partial X'} = 0$. A couple of $R' = R_0$ and $X' = -X_0$ satisfy the condition, leading $Z' = \overline{Z_0}$. Figure 6 shows the $P' - R'$ curve. The P' goes to the maximum 50% at $R' = R_0$. Especially, when $R' < R_0$, the value becomes smaller steeply. Thus, impedance matching is more important in this area. Because the output impedance of power sources is generally $R_0 = 50\ \Omega$, and that of actual speakers is $R' = 8\ \Omega$ or much less than $50\ \Omega$, the above matching condition is critical.

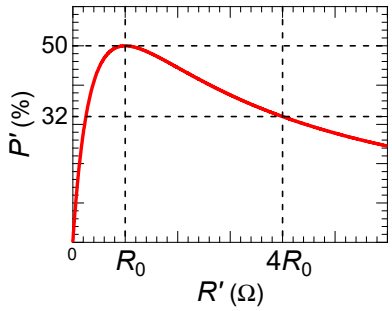


Figure 6. $P' - R'$ curve for impedance matching.

Figure 7 shows an electrical circuit with a M/B. The M/B comprises an inductor (coil) L and two variable capacitors, C_1 and C_2. The former capacitor set parallel to the load is called a load capacitor, and the latter series is a phase capacitor.

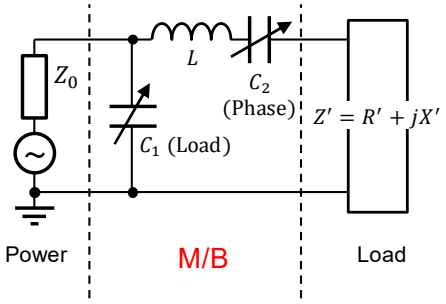


Figure 7. An electrical circuit with a M/B.

The values of these passive elements are determined by Equations 8–10. Eq. 10 comes from Eq. 9.

$$\begin{cases} C_1 = \dfrac{\sqrt{R'(R_0 - R')}}{\omega R' R_0} > 0 & (8) \\ C_2 = \dfrac{1}{\omega\left\{(\omega L + X') - \sqrt{R'(R_0 - R')}\right\}} > 0 & (9) \\ L > \dfrac{1}{\omega}\left\{\sqrt{R'(R_0 - R')} - X'\right\} & (10) \end{cases}$$

We provide its practice to students. First, we give each of their teams a target frequency for impedance matching of the circuit in Fig. 7. They start to measure impedance of the given speaker $Z' = R' + j\left(\omega L' - \frac{1}{\omega C'}\right)$. Then, they make a suitable coil by rotating a supporting tool like pedaling a bicycle, as shown in Figure 8.

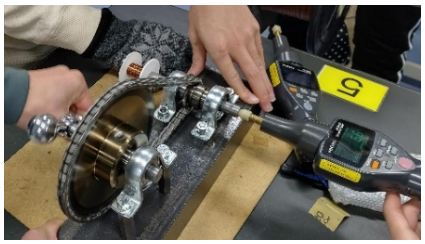


Figure 8. A photograph of making a handmade coil.

When the coil fabrication is finished, they measure its impedance $Z_L = R_L + j\left(\omega L - \frac{1}{\omega C_L}\right)$, where R_L and C_L are parasitic resistance and capacitance, respectively. They must add these parasitic values to $Z'$and then create a new speaker impedance $Z'' = (R' + R_L) + j\left(\omega L' - \frac{1}{\omega C'} - \frac{1}{\omega C_L}\right)$. The R' and X' in Eqs. 8–10 are changed to $R' + R_L$ and $\omega L' - \frac{1}{\omega C'} - \frac{1}{\omega C_L}$, respectively. According to Eq. 10, the minimum value of L, $L_{\min}$, can be calculated as $L_{\min} = \frac{1}{\omega}\left\{\sqrt{R''(R_0 - R'')} - X''\right\}$. If $L > L_{\min}$, the handmade coil is proven to be suitable for this purpose. After selecting appropriate C_1 and C_2 according to Eqs. 8 and 9, they finally check the combined impedance of the M/B and speaker, Z, to be $50 + j0$ [Ω].

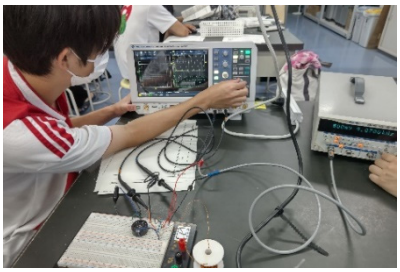


Figure 9. A photograph of impedance matching practice with an audio circuit.

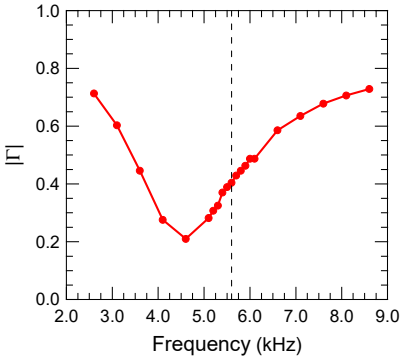


Figure 10. |Γ| value as a function of frequency. The target frequency is 5.6 kHz.

Students measure some parameters for impedance matching, as shown in Figure 9. A student team measured the absolute value of the voltage reflection coefficient, |Γ|, as a function of frequency (refer to Eq. 5), as shown in Figure 10. The target frequency was 5.6 kHz. The minimum value is obtained near the target frequency. The difference between the target and observed frequencies may be due to some line impedance.

The phase variation can be obtained by the Lissajous figures, as shown in Figure 11. Students measure the maximum height of the figure a and the difference between two points crossing the y-axis b. They finally obtain the phase angle θ by Equation 11. Note that this equation depends on inclination of the figure.

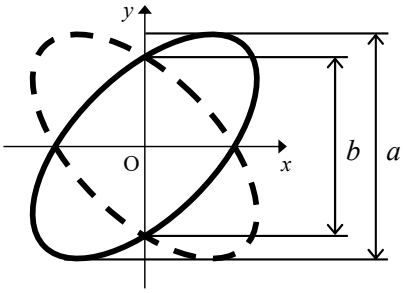


Figure 11. Lissajous figures.

$$\theta = \begin{cases} \sin^{-1}\dfrac{b}{a} & \text{(diagonal right, bold line)}, \\ \pi - \left|\sin^{-1}\dfrac{b}{a}\right| & \text{(diagonal left, broken line)}. \end{cases} \quad (11)$$

The team also measured θ as a function of frequency, as shown in Figure 12. The |Γ| presented in Fig. 10 is also shown as reference. The frequency where the minimum θ is obtained is the same value of the minimum |Γ|, demonstrating that $Z' = \overline{Z_0}$, as discussed before.

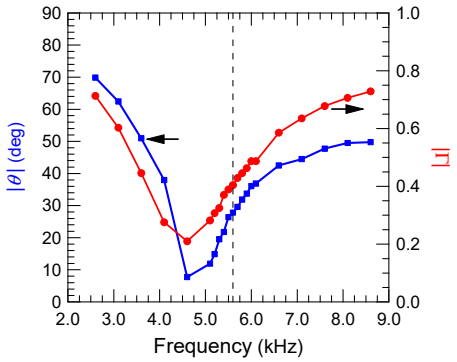


Figure 12. (left) θ and (right) |Γ| values as a function of frequency.

Practice 3: Impedance Matching in MHz Region with VNA

In a quarter of the sixth grade (first grade of the advanced course), students learn impedance matching in the MHz region. The two-port network model is used to analyze arbitrary electrical circuits. The Z- (impedance-) and Y- (admittance-) parameter analyses, as shown in Figure 13, are typical methods. The voltage and current input into a device under test (DUT) from the left side are V_1 and I_1, respectively. Those ones from the right side are V_2 and I_2, respectively. The relationship among these variables is expressed by Equations 12 and 13.

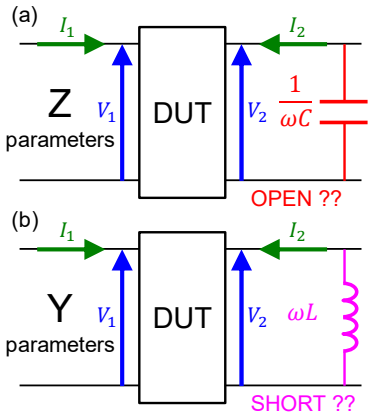


Figure 13. (a) Z- and (b) Y-parameter analyses.

$$\text{Z:}\ \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}, \quad (12)$$

$$\text{Y:}\ \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}. \quad (13)$$

To obtain each Z-parameter from Eq. 12, the left or right hand current, I_1 or I_2, should be zero. In other words, an open condition must be established. However, at a radio frequency, because the capacitive reactance $X_C = {}^{1}/_{\omega C}$ goes to zero, the open condition becomes impossible. Similarly, to obtain each Y-parameter from Eq. 13, V_1 or V_2 should be zero. A short condition must

be established. Any conductive lines accompany with inductance. Because the inductive reactance $X_L = \omega L$ goes to infinity at a radio frequency, the short condition becomes also impossible. After all, voltage and current cannot be measured independently at a radio frequency.

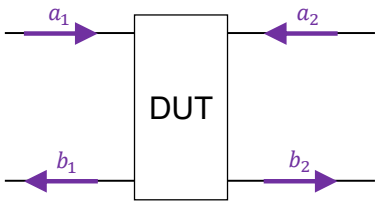


Figure 14. S-parameter analysis.

Instead of the Z- and Y-parameters, we must use S-parameters at a radio frequency. The input and output variables are the square roots of power a_n and b_n, respectively, as shown in Figure 14. The relationship is expressed by Equation 14,

$$\text{S: } \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}. \tag{14}$$

We obtain $\Gamma = S_{11}$. In the S-parameter analysis, the Smith chart, as shown in Figure 15, is convenient to understand the change of equivalent passive elements. From Eq. 5, we obtain Equation 15 that explains the Smith chart circle,

$$\left(u - \frac{R}{R+1}\right)^2 + v^2 = \left(\frac{1}{R+1}\right)^2, \tag{15}$$

where $Z \equiv {}^{Z_\ell}/_{Z_0} = R + jX$ and $\Gamma = u + jv$. On the Smith chart, resistance R increases from left to right (0 to ∞). Similarly, inductive reactance $+X$ increases clockwise, and capacitive reactance $-X$ increases anticlockwise. The $|\Gamma|$ equals to the line length (radius) between the measured point A and origin O, and the angle made by the line and positive x-axis indicates its phase angle θ. Impedance matching is accomplished at O, where $(R, X) = (1,0)$ and $(u, v) = (0,0)$. Using the Smith chart, we can know these values visibly without complicated calculation.

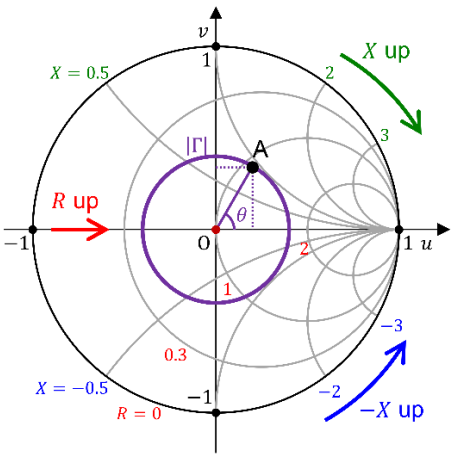


Figure 15. Smith chart.

We made a M/B used in the MHz region by using commercial elements: two trimmer capacitors and an inductor. The load is a simple LCR series. Figure 16 shows these ones.

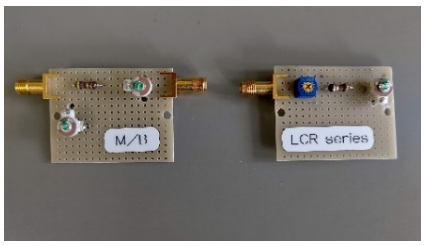


Figure 16. (left) M/B and (right) load for impedance matching in the MHz region.

The S-parameter analysis is performed with a vector network analyzer (VNA). The VNA is one of the most expensive apparatuses in electrical engineering. However, presently we can use a low-cost but high-performance VNA, NanoVNA. A NanoVNA is a palm-size apparatus. It can work either solely or with a PC. Students set their LCR loads arbitrarily to each other, and then they compete for the impedance matching. Figure 17 shows the practice.

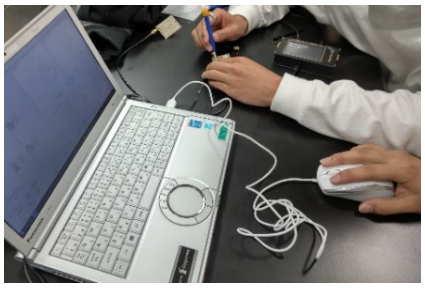


Figure 17. A photograph of impedance matching practice in the MHz region using a palm-size NanoVNA (top) with its control PC (left).

Practice 4: Impedance Matching of Waveguide in GHz Region with VNA

In the following quarter, students learn impedance matching in the GHz region, as a compilation of this education program. When the target frequency reaches GHz, the skin effect in electromagnetism becomes critical. The skin effect demonstrates that the current flows only at the surface of a conductor. The depth where the current can flow is estimated by the skin depth. The depth in copper at 2.45 GHz is approximately 1 μm. Thus, it is difficult to flow large current on a general circuit at such a frequency because the actual line resistance is so high.

To overcome this problem, the electrical power or signal should be flown as an electromagnetic wave in the space that is regulated by a waveguide. Impedance matching in a waveguide is basically to generate a standing wave inside the waveguide so that the short condition is accomplished at the walls. Figure 18 shows a waveguide system. The system is composed of a waveguide-to-coaxial adapter, a straight waveguide, and a dummy load having a sliding short bar to move the end wall. The latter two components are handmade.

The electromagnetic wave in a waveguide takes some propagation modes. The most basic one is the TE_{10} mode, as shown in Figure 19. The TE_{10} electromagnetic wave propagates along the wavenumber vector $\boldsymbol{k}$ by repeating reflections at the wall diagonally. The electric field vector $\boldsymbol{E}$ is along the y-axis, and the magnetic field vector $\boldsymbol{B}$ is on the xz-plane.

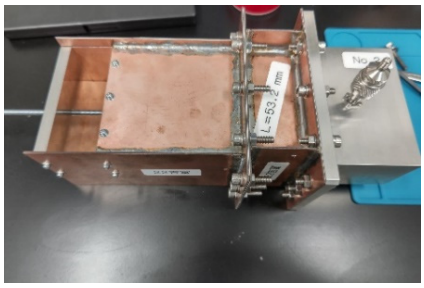


Figure 18. A waveguide system. The system is composed of (right) a waveguide-to-coaxial adapter, (center) a straight waveguide, and (left) a dummy load having a sliding short bar.

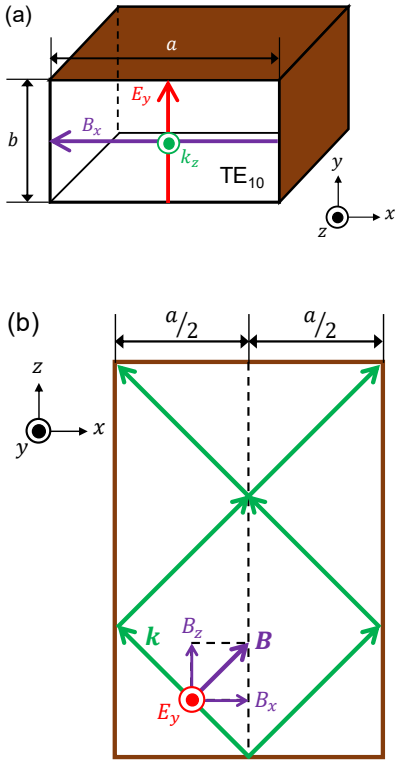


Figure 19. (a) Cross section and (b) top view of a TE_{10}-mode waveguide.

Students measure the S-parameters of a waveguide system using a NanoVNA, as shown in Figure 20. They learn variation of the characteristics by changing straight waveguide (from short one to the long) and moving the sliding short bar of the dummy load.

A student team measured $|\Gamma| = |S_{11}|$ as a function of frequency, as shown in Figure 21. The team obtained the minimum $|\Gamma|$ at 2.66 GHz in a waveguide of which the length is 246.4 mm. Like this, at present we have fortune that we can experience the VNA measurement easily with NanoVNAs.



Figure 20. A photograph of impedance matching practice of a waveguide (bottom) in the GHz region using a NanoVNA (right) and its control PC.

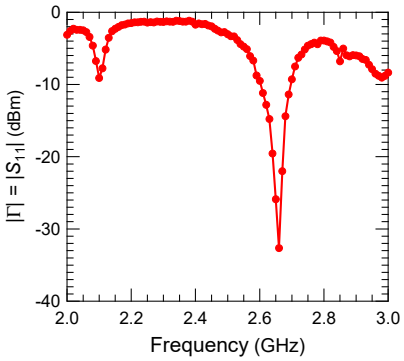


Figure 21. $|\Gamma| = |S_{11}|$ as a function of frequency (the LogMag characteristics in dBm).

Conclusions

A step-by-step education program of impedance matching in Ariake Kosen was explained. The education program comprises four practices. This education starts in a half of the fourth grade from electromagnetism theory with Maxwell's equations including the skin effect and electromagnetic wave (Practice 1). Actual impedance matching of an audio circuit in the KHz region is performed in a quarter of the next fifth grade (Practice 2). Finally, in the sixth grade (first grade of the advanced course), impedance matching of the circuit in the MHz region (Practice 3, a quarter) and that of a waveguide in the GHz region (Practice 4, another quarter) are experienced with the S-parameter analysis using a NanoVNA. Through this program, Kosen students will be expected to be radio-frequency electrical engineers.

Acknowledgements

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References

C Pozar, D. M. (2011). Microwave Engineering. 4th ed. New York: Wiley.

NanoVNA V2 Official Site. https://nanorfe.com/nanovna-v2.html.

A New Approach to English Education for Technical College Students

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Higher English proficiency is increasingly required for technical college students who aspire to become global engineers. However, it has been a difficult issue about how to keep the motivation of English learning at a constant high level for students with an engineering background in Japan. To effectively and steadily improve students' English skills, it is essential to explore new teaching methods in addition to traditional approaches. In this study, we tried a unique approach to improve the present situation of English education in our department. It was applied to the subject called "Basic Chemistry Experiments" for the 1st-grade students. The idea is to intertwine English learning and professional knowledge together so the students know the reason they should learn English and how to use English in their professional fields. We developed one set of interactive professional English learning contents and applied it to our 1st-grade students. It includes an interactive e-Book describing 20 lab equipment with written description, audio, photo, video and quizzes, a set of e-Book quizzes which tests their understanding on related background knowledge right after every experiment they did, a set of Microsoft Forms quizzes which is assigned to students every week for testing their vocabulary of lab equipment and chemical regents. Students practice these contents right after finishing the experiment or are given assignments for vocabulary tests (English to Japanese, Japanese to English and English spelling). During the whole year-long learning process, students also have a chance to experience making simple e-books by themselves. The feedback from students is very positive and contributed to the improvements of these contents. We also prepared video instruction contents to let students get hands-on with their mobile phones so they can learn at any time and any place they want.

Keywords: *English education, chemistry experiments, e-Book, interactive, motivation*

Introduction

For fostering engineers who are able to succeed on world-wide stage, many approaches have been conducted in KOSEN recently to improve the students' English skill. National Institute of Technology (KOSEN) have taken many initiatives such as launching 5-year global education projects in many colleges, hiring native English teachers and providing exchange programs of sending Japanese student to abroad and accepting foreign students from different countries to offer opportunities for communication and mutual culture understanding. With all these efforts, the English skill for KOSEN students has been improved and the TOEIC-IP average score has kept on improving during the past 5 years. However, comparing to other educational institutes such as high schools and universities, TOEIC score of KOSEN students is still at the lowest level. Therefore, it is hard to say that present situation of English education in KOSEN is good enough and all the initiatives taken are very effective. Many KOSEN students don't have a strong motivation to learn English even they understand that English is very important for their future careers. Therefore, we should rethink the way we teach English in KOSEN. Should English teaching be done only by English teachers? Are the teaching styles for high school students or university students good for KOSEN students? Is there any better way or method by which KOSEN students can learn English positively with a constant high motivation? 5 years ago, we started an unique approach by introducing English learning into an experimental subject (Basic Chemistry Experiments) for 1st grade students in our department. We think this is the better way to let students to be motivated in learning English because the importance of English becomes tangible, and they can see the reason they need to learn English and can learning it in a fun way because KSOEN students love experiments. Intertwining English learning with professional experiments can be a much more effective way to let them keep a constant motivation and get a better result. In this paper, the tailor-made interactive electronic contents we made and the way of practicing these contents in the students' experiments will be presented.

Development of Interactive Electronic Contents

Three types of electronic contents have been developed.

1. *Interactive electronic contents for lab equipment*

20 kinds of basic lab equipment were selected for this approach (Fig.1). The description for each of them is given in a style of words, photo, video, audio and quiz as shown in Fig.2. First, a photo is shown for the equipment and then there is a brief description of the equipment in written words. The English reading of the description is also available in audio form shown as a speaker icon. Both reading and listening abilities are tested. Under the description there is an online video link for students to experience the explanation by a native speaker. After getting the basic concept of the equipment, a quiz is designed for checking the students' knowledge about the equipment. There is an explanation for every selected answer on why their choice is correct or wrong. The final page for every lab equipment includes questions give in audio form to let students answer them with their own English. As shown in Fig.1, most equipment selected are lab glassware and others are safety tools such as lab coat, goggles, etc.

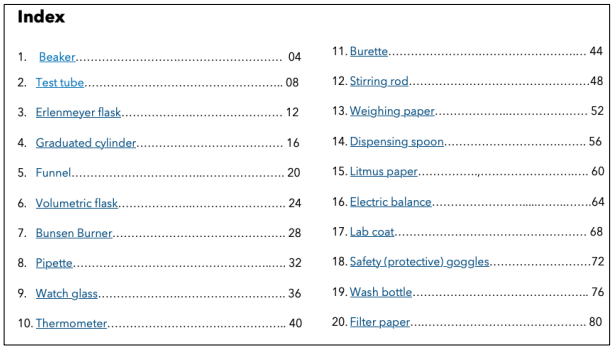


Fig.1 Index of Interactive e-Book for 20 lab equipment.

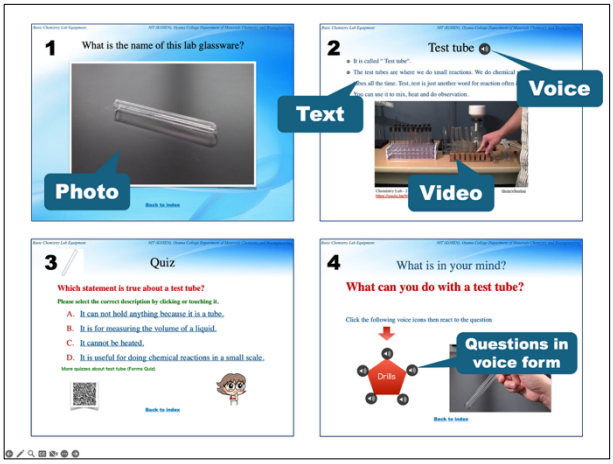


Fig.2 Example of 4-page contents including words, photo, voice, video and quizzes for every lab equipment.

2. *Quizzes for Every Experiment*

There 18 experiments in the subject of Basic Chemistry Experiments. For each experiment, one set of quizzes has been designed. It includes questions inquiring the background knowledge about the experiment, specific experiment skills and safety cautions. The quizzes are given in different styles such as questions in words, photo selection of lab equipment, and questions given by audio form. With these quizzes (Fig.3), the students can confirm their professional

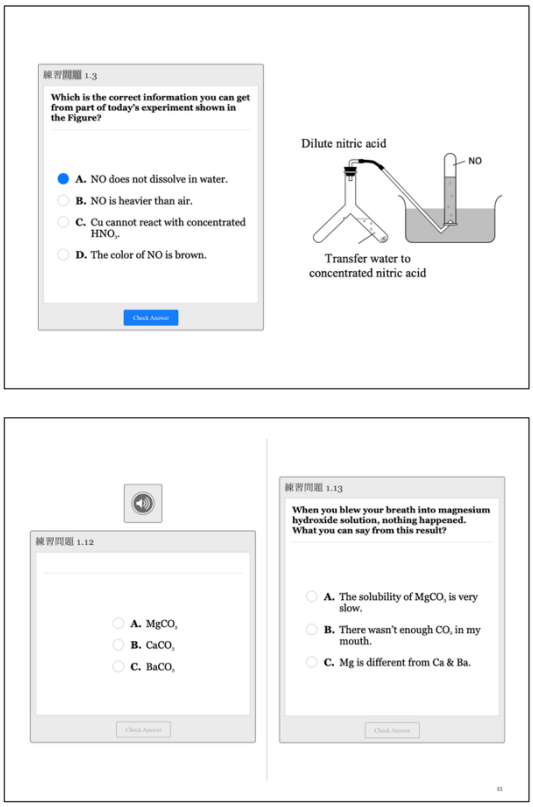


Fig.3 Examples of quizzes for every experiment.

knowledge while learning English to improve their reading, listening and speaking skills. They practice these quizzes right after they finish every experiment.

3. *Vocabulary Quizzes for Lab Equipment and Chemical Reagents*

A set of quizzes of English words for lab equipment and chemical reagents has been developed as an assignment. It includes three parts, translation of English to Japanese, translation of Japanese to English, and English word spelling check. 10 different lab equipment and 10 frequent-use chemical reagents were selected for the set of quizzes as shown in Table 1. The typical style of the quizzes is shown in Fig.4 and Fig.5, respectively.

Table1 List of vocabulary of lab equipment and chemical reagents

No.	Lab Equipment	Chemical Reagent
1	beaker	sodium chloride
2	test tube	sulfuric acid
3	Erlenmeyer flask	nitric acid
4	graduated cylinder	hydrochloric acid
5	funnel	sodium hydroxide
6	volumetric flask	manganese dioxide
7	Bunsen Burner	ammonia
8	pipette	hydrogen peroxide
9	watch glass	ethanol
10	thermometer	hydrogen sulfide

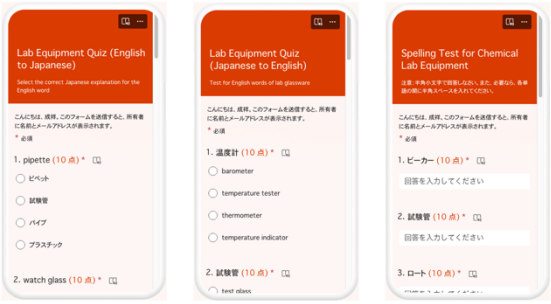


Fig.4 Mobile phone screenshots of quizzes for chemical lab equipment.



Fig.5 Mobile phone screenshots of quizzes for chemical reagents.

4. *Other English Learning Materials*

Besides the above contents, we also selected one experiment for total English learning. The description slides, experiment report and the teacher's explanation of the background knowledge about the experiment are all in English. We also prepared some instruction videos for using the developed contents by their own PC, iPhones or iPads. They can download the contents to their mobile devices and practice them after class by themselves.

Ways of Conducting the Electronic Contents

The purpose of developing these contents is to raise the students' motivation of learning English. Therefore, the contents have been applied to the subject of Basic Chemistry Experiments even at the early stage of development. This PDCA cycle led to constant improvement of the contents and students also benefit a lot from practicing them.

The subject of Basic Chemistry Experiments is scheduled once a week for 1st grade students in our department. For every 3-hour experiment, 15-20 minutes are used for practicing the contents. About 40 students are put into 10 groups and each group (4 students) has one iPad. The following practices are conducted.

1. Weekly practices

After each experiment, students start to practice English. First one is the quizzes for testing their background knowledge of the experiment they did that day. In one group, 4 students work together to figure the meanings of the questions and answer the quizzes. Then they can choose one of the contents for lab equipment to do further practice. After finishing the practices, every group is asked to submit a report about what they did and how they assess the performance of themselves. Another weekly routine work is the assignment. Assignment of vocabulary quizzes shown in Fig.4 and Fig.5 are given every week. To keep the students' motivation, the average score of these assignments counts as one experimental report in the first and second semester, respectively.

2. Making their own electronic contents

We arrange on experiment time (3hours) to let students to make their own e-Books by using the software Page with iPads. They can make questions in words, photos and voices and then ask students from other groups to answer the questions. Students had a fun time to engage, and it is also a good chance of experiencing digital contents making which may benefit them in the future.

3. Experiment Instruction in English

For every experiment a 50-minute instruction is given by teachers before the start of doing experiment. It includes explanation of background knowledge such as experimental phenomenon and related chemical reactions, details of every experiment step, and specific cautions students need to know. As mentioned above, one experiment, Making Oxygen and Measuring Its Density, is selected and teachers give the instruction in English. For achieving better learning result, it is arranged in the second half of the first semester after they have practiced other English learning contents several times. Students are also asked to submit their report for this experiment in English.

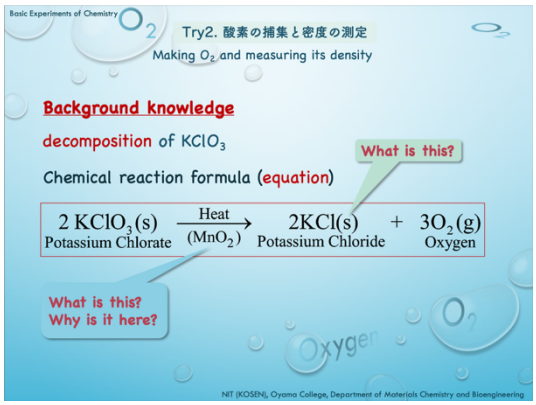


Fig.6 An example of the PPT slides used for the experiment instruction.

Results and Discussion

This project has been conducted since 2020. Students who attended this project gained progress in professional English by knowing technical words and expressions. Fig.7 shows their journey of making progress week by week by doing technical vocabulary quizzes. Fig.8 shows the score comparison for the same students who took part in the project at their 1st year in 2021 and then answered

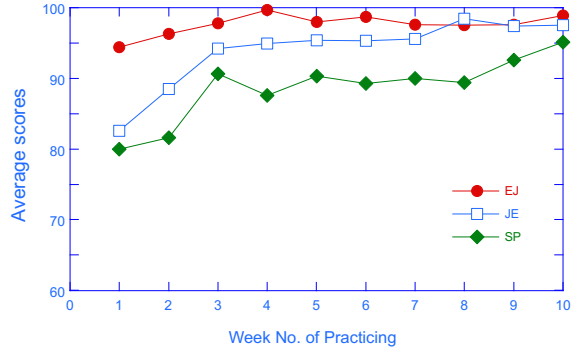


Fig.7 Changes in average scores for 3 types of lab equipment vocabulary quizzes. EJ: English to Japanese, JE: Japanese to English, SP: Spelling.

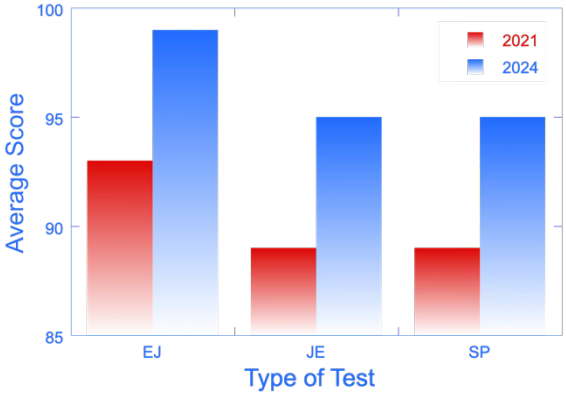


Fig.8 Results of lab experiment vocabulary test from the same students when they were 1st grade students in 2021 and 4th grader students in 2024. EJ: English to Japanese, JE: Japanese to English, SP: Spelling.

the same lab equipment vocabulary quizzes in 2024 when they became 4th grade students. With the experience in 1st year, most of them have kept a strong motivation of learning English and haven't forgotten what they learned.

Another evidence of showing the effectiveness of this approach is the questionnaires taken every year. Most of the answers are very positive. In 2024's questionnaires, when asked "Did you actively engage in professional English learning over this academic year?", 100% of them said "Yes". When asked "Was learning professional English using the developed electronic contents effective?", 92% replied "Yes" and other 8% replied "Basically". When asked "What were the advantages of learning professional English using an iPad?", the top three replies are as following:

1. It was great to be able to learn both technical knowledge and English at the same time.
2. Learning in groups was a great experience.
3. The quizzes related to each experiment were beneficial.

All feedback from the students who took part in this project during the past 5 years confirmed the effectiveness of the interactive electronic contents we developed and the ways we practice them.

Conclusions

The interactive electronic contents we developed are well intertwined with the subject of Basic Chemistry Experiments. With 5-year practicing, students are totally engaged with this approach and accepted it as a routine part of the subject. Students now have higher motivation in learning English because they feel enjoyable by practicing English with the chemistry experiments which they like the most. The progress that students achieved by practicing the contents and the yearly feedback from them proved the effectiveness of the contents we made and the ways we deal with the contents in practicing. Combining English learning with professional studies, especially experimental subjects is an effective approach of levitating students' motivation of English learning.

Acknowledgements

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References

The Institute for International Business Communication. TOEIC Program DATA & ANALYSIS 2024 (pp8).

S. Take, M. Iijima, T. Degawa, K. Nishii & H. Sakai. Proceeding of 88th ECSJ Annal Meting, Symposium of Opening the Future of Technology and Education. 3T07.

S. Take, M. Iijima, T. Degawa, K. Nishii & H. Sakai. Proceeding of 89th ECSJ Annal Meting, Symposium of Opening the Future of Technology and Education. 1Q07.

S. Take, M. Iijima, T. Degawa, K. Nishii & H. Sakai. Proceeding of 90th ECSJ Annal Meting, Symposium of Opening the Future of Technology and Education. 3S12.

S. Take, M. Iijima, T. Degawa, K. Nishii & H. Sakai. Proceeding of 92nd ECSJ Annal Meting, Symposium of Opening the Future of Technology and Education. S17_3_14.

Comparative Analysis of Disability Support in Thailand and Japan: Legal Frameworks, Institutional Approaches, and the Current Status in KOSEN

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The purpose of this study is to compare the legal frameworks and support systems for students with disabilities in Thailand and Japan, with a particular focus on KOSEN. While Thailand has established comprehensive laws promoting inclusive education and reasonable accommodation, interviews with Japanese faculty members at Thai KOSEN revealed a gap between institutional policy and actual practice. Specific challenges include the lack of formal individualized education plans, minimal accommodation requests at the time of admission, and a reliance on individual teachers' discretion. In contrast, Japanese KOSEN follow legally mandated procedures, and over 50% of students with disabilities receive support. However, even in Japan, some students hesitate to request accommodations, leading to delays. This study clarifies both the alignment and the disconnect between legal frameworks and on-site practices in Thailand, providing a basis for future considerations regarding more effective support implementation.

Keywords: *Disability Support, Inclusive Education, KOSEN, Disability Rights*

Introduction

Thailand has achieved economic growth through industrial agglomeration and the liberalization of trade within ASEAN. The country needs structural transformation to ensure further development. The Thai government launched the "Thailand 4.0" policy in 2015, aiming to advance industrial sophistication and value-added production by promoting infrastructure development and investment in key industries (Oizumi, 2017). It is essential to foster engineers with advanced expertise and practical skills, leading to the establishment of two KOSENs in Thailand. In order to ensure uniformity in education, the curriculum was designed based on the Model Core Curriculum used in Japanese KOSEN (Aburatani, Kano, Komatsu, Uehara, Teawchim, & Sittichivapak, 2023).

In recent years, the number of students with disabilities in Japanese higher education institutions has been increasing. As a result, universities and colleges are required to improve campus support systems and provide reasonable accommodations through institutional collaboration (Japan Student Services Organization, 2024). However, several challenges remain, including stagnant support provision rates, difficulties in accumulating expertise due to fixed-term employment of support staff, and insufficient specialized responses for students with developmental disorders (Japan Student Services Organization, 2019).

Given these challenges in Japan, similar issues may arise in the Thai KOSEN system. Currently, two KOSENs are operating in Thailand based on the Japanese education model. Understanding the similarities and differences between the support systems in Japan and Thailand could offer meaningful insights for developing effective support frameworks in Thai KOSENs.

This study aims to examine the legal systems for disability support in Thailand and compare them with those in Japanese KOSEN. It also investigates the current status of disability support in Thai KOSEN through interviews with Japanese teachers who have teaching experience at Thai KOSEN.

Methods

Four official documents (Constitution of the Kingdom of Thailand, 2017; Royal Thai Government, 2007; Royal Thai Government, 2008/2013; Notification of the Committee for the Promotion of the Provision of Education for Persons with Disabilities on Criteria, Rates, and Categories of Educational Subsidies in Higher Education,2018) concerning disability and education in Thailand were translated into Japanese and analyzed to ascertain their provisions. Two Japanese teachers who have teaching experience at Thai KOSEN were interviewed about the status of enrollment and support for students with disabilities in Thailand.

Results

(1) Principles of Equality and Education in the Kingdom of Thailand and situation

The Constitution of the Kingdom of Thailand declares that all citizens shall be equally protected under the law, and individual rights, freedoms, and equality must be respected (Constitution of the Kingdom of

Thailand, 2017). Furthermore, the government is obligated to ensure access to free and quality education for all children from preschool through twelve years of compulsory schooling. It must also support educational expenses for those in financial difficulty and promote lifelong learning. In this way, Thailand guarantees the right to education for all citizens, regardless of disability status (Constitution of the Kingdom of Thailand, 2017).

In actual practice at Thai KOSEN, it has been reported that students who face learning difficulties related to disabilities—such as delays in academic progress or challenges in interpersonal relationships—receive support through counseling and individualized learning assistance. These practices are generally consistent with the constitutional principles of ensuring continued access to education.

(2) The Rights of Persons with Disabilities

In 2007, Thailand enacted the Persons with Disabilities Empowerment Act (พระราชบัญญัติส่งเสริมและพัฒนาคุณภาพชีวิตคนพิการ) to improve the quality of life for persons with disabilities. The Act aims to prohibit discrimination against persons with disabilities and to guarantee equal participation in society. It specifies the responsibilities of national and local government agencies, as well as the private sector, to ensure access to medical care, education, employment, social activities, and reasonable accommodation in public services and facilities (Royal Thai Government, 2007).

The Act defines a "person with a disability" (คนพิการ) as someone who has impairments in vision, hearing, mobility, communication, mental or emotional condition, behavior, cognition, learning, or other functions that limit participation in daily life or social activities, and thereby requires special support (Royal Thai Government, 2007). Registered individuals are eligible to receive a variety of supports, including rehabilitation services, assistive devices, sign language interpretation, guide dogs, tuition exemptions, and access to education and political participation. Tax benefits and financial assistance are also provided in accordance with individual needs.

However, these institutional supports are not always fully utilized in practice. According to interviews, students with disabilities and their families tend to be reluctant to request accommodations proactively. Few students request support upon admission, and their difficulties often become apparent only after enrollment. Interviewees noted that rather than relying on formal institutional support, accommodations are often provided on a case-by-case basis in response to academic difficulties. This suggests that systematic, legally grounded support is not yet fully established at Thai KOSEN.

(3) Legal framework of Educational Support for Students with Disabilities

The Act on the Provision of Education for Persons with Disabilities (พระราชบัญญัติการจัดการศึกษาสำหรับคนพิการ), enacted in 2008 and amended in 2013, was introduced in response to the need for legal arrangements regarding the education of persons with disabilities. This Act ensures that individuals with disabilities, whether from birth or later diagnosed, have the right and opportunity to receive educational services and special support throughout their lifetime. It serves as a fundamental law to enable comprehensive support for persons with disabilities at all levels and in all types of educational systems（Royal Thai Government, 2008).

The Act also addresses inclusive education, defining it as an approach that enables persons with disabilities to study within the general education system All educational institutions under government jurisdiction are required to provide both inclusive and specialized education based on individualized education plans（Royal Thai Government, 2008).

These plans are intended to address individual special educational needs and must specify instructional guidelines, assistive technologies, learning materials, and support services. All educational institutions are obligated to create such plans and are required to review and update them annually.

The Act and its amendment establish a legal and institutional foundation to ensure equal educational opportunities for persons with disabilities while receiving special support. It forms the legal basis for inclusive education in Thailand.

Interviews revealed that some efforts are being made at KOSEN, such as adjusting teaching methods and classroom seating according to the needs of students. However, these responses are not part of a formal institutional system. Information about accommodations tends to be shared verbally and in meetings, without official documentation. As a result, discrepancies in support among teachers have been observed. This highlights a gap between legal mandates and educational practices on the ground.

(4) Admission Obligations of Higher Education Institutions

All higher education institutions under government jurisdiction in Thailand are legally obligated to admit a certain proportion and number of students with disabilities. Refusing admission based on their disability is considered unjust discrimination (Notification of the Committee for the Promotion of the Provision of Education for Persons with Disabilities on Criteria, Rates, and Categories of Educational Subsidies in Higher Education, 2018).

Interview findings indicate that the actual enrollment of students with disabilities at KOSEN is low. Students do not submit any requests for accommodations at the time of admission. However, some students experience difficulties during their studies, for example, in completing assignments or interacting with others, which reveals their need for support. In such cases, KOSEN faculty members provide individualized assistance for students.

Discussion

Legal Framework and Implementation of Support in Japan: In Japan, the Act for Eliminating Discrimination against Persons with Disabilities came into effect in April 2016. This law obligates elementary, secondary, and higher education institutions to provide reasonable accommodation to students with disabilities as necessary (Cabinet Office, Government of Japan, 2013). According to Article 2 of the Convention on the Rights of Persons with Disabilities, "reasonable accommodation" refers to necessary and appropriate modifications and adjustments that do not impose a disproportionate and undue burden, to ensure that persons with disabilities can enjoy and exercise all human rights and fundamental freedoms on an equal basis with others.

Under this framework, students and their guardians must apply for support, and the specific accommodation measures are determined through consultation with the institution.

In higher education institutions, various forms of support are provided to enrolled students with disabilities. In 2021, the support rate for students with disabilities (i.e., the proportion of those receiving support among all students with disabilities) was 53.4%, an increase from 45.7% in 2006. However, it has been pointed out that many students with disabilities have difficulty in articulating their needs (Matsuzaki, 2022). In this case, it is difficult for students to seek support, potentially delaying the start of necessary accommodations (Japan Student Services Organization, 2022).

Comparison of Disability Support in Japan and Thailand and Identified Issues: Although Thailand has established a comprehensive legal framework for supporting students with disabilities, several challenges remain in its practical implementation. Support-related information is mainly shared verbally rather than formally documented. Additionally, although reasonable accommodation is clearly stipulated in the law, support at KOSEN tends to rely on the discretion of individual teachers rather than being provided through an institutionalized system. Furthermore, although students are procedurally able to apply for accommodations at the time of admission, such applications are rarely submitted.

Conclusions

This study compared the legal framework for disability support in Thailand with the actual practices of educational support implemented at KOSEN, in order to examine the consistency between institutional systems and on-site practices. The findings indicate that, although legal structures related to educational equality and reasonable accommodation are relatively well established in Thailand, the actual support provided at KOSEN tends to rely on individualized, case-by-case responses.

It is important to further consider effective support strategies. It is also necessary to analyze the characteristics of the disability support system at KOSEN in Japan and identify practices that can be adapted.

References

Aburatani, H., Kano, S., Komatsu, M., Uehara, N., Teawchim, S., & Sittichivapak, S. (2023). Implementation of introductory engineering education at KOSEN-KMITL in Thailand: Fostering the 1st-year students' KOSEN mindset. Proceedings of the Conference on Engineering Education in the Era of Globalization I, Presentation No. 2C07. (in Japanese)

Cabinet Office, Government of Japan. (2013). Act for Eliminating Discrimination against Persons with Disabilities. Retrieved from https://www8.cao.go.jp/shougai/suishin/pdf/law_h25-65.pdf (Accessed on: July 20, 2025)

Constitution of the Kingdom of Thailand, B.E. 2560 (2017). Royal Thai Government Gazette.

Japan Student Services Organization (2019). Analytical Report on Support for Students with Disabilities in Universities, Junior Colleges, and KOSEN. Retrieved from https://www.jasso.go.jp/statistics/gakusei_shogai_syuga ku/__icsFiles/afieldfile/2021/02/10/analysis2016.pdf (Accessed on: July 20, 2025)

Japan Student Services Organization (2022). FY2021 Survey Report on Support for Students with Disabilities in Universities, Junior Colleges, and KOSEN. Retrieved from https://www.jasso.go.jp/statistics/gakusei_shogai_syuga ku/__icsFiles/afieldfile/2022/08/17/2021_houkoku_2.pd f (Accessed on: July 20, 2025)

Japan Student Services Organization (2024). FY2023 Survey Report on Support for Students with Disabilities in Universities, Junior Colleges, and KOSEN. Retrieved from https://www.jasso.go.jp/statistics/gakusei_shogai_syuga ku/__icsFiles/afieldfile/2024/11/11/2023_houkoku_3.pd f (Accessed on: July 20, 2025)

Ministry of Foreign Affairs of Japan (2014). Convention on the Rights of Persons with Disabilities. Retrieved from https://www.mofa.go.jp/mofaj/fp/hr_ha/page22_000899 .html (Accessed on: July 20, 2025)

Matsuzaki, J. (2022). Reasonable accommodation and preemptive measures for students and researchers with hearing disabilities. Trends in the Sciences. (in Japanese)

Notification of the Committee for the Promotion of the Provision of Education for Persons with Disabilities on Criteria, Rates, and Categories of Educational Subsidies in Higher Education, B.E. 2561 (2018). Retrieved from the Office of the Higher Education Commission.

Oizumi, K. (2017). What is “Thailand 4.0”? (Part 1): Thailand shifts toward high growth strategies. Pacific Rim Business Information, 17, 66. (in Japanese)

Royal Thai Government. (2007). Persons with Disabilities Empowerment Act, B.E. 2550 (2007). Royal Thai Government Gazette. Retrieved from the Office of the Council of State.

Royal Thai Government. (2008/2013). Act on the provision of education for persons with disabilities, B.E. 2551 (2008), and amendment B.E. 2556 (2013). Royal Thai Government Gazette. Retrieved from the Office of the Council of State.

Development of a Scratch Extension to Use Python in the Scratch Editor

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We have developed a Scratch extension that enables teachers and students to execute Python code directly within the Scratch editor. This extension supports teachers who use Scratch in STEAM education by facilitating the preparation of teaching materials. It also serves as an effective educational tool for students to learn Python. In this paper, we introduce the extension and present several examples to demonstrate its application.

Keywords: *educational tool, STEAM education, visual programming, development environment*

Introduction

Scratch, developed by the Scratch Foundation (2013), is a visual programming language that allows users to create programs by combining graphical blocks. It is designed to promote computational thinking and problem-solving skills of students. Scratch is not only a powerful tool for teaching programming, but also an effective platform for promoting STEAM (Science, Technology, Engineering, Art, and Mathematics) education. In fact, many teachers around the world incorporate Scratch into their classroom activities.

On the other hand, Scratch has certain limitations in handling the complex calculations that are often necessary in STEAM education. And students are generally unfamiliar with programming. As a result, teachers often need to prepare large and complex Scratch scripts in advance to support classroom activities.

Instead of creating large and complex Scratch scripts, teachers can also utilize Scratch extensions. For example, Scratch has some built-in extensions such as "Music" (which plays instruments) and "Translate" (which translates text into other languages). However, developing original extensions requires advanced programming skills.

To address this issue, Tokairin, T. & Nakano, M. (2025) have developed a Scratch extension that enables teachers and students to execute Python code directly within the Scratch editor. The extension supports teachers by facilitating the preparation of teaching materials because they can utilize many powerful Python modules to perform complex calculations within the Scratch editor.

Usage of the extension

First, open any web browser and navigate to

https://tmytokai.github.io/scratch-python/

Next, in the Scratch editor, click the button at the bottom-left corner to open the "Extensions Library". Then click the icon shown in Figure 1. After that, a set of blocks will appear in the “Block Palette” as illustrated in Figure 2.

The top block shown in Figure 2 loads Python code from a specified URL. The remaining blocks execute functions defined within the Python code.

Once Python code is loaded, no further network access is required. Therefore, Python code is executed very quickly. The appendix illustrates the technical architecture of the extension.

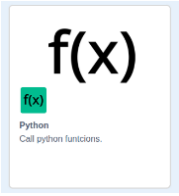


Figure 1: Icon of the extension.

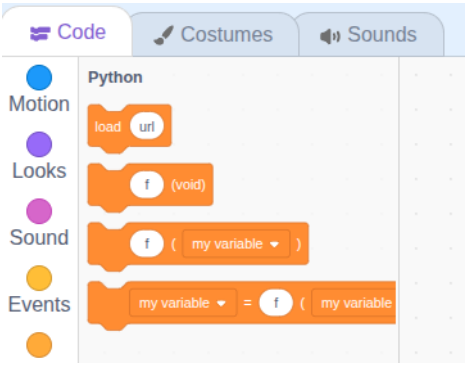


Figure 2: Blocks of the extension.

Examples

Example 1: Sorting

Here is an example of a sorting algorithm. Although sorting is one of the most fundamental algorithms, Scratch does not provide built-in blocks for sorting. As a result, users must create large and complex scripts on their own. Therefore, this example is useful in many applications.

First, upload the Python code shown in Figure 3 to any web server. This code includes a sorting function called "sort(x)". Next, execute the Scratch script shown in Figure 4. This script initializes a list x and sorts it by calling "sort(x)". The result is shown in Figure 5.

```
def sort(x):
    return sorted(x)

__export__ = ['sort']
```

Figure 3: Python code of example 1.

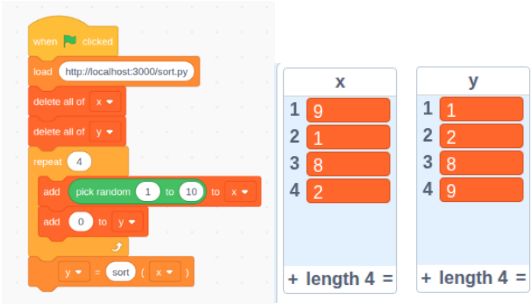


Figure 4: Scratch script of ex.1. *Figure 5: Result of ex.1.*

Example 2: Power spectrum

Complex calculations frequently arise in STEAM education. As an example, the power spectrum of list x can be easily obtained by Python code shown in Figure 6 and Scratch script shown in Figure 7. The result is shown in Figure 8.

Conclusions

We introduced a Scratch extension that executes Python code within the Scratch editor. This extension can be applied to a wide range of cases beyond the examples presented in the previous section. Therefore, it significantly reduces the workload for teachers.

Moreover, it serves as an precursor educational tool for students to learn Python in a familiar programming environment, i.e. Scratch.

Appendix

This extension is built on top of PyScript. PyScript, developed by the PyScript Development Team(2022), is a web-based platform that executes Python code directly in a web browser. For example, the HTML code shown

```
import numpy as np

def powerspectrum(x):
    return (np.abs(np.fft.fft(x))**2).tolist()
.
__export__ = ['powerspectrum']
```

Figure 6: Python code of example 2.



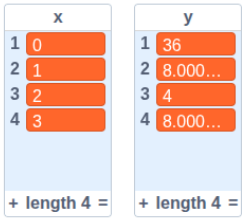


Figure 7: Scratch script of ex.2. *Figure 8: Result of ex.2.*

in Figure 9 displays random numbers in the browser's debug console.

```
<!doctype html>
<html>
<head>
<link rel="stylesheet"
href="https://pyscript.net/releases/2025.3.1/cor
e.css">
<script type="module"
src="https://pyscript.net/releases/2025.3.1/core.
js"></script>
</head>
<body>
<py-script>
    import random
    for i in range(5):
        print(random.randint(1, 100))
</py-script>
</body>
</html>
```

Figure 9: Example of PyScript.

References

PyScript Development Team. (2022). *What is PyScript?*. Retrieved from https://docs.pyscript.net/2025.3.1/user-guide/what/

Scratch Foundation. (2013). *About Scratch*. Retrieved from https://scratch.mit.edu/about/

Tokairin, T. & Nakano, M. (2025). Development of Scratch3 extension to collaborate with Python. *Proceedings of 30th KOSEN symposium 2025 in Okayama*, 241201.

APPLYING OPTICAL CHARACTER RECOGNITION AND DEEP LEARNING TO A WEB APPLICATON FOR STUDYING ENGLISH WORDS IN A SPECIALIZED FIELD OF STUDY

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Many English vocabulary learning applications are oriented towards general English contents and are not be suitable for university and vocational students to learning English vocabulary in their specialized fields. Therefore, we have developed Hi-lex, an English learning web application aimed at students learning English vocabulary in specialized fields. Hi-lex was developed using Python and Django, a web application framework for Python. In this study, we implemented a sentence input function using Optical Character Recognition (OCR) and an article suggestion function that enables users to learn by suggesting articles related to the Hi-lex helps users improve their English language skills by allowing them to create and store a customized vocabulary list from the English sentences they want to study. Users can then review their stored words in a flashcard-style format with their desired device. Since its launch in September 2023, the only way to enter text into Hi-lex was by copy and pasting or directly entering text into a the program. To enable learners to learn English words from printed texts, photographs and uneditable computer files, we added a text input function using OCR. To implement this function, we used open-source Python libraries such as Pytesseract, PyOCR, Pillow, and pdf2image. The implemented function first identifies whether the file is a PDF file or not when the file is entered into the file form, and converts it to an image file using Pdf2image if it is a PDF file. Then, it extracts the English words in the image using PyOCR and Pytesseract. The extracted English words are tokenized by the Natural Language Toolkit (NLTK), a Python plugin that was already used by the program. Once this process is finished, a profile of each word is displayed and a student can immediately obtain information such as the definition of the word, it's part of speech, related field and level of difficulty. Additionally, to make it easier for users to learn English words related to their major field of study, an article compliation function that enables users to learn by compiling articles related to the input text has been implemented in Hi-lex. The function summarizes text input into Hi-lex by user and uses the API to search for and present articles related to the summarized sentences on arXiv.

Keywords: *OCR, Second language acquisition, Spaced repetiton software, Autonomous learning*

Introduction

Vocabulary acquisition is a complex and crucial aspect of second language learning (Dionisio et al., 2022). While learning through applications has proven to be a useful method, most widely available applications focus on general vocabulary, making them less suitable for students in higher education who need to learn specialized terminology within their fields of study. To address this need, researchers at Hiroshima University and the National Institute of Technology, Matsue College have been developing and operating an English learning support web application since September 2023. This application, named the Hi-lex system, is built using Python and a web application frameword, called Django, and aims to provide a practical and efficient learning tool. Hi-lex allows users to find and learn specialized vocabulary, whether unfamiliar or familiar, as described by Fraser et al. (2025). The system features a front end (e.g., HTML, Bootstrap) and a back end (e.g., Python, JavaScript, Django), utilizing word lists and test data stored in a database to facilitate user learning. It is publicly accessible on AWS Lightsail and is currently being used by approximately 130 students at Hiroshima University and National Institute of Technology, Matsue College.

This paper details the development and evaluation of two extended functionalities implemented in Hi-lex: a function for inputting text from files using OCR and a function for searching for related articles based on the input text. The goal of these new features is to further enhance learning opportunities for users.

Usage of the Software

Fig. 1 illustrates the Hi-lex learning process. First, a user inputs English text into the system. The Natural Language Toolkit (NLTK) then transforms the words in the sentence into their basic forms and displays information such as meanings, parts of speech, and difficulty levels. These word lists provide crucial information that helps learners select both common and specialized vocabulary (Higa and Ashida, 2023). NLTK also supports sentence classification, normalization, and parsing. After reviewing the displayed words, the user selects the necessary English words to create a personalized vocabulary list. The system then generates word tests from this created list. To optimize memory retention, the word utilizes the SuperMemo2 algorithm, which determines the optimal interval for reviewing each word. Fig. 2 shows an example of the Hi-lex English vocabulary review function.

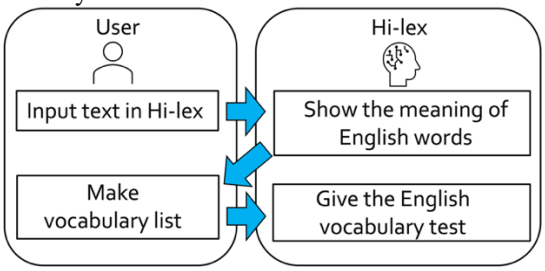


FIGURE 1. The Chart of Hi-lex Learning Process.



FIGURE 2. English Vocabulary Review Function

Development of the Sentence Input Function Using OCR

Previously, the only way to input English text into Hi-lex was for a user to type or paste it into a text field. This made it difficult to handle multi-page documents and handwritten text. To overcome this limitation, we implemented an OCR (Optical Character Recognition) function in Hi-lex. This feature recognizes characters in image data, converts them into text, and can extract English words from PDF and image files. The English input form is shown in Fig. 3. To accommodate PDF and image file uploads, we added a new file form using Python, and toggle buttons were added with HTML, CSS, and JavaScript to switch between the two input methods.

To implement this functionality, we utilized several libraries: Pillow for Python image processing, Pytesseract as the OCR engine, and PyOCR to act as a bridge between Python and the OCR engine.



(a)Text Form (b)File Form

FIGURE 3. The File Input Form

Since OCR primarily supports image files, we also integrated pdf2image to convert PDF files into images before processing. The file input workflow is illustrated in Fig. 4.

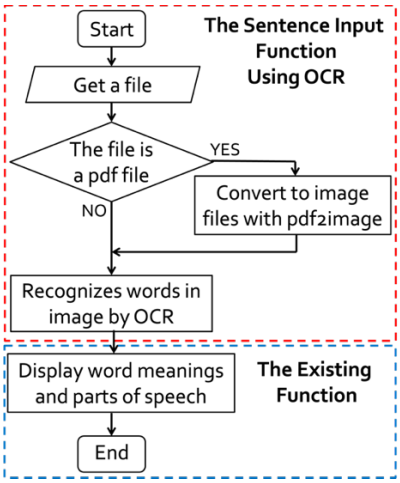


FIGURE 4. File Input Flow

The newly implemented OCR function in Hi-lex first identifies whether the file submitted by the user is a PDF or an image. If an image file is submitted, it uses OCR to recognize the English words within the image and converts them into text data. If a PDF file is submitted, it is first converted into an image file by pdf2image, and the same process is then applied. The resulting text data is then passed to existing functions to display associated meanings, parts of speech, and difficulty levels from the word lists.

An academic article of 326 words, shown in Fig. 5, was used for operational testing. After excluding common words that are not displayed, words not in the Hi-lex word list, duplicates, and proper nouns, the total number of target words was 95. The image file used for testing was a screenshot of the same article, with an image size of 750px × 1060px.

Fig. 6 presents the operational results. The PDF file conversion took 12.7 seconds from input to output and correctly identified 83 words (87.3% accuracy). The image file conversion took 7.9 seconds and correctly identified 80 words (84.2% accuracy). In both cases, the system successfully recognized the English words in the files and displayed their meanings, parts of speech, and

difficulty levels from the word lists. However, a notable limitation was that English words with line breaks or hyphens were not recognized, and some words not present in the original text were displayed due to misrecognition.

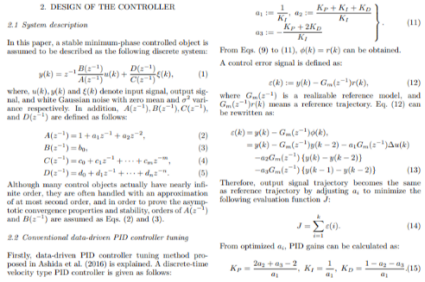
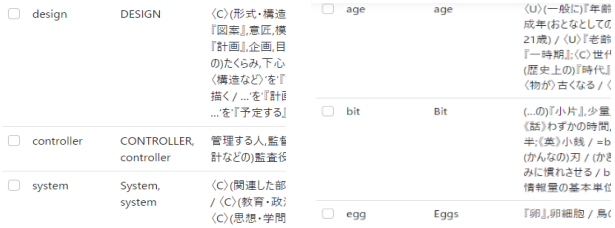


FIGURE 5. Article Used to Check the Operation



(a) Correctly Displayed (b) Misrecognition

FIGURE 6. Operational Results

Development of the Articles Suggestion Function

The current Hi-lex system allows users to learn the general meanings and example sentences of English words related to their field of study by manually entering them into a form. However, it lacks a specific function to facilitate this type of contextual learning. To enhance learning opportunities for users by exposing them to relevant English words and academic articles, we implemented a new function that suggests suitable articles based on user input.

The proposed system uses an LLM (Large Language Model) and aricles Database, a search engine specializing in academic information. Fig. 7 illustrates the workflow of this article suggestion function.

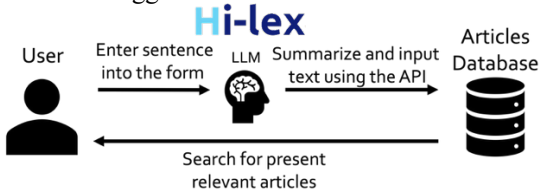


FIGURE 7. Chart of The Input-Friendly Article Presentation Function

A user first enters a sentence into the form, which is then summarized by the LLM. The LLM subsequently uses an API (Application Programming Interface) to send this summarized content to arXiv. It then receives information on relevant articles, which it summarizes and presents to the user in a list. The user can select articles of interest using a checkbox. The selected article is then automatically input into the form, and the system displays the meanings of the English words within it to facilitate further learning.

For summarizing the input text, we used Llama 3, a large language model published by Meta. To run the LLM locally without a network connection, we utilized the llama.cpp open-source platform.

Fig. 8 shows the operational results. Clicking a blue button displays the title, authors, and links of articles that are related to the text entered into the form.

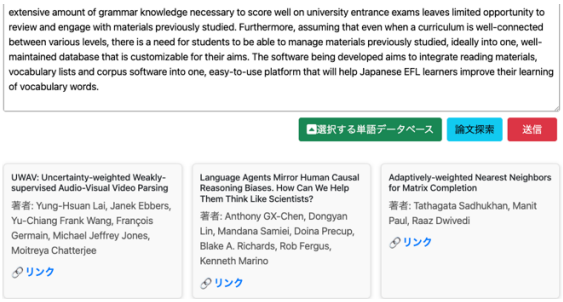


FIGURE 8. Operational Results

Clicking on the link will take you to Arxiv, where user can learn more English words related to specialized field of study. Additional functions, such as paper translation and keyword extraction, can also be implemented.

Conclusions

In this paper, we described the implementation of two new functions for the Hi-lex system: one for text input from files using OCR and another for suggesting relevant academic articles. We confirmed the successful operation of both functions through testing. Moving forward, the plan is to further enhance these functionalities and to ensure server redundancy. These improvements aim to provide a more comfortable and proactive English learning environment for users.

Acknowledgements

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References

Higa, M. (2025). *Hi-lex System* [Web application]. Retrieved from https://hi-lex.org

Dionsio, G. & Pascual, L. & Ramil G. (2022). Vocabulary and Learning Strategies in Second Language Learning. *International Journal of English Language Studie*, 4(3), 9.

Simon, F. & Higa, M. & Walter, Davies. (2025). Delivering an ESP Pedagogic Word List: Integrating Corpus Analysis, Materials Design, and Software Development. *Languages,* 10(3), 46. https://doi.org/10.3390/languages10030046.

Higa, M. & Ashida, Y. (2023). A Pedagogical Framework for the Development of Software for EFL Learners. *Hiroshima Studies in Language and Language Education,* 26, 63-77.

Local Industrial Collaboration Project at National Institute of Technology, Ichinoseki College: Local Storytelling, Kōdan, for Inbound Tourism

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This presentation introduces a local industrial-academic collaboration project at the National Institute of Technology, Ichinoseki College, combining STEAM education with regional cultural revitalization. The project focuses on promoting inbound tourism through Kōdan, a traditional form of Japanese storytelling, by incorporating foreign language subtitles and immersive technologies such as VR. Located in the Ichinoseki-Hiraizumi area—home to UNESCO World Heritage sites like Chūson-ji Temple—this region has rich cultural resources but remains underrepresented in Japan's mainstream tourism.

Ichinoseki College is an engineering-based institution offering interdisciplinary education in mechanical, electrical, computer science, and chemical-biology. This environment enables students to apply their technical skills—such as generative AI translation, sensor-based automation, and VR imaging—to real-world challenges. For this project, students are developing a system that automatically synchronizes projected subtitles and visuals with a Kōdan performer's voice. Eventually, this will evolve into an immersive experience where the audience can wear VR headsets to explore the historical context and narrative visually as the performer tells the story.

This initiative reflects the core values of STEAM education: interdisciplinary learning, creative problem-solving, and real-world application. By treating engineering as a form of "social doctoring," the project aims to solve a regional issue—how to attract and engage foreign visitors in rural areas—through a blend of Technology (T), Engineering (E), and the Arts (A).

Moreover, the project is structured as a Project-Based Learning (PBL) experience. Students are actively involved not only in designing and programming devices but also in collaborating with professional storytellers, collecting audience feedback, and iterating on the system based on real-world usage. This sustained, student-driven engagement fosters both technical competence and a deeper understanding of community needs, laying the groundwork for socially conscious engineers.

In summary, this project demonstrates how traditional arts and advanced technology can be merged in a STEAM-based framework to foster cultural understanding, encourage inbound tourism, and develop future engineers equipped with both technical and social skills.

Keywords: *STEAM education, fusion between engineering and Japanese traditional culture, AI, VR, entrepreneur*

1. Introduction

In recent years, there has been a growing emphasis on the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education into real-world applications that promote interdisciplinary learning and creativity. In particular, project-based approaches that connect students with local community issues are considered effective in nurturing both problem-solving skills and cultural understanding.

This paper presents a STEAM-based educational initiative developed at the National Institute of Technology, Ichinoseki College (Ichinoseki Kosen), which aims to enhance intercultural understanding through the fusion of traditional Japanese performing arts and advanced technology. The focal point of the project is the revitalization and modernization of "Kōdan", a traditional form of Japanese storytelling, by incorporating multilingual subtitles and VR technology to create an immersive experience for inbound tourists.

Ichinoseki City and its surrounding Hiraizumi area in Iwate Prefecture are home to several culturally significant sites, including Chūson-ji Temple's Konjikidō and Mōtsū-ji Temple, which are registered as UNESCO World Heritage sites. Despite their historical value, these rural areas have remained underrepresented in Japan's tourism landscape. However, recent developments—such as Morioka's selection as the second destination in *The New York Times*' "52 Places to Go in 2023"—signal growing global interest in Iwate Prefecture.

In the post-COVID era, foreign tourists have gradually returned to Japan, with many seeking "niche" experiences in rural areas beyond the typical tourist hubs of Tokyo, Kyoto, and Osaka. These travelers are drawn to the slower pace of life, the authenticity of local culture, and opportunities for deeper cultural engagement. For such visitors, "Kōdan" offers a unique and underexplored medium through which to experience Japanese stories and traditions.

To meet this demand, students at Ichinoseki Kosen

are working in collaboration with local storyteller Chifukutei Kinme (地伏亭金目) to develop a multilingual Kōdan performance enhanced by AI-generated subtitles, projected visuals, and VR elements. This project serves not only as a platform for inbound cultural exchange but also as a hands-on learning opportunity aligned with the principles of STEAM education and entrepreneurship training (See Fig. 1).

This paper aims to demonstrate how regional revitalization and cross-cultural communication can be promoted through a technology-driven reinterpretation of traditional performing arts, highlighting the educational benefits of interdisciplinary, problem-based learning in a real-world context.



Fig. 1 A performance held on Dec 12, 2024 at National Institute of Technology.

2. Methodology

2.1 System Design and Implementation

The current system comprises a PowerPoint slideshow with manually operated transitions, synchronized to the live Kōdan performance. A handheld sensor, developed by faculty member in the Division of Mechanical and Intelligent System Engineering, is used by the performer to trigger each Slides contain subtitles, illustrations, and brief summaries of key scenes or dialogues, created in advance by the author and refined through collaboration with the performer.



Fig. 2 A handheld sensor. Bluetooth 3-Mode Connection, Include 2.4G Dongle.

2.2 Technical Setup

The system only requires a laptop, a handheld Bluetooth sensor (See Fig. 2), and a projector. Subtitles and visuals are projected behind the performer. This setup allows performances to be conducted in any facility equipped with basic projection capability, making the method highly scalable and cost-effective.

2.3 Translation and Content Creation

Initial translations are generated using generative AI and subsequently edited to reflect historical and regional nuances. These are embedded in the slides along with contextual imagery. This content is shared with the performer in advance, allowing for co-creation and minor adjustments based on performance flow.

2.4 Educational Integration and Future Vision

Moving forward, the project aims to integrate high-performance sensors, portable screens, and generative AI-enhanced translation systems. Students from various academic divisions will collaborate to improve system design, imagery generation, and promotional strategies via SNS and web development. The long-term goal is to enable performances in various locations, including outdoor festivals, tourist sites, and lunch venues for international visitors.

2.5 Performance Record and Audience Feedback

Between December 2024 and June 2025, five performances were conducted (see Table 1):

Table 1 The list of performances and their feedback. Performances on May 24 and Jube 29 have no feedback yet because this paper is submitted on May 15.

No.	Date & Venue	Audience Type	Feedback Highlights
1	Dec. 12, 2024 – Institute of Technology, Ichinoseki College(Hagishō, Ichinoseki)	74 students (4 international)	"Subtitles aided non-Japanese speakers." , "Helped with understanding names and historical references." , "Increased familiarity and enjoyment for locals."
2	Feb. 22, 2025 – Nanohana Plaza (Omachi, Ichinoseki)	32 local residents (Japanese)	"Subtitles clarified people and places.", "Slides did not distract from narration.", "Local photos enhanced relatability."
3	Mar. 22, 2025 – Hagishō Community Center (Hagishō, Ichinoseki)	11 local residents (Japanese)	"Slides supported understanding.", "Repeat attendees found improvement."
4	May 24, 2025 – Nanohana Plaza (Omachi, Ichinoseki)	Local residents	No direct feedback recorded yet.
5	Jun. 29, 2025 – Higashiyama Community Center (Higashiyama, Ichinoseki)	Local residents	No direct feedback recorded yet.

Feedback consistently highlighted the value of visual and textual aids in enhancing understanding of historical narratives. Historical narratives performed in the events above are as follows.

1. December 12, 2024 (National Institute of Technology, Ichinoseki College)
・“The Okago Kirishitan Martyrdom Story: The Legend of the Ubaiwa Stone (大籠キリシタン殉教物語 姥石の由来)”

2. February 22, 2025 (Nanohana Plaza)
・“Never to Abandon the Cause: Story of Otsuki Gentaku (遂げずばやまじ 大槻玄沢)”
・“The Legend of Otakemaru: The Origin of Demon’s Remains (大武丸伝説 鬼死骸の由来)”
・“The Pride of Ichinoseki: The Drum of Time (一関の誇り 時の太鼓)”

3. March 22, 2025 (Hagisho Community Center)
・“The Legend of Evil King of Takkoku (達谷の悪路王伝説)”
・”The Legend of Hachiman Taro Yoshiie: The Origin of the Rock Faced Daibutsu (八幡太郎義家の伝説 岩面大仏の由来)
・”The Folklore from Hagisho: Hidehira of Obanagamori (萩荘の昔話 尾花が森の秀衡)”
・”The Ako Insident: The Assault by the Forty-Seven Ronin (赤穂浪士 討ち入りの場)”

4. May 24, 2025 (Nanohana Plaza)
・”The Man Who Gained Superhuman Strength from Ghost: The Tale of Mizoguchi Hannojo (幽霊に怪力をもらった話 溝口半之丞)”
・”The Kudan’s Mother by Komatsu Sakyo (小松左京 くだんのはは)”
・”The Three Years of Feigned Madness for Revenge by Hasegawa Shin (長谷川伸 敵討冗の三年)”

5. June 29, 2025 (Higashiyama Community Center)
・”The Illustrated Scroll of Karaumedate (唐梅館絵巻)”
・”Tokkobe Torako by Miyazawa Kenji (宮沢賢治 とっこへとら子)”
・”Wooden Statue of the Amida Triad and Twenty-Five Bodhisattvas (The Twenty-Five Figures) (木造来迎阿弥陀及菩薩像 二十五さま)”

3. Results

This section presents the results obtained through the implementation of the multilingual and multimedia-assisted Kōdan performances developed in collaboration with the National Institute of Technology, Ichinoseki College. The findings are categorized into five areas: (1) attendance and performance outcomes, (2) audience responses, (3) performer adaptation, (4) student participation and learning impact, and (5) feasibility and potential scalability of the project model.

3.1 Attendance and Performance Outcomes

Since December 2024, a total of five performances have been conducted under the title “Local Kōdan corroborated with National Institute of Technology, Ichinoseki College.” These included both school-based and community-based events (see Table 1). The pilot performance on December 12, 2024, was held at the college’s Multimedia Room and attended by 74 students, including four international students. Subsequent performances in February, March, May, and June 2025 took place in various local public facilities, with audiences ranging from 11 to 32 attendees (See Fig. 3 and 4). Although the later performances focused on Japanese audiences, the multilingual subtitles and image materials were maintained for continuity and refinement of the system.



Fig. 3 The Kōdan event poster held on March 22, 2025.



Fig. 4. A picture taken at the Kōdan performance held on March 22, 2025.

3.2 Audience Response and Interpretation

Audience feedback was collected after each performance via oral comments and post-event questionnaires. The multilingual subtitles and projected visuals were consistently evaluated as helpful in

enhancing understanding, particularly by international attendees. For example, during the pilot performance, one international student commented, “Even without understanding Japanese, I could follow the story because of the subtitles.” Japanese audience members also reported that the inclusion of subtitles helped them recall or better understand historical names and place references. One attendee noted, “The subtitles helped reinforce the key terms and allowed me to concentrate on the storytelling without confusion.”

Overall, responses indicated that the multimedia format supported audience engagement across different backgrounds. Importantly, the use of images alongside regional place names fostered a stronger sense of familiarity and connection, especially for locals. These findings suggest that the integration of digital support materials does not detract from the traditional performance but rather augments the audience's comprehension and emotional involvement.

3.3 Performer Adaptation and Operational Smoothness

At the outset, the storyteller — Chifukutei Kinme — expressed concerns about incorporating sensor-based slide transitions into a live Kōdan performance. However, with simplified procedures and minimal training, he became adept at operating the system. After initial success, he independently created PowerPoint slide decks for later performances and began integrating digital elements even in performances beyond the official project events.

In addition to technical and creative skills, students gained experience in project planning, cross-cultural communication, and public engagement—skills aligned with the college's entrepreneurial education goals.

His successful adaptation demonstrated the practicality of the system: a single performer can manage content transitions via handheld sensors while maintaining narrative flow. The setup’s simplicity—requiring only a laptop, projector, and a USB-connected sensor—proved especially effective in venues with basic audiovisual infrastructure.

3.4 Student Participation and Educational Impact

Students from various academic divisions at the National Institute of Technology, Ichinoseki College were engaged in multiple phases of the project. Initially, faculty in the Division of Mechanical and Intelligent System Engineering assisted with sensor design and prototyping. The script translation and subtitle creation were led by the coordinating researcher using generative AI, then contextually edited for clarity and regional accuracy.

As the project progressed, plans were laid to integrate students more formally through entrepreneurial coursework. These student teams would be responsible for designing promotional content via websites and social media, developing new language translations with advanced AI models, and creating immersive visual experiences using VR technology. Collaborative efforts with the Division of Conputer Engineering and Informatics, as well as students from the Electrical and Electronic Engineering and Chemical-Biology divisions, opened opportunities for a fully cross-disciplinary STEAM education model.

3.5 Scalability and Feasibility

The current model is highly adaptable due to its low-cost and low-complexity design. With only a laptop, a projector-equipped venue, and a single sensor device, performances can be held in diverse indoor settings. Future funding through municipal cultural grants or startup contests may enable the purchase of mobile projection equipment and wireless sensors, making outdoor and event-based performances feasible.

This expansion would allow Kōdan storytelling to be featured during seasonal tourism events or served alongside lunch at local inns and restaurants, enhancing visitor experiences. By aligning traditional arts with modern technology, this model positions itself as a scalable cultural tourism solution. The project’s next milestone will involve co-hosting an inbound-targeted performance in collaboration with Ichinoseki City Tourism Division before the ISATE 2025 presentation.

3.6 Summary of Key Findings and Transition to Discussion

The results of this pilot project demonstrate the feasibility and effectiveness of integrating multilingual subtitles and visual aids into traditional Kōdan storytelling. Positive audience reception, the smooth adaptation by the performer, and the active involvement of students in both technical and creative roles suggest that the hybrid performance model is both scalable and educationally valuable.

4. Discussion

This study demonstrates the educational and societal potential of integrating traditional performing arts with low-barrier digital enhancements. Through the implementation of a sensor-based, bilingual subtitle system, students were able to directly contribute to the storytelling process, allowing Kōdan to become more accessible and appealing to broader audiences, including international tourists and local communities.

The overwhelmingly positive audience responses, as shown in Table 1, indicate that the use of subtitles and images enhances understanding without diminishing the essence of live oral performance. This is particularly crucial in cases where archaic vocabulary, historical context, or regional dialect might present comprehension challenges.

From an educational perspective, this initiative aligns closely with the goals of STEAM education. Students were involved not only in engineering tasks but also in cultural translation, design, and communication. By incorporating elements of entrepreneurship, including outreach, promotion, and future monetization, the project has laid the groundwork for interdisciplinary education rooted in real-world applications.

Moreover, the scalability and simplicity of the system—as illustrated in Figure 1—enable its replication in other communities or cultural contexts. The next phase

will require further collaboration with local government and tourism boards to conduct performances for inbound tourists and assess cross-cultural reception more rigorously. A notable future direction includes the implementation of VR-enhanced experiences as seen in the proposed expansion model, which would deepen immersion and engagement.

Overall, the results validate the hypothesis that traditional arts, when combined with accessible technologies, can foster intercultural understanding and simultaneously provide a fertile platform for student-centered learning across academic disciplines.

5. Conclusion

This study presented an interdisciplinary initiative that combines traditional Japanese *Kōdan* storytelling with sensor-activated subtitles and projected visuals to make regional culture more accessible, particularly for international audiences. Through performances enhanced by a simple yet effective PowerPoint-based system, the project demonstrated a practical model of integrating cultural content with engineering, AI, and language education.

Audience feedback from five public performances indicated that the subtitle-supported format was positively received by both Japanese and international viewers, improving comprehension and enhancing engagement with unfamiliar historical and cultural topics. Moreover, the technological implementation proved cost-effective and scalable, allowing a single performer to control visual aids in real time using a compact sensor.

From an educational perspective, this project provided students with opportunities to participate in a real-world application of STEAM education—merging technical development with cultural literacy, creativity, and multilingual communication. It also demonstrated the potential for students to take initiative in promoting regional heritage through digital tools.

Looking ahead, the project aims to collaborate with local governments and tourism offices to expand multilingual *Kōdan* performances for inbound travelers. The integration of more advanced generative AI translation tools, VR visualizations, and broader student involvement across divisions will continue to evolve this initiative into a sustainable, community-driven educational model.

Study on University Courses on Discharge, Plasma, and Pulsed Power for Transfer Students from KOSEN Education

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Plasma, electrical discharge, and pulsed power are interrelated fields with wide-ranging applications, from semiconductor manufacturing to the prospective commercialization of nuclear fusion power generation. Despite their technological significance, these topics are rarely introduced in primary and secondary education in Japan, and awareness among students remains limited. In recent years, the number of university electrical engineering departments and courses covering conventional electrical engineering including the field of plasma, discharge, and pulsed power has declined, raising concerns about the availability of specialized education for students transferring from KOSEN. This study surveyed the curricula of third- and fourth-year undergraduate programs at single-faculty engineering universities and engineering faculties of comprehensive universities in Japan. Publicly available syllabus databases were searched, primarily using the keyword "plasma," to identify elective and compulsory courses addressing discharge, plasma, and pulsed power. Course availability and content were compared between major types, with additional attention to related offerings in mechanical engineering and material science departments. Findings indicate a marked decrease in courses explicitly covering these topics, corresponding to the overall reduction in electrical engineering programs. Related content was occasionally found in manufacturing process courses and in measurement and analysis courses. Comprehensive universities offered fewer relevant courses than single-faculty engineering universities, and course titles suggested consolidation of previously separate subjects. The current provision of such courses for students transferring from KOSEN is insufficient relative to societal needs and application breadth. Expanding interdisciplinary and specialized offerings could help address this educational gap.

Keywords: *University Course, Plasma, Discharge, Pulsed Power, KOSEN*

Introduction

Plasma, often referred to as the fourth state of matter, consists of a collection of charged particles—ions and electrons—formed when atoms and molecules are ionized, coexisting and moving collectively. In nature, plasma is observed in phenomena such as stars, auroras, and lightning (MEXT, 2010). Artificially generated plasma has been widely applied in industry, notably in semiconductor manufacturing (Eastman, 2006). In recent years, as a potential ultimate application, significant efforts have been devoted to the commercialization of nuclear fusion power generation, with active participation from private enterprises and investment from private capital (Pearson, 2023; Fusion Industry Association, 2025).

Although plasma has long been recognized as a natural phenomenon and is familiar in daily life through devices such as fluorescent lamps, it is rarely introduced in primary and secondary education (Kado, 2018). Despite its role as a foundational technology underpinning modern society and its promise as a next-generation energy source, public awareness of plasma remains limited (Kado, 2018).

Electrical discharge refers to the breakdown of an insulating medium under applied voltage, allowing current to flow. This phenomenon requires careful consideration in high-voltage applications (Lieberman and Lichtenberg, 2005). To ensure current flows only along intended paths, adequate insulation measures must be implemented to prevent unintended discharges. Conversely, intentional breakdown of insulation by applying high voltage is a common method for generating plasma from electrical energy.

Pulsed power technology stores energy over a relatively long period at low power and releases it in a short burst to achieve high instantaneous power (Miller, 1982). For example, electrical energy stored in a capacitor at low voltage and current can be rapidly discharged to produce high-voltage, high-current pulses, which in turn can generate plasma via electrical discharge.

While discharge, plasma, and pulsed power are distinct specialized fields, they are also closely interconnected. In electrical engineering departments at KOSEN and universities, these topics may be introduced in specialized courses such as high-voltage engineering, or in dedicated courses on plasma or discharge engineering. However, within the curriculum,

foundational subjects such as electrical circuits and electromagnetics are typically taught in the lower years, while discharge-, plasma-, and pulsed-power-related content is positioned as advanced coursework for upper-year students.

Given the breadth of electrical engineering, course content must be managed within limited instructional time. Consequently, fields with stronger direct links to current industrial demand are often prioritized, and emerging disciplines may displace traditional topics.

This study examines the current state of education in discharge, plasma, and pulsed power in higher education, with a particular focus on university-level courses available to students transferring from KOSEN.

Educational Activities Related to Discharge and Plasma at KOSEN

At KOSEN, a collaborative research initiative known as the "Discharge Plasma Network," led by Sasebo KOSEN, has been actively engaged in educational and research activities (Kawasaki, 2021). A survey conducted as part of this initiative asked whether respondents had encountered the term "plasma" during childhood. Results indicated that 90% of KOSEN students answered "yes," compared to 60% of liberal arts university students of the same age group. The study concluded that early exposure to technical concepts correlates with a higher likelihood of pursuing technical education at KOSEN (Kawasaki, 2021).

Given that plasma is seldom introduced in primary or secondary education, there is concern that students entering KOSEN or universities may have limited interest in or awareness of discharge, plasma, and pulsed power.

A survey conducted by a specialized committee on the status of courses related to these fields at KOSEN reported a decline in the number of such courses (IEEJ, 2025). Further details are presented in the IEEJ Technical Report.

Plasma-Related Courses at Engineering Universities

To assess the availability of plasma-related courses for students transferring from KOSEN, we examined third- and fourth-year undergraduate curricula at single-faculty engineering universities (Kikuchi, Nakamura, Sasaki and Takahashi, 2023). While the focus was on elective courses, some compulsory laboratory courses also include content on discharge, plasma, and pulsed power.

The findings indicate a decline in so-called "strong-current" electrical engineering courses, alongside a reduction in the number of departments majoring in conventional electrical engineering. In mechanical engineering departments, manufacturing process courses may address discharge and plasma—for example, arc welding in joining engineering, or electrical discharge machining in special manufacturing processes. In materials science departments, courses on analysis and measurement may introduce plasma in the context of atomic absorption spectroscopy or inductively coupled plasma analysis.

Plasma-Related Courses in Engineering Faculties of Comprehensive Universities

We also surveyed specialized elective courses, primarily in the third and fourth years, offered by engineering faculties (e.g., faculties of engineering or science and engineering) at comprehensive universities, assuming transfer from KOSEN (Kikuchi, Nakamura, Sasaki and Takahashi, 2024). Using publicly available syllabus databases, we searched primarily with the keyword "plasma."

The results show that plasma-related courses are less common in comprehensive universities than in single-faculty engineering universities (Kikuchi, Nakamura, Sasaki and Takahashi, 2024). Moreover, course titles often combine multiple topics—such as "High Voltage Plasma Engineering" or "High Voltage and Pulsed Power Engineering"—suggesting that courses once offered separately have been merged or reorganized. In some cases, no plasma-related courses were offered at all.

Conclusions

This study examined the state of plasma-related education in higher education, focusing on university courses for students transferring from KOSEN. The results indicate a decline in the number of electrical engineering departments and, correspondingly, in courses covering conventional electrical engineering. As a result, opportunities to study discharge, plasma, and pulsed power have diminished.

Nevertheless, some mechanical engineering courses on manufacturing processes and materials science courses on measurement address these topics from an applied perspective. In comprehensive universities, the number of related courses is even smaller, and course titles suggest consolidation of previously separate subjects.

Overall, the current provision of university-level courses on discharge, plasma, and pulsed power for students transferring from KOSEN appears insufficient relative to societal needs and the breadth of potential applications, with a continuing downward trend in availability.

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References

Ministry of Education, Culture, Sports, Science and Technology (MEXT) (2010). *Science & Technology Week*. Retrieved from

https://www.mext.go.jp/stw/common/pdf/series/plasma/plamap_E.pdf

Eastman, T. E. (2006). A Survey of Plasmas and Their Applications. *NASA - Plasma Physics Applied, Research Signpost.*

Pearson, R. (2023). Preface to the Special Issue: The Emergence of Private Fusion Enterprises. *Journal of Fusion Energy*, 42, Article 47.

Fusion Industry Association (2025). *Global Fusion Industry in 2025*. Retrieved from https://www.fusionindustryassociation.org/over-2-5-billion-invested-in-fusion-industry-in-past-year/

Kado, S. (2018). Present Description of Plasma Phenomena in Mid-high School Textbooks in Japan. *The 35th Annual Meeting of the Japan Society of Plasma and Nuclear Fusion*, 4Cp01. (in Japanese)

Lieberman, M. A. & Lichtenberg, A.J. (2005). *Principles of Plasma Discharges and Materials Processing*. John Wiley & Sons, Inc.

Miller, R. (1982). *An Introduction to the Physics of Intense Charged Particle Beams*. Springer.

Kawasaki, H. (2021). Discharge Plasma Network in KOSEN. *Journal of Plasma and Fusion Research*, 97, 6, 313-318. (in Japanese)

The Institute of Electrical Engineers of Japan (IEEJ), Research Committee on Discharge, Plasma and Pulsed Power Technology Education at KOSEN (2025). Educational Cases and Challenges Regarding Technology Education for Discharge, Plasma, and Pulsed Power at KOSEN and Universities Accepting KOSEN Students. *IEEJ Technical Report*, 1601. (in Japanese) in press.

Kikuchi, T., Nakamura, T. Sasaki, T. & Takahashi, K. (2023). A Study on Plasma-Related Courses in University Electrical Engineering Departments for Students Transferring from KOSEN. *The 29th Annual Meeting of the Japan Association for College of Technology*, B2-2. (in Japanese)

Kikuchi, T., Nakamura, T. Sasaki, T. & Takahashi, K. (2024). Plasma-Related University Courses for Students Transferring from KOSEN. *The 30th Annual Meeting of the Japan Association for College of Technology*, A3-2. (in Japanese)

IX.ROUNDTABLE SESSIONS

INTRODUCTION OF ROUNDTABLE SESSIONS

The Roundtable Sessions at ISATE 2025 were designed as interactive forums for in-depth discussion and the exchange of perspectives on key challenges and future directions in engineering education. Bringing together educators, researchers, and practitioners from diverse institutional and national backgrounds, the sessions fostered open dialogue beyond formal presentations.

The roundtables featured five thematic discussions, each addressing a critical aspect of contemporary and future engineering education. These themes included exploring synergy between the CDIO Framework and the Kosen Model Core Curriculum (MCC) for continuous program improvement; examining how data-driven approaches and generative AI can be used to redesign classrooms and engage all learners; and discussing collaborative teaching and learning facilitation between polytechnics in Singapore and National Institute of Technology (KOSEN) colleges in Japan.

Additional discussions focused on transferring the educational strengths and outcomes of the KOSEN system to future generations, as well as sharing experiences and innovative practices in work-based learning. Across all themes, participants actively exchanged experiences drawn from their own institutions, national contexts, and industry collaborations.

The atmosphere of the roundtable sessions was open and reflective, encouraging participants to speak candidly about both successes and challenges. Rather than seeking immediate conclusions, the discussions emphasized mutual understanding, comparison of educational models, and the identification of shared concerns and opportunities.

Through these dialogues, the roundtables outlined concrete directions for building international educational models and for deepening collaboration between academia and industry. As a result, the Roundtable Sessions played a significant role in advancing ISATE 2025's goal of fostering sustained international cooperation and innovation in engineering education.

ROUNDTABLE TOPIC 1

Exploring Synergy between CDIO Framework and Kosen Model Core Curriculum (MCC) for Program Continual Improvement		
ST2: Pedagogical Innovation in Teaching & Learning		
1. Sin Moh CHEAH	Singapore Polytechnic (SP)	Singapore
2. Dr Yasuyuki SHIMADA	NIT Kumamoto College	Japan
3. Dr Kuniaki YAJIMA	NIT Sendai College	Japan

Overview of the Roundtable

Both the Kosen MCC (Model Core Curriculum) and CDIO Framework (Syllabus and Standards) are novel approaches to assist in program redesign. MCC is used by National Institute of Technology Colleges in Japan and various affiliated institutions; whereas CDIO is used by institutions from around the world most notably in Europe and Asia. There are much in common in terms of the intent and comprehensiveness of both approaches and can potential complement one another, leveraging on each other's unique features to drive design/redesign of innovative curriculum in today's fast-changing world.

Keywords: CDIO Framework, Kosen MCC, Curriculum Innovation

Activities

1. Introduction and Context Setting by Lead Facilitators
   - Brief introduction to CDIO and MCC: emphasizing the uniqueness of each approach esp. for continual imrpovement (5 mins for CDIO, 5 min for MCC)
2. Participants to share challenges faced when introducing soft skills into their teaching using Padlet (a type of digital Post-It notes to be provided by SP), for example (not exclusive):
   - Progressive development of skills/attitudes (15 mins)
   - Design of real-world learning tasks that uses the skills/attitudes of interest (15 minutes)
   - Assessment of skills/attitudes (15 mins)
3. Participants to discuss complementary of CDIO and MCC (15 mins)
4. Participants interested in future collaborations can discuss possible areas where the team can work together after ISATE 2025, with possibility of continuing into ISATE 2026 (15 mins)

Possible questions (not exhaustive):

1. How to develop higher-order skills/attitudes, e.g. for sustainable development?
2. What are the appropriate context of learning for skill/attitude development?
3. How to optimize limited curriculum hours while covering learning of skills/ attitudes in addition to technical knowledge?
4. How to balance formative and summative assessment for skills/attitudes along with knowledge?

Follow-Ups

A follow-up can be expected after the conclusion of ISATE2025, to continue working on the activities via email exchanges and online meeting as deem necessary. It is also envisioned that the work done can be continued into ISATE2026 as another roundtable.

ROUNDTABLE TOPIC 2

Data on the Wall, [How can we] Flip our Classrooms to Engage All: An exploration of using GEN AI as an Instructional Designer		
ST3: Artificial Intelligence in Teaching & Learning		
1. Zhengping Liow	Singapore Polytechnic (SP)	Singapore

Overview of the Roundtable
Flipped classrooms have become a popular pedagogical strategy in higher education, but their success depends on the effective use of classroom time. As the 'success' of FCR is contingent on student's engagement with the materials before their in-class activities, both the creation and curation of high-quality pre-class and in-class materials/activities are paramount. As our classrooms are increasingly diverse, the one-size-fits-all in-class activities may not work for all students (Cheng et al., 2019) if there is mismatch with learners' learning preferences, or different levels of understanding after engaging with pre-class materials. Pre-class quizzes and student reflections can be used as actionable data to tailor differentiated instruction (DI), to meet the learning needs of students. Hence the term 'Data-enabled Flipped Learning with Differentiated Instruction' (DEFL + DI). In this roundtable, we seek to explore with the assistance of participants high leverage areas where Gen AI can assist in the implementation of DEFL + DI and to close student learning gaps and enhance their learning experience.

Keywords: Data-enabled Flipped Learning, Differentiated Instruction, Learning Data, Student Autonomy.

Activities
1. Introduction and Context Setting by Lead Facilitator - Participants will share their experiences with Flipped Classrooms. Facilitator will use white board to consolidate and group common challenges towards Problem Framing. 2. Facilitators will share SP's DEFL + DI Flipped Classroom framework and share current state of research and engage participants in identifying pain-points in implementing DI activities in the classroom. 3. A sample qualitative data set will be shared with the participants. Set A) students' reflection of what they have learnt in the asynchronous online classes and Set B) students' reflection of what they would want the tutors to have a discussion about. The underlying intention is for Set A to extend students' learning and Set B, to bridge learner's unmet learning gaps. Both sat can be downloaded online. Data would be sanitised with no trace to the identities of students. 4. Participants will then engage in smaller group discussions to identify how and what Gen AI can do to make DEFL + DI to be more accessible for lecturers and students. Participants will be guided to create a user experience journey from the perspectives of both lecturers and students. 5. A follow up discussion of challenges and learning points will be conducted. 6. A brief discussion of the 'follow-ups' as discussed in the section below.
Follow-Ups
1. Participants interested in future collaborations can discuss possible areas where the team can work together after ISATE 2025, with possibility of continuing into ISATE 2026. 2. Future collaborative research output could be a comparison study of different DI activities but measured with a common instrument. 3. A possible output could also be a playbook on how to leverage Gen AI as an instructional designer with contributions from various institutions in ISATE.

ROUNDTABLE TOPIC 3

Possible Approaches for Collaborative Teaching and Facilitation of Learning between Polytechnics in Singapore and NIT Colleges in Japan		
ST2: Pedagogical Innovation in Teaching & Learning		
1. Shwu Lan NGOH	Singapore Polytechnic (SP)	Singapore
2. Mr. Eduardo Carabez Andrade	National Institute of Technology, Akita College	Japan

Overview of the Roundtable

This roundtable aims to build upon the discussion initiated at ISATE2024 hosted by Singapore Polytechnic, focusing on collaborative approaches to student guidance through joint teaching and learning facilitation between Polytechnics in Singapore and National Institute of Technology (NIT) Colleges in Japan.
The main intended outcome of this session is to support the planning and implementation of a potential pilot collaboration between participating institutions. In addition, the roundtable will explore relevant domain, pedagogical approaches and facilitation methodologies to strengthen cross-institutional collaboration in today's dynamic and fast-changing educational landscape.

Keywords: Collaborative facilitation, Collaborative learning, Students' guidance

Activities

1. Introduction and Context Setting by Lead Facilitators (5 min)
2. Participants will reflect on and share their experiences () or views in collaborative teaching and learning facilitation with local or overseas partners using Padlet (a type of digital Post-It notes to be provided by SP), for example (not exclusive):
   - Challenges faced during cross-institutional collaboration (25 min)
   - Effective strategies or lessons learned (25 min)
   - Institutional or cultural considerations (15 min)
3. Participants interested in future collaborations can discuss possible areas where the team can work together after ISATE 2025, with possibility of continuing into ISATE 2026 (20 mins)

Possible questions (not exhaustive):

1. What are some key learning points from your previous experiences with collaborative teaching or facilitation?
2. What are some ideas that came to your mind when it comes to collaborative teaching and facilitation of learning between Polytechnics in Singapore and NIT Colleges in Japan (what came be done? e.g. lecture, case study, seminar, how to do it?, etc.)
3. What are some constraints that your institution faced in terms of doing the collaborative teaching and facilitation of learning?
4. Which area(s) in the above ideas for collaborative teaching and facilitation of learning that is/are more implementable? Which domain(s) do you think we can try this?
5. How should the collaborative teaching and facilitation of learning be executed among participating institutions? What are the resources involved?

Follow-Ups

A follow-up can be expected after the conclusion of ISATE2025, to continue working on the activities via email exchanges and online meeting as deem necessary. Possible activities include:

1. Continued exploration with interested institution(s) on how to operationalize a pilot run
2. Execute a trail or pilot run
3. Survey of staff and students experience after implementation

It is also envisioned that the work done can be continued into ISATE2026 as another roundtable.



ROUNDTABLE TOPIC 4

Providing the FRUITS of KOSEN to future KOSEN		
ST2: Pedagogical Innovation in Teaching & Learning		
1.Sachiko Yoshida	Toyohashi University of Technology	Japan
2.Akihiro Wakahara	Toyohashi University of Technology	Japan

Overview of the Roundtable
In the 60-odd years since KOSEN colleges were established, they have achieved great fruits in their mission to provide advanced engineers with the social implementation ability. The KOSEN education, which respects inspiration and concentration on technology, plays an important role in technological development in Japan. Meanwhile, the KOSEN education faces several challenges, one of which is to ensure the number and quality of teachers who are responsible for education. In this presentation, the Toyohashi University of Technology would like to make some proposals regarding teacher training for the-future of the KOSEN education.

Keywords: KOSEN teacher training, female engineers, education skills, inclusion of engineers

Activities
We present three themes about KOSEN teacher development through KOSENGIKADAI collaboration. Yoshida explains challenges, and Wakahara makes some proposals about (i)Reproduction of KOSEN personnel, (ii) Establishing of role models for female engineers, and (iii) Inclusion of KOSEN engineers in Japanese society.
Follow-Ups
KOSEN Teacher Training Program from 2017 in Toyohashi University of Technology

ROUNDTABLE TOPIC 5

Sharing experiences and innovative approaches to work-based learning

ST2: Pedagogical Innovation in Teaching & Learning

1. Meiju Keinänen	Turku University of Applied Sciences	Finland

Overview of the Roundtable
This roundtable focuses on discussion of work-based learning to create better pathways to meet the changing demand for skills, facilitate the access of young people and adults to the evolving labour market and build sustainable career pathways for all. The aim of the roundtable is to the exchange of experiences, innovative approaches, and good practices regarding internships, apprenticeship training, work-based learning and business-education collaboration.

Keywords: work-based learning, internships, apprenticeship training, business-education collaboration

Activities
Welcome and introduction At the beginning of the roundtable, the agenda and activities of the session are introduced, and brief introductions are made. Next, the concept of work-based learning from three different aspects: education-driven, student-driven and business-driven, is described. Additionally, some concrete examples are presented. **Activity 1. Pair/small group discussions** To discuss experiences, innovative approaches, and good practices regarding internships, apprenticeship training, work-based learning and business-education collaboration. Each pair or small group selects a spokesperson to summarize their discussion. **Activity 2. Sharing Outcomes of Discussions** To share the insights gained from the pair/small group discussions with all participants. **Activity 3. Closing remarks** To summarize key takeaways and feedback discussion. Additionally, if topics for co-development are identified, their continuation is agreed upon.

Follow-Ups,
Hopefully, after the roundtable topics for co-development are identified and actions will start or some new ideas and practices to take home.

X. WORKSHOPS

INTRODUCTION OF WORKSHOPS

The **Workshops** at ISATE 2025 were designed as interactive and practice-oriented sessions, providing participants with opportunities to explore innovative teaching approaches through hands-on discussion and shared experiences. These sessions created an open and energetic learning environment, encouraging active participation and reflection among educators from diverse backgrounds.
The workshops focused on **two key themes**. The first theme, *"Activating Learning: Transforming Traditional Teaching into Engaging Classrooms,"* addressed strategies for shifting from instructor-centered instruction to more active and learner-centered classroom practices. Participants exchanged ideas on how to design learning activities that promote student engagement, autonomy, and collaboration, while also considering practical constraints within real educational settings.

The second theme, *"Play to Learn: Making National Education Fun Through Game-Based Learning,"* explored the use of game-based learning as a tool to enhance motivation and deepen learning. Through concrete examples and discussion, participants examined how game elements can be effectively integrated into curricula and how such approaches can support critical thinking, teamwork, and decision-making.

Across both workshops, **active discussions took place on implementation methods and the measurement of educational effectiveness**. Participants shared challenges and insights related to introducing new pedagogical approaches, assessing learning outcomes, and ensuring sustainability within their institutions. These discussions highlighted the importance of balancing innovation with evaluation and evidence-based practice.

Overall, the Workshops contributed significantly to ISATE 2025 by providing practical perspectives on educational innovation and by fostering a collaborative space where participants could translate ideas into actionable approaches for their own teaching and learning contexts.

WORKSHOP TOPIC 1

Title	Activating Learning: Transforming Traditional Teaching into Engaging Classrooms
Facilitator	Dr. Nitima Sutapin, a lecturer from the Division of Science and Liberal Arts, Mahidol University, Kanchanaburi Campus,Dr. Chutamas Sukhontapatipak, a lecturer from the Division of Conservation Biology, Mahidol University Kanchanaburi Campus,
Workshop Objectives	By the end of this workshop, participants will be able to:1) Understand the principles and benefits of transforming a lecture-based classroom into an active learning environment.2) Experience active learning strategies through hands-on participation.3) Develop the skills and confidence to facilitate active learning in their own teaching contexts.
Abstract	In response to educational policies aimed at cultivating students' 21st-century skills, school environments have increasingly shifted toward student-centered and active learning approaches. This shift calls for corresponding changes within higher education institutions, where traditional lecture-based teaching remains prevalent. Although university lecturers are often evaluated through national quality assurance frameworks—and their teaching practices appear aligned with policy expectations on paper-many still lack the practical confidence and pedagogical training required to effectively implement active learning in the classroom.A key reason for this gap is that many lecturers themselves were educated in passive, teacher-centered environments. As a result, they may have limited firsthand experience with active learning methodologies, making it challenging to adopt a facilitator mindset. To address this, transformative learning offers a powerful approach. By guiding lecturers through reflective and experiential processes—allowing them to critically examine their past learning experiences, engage with active learning strategies, and reframe their teaching perspectives—they can better understand and embrace the role of an active learning facilitator.This workshop is designed to support educators in making this transition. Specifically, it aims to: (1) deepen participants' understanding of the principles and benefits of transforming lecture-based classrooms into active learning environments; (2) immerse participants in hands-on, active learning experiences; and (3) build participants' skills and confidence to facilitate active learning in their own teaching contexts. Through interactive activities, peer discussion, and guided reflection, participants will gain both the theoretical grounding and practical insight needed to foster more engaging and student-centered classrooms in higher education.

WORKSHOP TOPIC 2

Title	Play to Learn: Making National Education Fun Through Game-Based Learning"
Facilitator	Mr. Shaun Tay, Lecturer from School of Technology for Arts, Media and Design, Republic Polytechnic
Abstract	Join award-winning educator Shaun Tay as he takes you behind the design of *Diplomats… in Space!*, a large-scale, real-time card game crafted to deliver an impactful Game-Based Learning (GBL) experience. Designed for Institutes of Higher Learning, this engaging simulation supports up to 40 players and immerses students in strategic thinking, negotiation, and resource management—mirroring how Singapore navigates real-world national and international dynamics in a safe and structured environment. In this hands-on workshop, educators will explore the pedagogical design behind the game. Participants will uncover how Game-Based Learning empowers students to take ownership of analysis, decision-making, and collaboration, turning gameplay into a powerful platform for critical thinking and reflective learning.









XI.CULTURAL ACTIVITIES

CULTURAL JOURNEYS

The Cultural Journey was held on Friday, September 12 (Day 4), as a special program of ISATE 2025, offering participants an opportunity to experience the cultural, historical, and creative dimensions of the Tokai region beyond the academic sessions.

On the morning of the Cultural Journey, participants gathered at 8:20 a.m. at the plaza south of Meitetsu Toyota Hotel, where a relaxed and anticipatory atmosphere filled the meeting point. After a brief orientation, participants departed by bus, each group heading toward one of three carefully selected destinations. These destinations were designed to reflect different aspects of Japanese culture—industrial heritage, traditional craftsmanship, and contemporary creative culture. Participants selected their preferred destination in advance, and buses were allocated accordingly.

Throughout the journey, the Cultural Journey served not only as a recreational activity, but also as a space for informal interaction and dialogue among participants, allowing conversations that began in conference rooms to continue in a more open and reflective setting.

Toyota Commemorative Museum of Industry and Technology

Participants visiting the Toyota Commemorative Museum of Industry and Technology experienced a journey through Japan's industrial and technological development. Set within a historic factory site, the museum provided an immersive environment where traditional textile machinery and modern automotive technologies coexist.

As participants explored the exhibits, discussions naturally emerged around engineering education, innovation, and the relationship between industry and society—topics closely aligned with the core themes of ISATE. The visit offered a tangible perspective on how technological advancement can be rooted in craftsmanship, continuous improvement, and social contribution.

Traditional Tie-Dyeing Experience (Arimatsu–Narumi Shibori)

The Arimatsu–Narumi Shibori experience introduced participants to one of Japan's most renowned traditional textile arts. In a calm and hands-on setting, participants engaged directly in the process of tie-dyeing, guided by skilled artisans.

The atmosphere was both focused and relaxed, as participants carefully applied techniques that have been passed down through generations. This experience encouraged reflection on the value of experiential learning, cultural preservation, and the role of tradition in contemporary education. Conversations often extended beyond technique, touching on parallels between craftsmanship and engineering education, where learning through doing remains essential.

Ghibli Park

At Ghibli Park, participants immersed themselves in the imaginative world inspired by the works of Studio Ghibli. Surrounded by detailed environments and carefully designed spaces, the visit evoked a sense of creativity, curiosity, and storytelling.

Walking through the park, participants shared moments of wonder and enjoyment, creating a relaxed atmosphere that fostered spontaneous interaction across institutions and countries. The experience highlighted the power of creativity and narrative in shaping cultural understanding, offering inspiration that resonated with discussions on education, innovation, and human-centered design.

Across all three journeys, the Cultural Journey provided a meaningful complement to the academic program of ISATE 2025. By engaging with industrial heritage, traditional craftsmanship, and contemporary creative culture, participants gained shared experiences that strengthened connections and enriched the overall Symposium experience.

BANQUET

Cultural activities were not limited to the Cultural Journeys. On the evening of September 10 (Day 2), a banquet was held at the Meitetsu Toyota Hotel. At this banquet, Wa-Daiko(traditional Japanese taiko drums) were performed, and an opportunity to experience them was also provided. Participants engaged in cultural exchange with each other in a relaxed atmosphere.

These Cultural Activities thus played an important role in reinforcing ISATE 2025's aim of fostering not only academic exchange, but also mutual understanding and collaboration through shared cultural experiences.

XII. ACKNOWLEDGEMENTS/ SPONSORS

We would like to express our **sincere and heartfelt appreciation** to the organizations and companies whose generous support made **ISATE 2025** possible. Their sponsorship played a vital role in the successful planning and implementation of the Symposium, contributing not only to its smooth operation but also to the creation of an environment that fostered meaningful academic exchange, international collaboration, and innovation in engineering education.

Through their continued commitment to education, research, and the development of future generations of engineers, our sponsors have significantly supported the goals and values of ISATE 2025. We are deeply grateful for their trust, cooperation, and encouragement.

On behalf of the Organizing Committee, we extend our **profound gratitude** to all sponsoring partners for their invaluable contributions to the success of ISATE 2025.

evoltz Inc. (URL : https://www.evoltz.com/)

evoltz Co., Ltd. is a specialized manufacturer dedicated to protecting wooden homes from earthquakes through the planning, development, and sales of seismic control devices. With an unwavering commitment to structural integrity and world-class engineering, we deliver long-lasting safety and durability for residential buildings.

Our flagship product, the “evoltz” seismic control device, is based not on resistance—which works by “withstanding” shaking—but on vibration control, a technology that absorbs and dissipates seismic energy. From the initial tremor to aftershocks and repeated motions, evoltz reduces a wide range of shaking forces, helping to minimize structural damage and preserve the home’s overall performance.



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KOJIMAGUMI Co., Ltd (URL : https://www.kk-kojimagumi.co.jp)

Since our founding in 1919, we have leveraged our proprietary technological expertise to undertake dredging, reclamation, and port civil engineering projects. We have also engaged in marine, riverine, and land-based construction work, contributing to environmental improvement and improving people's daily lives.

Dredging, essential to ports, involves excavating and removing sediment to maintain required water depths and navigable areas. This sediment originates from river runoff, flood-causing deposits in waterways, and the arrival of large vessels for international trade. The dredged material can be utilized to create land elsewhere.

We are promoting work-style reforms, ensuring proper holidays, preventing excessive overtime, and increasing the number of construction management and vessel crew personnel. Simultaneously, we are advancing the development of autonomous operation systems for work vessels, digitalization, the use of biofuels, and energy conservation.



Furthermore, we plan to participate in offshore wind power generation facility construction starting in 2028.

ISA, Inc. (URL : https://www.isa.co.jp/)

ISA is an educational services company providing global learning opportunities for Japanese teenagers. Since its founding in 1970, ISA has been committed to providing not merely opportunities for cross-cultural learning experiences or motivation for English study, but rather living learning experiences grounded in the principles of liberal arts education. These experiences empower children to break free from existing frameworks, exercise autonomy in their learning, and develop the resilience to thrive in this world. Today, ISA delivers global education programs to over 1,000 schools and boards of education nationwide, with 90,000 teenagers annually participating in its global learning initiatives.

XIII. END OF PROCEEDINGS

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