Invited Oral Session
ENGAGING TODAY’S MILLENNIALS USING CURRICULUM BASED ON CHEMICAL PRODUCT DESIGN

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Abstract

This paper offers a curriculum model from the Diploma in Chemical Engineering of Singapore Polytechnic that takes on the challenge of providing an educational context to enhance engagement and meaning for many of our students, which are often referred to as the “millennials”. They are often depicted as very different in certain fundamental aspects as compared to students from previous generations. Specifically, the paper shares our approach in using the CDIO Framework (www.cdio.org) in designing a 3-year curriculum to meet this challenge. The approach is also applicable to other engineering programs seeking to re-design the curriculum for similar outcomes. It firstly summarizes the attributed characteristics of today’s millennials; and why a different curricular form and focus is necessary, with special emphasis on the context of chemical engineering education. Secondly, the "traditional" approach in chemical engineering education, which is based on chemical process plant design using computer simulation and modeling is outlined, and certain key limitations identified. We suggest that this approach is not particularly effective in engaging students in learning as no chemical plants actually get built. The paper then proposes that chemical engineering education should include the teaching of chemical product design in order to complement the teaching of process plant design. To develop the new curriculum, we introduced various "soft" skills into our diploma via two threads: one by integrating CDIO skills (such as teamwork, communication, thinking skills) in various core modules; and another by integrating C-D-I-O (conceiving, designing, implementing and operating) skills in creating innovative chemical products or systems as students’ final year capstone project. The result is a curriculum model that simultaneously delivers two important outcomes: a) students who are motivated to learn chemical engineering as they are able to apply that knowledge for the betterment of the less-privileged members of the community and; b) graduates who are desired by employers for their deep knowledge in chemical engineering and competency in chemical plant operations. This paper also emphasizes certain unique features of the curriculum model highlighting examples of student projects with innovative chemical products.

Keywords: chemical engineering, chemical product design, sustainable development, design thinking

Introduction

Singapore Polytechnic (SP) has articulated its mission to be "a future ready institution that prepare our learners to be life ready, work ready and world ready", and that its vision is to nurture "a caring community of inspired learners committed to serve with mastery." These are most appropriate in positioning the institution to respond to today's fast changing world, where the purpose of education has evolved to better prepare students beyond classroom learning and the immediate working world. Education now needs also to equip students with knowledge, skills and attitudes essential for tackling the broader challenges of life in the 21st century.

This is especially important for today's students, often referred to as millennials, which approach their learning and have expectations quite differently from students of yesteryear. Millennials are generally framed as those born between 1982 and 2000, and are attributed to have “different” interests, goals, and learning preferences than students in the past (Taylor & Parsons, 2011). Millennials want to see relevance and meaning in what they are asked to learn and do, and they also like more immediate gratification and recognition - they need to feel like what they are doing is important and that they are on the right track, as perceived by them. Millennials also display a short attention span and are easily distracted. There is therefore a need to engage these students differently. Although he did not use the term millennials, Prensky (2005) refers to these students as those who “tune us out.” They live in a world that engages them differently than the world that we experienced. They find school much less interesting than the myriad of devices they carry in their pockets and backpacks. They are growing up in a world in which musicians, movie makers, TV stars, game designers, etc working very hard to earn their attention. When what is being offered isn’t engaging, these students truly resent their time being wasted. In more
and more of our schools, this group is quickly becoming the majority. Their possible motto, metaphorically speaking, is “Engage me or enrage me”, and they are “convinced that school is devoid of interest and totally irrelevant to their life” (Prensky, 2005).

Brief Review of Student Engagement

A thorough review of the topic of student engagement is beyond the scope of this paper, and has been provided by Trowler (2010). According to Harper & Quaye (2009), any attempt to engage students is an effort that goes beyond involvement or participation – it requires feelings and sense-making as well as activity. Acting without feeling engaged is just involvement or even compliance; feeling engaged without acting is dissociation. Fredricks, Blumenfeld & Paris (2004), identify three dimensions to student engagement, and we need to engage them on all these dimensions, as explained below:

1. Behavioral engagement: Students who are behaviorally engaged would typically comply with behavioral norms, such as attendance and involvement, and would demonstrate the absence of disruptive or negative behavior.
2. Emotional engagement: Students who engage emotionally would experience affective reactions such as interest, enjoyment, or a sense of belonging.
3. Cognitive engagement: Cognitively engaged students would be invested in their learning, would seek to go beyond the requirements, and would relish challenge.

Pinder-Grover & Groscurth (2009) noted that the most striking differences that millennials bring to the classroom are their preferences for collaborating, connecting and creating social change (italics in original), and cited many research studies supporting this claim. Kuh (2008) suggests using capstone courses and community-based projects to help students learn from one another and address social problems outside the classroom, noting that this approach is useful in achieving two essential learning goals. First, students learn to work and engage problems in the company of others, which means they must articulate their understandings, justify claims, and work together to solve problems. Second, students learn to deepen their understanding by listening to the insights of others, particularly those with backgrounds and experiences different from their own. These approaches form the guiding principles for our present effort.

Traditional and Revamped Chemical Engineering Education

Chemical engineering education had historically focused on the teaching of chemical process plant design, where students used simulation software to model a chemical processing plant to produce a given product of a certain purity based on some given raw material(s). Such a project is typically cast as final year capstone project, as it requires students to integrate various core chemical engineering principles learnt in earlier years, such as fluid mechanics, heat and mass transfer, process control, etc. These subjects are taught as separate core modules, and students are often told: "not to worry, learn these first; they will be useful to you later in your design project." The problem with this approach, besides not being particularly interesting and engaging for millennials, is the fact that no chemical processing plant is ever being built! Although such simulation exercise is useful in assessing students' ability to apply what they had learnt, it left students with a sense of "incompleteness" - whatever design they came up with may looked good on paper, but one can never really know.

In addition, traditional chemical engineering education, as for much of other engineering education curricula, has focused primarily on covering technical content, and failing to sufficiently incorporate the systematic infused teaching of soft skills such as teamwork and communication. This is typically relegated to the responsibility of faculty from the Language or Humanities schools. Issues such as ethics and other attitudinal or behavioral aspects are often not even included in the full-time curriculum programme.

Discussions of Work Done

The general framework for curriculum re-design based on CDIO is shown in Figure 1. The Singapore Polytechnic (SP) design thinking framework was added to complement CDIO, especially during the “conceive" stage. The design thinking approach focuses on three mutually supporting elements (Brown, 2009), namely that of user empathy (“What is desirable to users?"), technical feasibility (“What is possible with technology?”) and economic/business viability (“What is viable in the marketplace?”). This move is aimed at inculcating greater user empathy in our students during problem formulation, instead of diving straight into offering a solution that may not meet the requirements of the targeted user. This model allows us to design a curriculum that is able to effectively target all three aspects of student engagement: i.e. behaviorally, emotionally and cognitively. We believe this general framework is applicable to any discipline seeking to engage students in an effective manner.

![CDIO Framework](Image)
Based on the curriculum framework depicted in Figure 1, the Diploma in Chemical Engineering (DCHE) Course Management Team formulated its own curriculum model for student engagement. Cheah (2008) previously provided a comprehensive account of the changes facing the chemical engineering industry and the education of chemical engineers; as well as the adoption of the CDIO Framework by DCHE to revamp its 3-year curriculum. Also, post this implementation period, further innovations and changes have been made based on pertinent feedback from evaluations (Cheah, Phua & Ng, 2013). A key change to note is the introduction of chemical product design (Cheah, 2010; Cheah & Ng, 2010) and design thinking (Cheah, 2012; Ng & Cheah, 2012, Chua & Cheah, 2013) into the curriculum, whereby students are encouraged to identify areas of needs where solutions are possible via applications of appropriate chemical engineering principles. Specifically, we introduced two new modules, one in Year 1 entitled *Introduction to Chemical Product Design*, and another in Year 2 entitled *Chemical Product Design & Development*. This serves to support the execution of Year 3 capstone *Final Year Project* where students can come up with innovative chemical products for the less fortunate at the bottom-of-the-pyramid. In our core modules, besides teaching students the application of chemical engineering principles in process and equipment design (i.e. the "traditional" approach), we also include applications to chemical product design. For example, in the Year 2 core module *Heat Transfer and Equipment*, our students not only learnt about applications of heat transfer theories to the design of heat exchangers used in virtually all chemical processing plants, which they use in their Year 3 *Plant Design Project*, they also used the same formulas and equations to the design of water heater or a solar cooker that can be used in the *Final Year Project*.

At the same time, we integrated selected "soft" skills into the curriculum, to better develop graduate with certain attributes (e.g., communication, teamwork and thinking skills) desired by the employers. This is achieved by two important threads as explained below:

(a) Infusion of Parts 2 Personal and Professional Skills and Attributes of the CDIO Syllabus (such as critical and creative thinking, hypothesis testing, ethics, information literacy, etc) and Part 3 Interpersonal Skills of the CDIO Syllabus (teamwork and communication) into various core modules. Collectively we refer to these skills as "CDIO skills" and they are introduced via integrated learning experiences which are 3-4 hours of laboratory activities or assignments; which we termed "engineering practice" (Cheah & Yang, 2013).

(b) Infusion of Part 4 Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context, whereby skills in creating innovative chemical products or systems is introduced. We refer this as "C-D-I-O skills" to distinguish them from the "CDIO skills" mentioned in part (a). These C-D-I-O skills enable our students to carry out chemical product design as fulfillment of the diploma's final year capstone project.

Figure 2 shows the revised DCHE curriculum model incorporating the integration of basic mathematics and sciences (chemistry, biology and physics) modules, core chemical engineering modules (such as fluid mechanics, heat transfer, separation processes, and chemical reaction engineering), and a selection of free electives in Year 3. This supports the development of chemical process design and chemical product design at the end of the 3-year diploma. Where appropriate, chemical product design is further integrated with chemical process design, in learning contexts that require students need to come up with a flow sheet of how the chemical product can be scaled-up for production.

![Figure 2. DCHE model for engaging students in chemical product design](image-url)

Also shown in Figure 2 is the integration of various CDIO skills (shown as curved arrows) such as teamwork and communication, critical and creative thinking, systems thinking, ethics, global mindset, etc into core modules in our curriculum. With CDIO as the basis of our curriculum design, our model therefore emphasizes not just on students being able to integrate their technical knowledge into their projects, but they are also able to consider the economic and societal impact of their design as well.

At this point, it is worth clarifying our notion of "chemical products or systems". This refers to "technology that uses chemical engineering principles" as defined by Shaeiwitz & Turton (2003), which we felt is more appropriate for the outcomes expected of our diploma-level students. We also clarify "innovative" outcome of our approach to mean engineering products and systems that are driven by social, environmental or sustainability issues; and add values to the community-in-need. In other words, anything that is new to the community is counted as innovation, even if similar products are available elsewhere or if the change is an incremental one. Some of these innovative products emerged from the capstone projects include waste-to-gas digester, seaweed-to-fertilizer, rain water harvesting system, insulation material from sugarcane bagasse, pedal-powered filtration unit, and floating toilet system. As will be illustrated later, some of these projects have already been successfully implemented or in process of
being implemented, both locally in Singapore and in various countries in the region, including Indonesia, Myanmar, Nepal and Cambodia.

Figure 1 also shows the use of appropriate technology to drive the “I” (implement) and “O” (operate) phases of CDIO – in delivering innovative chemical product design envisioned in our curriculum outcome. Appropriate technologies – a term attributed to Schumacher (1973) – are usually characterized as small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community (Hazeltine & Bull, 1999). The core principle of appropriate technology is to include local communities in technology selection and development, innovation and implementation, all in an environmentally sustainable manner (Tharakan, 2006). Appropriate technologies are often perceived as “low tech” and unimportant, and not usually addressed in engineering education or university research (Sandekian et al., 2007). However, we felt that they are indeed very suitable at the diploma-level, as our students need not master a very high level of technical competencies at this level of study. The students, in fact, proved to be very capable to design and implement a workable product or system consistent with the needs of the poorer sections of the wider global community and within the goals of sustainable development (Chua & Cheah, 2013).

In addition, to further strengthen the three aspects of student engagement, we also linked the outcome of our curriculum model (Figure 2) to the ideals of sustainable development espoused in the Brundtland Report, which explained it as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN, 1987). Specifically, as shown in Figure 3, we draw parallels between the three circles of design thinking and three circles of sustainable development.

This mapping process (Figure 3) helped addressed a common problem in many initiatives aimed at addressing sustainable development issues: that they had been narrowly focused only on environmental issues (Kagawa, 2007; Segalas et al, 2010). Nagel et al (2012) had earlier suggested that both design and sustainability are not mutually exclusive, and that if we are to prepare our students to deal with the complex problems of sustainability, we must provide them with a holistic education incorporating all contexts of sustainability. In terms of curriculum design, our model serves as a useful tool that explicitly emphasizes placing equal focus on all three aspect of sustainable development when designing chemical products.

We now share some case studies from recent student final year projects. These are necessarily brief. For more detailed discussion of work done, see the work of Oh & Yang (2014).

**Case Study (1): Floatable Toilet System in Cambodia**

In this project, our students designed a toilet system that can float on water for a community-in-need in rural Cambodia, which was under threat of poor sanitary condition due to frequent floods in the region, using existing toilet systems which are very rudimentary. The students visited the village several times, the first of which is to speak to the villagers, where they also applied design thinking methodology in order to ascertain the villagers’ needs. They then proceed with several iterations of the design back in Singapore and eventually developed a prototype that was tested in Cambodia. With the help of local craftsmen, the floatable toilet was largely constructed from bamboo, a locally available and renewable resource. Besides the floating structure, the team also designed a separation system that removes urine from faeces; an anaerobic digester to help convert the human waste into fertilizers, as well as a system to capture the biogas was produced to be used as fuel. Subsequent visits included gathering feedback from the villagers and making improvements to the system. They also include training for the villagers in using the new system.

![Figure 4. Conceptual Design of Floating Toilet and Portion of the Actual Prototype](image)

**Case Study (2): Herbal Soap Production in India**

In this project, our students developed a suitable formulation to produce herbal soap using locally available natural resources in Sikkim, India such as sunflower oil, coconut oil, mint and lemongrass. The Yuksam community in Sikkim planted and harvested cardamom to earn a living. A few years ago, a disease struck the cardamom plants and wiped out the entire plantation. The villagers suffered a massive loss of income. Through empathy studies and interviews with the local community, several ideas were conceptualized such as paper and soap making. After several rounds of communication with the local community, it was found...
that there was another organization aiding them in a project involving paper making. Hence, our students embarked on soap making, developed a suitable formulation, and renamed it as ‘herbal soap’ because it utilized plant-based ingredients. This project is still ongoing. The next phase of this project is to explore sustainable processes and technology that is suitable to be implemented at Sikkim to produce the herbal soap in larger amounts.

Case Study (3): Pavement Bricks for the Philippines

In this project, our students conducted a feasibility study of converting solid waste into usable and valuable product. In particular, the study focuses on Las Pinas, Metro Manila Philippines, which is one of the densest cities in the world. Newly migrant families live in makeshift squatters, with poor sanitation and environment in the city’s dumpsite. A major concern for this community is the lack of proper regular jobs and disposable income. In addition, within the improvisational community, sandbags were used as a substitute to lie on the muddy grounds as walkways. During the monsoon season, flooding in the slums resulted in the sandbags being washed away. Replacement of sandbags is expensive and tedious. Our students formulated a paving brick to replace sand bags; using plastic waste, coffee grounds and gravels all available from the dumpsite. The paving brick prototype was tested by an independent external party, where it passed all the requirements of various applicable Standards.

Figure 6. Pavement Bricks from Waste Materials

Discussions

The curriculum model presented in Figure 1 allow us to directly engage students in all three aspects of cognitive (head), psychomotor (hand) and affective (heart) domains of learning that will allow transformative learning to occur (Sipos et al., 2008). Working on sustainability-themed chemical product design projects provided the students with opportunities to connect and collaborate with real people from community-in-need, to solve real-world social or environmental problems using knowledge gained in class, facilitated a high level of self-efficacy for our students (Wals and Jickling, 2002). This, in turn, encourages their motivation and engagement for further learning, hopefully resulting in better attainment overall in the longer term. At present, we only have anecdotal evidence on this, as we did not conduct a course-wide evaluation on our students. Conversations with our students who took part in these sustainability-themed capstone projects suggested that most experienced a high level of engagement in these projects. Many noted that working on such projects had been an eye-opener and an enriching experience for them, and they are now more inspired to make a difference to the less fortunate using their knowledge. They also noted that they are now more appreciative of what they have and not to take things for granted. However, it is probably too early to tell if long-term transformative changes in students’ attitudes, values or behavior as envisioned by Elliott (2010) had indeed taken place as we have not yet carried out any formal study on the impact of such curriculum re-orientation.

Conclusions

We have shared a curriculum model built around chemical product design which is able to meet the demands of both employers and students generally referred to as millennials. The curriculum is designed using the CDIO Framework supported by design thinking in the “Conceive” and “Design” phases, and utilizes appropriate technology to realize the “Implement” and “Operate” phases respectively. It is able to effectively engage millennials in their studies and deliver on the “traditional mandate” of our polytechnic education, which is to prepare graduates for the industry.

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Activities of Global Technology Education in NUT-KOSEN-TUT

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Abstract

Toyohashi University of Technology (TUT) and Nagaoka University of Technology (NUT) are joining effort with KOSEN (Japanese colleges of technology) to develop global engineering leaders whom possess practical and innovative skills. In this presentation, the roles of TUT in this project and its current activities are presented. In this joint project between NUT-KOSEN-TUT, TUT is mainly responsible for the “Development of global human resources”. A brief overview of several core components of the project are as follow: (a) Global internship program through oversea education base in Penang, Malaysia, (b) Global faculty development in collaboration with City University of New York, Queens College (QC), (c) International Conference of Global Network for Innovative Technology in Penang (IGNITE-2014), and (d) International Alumni Joint Meeting in Penang (IAJM-2014). The implementation details and outcomes achieved so far in this on-going project are described as well.

Keywords: global internship, global faculty development, international conference, international alumni meeting

Introduction

In the globalized world nowadays, remarkable progress and significant advancements have been achieved which resulted in dramatic changes in our thinking behaviours, economic strategies and industrial frameworks. In order to fulfil new demands and to face daunting new challenges in this era, an innovative and effective strategy development is indispensable to resolve the obstacles in human resources, research and developments. One of the keys lies in education where a reform or revolution of new educational approach and strategies at higher education level would be the only way that could enable such transformation.

In the endeavour to foster human resources well equipped with excellent skills for a global society, a joint initiative between Nagaoka University of Technology (NUT), Institute of National Colleges of Technology (KOSEN) and Toyohashi University of Technology (TUT) which is also known as “Tri-Institutional Collaborative/Cooperative Educational Reform Project” is formed under the National University Reform Enhancement Promotion Project supported by MEXT (Ministry of Education, Culture, Sports Science and Technology), Japan.

In our mission to cultivate developed global engineering leaders that possess outstanding practical and innovative skills, two approaches are implemented which are through global internship and faculty development programs. By utilizing our overseas education base, TUT-USM Technology Collaboration Center (in short, TUT-USM Penang), this could be achieved by infusing bilingualism into our program for the students as well as faculty and staff members.

TUT-USM Penang (Figure 1) is an overseas education base in Penang owing to the collaboration between TUT and Universiti Sains Malaysia (USM). It was launched on December 4th, 2013. With the support of USM in regards of orientation and language lessons, the 1st batch of students arrived at Penang for their overseas internship in 2014. Throughout their internship program, their progress and interim report were assessed at TUT-USM Penang. As for Global faculty development program, it consists of (i) Intensive English development, (ii) Lecture delivery in English, (iii) Attending lectures related to each faculty's specialty, and (iv) QC Mentor assignation to ensure efficient learning of faculty members. One of the expectations is to develop research collaboration between QC faculty

Figure 1: TUT-USM Technology Collaboration Center at Penang, Malaysia.
members/lecturers leading to future joint research projects. IGNITE-2014 was an international conference where latest inventive technological advances and research works in various application fields were presented. Finally, International Alumni Joint-Meeting (IAJM-2014) is also established for the development of alumni networks among NUT-KOSEN-TUT.

Apart of being a platform for “Global human resources development program” and “Tri-institutional Collaborative/Co-operation Education Reform Project Fostering Globally-Engaged, Practical and Innovation Engineers” TUT-USM Penang also serves as focal point for global education program for ASEAN countries, a gateway for prospective students to study in Japan, and a pivotal point for inter-regional university-industry linkage.

Methods or pedagogy

There methods of implementations for this project are described as follow:

a. Education system and global internship

The overall education system and syllabus were reviewed and taking into account new objectives in the development of global human resources, novel ‘Spiral-up Education system’ is developed. The enhancements towards global education consist of both fundamental and specialized subject studies, graduation research, language liberal arts, experiments, and internship throughout the path towards post-graduate education as shown in Figure 2. Besides that, global programs such as summer school, short-term stay, exchange, conventions and conferences are also integrated into the education path. Emphasis is given on the international internship where the students have the opportunity to gain first-hand experiences and exposures from Global/Multinational companies with a diverse multicultural background in Penang, Malaysia.

b. Global faculty development

In the development of the faculty members (lecturers), a strong collaboration is established with City University of New York, Queens College. The aims are for intensive English development of the faculty members (NUT-KOSEN-TUT) and research network establishment in the related and specific field of expertise. Selected potential candidates will undergo intensive English development program as well as attending the lectures for both undergraduate and post-graduate courses in related field of specialties. The selected faculty members would spend 3 months improving their English competency at Toyohashi Tech before leaving to Queens College, New York, USA for another 6 months. Upon completion of their training, they are required to present their lectures in English at TUT-USM campus at Penang, Malaysia and also to several education institutions nearby. Clear outline of the program is shown in Figure 3.

In commemorative of the launching of TUT-USM Penang, the first IGNITE 2013 symposium was held on 5th December 2013[1]. On the subsequent year, IGNITE 2014 was organized with the objective of announcing advanced research findings in various technological fields [2]. TUT-USM Penang was utilized as the venue for the conference which marks its important role as the pivotal education and research focal point for ‘Tri-Institutional Collaborative/Cooperative Educational Reform Project’.

d. Development of Joint-Alumni Network among NUT-KOSEN-TUT.

In the initiative to forge and foster strong network with the alumni of NUT-KOSEN-TUT, an alumni gathering was organized to gather not only TUT alumni but also the Tri-Institutional alumni that includes NUT and KOSEN. Alumni from Malaysia, Indonesia, Vietnam, Thailand, Laos and Pakistan were invited to participate in the Overseas Alumni Association Meeting which was held at TUT-USM campus, Penang. An overview of the current status and future development of Tri-Institutional Collaborative Educational Reform Project and Toyohashi Tech were presented. After that, representatives for the Tri-Institutional overseas branch alumni network were nominated and selected in order to lead the overseas alumni associations’ administration and liaison with the alumni association in Japan.

Results and Discussion

Following an overwhelming reception for global internship program which was initiated in year 2013, twelve students (10 Japanese and 2 Malaysian students) were dispatched for their global internship in the beginning of Year 2014 for their 2 months internship program in Penang. The students began their internship with a week of orientation at USM as part of their preparatory to adapt to the multicultural local environment in Penang. All the students were dispatched to 10 different companies, namely Advantest Engineering, Toray Industries, Continental Automotive components, Altera Corporation, Keysight Technologies, Ambu, SAM Engineering & Equipment, Mini-Circuits Technologies, Cerca Insight and ISO Technology. Based on the students’ field of study, they were dispatched to the companies of similar field respectively. During the internship, the supervisors of these particular students were encouraged to visit and establish a possible industry-university network that would enable future research collaboration. Mid-term and final presentations were done in order to evaluate the students’ adaptabilities and progress throughout their internship as shown in Figure 4.

As for global faculty development, 10 lecturers were selected and dispatched under this program which was officiated on April 1st 2014 as shown in Figure 5. During their 3 months English pre-training at Toyohashi Tech, the faculty members had attended English program that was specifically customized as part of their training preparatory prior to QC, New York. Throughout this period, communication between the faculty members and students at QC College were also done through video conference calls as part of their English practice and preparation towards life in New York. At the end of their training in Toyohashi Tech, the faculty members gave mock lectures to students and other audience based on their specialized subjects in English. Besides focusing on their English improvisation, emphasis was also put on the prospective research collaborations between the faculty members and also Toyohashi Tech.

![Figure 4: The students in their internship’s mid-term presentation in Penang, Malaysia.](image)

![Figure 5: Opening ceremony of the Global Faculty Development Program (1st batch).](image)

Throughout their program in New York and Penang, every faculty members shared their thoughts and experiences through periodic reports which are available in Toyohashi Tech’s Center for International Education homepage [3]. The English proficiencies of the faculty members before and after the program were evaluated using TOEIC exams which had shown significant scores improvement. In addition, Telephone Standard Speaking Test (TSST) was also used for periodic assessment of their speaking abilities which had shown noticeable improvement as well. In the final stage of their training program, the faculty members were based at Penang and given the opportunity to apply their upskilled English lectures to USM and also other educational institutions. Real time lecture from Penang...
was also delivered through Global Innovative Network (GI-Net) for the Tri-Institutions in Japan. From the evaluation tabulated from the attendee of the lectures, satisfactory results were obtained and significant improvements were observed in the lectures delivery by the faculty members. From the collective assessment of questionnaires obtained from students (undergraduate and postgraduate), faculty members of institutions, company employee and others who had attended the lectures; the average assessment score was 4.12 (1: poor ~ 5: excellent) with average attendance of 34 participants per lecture. Figure 6 and 7 show the completion of the faculty members’ development program at different stages in New York and Penang, respectively.

Figure 6: Final wrap-up presentation at Queens College, New York, USA.

Figure 7: Closing ceremony at TUT-USM campus, Penang, Malaysia.

IGNITE 2014 which was held from 14th to 16th of December 2014 at TUT-USM Penang not only had attracted tremendous interest from researchers and students from USM and Tri-Institutional collaborative institutions but also participants from multinational corporations industries at Penang. A total of more than 100 participants attended the event inclusive of researches and students from Japan. 70 oral and poster presentations, two keynotes lectures and tutorial sessions were conducted which drew great interest and enthusiasm towards the latest advancement in science and technology. This successful event was also attended by the President of Toyohashi Tech, Dr. Takashi Onishi. Figure 8 shows the group picture taken at the reception of IGNITE 2014 at JEN Hotel [2]

Figure 8: Participants of IGNITE 2014.

In the successful overseas alumni association gathering that was held on 13th December 2014, a total 110 people had turned up for the meeting and gathering which includes 40 alumni from the aforementioned countries, 70 faculty staffs and students (Figure 9). After the latest development of Toyohashi Tech and Tri-Institutional collaborative projected were presented, overseas alumni association branch are established and the representatives were selected for each countries. With the aim of maintaining the strong network between the alumni of the NUT-KOSEN-TUT, the representatives play vital roles in liaising with the alumni headquarters, alumni branch management and future networking activities. Opinions exchange between all alumni members and the staffs with great anticipation towards the current and future development of the Toyohashi Tech in Tri-Institutional Collaborative Project had led to a fruitful event [4]. The overseas alumni branch in Malaysia has been successfully established and with the co-operation of the representatives from other countries, similar establishment will be implemented in other countries in the very near future.

Conclusions

With the overwhelming and fruitful achievements in every aspects of educational development of global internship, faculty develop program, international IGNITE conference, and joint alumni association network; It is envisioned that further development in this direction would enable the accomplishment of the missions set in ‘Tri-Institutional Collaborative / Cooperative Educational Reform Project’. As we have already moved into a new fiscal year, the project is progressing with excellent momentum upholding higher expectations and developments in all areas.
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Figure 9: Participants at the Joint Alumni Network between NUT-KOSEN-TUT on 13th December 2014 at Northam Hotel, Penang, Malaysia.
ACADEMIC AWARDS: TOWARDS THE PURSUIT OF T&L EXCELLENCE IN NP
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Abstract

Teaching & Learning (T&L) is at the centre of our work at Ngee Ann Polytechnic (NP). As lecturers, we are expected to develop key T&L competencies to enable us to provide rich learning experiences for our students. A Pedagogical Development Roadmap was drawn up in 2013 to scaffold the enhancement of lecturers’ pedagogical knowledge, skills and awareness of educational changes, over the period of their teaching career. The roadmap includes milestone programmes that scaffold a lecturer’s teaching career. It also includes milestone programmes which support lecturers as they progress through various academic leadership positions in course leadership and staff development.

Beyond the staff developmental roadmap to enhance the T&L awareness, skill sets, and practices of all lecturers, the Polytechnic has established and evolved a structured approach to identifying, recognising, rewarding, and learning from lecturers who demonstrate their pursuit of T&L excellence through considered efforts to strengthen the learning experience for their students, purposeful growth and sustained professional development as educators, guidance of colleagues in their efforts to enhance the quality of the teaching and learning.

This presentation will outline the key features of NP’s Academic Awards framework and how the framework has allowed the Polytechnic to recognise strong T&L efforts, encourage the pursuit of T&L excellence, grow its T&L talent pool, and strengthen its impact on the community.

Keywords: Rewards & Recognition, Academic Awards, Teaching & Learning Excellence, Professional Development

Introduction

Teaching Excellence awards have been implemented across many different institutions and at various levels – from local institution awards to national level recognition of teachers. These awards are used to recognised and reward the efforts of teachers in their teaching & learning (T&L) practices, to encourage teachers to pursue innovations in T&L and also to identify teachers for further professional development (Chism, 2006). Ngee Ann Polytechnic (NP), an institution of higher learning in Singapore has also established the Academic Awards with similar objectives - to recognise, reward and share good T&L practices.

This paper will outline the key features of the Academic Awards framework, and how the framework has allowed the Polytechnic to recognised strong T&L efforts, encourage the pursuit of T&L excellence, grow its T&L talent pool, and strengthen its impact on the community.

Background

NP was established in 1964 as the Ngee Ann Technical College, a post-secondary institution which developed graduates with professional, technical skills. Over the years, the institution’s courses have expanded to 49 diplomas from 11 Schools/Divisions with over 16,000 students. The diplomas offered range from Engineering to Life Sciences to Humanities. NP has more than 16,000 enrolled students.

NP’s mission is to develop students who are not just global smart professionals but also graduates who are passionate learners with a heart for the community. To achieve this, NP’s lecturers must be able develop and demonstrate the appropriate T&L competencies needed to shape a unique NP learning experience that nurtures these outcomes.

NP’s Pedagogical Development Roadmap

The NP Pedagogical Development Roadmap (Fig. 1) was re-cast in 2013 to scaffold the enhancement of lecturers’ pedagogical knowledge, skills and awareness of educational changes, over the period of their teaching career. All new lecturers who join NP are enrolled into a series of developmental milestone programmes that are aimed at strengthening their T&L capabilities and inculcating a commitment to continuous professional development.

Milestone Professional Development in Education (PDE) programmes are tailored to support the specific role-based T&L needs of lecturers as they progress through their careers, typically within the first 10 years, from beginning lecturer through to lecturers with academic leadership responsibilities for module and course curriculum, academic quality, teaching teams, and change-initiatives. They are designed to anchor and strengthen 4 particular T&L competencies that NP deems critical for it to provide an effective and engaging NP learning experience; designing learning,
managing learning, assess learning and to use Info-Technology for learning.

Awards (Development Suite) that recognise innovative efforts and contributions to the T&L growth in others. They may then be recommended by the School’s Panel for NPTA consideration. Over the last 10 years, 574 STAs have been presented to deserving lecturers who have demonstrated the traits recognised by the award.1

(i) School Teaching Award (STA)

At the School level, lecturers are recognised for their pursuit of excellence in facilitating effective learning, student development as persons and professionals, and the continuous effort to develop oneself as a teaching professional (Fig 2).

Nominations for the STA are open to staff and students. Staff that receive at least one nomination will be flagged for STA consideration. For the last decade, between 60-70% of full-time staff have been nominated each year. Nominations however, serve only as an initial trigger for consideration and the number of nominations received by each lecturer has no bearing on the final selection which is evidence-based.

NP presents the awards comprising a certificate, and a cash quantum, at its Graduation Ceremony for the various diplomas. This enables NP to celebrate their T&L efforts with graduates, their parents, and their colleagues.

(1) Key Features of the Academic Awards (Teaching Suite)

This suite comprises two levels of individual awards for the pursuit of excellence by full-time lecturers; the School Teaching Award and the NP Teaching Award.1

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NP’s Academic Awards Framework

Over the last decade, however, NP has been gradually remaking its Academic Awards Framework to lift its value beyond being just a scheme to recognise efforts and contributions to T&L, to a more purposeful platform for NP to identify T&L talents and nurture these talents into T&L leaders who are able to, in turn, influence and shape the pursuit of T&L excellence in the polytechnic.

A major effort has been to try and shift the perception that the Academic Awards is a contest ‘won’ by the lecturers who are most ‘popular’. The Academic Awards is in fact NOT a competition to be won, but an honour presented to deserving staff who are RECIPIENTS. The Awards framework emphasises a more standards based, self-evidencing quality of awards that focus on T&L impact, continued T&L development and contributions to the T&L growth in others. Lecturers who are able to fulfil the selection criteria will have an opportunity to receive the award, either as individual lecturers or as members of teams.

There are two types of awards – Academic Awards (Teaching Suite) that recognise individuals for their pursuit of T&L excellence and the Academic Awards (Development Suite) that recognise innovative projects involving the design and development of engaging, and effective curriculum experiences and learning materials. There are 2 levels for each award – at School/Division level and at NP level. All awards recipients are selected by Selection Panels convened at School/Division or NP level. The Panels base their selection of award recipients on evidence provided by the individual lecturers or the project team members.

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STA recipients are selected by a School Selection Panel, which comprises School Senior Management and Reporting Officers of the lecturers nominated for the Award as well as the School/Division Awards Co-ordinator. The Panel reviews the evidences of each nominee which must include a teaching portfolio, feedback from students, validation comments by reporting officers, and a lesson observation report. Each School/Division can select up to 10% of their academic staff headcount to receive the STA, subject to Principal’s endorsement. Over the last 10 years, 574 STAs have been presented to deserving lecturers who have demonstrated the traits recognised by the award.

(ii) NP Teaching Award (NPTA)

Lecturers who have, over time, evidenced strong fulfilment of the 3 STA criteria, may be on the School’s Selection Panel watch list for the NPTA if they continue to demonstrate innovative T&L thinking, as well as the ability to influence the T&L growth and innovation efforts of others (Fig 2). They may then be recommended by the School’s Panel for NPTA consideration by an NP Selection Panel.

1 Adjunct/Associate Lecturers who demonstrate the pursuit of excellence in T&L are also recognized through a separate Associate Lecturer Teaching Award.
An NP level Selection Panel comprising Senior Management of the Polytechnic, past Award recipients, and Awards Co-ordinators, are invited to review the evidences for each nominee against the stated criteria before selection of the year’s NPTA recipients. There is no cap on the number of nominees or recipients for NPTA and there can also be no Award recipient for the year if none of the nominees meets the NPTA selection criteria. The final selection list must be endorsed by the Polytechnic’s Principal. Since the establishment of this award in 2007, there have been 8 recipients with 2 being repeat recipients of this top award.

The following figure summarises the criteria for the STA and the NPTA.

<table>
<thead>
<tr>
<th>School Teaching Awards</th>
<th>NP Teaching Awards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitating effective learning: Strategies &amp; techniques</td>
<td>Innovative T&amp;L thinking and influencing teaching and learning growth and innovation in others</td>
</tr>
</tbody>
</table>

Figure 2: Summary Criteria for STA & NPTA

(2) Key Features of the Academic Awards (Development Suite)

The Academic Awards (Development Suite) recognises and rewards efforts by lecturers to design and develop innovative and effective curriculum experiences and learning materials. These efforts are usually team-based.

The awards are selected based on a set of 4 criteria – innovative T&L design concept, relevance & appropriateness of the development, value & impact, and the pursuit of excellence.

Figure 3: Academic Award (Development Suite)

Teaching teams with such projects may submit their documentation of evidence through their School/Division for a first step evaluation review by an NP Evaluation Panel, made up of a representative from every School and Division, which will review the merits of the project against the criteria. This Panel will then submit its evaluation critique to an NP Selection Panel comprising Senior Management, past Award recipients, and Academic Awards Co-ordinators, for the final review and selection.

There are two categories of Academic Awards (Development Suite) – the School Academic Development Award (SADA) and the NP Development Award (NPADA). NPADA is further divided into 3 levels - Silver, Gold and Platinum. The criteria for selection for both SADA & NPADA are essentially the same (see figure 4 below). The key difference is that an NPADA-level project is a significant step-up from SADA level projects in terms of the quality and impact of innovation.

At School/Division level (SADA), the T&L innovations are usually learner-centered developments that are new to and have had a change-impact on T&L practices within the School/Division. These would however tend to be of smaller scope and may be variations of developments that can be found in other Schools/Divisions at NP. At NP level (NPADA), the projects must be able to demonstrate “breakthrough” qualities that are potentially scalable/transferable for even wider impact on other Schools/Divisions in the institution.

As with the teaching suite, recipients of this award must first be endorsed by the Principal. A total of 25 deserving projects found to have amply demonstrated the criteria, have been awarded over the last 10 years.
Key Features of the Post-Awards Feedback Exercises

At the end of the Academic Awards cycle each year, a series of feedback exercises is conducted with the range of awards stakeholders. This enables the feedback to trigger and shape on-going T&L development of lecturers, projects, and T&L capabilities in Schools/Divisions.

(i) Post-Award Feedback for Academic Awards (Teaching Suite)

Regardless of whether they have been selected to receive the Award for the year, all lecturers who have received at least one nomination to be considered for the year’s award will receive a nomination report. This report consists of nomination ratings against key desired attributes and comments by nominators. This serves as feedback for reflection as well as a form of recognition for the 60%-70% of staff who get nominated by students and peers each year.

The portfolios of evidence submitted by nominees as part of the Academic Awards exercise provides the management with feedback on and insights into the T&L strengths in each School/Division. An analysis of the portfolios is done by the Academic Awards Administration team, and a summary of the pattern of T&L strengths and potential areas for further development of the year’s award recipients is discussed with each School/Division for information and onward staff development planning.

(ii) Post-Award Feedback for Academic Awards (Development Suite)

As with the Academic Awards (Teaching Suite), all projects submitted for Academic Awards (Development Suite) for the year’s Awards consideration will receive detailed development feedback based on the comments and observations made by the NP Evaluation and Selection Panels. The Academic Awards Administration team will meet with the project team members and their School/Division Academic Awards Coordinators to update and share this feedback so that it feeds forward into and shapes onward improvements and enhancements to each project.

Identifying & Developing the Academic Talent

Receiving the NP Academic Awards is not the end of the journey for lecturers. Rather, it is the start of the next developmental journey in their pursuit of T&L excellence. This is signalled through discussion with recipients about opportunities which are identified for them to help them further develop their T&L competencies and to enable them to contribute to various academic initiatives. Opportunities are also created to enable them to share their experiences and expertise with colleagues within their Schools/Divisions, in NP, and even beyond.

Based on their T&L strengths as profiled in their teaching portfolios and the academic development project submissions, Schools/Divisions are able to identify potential expertise to lead or ‘champion’ new T&L directions, contribute to T&L innovation and change efforts, and provide T&L advice and input to curriculum teams. Some recipients may be also asked to undertake roles such as mentor to potential academic award recipients or to serve as Academic Awards Evaluation or Selection Panel members responsible for reviewing, critiquing and giving developmental feedback to submissions of evidence for the STA or the Academic Awards for development.

(i) Practicum Pedagogical Coaching

With effect from 2014, the Polytechnic has formalised a Practicum Pedagogical Coaching process as an integral practicum component of the PDE 1 programme for all new academic staff.

Pedagogical coaches must have amply demonstrated their pursuit of T&L excellence including an openness to innovate, and a willingness to further develop their T&L knowledge and skills. These are critical attributes the Polytechnic wishes to see modelled for new academic staff.

The STA recipients offer a natural pool of T&L talent from which to identify candidates with strong potential to serve as pedagogical coaches. They are then provided with training and development to enable them to provide appropriate, constructive, and timely interventions, feedback and suggestions to build pedagogical confidence, thinking, and considerations in the new staff and to model good T&L thinking and competencies for them. (Tan & Yap, (2012) & Tan, Viswanathan & Williams (2015).

(ii) Representatives of NP’s T&L Strengths and Efforts

Recipients are identified based on their T&L strengths are given the opportunity to be representatives of NP’s T&L strengths and developmental efforts on a range of platforms. These could include Joint-Polytechnic T&L projects, international conferences, and symposia. They provide recipients with new developmental opportunities to interact with, learn from, and share NP’s T&L strengths and projects with the wider education community. Such opportunities enable the awards recipients to gain fresh insights into educational trends and research, strengthen their understanding of learning, and establish contacts with communities of educators. Awards recipients are then expected to bring these new understandings and fresh insights back and seek ways to share with and influence T&L practice in the NP community.

Next Steps in Academic Awards

Since the inception of the awards in 1996, the structure of the Awards has gone through a number of reviews, and with each review, the standard and rigour of the awards have been lifted. Correspondingly, the quality of STA recipients and the Academic Awards (Development Suite) projects have also strengthened over the years. However, there is still more to be done to further strengthen the framework.
(1) External Review

While the Awards have gained strength and rigour over the years, it has remained very much an internal awards process. It is timely to seek external input which could provide NP with new perspectives on alternatives and fresh ways to further leverage on the framework to grow the T&L talent pool and NP T&L capabilities.

(2) Insights into T&L Strengths

At institutional level, there is a rich store of T&L insights, practices and innovation captured in the teaching portfolios and academic development project documentations submitted for STA or SADA/NPADA considerations. These are currently being stored intact in a database. This information, if it could be better coded and analysed, would enable the Polytechnic to draw significant institutional insights on its Teaching strengths and innovation quotient for onward planning and development of its staff and its programmes.

(3) More systematic approach to Recipients’ Post-Award Development

At present, the post-award roles possible are varied in terms of involvement and impact and they are not undertaken equally by all Awards recipients. A more structured programme for Award recipients would ensure that staff with potential and interest in T&L development will have the opportunity to do so. This would also allow promising STA recipients to work towards the NPTA as they gain recognition and credibility for their contribution towards the development of T&L at NP.

As for the NPTA recipients, larger opportunities can be identified for them to influence T&L policies and practice within NP and beyond. The Polytechnic is currently identifying more strategic ways to leverage on the talents of its NPTA recipients.

(4) More deliberate efforts to influence the development of all teaching staff

While the on-going development of the Awards recipients is a key feature of the Academic Awards Framework, these development efforts benefit primarily the recipients who are already the top 10% of NP’s academic staff strength. While the Framework does include features to encourage and enable this top 10% to influence the development of the wider T&L community, there is a need to design more deliberate strategies, beyond the current Pedagogical Practicum Coaching of new hires, and sharing of fresh ideas from conferences and other platforms, to enable this group to have a greater influence in shaping the T&L practices of all teaching staff.

Conclusions

The Academic Awards in NP are not popularity contests and neither are they merely tokens of recognition for lecturers who have done some good T&L work in the year. The Polytechnic has taken deliberate steps over the last 10 years to systematically strengthen the NP Academic Awards Framework to ensure that it is purposefully developmental – of awards recipients, projects, Schools/Divisions and the larger teaching body.

Despite having made significant steps in improving the rigour and robustness of the framework, the Polytechnic recognises that there is still more that can be done and it has outlined 4 aspects it intends to look into. These include getting external inputs on its framework, making institutional meaning of the volume of awards data that it has collected over the years, having a more systematic approach to post-award development efforts for recipients, and a more deliberate approach to enabling these recipients to influence the development of all teaching staff and ultimately, further strengthen the quality of its programmes and graduate outcomes.

References


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SAFETY DESIGN IN THE AGE OF ANTHROPOCENE
-An Indispensable Component of Engineering Education-

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Abstract

Human impacts on earth became so apparent and reached beyond the level which could not sustain its autonomous stability. In addition, the author recognizes equally serious possible impacts of human activities on our life, namely man-made-things became direct threats to the daily life of the people. While man-made-things have ensured the safety of peoples’ life, have improved the quality of life, and have contributed the extension of the frontier of mankind, at the same time, man-made-things not only destroy the inherent autonomy of the natural environment, but also may intensify the violence of nature, and may accidentally and unintentionally harm people, and even they may intensify the violence of malice. Engineers, as designers of man-made-things, have to consider full range of possible impacts of their designed products and services to avoid such possible harms. The author identifies four areas of safety design to be considered by engineers.

1) safe design of products and services not to harm people, 2) safe design of products and services (especially infrastructure) not to intensify the violence of nature, 3) safe design of products and services not to be mal-used by intended criminals and terrorists, 4) safe design of products and services not to undermine the autonomy of natural environment. This is the extension of Krutzen’s idea of Anthropocene and it seems coherent to the definition of harm given by the recent version of ISO/IEC Guide 51. The author will give a historical review of harms and threats to mankind, and then introduces four aspects of safety with several sets of examples. The author believes this set of design principles will become a necessary element of engineer education and practice in the coming years, characterized by the concept of Anthropocene.

Keywords: Anthropocene, safety design, man-made-things, artifacts, threats to mankind, engineering education, Paul Krutzen, system safety, system safety engineer examination

Introduction

At the turn of the century, Paul Jozef Crutzen, a Dutch Nobel prize winning atmospheric chemist, proposed using the term ‘Anthropocene’ for the current geological epoch to recognize the central and critical role of mankind in geological and ecological processes of this planet (Krutzen, 2000). The current geological epoch is called ‘Holocene’ and it started 11,700 years ago. Although Krutzen did not say anything about from when Anthropocene started, some suggest to date back to the beginning of the Holocene and some suggest the beginning of the industrial revolution.

In addition to the human impacts on earth’s environment, the author recognizes other equally serious impacts of human activities on our life. It is man-made-things’ impacts on safety. Man-made-things became direct threats to safety of the people.

While man-made-things have ensured the safety of peoples’ life, improved the quality of life, and contributed the extension of the frontier of mankind, at the same time, man-made-things not only destroy the inherent autonomy of the natural environment, but also may intensify the violence of nature, and may accidentally and unintentionally harm people, and even they may intensify the violence of malice. Engineers, as designers of man-made-things, have to consider full range of possible impacts of their designed products and services to avoid such possible harms to our life.

Historical Overview of Threats to Mankind

The Bureau of Census of the United States has a good collection of scholarly works on long range historical estimates of world population. Figure 1 shows those estimates. Markers show upper and lower range of the estimates.

Source: U.S. Bureau of Census. Historical Estimates of World Population (Collections of studies by various scholars)
Figure 1 Population Growth, livelihood and the mode of competition

According to the studies of anthropologists, mankind in the age of hunters and collectors requires space of one square kilos to survive. The land surface area of the earth is 150 million square kilos. It means that hunting and collecting can sustain maximum 150 million populations on the globe. It is interesting to find that when the estimated population of the world reached to that upper limit, people found another way of living to earn their livelihoods. And through this change, the inter-specific competition has transformed to intra-specific struggles over land and foods.

Figure 2 shows changes of the global population density during last 10,000 years. The population density go beyond the limit of one person per square kilos around two or three thousand years ago. The population density of Japan was checked too. Throughout almost whole time period, population density of the people in the land of Japan has been ten times higher than the world average. Because of that, sometimes we suffered by famine.

Figure 2 Population Density Growth


Figure 3 Energy Consumption per Population

When the population density increases, by the help of farming, it creates another problem, lack of foods. War is another outcome, and crimes and epidemics too. Mankind began to face another kind of threats along with the increased population density.

Finally, life became dependent on high level of energy usage after the industrialization. The higher the energy usage, the larger hazards we have to have. Energy itself is a source of harms. A primitive man consumes only 2000 kcal per day. It’s just enough to sustain biochemical process of human body, metabolism. And today, we consume almost one hundred times larger energy per person. And those energies are used for transportation, agriculture and industry, commerce and lighting or heating at home. (Figure 3) famous Japanese physicist, Torahiko Terada once wrote:

“When the human race was still in its primitive stage and people lived in rugged caves carved out of the mountain rock, they would not have been bothered by most earthquakes or storms, and they had no structures that could be destroyed by the forces of nature.” Just as wild animals and birds are able to withstand earthquakes and storms, so too would those uncivilized people have been able to survive with remarkable ease the natural disasters occurring year in and year out, and thus to maintain their social groups. ... Recovery from disasters was an individual matter as well, and there would have been no disasters from which individuals could not recover.”

We can summarize that there are three sources of threats to mankind. Nature, mankind itself (mal-intention of mankind) and man-made things. Nature appears as threats to us in the form of floods, earthquakes, volcanic eruption, and etcetera. And recently, more precisely in the age of the Anthropocene, nature appears as much serious and complex threats to us.

Mal-intentions of people have also became more and more serious sources of threats. Struggles over land of foods appeared as very primitive forms of violence in old days, but nowadays crimes or terrorism can make use of man-made things such as weapons, and intensifying the result of malice in terrible magnitude.

Man-made things also have unintended side effects to harm people. Jomon people in ancient Japan had nothing that could be destroyed by earthquakes. But now we have many things that could be destroyed. Terada Torahiko, a Japanese famous physicist, wrote many inspiring essays seventy years ago (Terada, 1938) . He talked about disasters which hit Jomon people a thousand years ago. They must be the same magnitude as today. But the damage created by those today is far more serious than the old day ones. Because man-made things accumulate energy, and once something happens it crushes. Another aspect is civilized society itself is the fact that very complex structures, and more vulnerable
To cope with those different kind of threats, mankind has developed various measures. Against the violence of nature, various kind of civil works has been carried to protect people’s community from disastrous effects of natural violence. City planning, disaster prediction technique and insurance systems are other examples of those traditional measures. And currently Business Contingency Planning (BCP) is widely cultivated by companies and infrastructure managers. (Table 1) Against the destructive effects of human activities onto the self-autonomy of nature, wide range of environmental measures begun to be implemented at global scale, such as green house gasses (GHGs) reduction efforts, global pollutants management, etc. Against the malice of people, criminal code, police system, national defense has been the traditional menu. But recently various type of dual-use technology control scheme has been invented and been implemented, such as Wassenaar Arrangement, Missile Technology Control Regime (MTCR), in addition to various other types of dissemination control schemes of weapons. And against unintended harmful side effects of man-made-thing, safety standards, safety regulation, and various kind of safety management techniques have been developed during last couple of decades.

Table 1 Measures to cope with the threats of man-made-things

<table>
<thead>
<tr>
<th>Type of threats</th>
<th>Traditional measures</th>
<th>Additional measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature, violence of</td>
<td>Civil works, city planning, disaster prediction, insurance, etc.</td>
<td>Business Contingency Planning (BCP)</td>
</tr>
<tr>
<td>Nature, destruction of the autonomy of</td>
<td>Threats were negligible before industrialization</td>
<td>Management of GHGs, pollutants, etc.</td>
</tr>
<tr>
<td>Malice of</td>
<td>Criminal code, police, national defense, religion, ethics, education, etc.</td>
<td>Dual-use technology control</td>
</tr>
<tr>
<td>Man-made-things, unintentional effects of</td>
<td>Threats were negligible before industrialization</td>
<td>Safety standards, safety regulations, safety management</td>
</tr>
</tbody>
</table>

How Global Society is responding?

Then how the international community is responding to these issues? All four type of threats are global in nature. So that the responses to these require concerted action of all players of the international community.

The authors have developed a metric to measure the level of commitment to selected global issues (Lien et al., 2014a and 2014b). It is called Global Support Index (GSI). It is based on the analysis of the ratification data of countries to more than one hundred multilateral conventions on various global issues. The conventions covered by this ratification database are shown in ANNEX I. There six policy domains, Human Rights (H), Peace and Security (P), Trade, Commerce & Communication (C), Environment (E), Intellectual Property (I), and Labor (L). Under these domains, there are also sub domains, such as Arms Control and Disarmament, Non-Nuclear Zones, Non-Nuclear Proliferation, Cybercrime and Terrorism (preceding four sub-domains belong to P domain), Trade and Commerce, Transportation and Communication, Measurement and Technical Standards (belong to C domain), Environment, Nuclear Safety (belong to E domain), and Basic Labor Rights, Occupational Health and Safety (belong to L domain). Under these sub domains, more than hundred multilateral conventions are covered. These conventions are considered sufficient to describe major global policy agenda given in Table 1.

SGI is a weighted average of wach country’s support level (= 1 if the country has ratified the convention at given year, and = 0 when not yet ratified) to specified multilateral conventions. In the case of global environment area, ten multilateral conventions are selected to describe the country’s behavior in this policy domain. World Heritage Convention (WH), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention (Ramsar), Convention on Migratory Species (CMS), Vienna Convention for the Protection of Ozone Layers (Vienna), Basel Convention (Basel), Convention for Bio-Diversity (CBD), UN Framework Convention for Climate Change (FCCC), Prior Information Consent Convention (PIC), and Pertinent Organic Pollutant Convention (POPs).

Figure 6 Global Support Index (SGI), Environment

In the case of Arms Control and Disarmament sub domain, nine conventions data are collected, namely, Hague 1899 and 1907, Geneva, Partial Test ban Treaty (PTBT), Non-Nuclear Proliferation Treaty (NPT), IAEA Safeguard (IAEA), Biological Weapons Convention (BWC), Chemical Weapons Convention
(CWC), Comprehensive Test Ban Treaty (CTBT), Australia Group (AG, Nuclear weapon related technology export control), Missile Technology Control Regime (MTCR), and Wassenaar Arrangement (WA). Figure 7 shows SGIs of those ten conventions.

In the sub-domain of Cybercrime and Terrorism, fourteen conventions data are collected, namely, Aircraft, Unlawful Seizure, Civil Aviation, Diplomatic Agents, Hostages, Airport Protocol, Maritime, Fixed Platform, Plastic Explosives, Terrorist Bombings, Terrorist Financing, Nuclear Terrorism, Nuclear Materials, and Cybercrime. Figure 8 shows SGIs of those fourteen conventions.

In the case of nuclear safety sub-domain, Early Notification of a Nuclear Accident (CEENA), Assistance in the Nuclear Accident (CACNARE), Convention on Nuclear Safety (CNS), Safety of Spent Fuel Management (JCS). And GSI for this domain is shown in Figure 9.

Quick review of above mentioned four figures reveals that in every policy domains, global community is very swiftly responding to these policy issues, such as global environment, arms control, cybercrime and terrorism and nuclear safety. These correspond to the various types of threats to mankind, destruction of the autonomy of nature, malice and man-made-things, described in the Table 1.

Safety Design: An Indispensable Component of Engineer Education

The paper first reviewed the historical transformation of various types of threats to mankind and then reviewed historical development of responses of the global community to several policy domains. The responses are measured by Global Support Index (GSI). Here in this section, the paper finally presents our university's response to this situation in the context of engineering education.

Nagaoka University of Technology (NUT) has been offering a series of unique, safety focused education programs since 2002 (For detail, see ANNEX III). At first, Mechanical Safety Engineering Course was launched in 2002 as a course attached to Mechanical Engineering Department at NUT.

Later in 2006, it was renewed and its scope was expanded from just mechanical safety to system safety (DOD, 1969). This program, Professional Master Program for System Safety, was created as a specialized educational program for professional engineers. While student size of the program is small (15 intakes per year), many professionals who are working in industry and government agencies, specialized in safety engineering and safety management, has enrolled to this program. The educational component structure of the System Safety Course is given in ANNEX II. There are three layers, principles, common safety tools, and safety of specialized sectors and subjects.

Six year later in 2012, another safety related educational program was launched in the field of nuclear engineering. Its name is Master Program for Nuclear System Safety.

In addition to that NUT is working together with industry expert and established completely third party qualification scheme for system safety engineers.

The recognition of NUT behind these recent development of its educational programs is that safety design became an indispensable component of engineer education. Engineers should be trained to understand and design various man-made-things to properly manage various types of hazard described in this paper. Especially, evidence-based risk analysis is the basis of all safety design and authors are trying to develop such risk analysis framework (Zhang, 2015). Traditional thinking of engineers are typically focused on performance, cost, new functions, efficiency, etc. But safety consideration in design is becoming more and more important and indispensable in the age of Anthropocene.

Conclusions
Human activities reached to the magnitude which could destruct the self-regulatory mechanism of nature. In addition to that, man-made things have appeared as direct threats to lives of people through various channels. Global society is responding to cope with this situation by establishing and enforcing global governance schemes in various policy domains such as environment, dual-use technology control, safety, etc. According to the author's analysis, the global community has been responding very swiftly to emerging global policy issues relating to threats created or enhanced by man-made-things. There is a growing recognition about better governance of unintended side-effects of man-made-things.

Nagaoka University of Technology is also responding to these issues and has launched a series of educational programs focused on safety and successfully developed an educational components structure for these educational programs. The author believes that these components should be shared by other educational institute engaged in engineering education of young and adult engineers.

Acknowledgements

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References


ANNEX I  List of Multilateral Conventions used for Global Support Index (GSI) Analysis

<table>
<thead>
<tr>
<th>Domain</th>
<th>Sub Domain</th>
<th>Conventions in acronyms or shortened names</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arms Control and Disarmament</td>
<td>Hague 1899, Hague 1907, Geneva, PTBT, BWC, CCW, CWC, CTBT, APM</td>
</tr>
<tr>
<td>P: Peace and Security</td>
<td>Non-Nuclear Zones</td>
<td>Tlatelolco, Rarotonga, Bangkok, Pelindaba, CANWFZ</td>
</tr>
<tr>
<td></td>
<td>Non-Nuclear Proliferation</td>
<td>NPT, IAEA</td>
</tr>
<tr>
<td></td>
<td>Cybercrime and Terrorism</td>
<td>Aircraft, Unlawful Seizure, Civil Aviation, Diplomatic Agents, Hostages, Airport Protocol, Maritime, Fixed Platform, Plastic Explosives, Terrorist Bombings, Terrorist Financing, Nuclear Terrorism, Nuclear Materials, Cybercrime</td>
</tr>
<tr>
<td>C: Trade, Commerce &amp; Communication</td>
<td>Trade and Commerce</td>
<td>IMF, WB, GATT, WTO</td>
</tr>
<tr>
<td></td>
<td>Transportation and Communication</td>
<td>ITU, UPU, IMO, ICAO</td>
</tr>
<tr>
<td></td>
<td>Measurement and Technical Standards</td>
<td>Metre, ISO, IEC, TBT</td>
</tr>
<tr>
<td>E: Environment</td>
<td>Environment</td>
<td>FAO, ICRW, WH, CITES, LC72, Ramsar, Air Pollution, LOS, CMS, Vienna, Montreal, Basel, CBD, FCCC, Kyoto, PIC, POPs</td>
</tr>
<tr>
<td></td>
<td>Nuclear Safety</td>
<td>CEENA, CACNARE, CNS, JCS</td>
</tr>
<tr>
<td>L: Labor</td>
<td>Basic Labor Rights</td>
<td>C29, C105, C87, C98, C100, C111, C138, C182</td>
</tr>
</tbody>
</table>
### ANNEX II  Structure and Components of System Safety Education

<table>
<thead>
<tr>
<th>Category</th>
<th>Educational Components of System Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principles</strong></td>
<td>Introduction to System Safety (History, Human Rights, Principles)</td>
</tr>
</tbody>
</table>

### ANNEX III  Chronology of Safety-Related Events at Nagaoka University of Technology, Japan and the World

<table>
<thead>
<tr>
<th>Events at Nagaoka University of Technology</th>
<th>YEAR</th>
<th>Events in Japan and World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Safety</td>
<td>2001</td>
<td>Ministry of Health and Labour, Guideline for Comprehensive Safety of machines</td>
</tr>
<tr>
<td>Graduate Course for Mechanical Safety</td>
<td>2002</td>
<td>ISO12100 Food Safety basic Law</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>ISO12100 Food Safety basic Law</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>Chuetsu Earthquake</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>Occupational Safety law amended, Risk Assessment become mandatory for manufacturers</td>
</tr>
<tr>
<td>Professional Graduate program for System Safety</td>
<td>2006</td>
<td>Consumer Safety Law amended, Reporting of Serious Accidents become mandatory</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>Chuetsu-oki Earthquake</td>
</tr>
<tr>
<td>Research Center for Safe and Secure Society</td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>Consumer Affairs Agency (CAA)</td>
</tr>
<tr>
<td>System Safety Engineer (SSE) Qualification System Launched</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>Annual Bulletin Study on Safe and Secure Society</td>
<td>2011</td>
<td>Tōhoku Earthquake (M9.0) and Tsunami</td>
</tr>
<tr>
<td>Master Course for Nuclear System Safety</td>
<td>2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td></td>
</tr>
<tr>
<td>JST/RISTEX supported program on Evidence-based advanced risk management project started</td>
<td>2014</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td></td>
</tr>
</tbody>
</table>
PROFESSIONAL DEVELOPMENT OF LECTURERS IN POLYTECHNICS: THE REPUBLIC POLYTECHNIC’S EXPERIENCE
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Abstract
Republic Polytechnic (RP) has adopted problem-based learning (PBL) as the main pedagogy to achieve its mission of graduating practice-oriented and knowledgeable professionals for Singapore. This necessitates an integrated academic professional development programme that builds the competencies and capabilities of the lecturers to successfully implement this educational innovation. This presentation shares RP’s experience in implementing a professional development programme to support lecturers in facilitating PBL since 2002. Specifically, two key features of the programme are discussed: [a] a structured training roadmap and [b] extensive peer coaching practices, which contributed significantly to the success and long term sustainability of the professional development programme.

Keywords: Professional development, polytechnics, lecturers, training roadmap, peer coaching

Introduction
The mission of polytechnics is to prepare students to graduate as practice-oriented and knowledgeable middle-level professionals able to contribute to the technological and economic development of Singapore. This is critical today with the rapid advancements in technology and a knowledge-based economy. Students need to be equipped with industry-relevant knowledge, and 21st century competencies such as problem solving and higher-order thinking skills, working collaboratively and life-long learning skills to enable them to stay relevant, resilient and competitive (Graham, 2012). A key pre-requisite to high quality education and training for students is high quality teaching by well-trained academics (Caena, 2011; Darling-Hammond, Holtzman, Gatlin, & Heilig, 2005).

Professional development in polytechnics
All polytechnics in Singapore have put in place professional development programmes for their lecturers. Each polytechnic has a staff development unit responsible for such programmes, also known as the centre for educational development, centre for professional and leadership development, learning academy or teaching and learning centre. The strong emphasis on nurturing high quality education and a culture of continuous learning is evident when all polytechnics collaborated to jointly create a professional development competencies framework for polytechnic lecturers in 2014. Six competency domains relevant to the current educational and industry landscape were developed: curriculum design and development, facilitation of learning, assessment for and of learning, holistic student development, dual professionals and reflective practitioners. This competencies framework is timely as it provides guidance on the focus areas and programmes needed for professional development of polytechnic lecturers.

Professional development for problem-based learning (PBL)
Educational institutions adopting PBL around the world recognised that professional development of faculty is a key driver for successful PBL implementation. However, the longer term effectiveness and sustainability demand the astute juggling of multiple interrelated factors including formal requirements for training, institutional support for innovation and continuous learning, human resource incentives and policies, and the design and execution of the professional development programmes based on several key principles (Avalos, 2011; Kolmos, Du, Dahms, & Qvist, 2008). Studies on the effectiveness of professional development to support PBL had distilled five guiding principles in many successful programmes (McLean, Cilliers, & Van Wyk, 2008; Schreurs & De Grave, 2010).

The first principle of effective professional development is for theory-based programmes. In PBL, constructivist learning, collaborative learning, self-directed learning, reflective learning, adult learning and instructional design principles (De Graaf & Kolmos, 2003) provided useful theoretical framework for the design and development of the training programmes.

The second principle is longitudinal programmes integrated with practice, feedback and peer support rather than one-off training events. A change of mindset about knowledge, teaching and learning is needed to implement the PBL approach, and this happens progressively over time. Moreover, it takes time and efforts to plan, apply, reflect and improve on PBL practices in lessons (Norman & Schmidt, 1992).

The third principle is flexibility in the use of instructional methods to best achieve the professional development outcomes. Four types are common: workshop, coaching activities, work-based learning, and e-learning. They can be used singly or in combinations.
The fourth principle is choice of programmes targeting the needs and experience level of faculty members. Novice lecturers benefit from a broad-based preparatory programme while experienced lecturers have a choice of areas to deepen their competencies and address knowledge and skills’ gaps. Lecturers could further specialised as experts in specific domains.

The final principle is a systematic and quality approach in designing professional development programmes, starting from needs assessment, developing the materials, delivering the programme, and evaluation and feedback. The trainers of the programme must also demonstrate domain expertise and good role modelling of PBL practices.

**Professional development of lecturers in RP**

RP’s professional development programme is guided explicitly and implicitly by the factors and principles mentioned in the previous section.

Goh (2012) described the early phase of the PBL professional development programme in RP from 2002 to 2003 as centred on formal and informal discussions among pioneer staff over the aims of education, educational trends and industry’s feedback on competencies of polytechnic graduates. Establishing a shared educational philosophy was essential to formulate RP’s own model of PBL, contextualised to the Singapore’s educational system and characteristics of students (Yew & O'Grady, 2012).

When the framework and lesson structure of RP’s PBL were formalised, the challenge was implementing intensive foundational training for lecturers on classroom facilitation. Reviews and evaluations of the early training programmes soon revealed the need to add more training areas, in curriculum design, understanding youths, and academic leadership. Feedback also suggested that lecturers felt overwhelmed by the introduction of many educational theories; instead they wanted more practice, feedback and peer support to integrate ideas and strategies learnt from training to their PBL lessons. The more experienced lecturers at this point have also started to ask for more varied and new training areas to further their professional growth as educators. This is expected as lecturers being adult learners prefer training that is perceived to be practical and directly relevant to their work (Brookfield, 1986).

Informed by the lessons learnt in the early years and relevant theories of adult learning, work-based learning and PBL, the various professional development activities were consolidated and sequenced into the first academic training roadmap in 2009. The training roadmap continues to be reviewed and evolved in 2012 and 2015, and now forms an integral part of RP’s professional development programme.

Given that PBL is practiced across all diploma programmes in RP, there is a need to articulate the standards of facilitation and assess the competencies of lecturers against those standards. In 2003, a certificate in facilitation programme was launched which incorporated a teaching portfolio, assessment of video recorded lesson based on the criteria in the PBL facilitation standards, and an interview for the candidate to articulate the evidence of good facilitation practice and demonstrate critical reflection of practice (O’Grady & Ong, 2007). In tandem with the certification of facilitation programme, a peer coaching framework was also established where certified facilitators could observe and provide feedback to improve the facilitation skills of lecturers preparing for the certification (Goh, 2012).

In 2006 and 2014, similar certification programmes were extended to certify staff in the design of PBL problems and lessons employing other pedagogical approaches.

Considering the professional development programme at RP as a whole, two salient features have taken into account the multiple interrelated factors and embodied many principles of effective professional development programmes: [a] a structured training roadmap, and [b] extensive peer coaching practices. The next sections elaborated on the training roadmap and peer coaching practices in their current form at RP.

**Structured Training Roadmap**

A structured training roadmap charts the various types of programmes that develops lecturers for different academic roles and diverse student-centred practices, signposts key professional development milestones, and affords pathways for higher career aspirations and life-long learning. The training roadmap should also be robust and responsive to meet the demands of the various stakeholders in the polytechnic, changing organisational needs and educational landscape.

**Training roadmap in RP**

The training roadmap allows RP to be strategic and systematic in achieving the outcomes of the professional development programme, by developing lecturers who are able to:

- apply learner-centric pedagogies and leverage technologies to enhance their teaching and learning practices;
- apply principles of adult learning and youth psychology to motivate and engage their learners of diverse needs and abilities;
- adopt appropriate frameworks and incorporate professional practices and industry standards in the design of curriculum and assessment; and
- engage in continual professional development to keep abreast with industry and pedagogical trends.

**Longitudinal plan for professional growth**

Professional growth of lecturers requires a longitudinal effort, where the training needs change with the roles and experience levels of the lecturers (Guskey & Yoon, 2009). For new lecturers, the training roadmap maps out the workshops and learning activities
to equip them with the essential knowledge, skills and values to carry out their academic functions. This is pertinent as while the majority of new lecturers might possess substantial industry experience, they lack the pedagogical, curriculum and assessment groundings. More importantly, RP’s PBL approach is a significant departure from their past educational experience that necessitates adoption of different beliefs and enactment of new roles in teaching and learning. These include curriculum centred around problems and applying knowledge and skills, teaching focusing on facilitating learning and assessment of both the outcomes and the process of learning.

As lecturers gain experience, the professional development workshops and activities focus on deepening their competencies as facilitators, developers of curriculum and assessment and module managers. A quality benchmark for effective teaching and learning is for the lecturers to attain the certificate in facilitation. Lecturers could also opt to specialise and undergo certification in problem crafting and lesson design.

For experienced lecturers who continue on to assume academic leadership roles such as programme chairs and certification panel members, a tailored training programme supported with peer coaching by existing leaders is put in place to help them gain the institutional knowledge and expertise needed for their new roles.

Professional development milestones and continual learning

The training roadmap lays out significant professional development milestones for lecturers. The first is the completion of 84 hours of foundation training. The next milestone is the certification of facilitation to the institution’s standards of effective teaching and learning within a stipulated time frame. Certified lecturers are offered pathways to gain formal qualification through the articulation to a specialist diploma in applied learning and teaching and sponsorship to complete a master’s degree in education. All lecturers are provided with an annual training budget and are expected to be engaged in at least 20 hours of academic professional development yearly, to further develop their teaching capabilities and to keep up with educational trends.

Flexibility and variety in what to learn and how to learn

The training roadmap caters for flexibility in the training areas and activities to achieve the professional development outcomes. The choice of training areas include teaching practices, curriculum and assessment, pastoral care, adult learning, module and programme management, educational technology and research. The contents developed are informed by well-established theories and practices in each area. Four main training activities are used singly or in combinations: workshop, peer-coaching, work-based learning and e-learning. E-learning or blended learning are now being used extensively to mitigate the clash between time to attend training physically and other work responsibilities. E-learning affords lecturers the flexibility to learn at their own time, place and pace.

Open to pedagogical and instructional innovations

RP’s pedagogical approach is anchored on PBL. However, there is flexibility to introduce other innovative pedagogies that can best achieve specific learning goals. Over the years, case-based learning, cognitive apprenticeship, experiential learning, interactive seminars, project-based learning and skills based learning have been included in the repertoire of professional development courses for lecturers. Emerging instructional strategies and tools such as flipped-classroom, peer instruction and the use of e-portfolio and online social media platforms for learning are also introduced in short hands-on workshops.

While lecturers are encouraged to experiment, implementation of any new teaching approach is planned and studied carefully to ensure that it benefits students’ learning and achieves the desired module outcomes. A work-based learning approach is usually adopted (Boud & Solomon, 2003), where a small group of lecturers involved in the implementation and staff developers collaborate to conduct lesson studies and evaluation research, to determine and report on the efficacy of the teaching innovation.

Responsive to external and internal needs

The training roadmap has to be responsive to external changes in education and future employment landscape. For example, a key recommendation of the Applied Study in Polytechnics and ITE Review (ASPIRE) Committee (2014) was to strengthen the education and career guidance efforts in the polytechnics. In response to this, workshops and training activities were swiftly developed, training lecturers to help students access accurate, up-to-date information and make well-informed education and career choices for their future.

In a study on new lecturers who have completed the foundational professional development programme at RP, Lim and Choy (2014) found that lecturers needed more support in the assessment of students in a PBL environment. This is not surprising as assessment is a complex and frequently high stake area in education (Nitko & Brookhart, 2011). Based on a training needs analysis, a comprehensive series of nine workshops were developed to train lecturers, covering the design, conduct, review and report of assessment. Peer coaching was also introduced to help new lecturers gain the skills and confidence to carry out continuous assessment of students. This example demonstrates how a gap identified internally through research was addressed in the overall training roadmap for lecturers.

Peer Coaching Practices

Peer coaching is a way for lecturers to help fellow lecturers to improve teaching or learning situations. It is
collaborative in nature and commonly utilises a three-step process (Robbins, 1991; Showers & Joyce, 1996):
1. Pre-observation discussion on focus of coaching
2. Observation of actual practice
3. Post-observation debrief and reflection to improve practice.

Practices similar to peer coaching include peer review, collegial observation and lesson study. However, peer coaching differs from mentoring in being confined to improving a specific practice, of shorter duration, non-judgmental in outcomes and can be done by anyone skilled in the practice, not necessarily a senior staff mentoring someone junior (Gottesman, 2000). For peer coaching to be successful, there must be mutual trust among lecturers to reflect on a current practice and to participate in collegial efforts to make improvements to practice (Lieberman & Miller, 2000).

Peer coaching in RP

Peer coaching in RP follows the three-step process mentioned above and is implemented at various levels. It supports new lecturers in acquiring the requisite knowledge, skills and disposition to effectively facilitate PBL lessons. For experienced lecturers, peer coaching provides guided practice, formative feedback and reflection on practice to support them in attaining certification to RP’s teaching and learning standards. Peer coaching for academic leaders provides the role-modelling and institutional knowledge to prepare them for assuming peer review and coaching roles.

All peer coaches undergo a “peer coaching: developing and reflecting on practice” workshop to equip them with the knowledge and skills to coach their colleagues. The training coordinator in each school matches the lecturer to be coached with a suitable peer coach, and the number of coaching sessions and timeline are agreed upon. Administrative support is provided with online forms to ease the recording of the pre-, post-, and observation data. Peer coaches and lecturers being coached are both awarded professional development hours as an incentive and recognition for their efforts and time invested in the learning activity.

Benefits of peer coaching in professional development

Peer coaching helps sustain professional development efforts as lecturers who have acquired the skills become potential peer coaches for other lecturers (Joyce & Showers, 1982). At RP, peer coaches increase the pool of staff developers available that are not only skilled in coaching but have the same subject matter expertise as the lecturers being coached. This allows for deeper understanding of the conceptual and contextual challenges of teaching in the discipline, and better coaching outcomes.

Studies have shown that peer coaching works as the transfer from training to practice is direct, can be done as part of work and during work hours, which is the essence of work-based learning (Garet, Porter, Desimone, Birman, & Yoon, 2001; Showers & Joyce, 1996). In RP, peer-coaching and work-based learning activities have also been consistently ranked by RP’s lecturers as the most useful professional development activities (Lim & Choy, 2014). They have been introduced progressively in more areas such as training to develop new diploma programmes and to design alternative instructional and assessment strategies.

Peer coaching also increases the buy-in of the professional development programme in RP as lecturers reap benefits from improving their own teaching and learning practice, and becoming active contributors helping their colleagues to succeed. Lecturers also “walk the talk” of engaging in continuous learning, just as they expect their students in PBL to do (Gottesman, 2000).

Peer coaching has been an extensive and successful practice in support of RP’s certificate in facilitation programme. A study by Goh (2012) has found peer coaching to be the key contributory factor in raising the first attempt success rate from 55% to over 70%. Since its inception in 2003, over 400 lecturers have attained the certificate in facilitation (Goh, 2014).

Future Developments

Professional development of lecturers at polytechnics will continue to evolve, needing regular reviews to check its relevance and to respond to shifts in internal and external educational environments.

Emerging educational technology such as immersive virtual environment, interactive, collaborative online platforms and learning analytics tools promise significant affordances in the teaching and learning of 21st century competencies (Avalos, 2011; Schreurs & De Grave, 2010). Lecturers will need to be trained to harness and implement them effectively in their lessons.

The training roadmap is likely to incorporate more train-the-trainer programmes in response to the national SkillsFuture Council (2015) initiatives. Lecturers will need to be equipped with the knowledge, skills and acumen to co-develop curriculum, teaching and assessment practices with industry partners.

There will also be increasing focus on accountability of professional development programmes, to justify the investment of time and resources. Research on the impact of professional development will move from not only studying the satisfaction level, learning and behaviour changes of lecturers, but to the more complex outcomes of changes in organisational practice and impact on students’ learning (Desimone, 2009).

Conclusion

This presentation shared the experience of RP in implementing a professional development programmes for lecturers to support educational innovations such as PBL. Specifically, it highlighted two key features, a structured training roadmap and extensive peer coaching practices which contributed significantly to the success and long term sustainability of the professional development programme. The insights discussed may be of value to educational institutions that are enhancing...
their professional development programmes for supporting lecturers in their pursuit of academic excellence.

References


THE MEXICAN KOSEN AT THE UNIVERSITY OF GUANAJUATO: AN INNOVATIVE APPROACH IN TECHNOLOGICAL AND SCIENTIFIC EDUCATION THROUGH INTERNATIONAL COOPERATION

ta.e.

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Abstract

The National High School System in Mexico provides capabilities for developing mathematical-logical thinking and communication skills, for the students to continue university studies. The Technical education offered in our country is mainly oriented to equipment operation, with occasional participation in solving or analyzing problems found in the industries. In The Bajio region, central Mexico, are being placed increasingly Japanese automotive assembling industries and many suppliers. This arrival has impacted the local economy and is requiring highly skilled professionals. Hence, the University of Guanajuato (UG) and Nagaoka University of Technology (NUT) designed a Technological High School Program with an International Profile, similar to the Japanese Kosen system. It is expected that the graduates from this program will be capable of solving complex problems by using a solid scientific and technological knowledge. In the beginning, two areas will be offered: Materials Science and Mechatronics, plus a consistent formation in fundamental scientific areas, engineering, human sciences, communication, and teamwork. Moreover, some short stays in industries will be carried out. The students will become fluent in English and Japanese languages for technical and daily communication. The students will be exposed to the Japanese culture through video conferences and seminars from Japan, and it count on with volunteer Japanese professors in Mexico. Moreover, Mexican students could carry out short stays in the Kosen’s institutions in Japan. The overall program will last five years. The graduates after concluding the program could follow their bachelor studies at UG, or at NUT, or to work in the industry. This program will be supported by the Division of Natural and Exact Sciences, the Division of Engineering, and the High School System located in Guanajuato city and Salamanca city, from the UG, Mexico. From Japan, NUT, as well as Nagaoka and Oyama Colleges from the Kosen system, have recently celebrated a cooperation agreement with the UG. The Mexican Kosen is the first academic program of its kind offered in Mexico, where highly skilled professionals must count on with a strong scientific, engineering and language preparation. This way UG and NUT contribute to the development of the state of Guanajuato, Mexico.

Keywords: Kosen, Mexican Kosen, high school system, mechatronics, materials science, international education.

Introduction

According to the "Education to Employment: Designing a system that works" report by McKinsey & Co., in (Moursherd, D. Et al. 2014); which embraces nine countries, including Mexico, two related world crises are confronted: high levels of unemployment and a shortage of individuals with critical job skills. However, the governments have had difficulties to develop effective responses or even to define what they need to know.

The Organization for Economic Cooperation and Development (OECD) reported that there is more than one individual between 15 to 24 years old that are not employed nor are attending to school or are in training (OECD, 2012). Moreover, at a worldwide level, the International Labour Organization (ILO) estimates that 75 million of young people are unemployed. At the same time, there is a shortage of people with critical skills (ILO, 2014).
In countries like Germany, Saudi Arabia, USA, Brazil, India, Morocco, Mexico, Turkey and the United Kingdom, only 43% of employers agreed that they could find workers with sufficient labor training. The McKinsey Global Institute (Moursherd, D. 2014) estimates that there will be a global deficit of 85 millions of workers with high and medium work skills in 2020.

Over the recent years, in the state of Guanajuato, Mexico, a variety of companies have been established. The Study of Labor Market carried out in Guanajuato (2013 reported that of 320 companies surveyed, from four economic sectors, 71% of them are from the manufacturing sector. Moreover, it has led to the installation and opening of transnational corporations, and it is generating new jobs. These companies concentrate mostly in the auto parts sector with 77.34% out of them, followed by the leather and footwear, metal, and plastic industries (Secretary of Sustainable Economic Development, 2013).

A strategic dimension of the Development State Plan of Guanajuato 2035 indicates that there should be an education for competitiveness and effectiveness and training for work (Secretary of Sustainable Economic Development, 2015). This report entails the necessity of formulating and updating the study programs to provide education with quality at the high school and university levels, which it is efficient and relevant for international, national and state development.

In Mexico, the high school studies provide competencies and skills to pursue university studies or to integrate into the labor force.

An educational institution should be monitoring its environment and anticipate changes in its environment. Therefore, the higher education institutions should make contributions by designing innovative educational programs to drive the social and economic development of its inhabitants.

Therefore, the goal was to design a Technological High School Program with and International Profile (BTPI), similar to the Japanese Kosen system. It is expected that the graduates from this program will be capable of solving complex problems by using a solid scientific and technological knowledge.

In the beginning, two areas will be offered: Materials Science and Mechatronics, plus a consistent formation in fundamental scientific areas, engineering, human sciences, communication, and teamwork.

Methodology

Focus group to elaborate the proposal. A focus group developed this proposal. The members were from Directorate of the School of High School System; Directorate of Academic Cooperation; Department of Educational Model, and professors from the Departments of Electronic and Mechanical Engineering from Campus Irapuato-Salamanca and the Department of Chemistry from Campus Guanajuato. Moreover, Nagaoka University of Technology, Japan, also contributed to putting together this proposal.

Analysis of educational and industry needs. To know the requirements of the educational sector to prepare labor force; data from the Ministry of Public Education (SEP, 2014), the National Institute for Educational Evaluation (INEE, 2013), Ministry of Education of Guanajuato (SEG, 2014): Sustainable Economic Development Secretariat of Guanajuato (SEDS, 2013) were analyzed. Similarly, some officials attended several sessions of the Automotive Cluster of Guanajuato (CLAUGTO) to know desirable competencies of technicians and middle managers of this sector.

Access to Education. The Ministry of Education through the undersecretary of middle higher education estimates that in 2018, at least 80% of people will count with high school studies (SEP, 2013). Therefore, the University of Guanajuato has proposed to create a new high school program called Technological High School Program with International Profile (Bachillerato Técnico con Perfil Internacional, BTPI, by its Spanish acronym). This program is also denominated like Mexican Kosen. This way the University of Guanajuato is responding to the growing demand for skilled professionals in the automotive industry related areas: metal-mechanics and materials science.

Industries arrival impact. At present, there are many automotive industries settled in the state of Guanajuato, as well as the part suppliers are arriving. This situation is attracting more foreign investment due to the competitive situation for economic development. Besides, the Bajio region in the central part of Mexico offers an excellent connectivity with the American border, as well as there are skilled workers in the booming developing industry.

Results and Discussion

Structure of the Technological High School Program with International Profile. The overall program will last five years: the High School System will offer the first three years, and the last two will function with the participation of two Guanajuato University divisions. After completing the five-year program, the participants could continue their bachelor studies at the University of Guanajuato, or at the Nagaoka University of Technology (Figure 1).

Figure 1. Course development and BTPI functioning.

The BTPI program will have two orientations: Mechatronics, which will be offered in Salamanca High School and Materials Science in Guanajuato High School. This program has four main education areas (Figure 2).
General area. The activities are focused to promote the personal development, social responsibility, creativity, and entrepreneurial spirit, as well as to develop cultural and intercultural skills.

Basic area. This area constitutes the BTPI Education Program nucleus. The area is made up of specific courses that will help the students to develop the specific skills to cope efficiently with different settings and situations throughout his/her life. The subject include mathematics, fundamentals science, communication, social sciences, English and Japanese languages, sports and cultural activities and management.

Complementary areas. The student will perform research under the professor guidance. Students will attend conferences, as well as industries stays, academic contests, and cultural events will be included to complement their personal and professional profile development.

Specialized area. The students will take either subject from Mechatronics or Materials Science that will allow them to perform in their professional life or to continue university studies. The subjects include practical workshops and experimentation in laboratories.

Credits system. One academic credit corresponds to twenty-five hours of student work, inside and outside the classroom. The total number of academic credits is 136 for the BTPI.

Applicants profile. The student must possess knowledge of mathematics, physics, chemistry and English. The student must also show the capability to communicate effectively orally and in writing. The applicant must be willing to teamwork and show the desire to learn about other cultures.

Graduate profile. After finishing the program, the student will be able to solve current problems in industry. They will be aware of production processes for its improvement. Students will know the fundamentals of the different types of materials and the use of simple tools, as well as automated equipment. Graduates will show leadership skills and teamwork and intercultural abilities. It is expected that at the end of 6 semesters, the graduate shall communicate in their mother tongue as well as English and Japanese.

Faculty. Professors from UG hold M.Sc. and Ph.D. degrees in their specialization areas, as well as the ability to teach in English. Professors from Japan will also participate through short and long stays as well as by video conferences.

Languages: Spanish, Japanese, English languages will be utilized as a medium of instruction to put in practice theoretical skills, as well as the cooperation between professors from both countries. The students will accomplish 800 h of Japanese language, including basic courses as well as the specialized technical language. Native Japanese teachers will participate in this Program. The stays in Japan would help to develop the intercultural awareness and to practice the foreign languages in a natural environment (Figure 3).

Support and international collaboration. This program will be supported by professors of the Division of Natural and Exact Sciences and the Division of Engineering, and the High School System located in Guanajuato city and Salamanca city, from the UG, Mexico. From Japan, Nagaoka University of Technology, as well as Nagaoka and Oyama Colleges from the Kosen system, will provide support. These institutions have recently celebrated a cooperation agreement with the University of Guanajuato.

Program approval. This Program was approved by the University of Guanajuato government bodies after submission of the complete curriculum description.

Conclusions

The Technological High School System with International Profile at UG will contribute to the UG internationalization goals by preparing highly skilled professionals to foster technology development in education institutions and industry. Our graduates will also work with a deep sense of social responsibility.
The BTPI is the first academic program of its kind offered in Mexico, where highly skilled professionals must count on with a strong scientific, engineering, and foreign language preparation. This academic program is an example of international collaboration among Japanese Higher Education Institutions and the University of Guanajuato.

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References


Developing World-ready Professionals:  
An outcomes-based, practice-driven approach by NYP

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Abstract

NYP adopts an outcomes-based and practice-driven approach to pre-employment education and training for its 16,000 full time students, to better prepare them for work and life, equipping them to be life-long learners and to contribute to the technological, economic and social development of Singapore.

NYP has, since its inception in 1992, implemented training environments and systems based on the Teaching Factory® concept, where students undergo training in environments emulated after real industry settings and norms. This approach has helped students to gain practical knowledge about industry practices and work models as they are learning the specialist skills of their chosen domains.

Internship is one other significant pillar of the outcomes-based and practice-driven training approach. All NYP students must undergo internship in their final year of study. The regular internship is from 10 to 12 weeks in duration, coupled with a capstone project to last a full semester. This model strikes a good balance for students to gain some in-depth understanding of the industry and job roles relevant to their chosen disciplines, as well as helping them to further consolidate their training and hone their project development skills.

The Enhanced Internship Programme offers longer internship durations of up to 24 weeks or longer to allow even deeper immersion of the interns into the industry environment and practices. Other enhancements over the regular internship programme include (1) More stringent and specific outcomes defined jointly by the host organisations and NYP and (2) Closer and more regular interactions between internship mentors from both sides to give inputs to the formative learning and training process of the interns to achieve the learning outcomes.

Collectively, the key elements and concepts of the outcomes-based and practice-driven pre-employment training approach in NYP have helped its graduates to be more work and market ready.

Keywords: Outcomes-based, Practice-Driven, Pre-Employment Training, Teaching Factory, Internship, Polytechnic

Introduction

In Singapore, polytechnic education has the primary mission to train work-ready technologists and mid-level professionals to support the technological and economic development of Singapore (Chan L.M., 2008). The 5 polytechnics collectively offer a comprehensive range of mainstream and niche courses in domains including business, design, engineering, health & life sciences, information technology, media, psychology and optometry.

The number of polytechnic graduates each year has steadily risen from around 20,000 in 2009 to more than 24,000 in 2013 (“Education Statistics”, 2014). A significant number will enter the work force immediately, with the rest either serving national service or pursuing further studies.

Polytechnic graduates are much sought after by industry, with about 89% finding employment within 6 months of graduation in the last 2 years (“Polytechnic Graduates”, 2014). They are in demand because the practice-oriented nature of polytechnic education has helped them develop relevant and specific work skills to the jobs that they are trained for.

Nanyang Polytechnic (NYP) was set up in 1992 to join the three earlier polytechnics set up in Singapore. Some of NYP’s key missions are: (1) to provide quality pre-employment training (PET) to school leavers; (2) to provide relevant continuing education and training.
NYP has 7 schools and about 1,400 staff, offering 52 full-time diplomas to about 16,000 students. NYP also offers a wide range of continuing education and training programmes to adult learners, at the diploma, specialist diploma and advanced diploma levels as well as customized professional development programmes.

PET is a milestone programme for many youths in Singapore and a key pillar of NYP’s core business. This paper presents a high-level view of the outcomes-based and practice-driven approach adopted by NYP to train its PET graduates to be more work-ready.

Training Concept and Approach

NYP aims to develop all-rounder graduates with the attributes described in Figure 1 below.

![NYP Graduate Attributes](image)

These attributes are expected to form as a result of consolidated student learning outcomes from all the curricula and co-curricular learning throughout the diploma programmes.

NYP adopts an outcomes-based and practice-oriented approach to teaching and learning. This approach is guided by the NYP Integrated Objective/Outcome-based Teaching and Learning Framework (iO2B) and anchored by principles of Contextual Teaching & Learning.

The iO2B framework is shown in Figure 2. The graduate attributes provide both the source inputs and ‘end-in-mind’ to drive the derivation of learning outcomes, progressively filtering from the higher-level course learning outcomes to module and detailed instructional learning outcomes.

![NYP iO2B Framework](image)

The iO2B framework takes reference from the Triangle of Effective Learning (Biggs, 2003) represented in Figure 3. The Triangle of Effective Learning shows that teaching and learning is enhanced by the constructive alignment of explicit articulation of learning outcomes, appropriate use of instructional activities that support those learning outcomes, and assessment strategies that allow the students to demonstrate skills and knowledge expressed in those learning outcomes.

![Triangle of Effective Learning](image)

Three levels of learning outcomes are defined: (1) Course Learning Outcomes (CLOs), (2) Module Learning Outcomes (MLOs) and (3) Instructional...
Learning Outcomes (ILO). The CLOs are established from context-specific intent and synthesized with the NYP Graduate Attributes. The MLOs and ILOs are then designed and developed to support the CLOs to ensure constructive alignment of stages of teaching and learning, and assessment. A ‘Curriculum Map for Outcomes and Objectives’ helps to make this alignment explicit to ensure that the intended CLOs are realized by the MLOs, which in turn resulted from the ILOs being accomplished. Figure 4 illustrates curriculum mapping of the different levels of outcomes, with direct relationships depicted by solid lines and in-direct relationships depicted by dashed lines.

*Figure 4: Curriculum Mapping of Different Outcome Levels*

Curriculum mapping is very important as it helps to ensure alignment of the cascaded ILOs, MLOs and CLOs to realise the course outcomes. It also ensures that the course architecture (division into the modules) is balanced, optimal and effective.

Though the Curriculum Mapping of ILOs, MLOs and CLOs ensures that the strategic educational intents are addressed, it does not provide information on timing or sequencing of modules within a course. This information can be visually presented, for example, as an Integrated Course Map, illustrated in Figure 5.

*Figure 5: An Integrated Course Map*

Many of NYP’s PET courses have developed their corresponding course maps which provide a clear road map to help lecturers identify ways in which the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to modules and co-curricular activities that make up the curriculum.

The iO²B framework provides the conceptual and implementation perspectives of outcomes-based teaching and learning in NYP. Underpinning and complementing this framework to deliver on the outcomes are the practice-oriented training methodologies and programmes which NYP has developed or adapted.

The “Teaching Factory®” (TF) concept of teaching and learning was conceived, developed and implemented in the early 80's. It was first used and refined in the training institutes then under the Economic Development Board (EDB) of Singapore. When some of these institutes were absorbed into NYP in 1992, TF continued to evolve in NYP under its originator, Mr. Lin Cheng Ton, who had moved from EDB to become the founding principal of NYP. TF has now become the hallmark concept of NYP’s teaching and learning (Ho E., 2009).

*Figure 6: Teaching Factory Concept*

TF encapsulates all the core elements of Contextual Teaching and Learning (CTL). Figure 7 shows how TF manifests itself in CTL.

*Figure 7: TF and CTL*
In essence, TF provides an industry-like, project-infused training environment with real-life requirements, state-of-the-art equipment and facility design and institution management to optimise competency and expertise development of students.

An important and integral TF component is the industry project platform whereby staff and students work closely as a team on real-life industry problems with cost, quality, and time constraints, and which often require multi-disciplinary skills residing in different NYP schools. This produces key outcomes that include: (1) continuous development of staff capability to enable further acquisition of more advanced skills and training of critical expertise in students, (2) a more inspiring and engaging learning environment for students, and (3) further development and reinforcement of a borderless work culture across departments and schools.

TF drives organisational excellence and is underpinned by (1) a wealth of innovative ideas and concepts; (2) a strong, progressive and supportive organisational culture; (3) strong and deep capabilities; and (4) an extensive network of partnerships. These success factors feed off each other and work in concert to provide a firm platform for TF to be implemented in different schools, with their diverse range of needs and contexts in teaching and learning.

TF has manifested itself in various forms such as specialist centres in the School of Engineering, Centre of IT Innovation in the School of IT, Teaching Enterprise in the School of Business Management, Teaching Clinics in the School of Health Sciences, Bioinnovation Centre in the School of Chemical & Life Sciences and Integrated Creative Studio in the School of Design and School of Interactive & Media Design.

Beyond the classroom, the Internship Programme has been an integral part of NYP’s PET course structure to nurture work-ready graduates. NYP facilitates internship opportunities to all students in every graduating cohort (i.e. students in their final stage of study, as illustrated in Figure 8, the diploma structure from the School of Engineering below.)

Internship is an intensive and impactful learning experience. A well-structured, quality internship programme will encourage students to gain and deepen relevant skills and help cement their aspirations to pursue a long-term career in the industry. In contrast, an ineffective implementation or an unpleasant internship experience or both may diminish the perceived values of work-based experiential learning.

NYP’s Framework for PET Internship Programme stipulates a set of Intended Learning Outcomes to be defined based on four key objectives of career preparation – (1) relating or applying knowledge and skills to work practice; (2) deepening skills relevant to a career in a chosen discipline; (3) gaining a broader perspective and knowledge of the industry, players, and careers in respective professions; and (4) recognising the reality of the work environment and the importance of work values and culture.

The Internship Programme and final year project work (or its equivalents) are critical elements in the professional development and career preparation of NYP students. There are two generic models adopted in NYP, as shown in Figure 9. Model 1 is a combination of a 12-week internship programme and a 12-week final year project work. Model 2 is a 24-week internship programme with substantial project-based learning. Notwithstanding the model adopted, the full 24-week period constitutes the career preparatory programme in NYP.

Among the 2 models, the majority of students go through model 1 while model 2 is gaining traction and acceptance with host companies offering internships.

A more structured, longer duration internship programme, designed and managed with clear learning outcomes in mind, benefits all parties involved. The student interns will have more meaningful immersion experiences and be able to develop deeper skills in, and appreciation of, the industry sectors relevant to their courses of study. For the industry partners, it could help in their talent scouting and staff recruitment when high-performing interns become employees after graduation. For industry sectors or nature of work that come with steep learning curves, a longer duration internship programme strikes a good balance between the training and productive stages of the internship cycle.
Discussions

The School of Engineering (SEG) of NYP was one of the early adopters of outcomes-based training in NYP. The TF Concept was implemented from the very beginning and refined over the years. Complementary concepts such as Accumulated Experience Sharing (AES®) and Integrated Technology Teaching and Learning (ITL) were spawned along the way.

AES® is a knowledge management system that systematically captures project development experiences and knowledge abstracted from significant projects and organises them for easy reference. It provides a rich repository of project cases—documented design concepts, challenges, solutions, and technology applications. This repository is shared with staff and students, who use the knowledge in their projects, further generating more project cases for the repository, as illustrated in Figure 10 below.

![Figure 10: Accumulated Experience Sharing](image)

The ITL concept, on the other hand, ensures that students not only master key technologies in their chosen specialisation, but also learn how different technologies are integrated into real-world systems and applications. To achieve this outcome, skills and knowledge learnt from different modules and years of study are woven and integrated. Figure 11 illustrates the integration of skills across modules and years of study.

![Figure 11: Integration of skills training](image)

In 2009, SEG started adopting the CDIO model for 5 of its courses. The results and positive experiences from both lecturers and students in the initial phase provided the affirmation and impetus for CDIO to be adopted by all 11 diploma courses and 2 programmes in SEG. NYP became a CDIO collaborator in 2011.

As of April 2015, all the SEG courses implementing CDIO have been self-assessed to have achieved level 3 or higher in compliance in the 12 CDIO standards.

The CDIO framework and the TF concept have many things in common. Both are oriented towards training work-ready engineers and both advocate providing the appropriate teaching and learning context, activities, facilities and environment to meet the goal. Projects, active and experiential learning also feature prominently in CDIO and TF.

SEG has also been working closely with a number of industry partners to provide more structured, and meaningful, internship programmes to the students. The demand for SEG interns has outstripped supply in the last 3 years. The interns have given positive ratings and feedback about their internship experiences. There have been job offers made, and taken up. Some companies are even willing to offer scholarships to get a head start in the talent scouting process.

Conclusions

The outcomes-based and practice-oriented approach adopted by NYP for pre-employment training has so far proven to be effective in producing work-ready graduates. It will continue to evolve to stay relevant in the midst of changing training needs and learner profiles, emergence of new tools and platforms for education, and new insights from educational research.

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References


Polytechnic Graduates Maintained High Employment Rates and Salaries in 2014
Developing a Virtual Reality-based Simulation System for Practical Training in Vocational Education and Training

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Abstract

Virtual Reality (VR) technologies replicate a virtual environment to provide users a sensory simulation of the environment being presented. In Hong Kong Institute of Vocational Education (IVE), we are developing a VR-based Simulation System having four screens surrounding a user to simulate an immersive environment commonly known as the cave automatic virtual environment (CAVE). The contents projected on the four screens are 3D in nature and the user has to wear a pair of 3D glasses in order to sense the “depth”. Through a motion detector embedded in the glasses which detects head motion of the user, the system is able to interactively update the screen contents according to the head motion and give the user immersive sensation. The user can also interact with objects in the virtual environment with different kinds of user interface where appropriate.

The objective of the VR-based simulation project is to apply the virtual reality technologies for practical training in vocational education and training (VET). The system is applicable to various applications in engineering areas including simulation of any workspaces for operations and maintenance training in electrical and mechanical services. For example, the system can simulate the workspaces of a lift or an escalator, an air compressor room, a power plant, etc. Workplace training is considered essential and beneficial to VET students in addition to practical training in school settings. Nevertheless, in some workplaces, the environment is full of danger and inappropriate operations can result in severe casualty. The VR-based simulation project manages to provide a solution for practical training in VET that can complement the shortcomings of workplace training and ensure that students can acquire a range of skills including safety operations under various environments. In this paper, we present details of the design concept for developing the VR-based simulation system. With the first application that is being developed on the system for preparing students working in a typical hospital’s plant room, we also share some initial findings and results, and discuss possible future works.

Keywords: CAVE, simulation, workplace training, virtual reality, vocational education and training

Introduction

Cave automatic virtual environment (CAVE) is generated using computers giving users visual and audio simulations. Users are impressed with a feeling that they are inserted into the virtual environment. Each user usually is provided with a pair of stereoscopic glasses to view a huge image that is projected onto four to six connected screens surrounding the user. Some of the CAVE systems also provide each user with a head-mount instrument to detect the orientation of the head. The contents of the screens are view-dependent that is updated according to the head movement to simulate what the user should see in the reality. Therefore, it is sometimes called Virtual Reality (VR).

CAVE was firstly introduced in 1992 by Cruz-Neira, Sandin, Defanti, et al. (1992); (1993). It provides users with a very broad field of view that significantly improves the feeling of presence in the virtual environment. Moreover, users do not have to rely on a virtual representation of their own bodies. Instead, they could physically enter the virtual space that greatly enhances the immersive feeling (Cruz-Neira, Sandin, Defanti, et al. 1992; 1993; Kuhlen and Hentschel 2014). The immersive virtual environment allows users having a faster and more comprehensive understanding of complex spatial relationships and allows interacting with objects in the environment using more natural controllers. For example, a user can use LED gloves (motion can be tracked by a camera tracking system) to magnify and rotate the 3D brain structure data in the virtual environment (Defanti, Dawe, Sandin, et al. 2009; Kuchera-Morin, Wright, Wakefield, et al. 2014).

Primarily, there are two categories of CAVE systems, panel-based system and projector-based system. For a panel-based system, each screen is made by a matrix of LCD panels. These LCD panels can display images with higher brightness and contrast compared with the projector-based system. These virtues can alleviate the undesired mismatch between vergence and accommodation which causes less eyestrain. This is particularly important when users focus on near-field virtual objects (Kuhlen, and Hentschel, 2014). However, panel-based system usually lacks floor projection, which significantly limits their immersive character. CAVE2 at the Electronic Visualization Laboratory is an example of the panel-based system (Reda, Febretti, Knoll, et al. 2013). For a projector-based system, images are projected onto the...
screens using digital projectors. However, the resolution of the system is usually low compared with the panel-based system. To increase the resolution, a number of relatively small projectors are arranged in a matrix with slightly overlapping image tiles. The soft-edge blending technique allows achieving a seamless transition between the tiles to increase the quality. The aixCave (Kuhlen and Hentschel, 2014) at the RWTH Aachen University and the StartCave (Defanti, Dawe, Sandin, et al., 2009) at California Institute for Telecommunications and Information Technology at the University of California San Diego are two examples of the projector-based system. Researchers applied CAVE in different visualization applications. Bryson and Levit (1991) demonstrated the virtual wind tunnel using CAVE. Nowke, Schmidt, Albada, et al. (2013) applied CAVE to simulate biologically realistic neural networks. Sampaio, Henriques and Martins (2010) and Sampaio, Ferreira, Rosario, et al. (2010) applied the techniques for development of models related to the construction process in civil engineering education. Gibbon (2008) applied the virtual reality technologies (Cheung, Siu, Feng, et. al, 2008) to demonstrate the circuit issues concerning operational amplifiers and a resonant circuit in the electrical engineering field. Su, Hu, and Ciou (2006) proposed simulation control testing in electrical engineering field.

Project initiative

Traditional hands-on training for students is limited to workshop environment. In case of emergencies such as fire or leaked gas, trainees might not be able to perform necessary actions due to lack of training in unfamiliar situations and this could lead to catastrophic consequences. An immersive virtual reality 3-D environment can help trainees to get familiar with different situations in multiple work sites with the use of scenario exercises. The use of simulation training has been used and proved extremely useful for decades in transportation industries in the form of flight, train and car simulators. However, simulation training for other industries is not widely used due to high development and maintenance cost. The situation has been changing in recent years as technological advancements in necessary hardware and software have significantly lower the cost to create an interactive virtual reality-based (VR) simulation and visualization system.

In order to provide vocational education and training (VET) a means to improve its effectiveness of training, Engineering Discipline of Hong Kong Institute of Vocational Education (IVE) is initiating to develop an interactive VR-based simulation system equipped with a projector-based CAVE system. The system aims to create training experiences for trainees and let them become more competent in performing maintenance tasks in multiple locations and improve the ability to react in emergency situations. Students can engage with different situations and directly apply knowledge they learnt from classes. This learning mode well fit into the constructivist learning model (Piaget, 1964) which suggested that students learn by expanding his/her knowledge through experiences.

The system will also adopt a student-centred approach that provides learners with an experience of working on a simplified simulated world. At the same time, the simulation manages to maximize training safety and minimize risk. It will provide a range of flexibility in customizing different parameters of the scenarios and the trainings that allow flexible training time for individual or group trainings.

![Figure 1](image1.png)

**Figure 1.** proposed system architecture and design of our CAVE system
System design

The interactive VR-based simulation system comprises four major hardware components: Scenario Control System, Tracker System, Image Generation System and Projection System. Figure 1 summarizes the proposed system architecture and design.

The Scenario Control System allows trainer adding and editing scenarios using the trainer instructor workstations. The workstation is also connected to multiple displays to simulate a control room console with display for plant room system status and plant room system schematics. Trainees are required to inspect the schematics to identify maintenance work required and locate the fault. Each trainee will be given a pair of LCD shutter glasses and enter the projection room to start the training. The projection room has a cube-looking structure with four screens: front, left, right and floor screens. For each screen, there is a stereoscopic projector projecting stereo images onto the screen which is 4m x 2.75m in size. Figure 2 shows the projection room.

The Tracker System consists of 12 infrared cameras installed in the projection room and connected to the tracker server. The cameras are used to detect positions and orientations of trainees in the projection area in real-time and the tracker server sends information to the Image Generation System. Upon receiving position and orientation signals, the Image Generation System renders computer graphics accordingly and updates the view contents that should be seen by the trainee in the reality. Finally, the Projection System projects rendered views onto the screens and combines with surround sound system to create an immersive virtual reality environment. This coordination among different sub-systems accounts for the interactivity between the trainee and the virtual environment. Figure 3 shows a stereo image projected onto one of the four screens. Note that the stereo image appeared to be blurred as the left view and the right view are overlapping each other. This gave a feeling to the trainee that he was walking on a crane high on top of a building.

Pilot application

Applications based on our VR-based simulation system are broad which can include various kinds of training programs. As a start, we plan to develop learning contents for plant room maintenance. We simulate a plant room environment with reference to an engine plant room of Tsuen Kwan O Hospital in Hong Kong as shown in Figure 4. We captured some pictures of the plant room and our engineers programmed the virtual environment with 3D Unity Game Engine to simulate the environment. Our 3D models have three different levels showing different extents of environmental details.

In the pilot application, we design several scenarios for electrical and mechanical maintenance in the plant room and they can be classified into three categories: safety, maintenance and other. For example, for the safety category, we have scenarios of handling unknown fluid on floor and carrying out atmospheric test in a confined space. For the maintenance category, we have scenarios of handling situations of a drop in air-flow, water leakage of condenser water pump strainer, and pressure drop on compress air system. We also have scenarios of lifting water pump which belongs to the other category. Figure 5 shows the scenario with some chemical fluid on the floor of the engine plant and a screenshot of the procedure in handling the fluid. The