

## TEACHING INFORMATION LITERACY IN CONTEXT: CASE OF CHEMICAL ENGINEERING EDUCATION

Sin-Moh Cheah & Katerina Yang

School of Chemical & Life Sciences, Singapore Polytechnic, Singapore

Email: smcheah@sp.edu.sg

### Abstract

Information literacy is an important skill for today's engineers. This paper shares the work done by the Diploma in Chemical Engineering (DCHE) Course Management Team (CMT) to introduce information literacy skills to its students, using the CDIO approach. The paper first provide some background discussion on the importance of information literacy, arguing that although it may appear to be a generic competency, it ought to be taught in the context of each engineering discipline. We outline the general approach based on the proven CDIO methodology to systematically integrated information literacy skills into a core module in the 3-year DCHE curriculum. This involves firstly the clarification of what information literacy constitutes in the CDIO syllabus, followed by the development of a full set of underpinning knowledge that clarifies what exactly the different sub-components of information literacy mean. This is followed by a faculty survey to ascertain the level of competency desired for students at the diploma-level. We then share the design of learning task where information literacy competency is embedded, ensuring that there is alignment between intended learning outcomes and the attendant assessment. In a nutshell, the learning task requires student to assess the suitability of several competing chemical processes from the sustainability standpoint. Besides assessing for factual and technical accuracy, students are required to submit a 2-page reflective journal, where among other things, they are to discuss how they have learnt to manage information effectively. The students were then surveyed on their learning experience and the results indicated that while the majority of students found the framework useful, and indicated that they will use it for other modules, there remains challenges in writing reflective journal and in using the information obtained effectively to complete the given assignment. Several ideas for moving forward with this initiative are also discussed.

**Keywords:** *information literacy, chemical engineering, sustainable development, CDIO*

### Introduction

The key characteristic of the post industrial 21<sup>st</sup> century is that it is information abundant and intensive (Bundy, 2004). EMC, a global leader in enabling

businesses and service providers to transform their operations and deliver information technology as a service, reported that the world's information is doubling every two years; and estimated that a staggering 1.8 zettabytes of information were created in 2011. It further estimated that by 2020 the world will generate 50 times the amount of information ([www.emc.com](http://www.emc.com), accessed Sep 2, 2013).

Mitchell Kapor, the founder of Lotus Development Corporation, famously said that "*Getting information off the Internet is like taking a drink from a fire hydrant.*" This statement clearly reflects the challenge one faced when searching for information in the world wide web. Today's individuals are faced with diverse information choices in their studies, in the workplace, and in their lives. Information is available through community resources, special interest organizations, manufacturers and service providers, media, libraries, and the internet. Increasingly, information comes unfiltered. This raises questions about authenticity, validity, and reliability. In addition, information is available through multiple media, including graphical, aural, and textual. These pose special challenges in evaluating, understanding and using information in an ethical and legal manner. The uncertain quality and expanding quantity of information also pose large challenges for society. Pope (2009) reported on the perhaps not so surprising discovery that despite the vast resources now easily available to students on the World Wide Web, many students have difficulty with using this resource. She reported that students "tend to either not know where to start or choose literature that is too narrow (non-survey technical articles), which they have difficulty understanding. Other groups favor survey articles and wikipedia entries without seeking more in-depth knowledge, which leads to a surface understanding that prevents them from addressing challenges they face during their project."

Sheer abundance of information and technology will not in itself create more informed citizens *without* a complementary understanding and capacity to use information effectively (Bundy, 2004). Information literacy is thus required because of the ongoing proliferation of information resources and the variable methods of access. According to the American Library Association, information literacy is the ability to "recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information" (ACRL, 2000). Here, we would like to

take a broader view espoused by the UNESCO (Abid, 2004):

*“Information literacy forms the basis for lifelong learning. It is common to all disciplines, to all learning environments and to all levels of education, while recognizing the disparities in learning styles and in the nature and development of literacy in different countries. It enables learners to master content and extend their investigations, become more self-directed, and assume greater control over their own learning, information literacy should be introduced wherever possible within national curricula as well as in tertiary, non-formal and lifelong education.”*

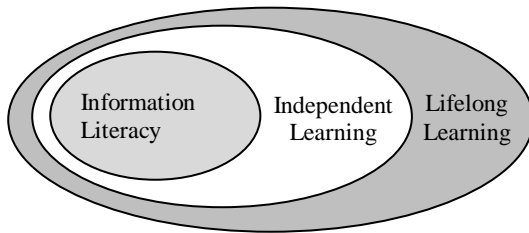


Figure 1. Relationship of information literacy to lifelong learning

### Information Literacy and Engineering Education

Rosenzweig and Gardner (1994) reported on their survey in *Chemical Engineering Progress* that, “chemical engineers today spend a considerable amount of time retrieving and using information on a wide variety of topics...” but, “depended on personal collections and other engineers for their information, and were not making good use of the growing number of electronic options. More than half the survey respondents attributed this to their inability to find and use appropriate information”.

The electronic options no doubt had grown tremendously since Rosenzweig and Gardner cited their findings. However, the ability of our students to effectively make use of freely available information afforded by the Internet had apparently not kept up with such development. For example, a recent report by Mullen and Kajiwara (2002) noted that: “...experiences in the engineering classrooms have taught us that the students have not kept up with the changes. The students have discovered the Internet but do not use it in a sophisticated way”. This need is especially more important today, in particular for engineering curriculum that adopted the CDIO approach where a basic-level design-implement experience is introduced in the very first year of curriculum (CDIO, 2010) as a way to make learning engineering more interesting. The importance placed on information literacy can be exemplified by a survey of professional engineers conducted by Mosberg et al (2005) who noted that, of the 23 items deemed important in engineering design, “seeking information” was the fourth highest rated,

behind “understanding problem”, “constraints” and “communicating”.

Candy (2002) noted that although information literacy appears to be a generic competency, it is however, also a strong context-dependent element as well. He noted that “while there may be some aspects of information literacy that can be applied irrespective of the particular field of study, it is also the case that a person who is more expert than another in any given field or study or practice is likely to have a more well-developed sense both of where relevant information is to be located, and how it may be retrieved and evaluated.” Various authors had henceforth called for the need to include information literacy in teaching of engineering programs (Lickie & Fullerton, 1999; Pilerot & Hiort af Ornäs, 2006; Breen et al, 2010).

### The CDIO Way: Integrating Information Literacy into Chemical Engineering Curriculum

The Diploma in Chemical Engineering (DCHE) in Singapore Polytechnic (SP) had adopted CDIO as the basis of its chemical engineering education since 2006. Recognizing the importance of information literacy in the education of our students, we embark on an initiative to integrate information literacy into our curriculum. Prior to this, information literacy is only taught to students as part of their Year 3 Final Year Project workshop, to better prepare them in carrying out literature review.

We are now embarking on a new initiative to integrate information literacy into core modules. We selected the Year 3 module *Chemical Reaction Engineering*, the topic of which is familiar to both of us. For this initiative, we used the same tried-and-tested approach that we used in part efforts to integrate various CDIO skills into our chemical engineering curriculum (Cheah, Phua & Ng, 2013). We firstly consulted the relevant section of the CDIO Syllabus, which in this case, is Section 2.2 “Experimentation, Investigation and Knowledge Discovery” under Part 2 “Personal and Professional Skills and Attributes”:

#### 2.2.2 Survey of Print and Electronic Literature

*The literature and media research strategy*  
*Information search and identification using library, on-line and database tools*  
*Sorting and classifying the primary information*  
*The quality and reliability of information*

As in other earlier approaches, we handled the effort firstly by asking the two key questions posed by Crawley et al (2007) before proceeding to design the learning task that inculcates the necessary skill set:

- What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave the university, and at what level of proficiency?
- How can we do better at ensuring that students learn these skills?

For the first question, we turn to UNESCO for the information literacy needs in Figure 2, which show 8 sub-component or skill sets.

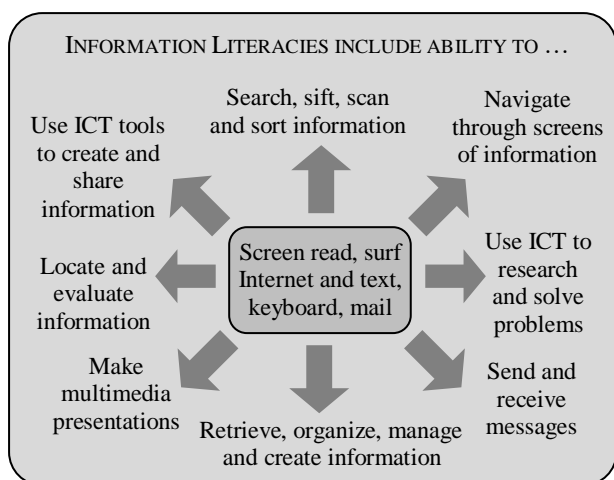


Figure 2. Information Literacies (UNESCO)

Crawley et al (2007) identified five levels of proficiency for a given CDIO skill:

1. To have experienced or been exposed to
2. To be able to participate in and contribute to
3. To be able to understand and explain
4. To be skilled in the practice or implementation of
5. To be able to lead or innovate in

For information literacy, our survey among the 24 faculty placed it at an average value of 3.6, which we felt is acceptable for diploma-level graduate. We then developed the underpinning knowledge for each of the sub-component skill set. We felt that, although on the surface such skill sets appear self-explanatory, there is a need to explicitly elaborate on what each means, supplemented by relevant examples in the context of chemical engineering. An example of the underpinning knowledge for “Locate and evaluate information“ is shown in Table 1.

Table 1. Sample Underpinning Knowledge

After you found what seemed like the stuff you are looking for, you now need to evaluate if you have gotten the *relevant* information. In the case of chemical processes for instance, the relevant information would be processes that shows potential at least at the pilot scale, if not already available commercially. It should not include processes that had only been studied in the lab, or merely those of intellectual curiosity or theoretical possibility. Also, if you are comparing different processes from sustainability point of view, be mindful that you must look at each process holistically, i.e. considering all the factors listed in the earlier paragraph. For example, an endothermic processes operating at high temperature and pressure is less sustainable compare to one that requires lower temperature and pressure. As another example, a process that produces harmful waste or side product that is difficult to separate tend to be less sustainable as well.

Next, we designed a student-centered learning task that simulate a real-world scenario (see Table 2) where students need to evaluate a given process for the production of the ethyl acetate (Figure 3), against other competing processes, from the sustainability point of view. This task requires them to use the Internet or Library to search for the necessary information in order to complete the task at hand.

Table 2. Selected Section of Case Scenario

As part of the company expansion strategy, *PureX Chemicals* is interested in entering the attractive market of supplying ethyl acetate. Ethyl acetate is widely used in the chemical processing industry as solvent. The plan is to utilize a new technology of ethanol dehydration-dehydrogenation to produce ethyl acetate. Mr. Chin Bo Yeong told you:

“Find out more about this new technology and include any suitable flowsheet to illustrate the process. Do check up on other existing method(s) of ethyl acetate production, and make an evaluation if the new technology is more desirable from a sustainability perspective.”

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“Based on your findings, prepare a set of PowerPoint slides for my presentation to Senior Management.”

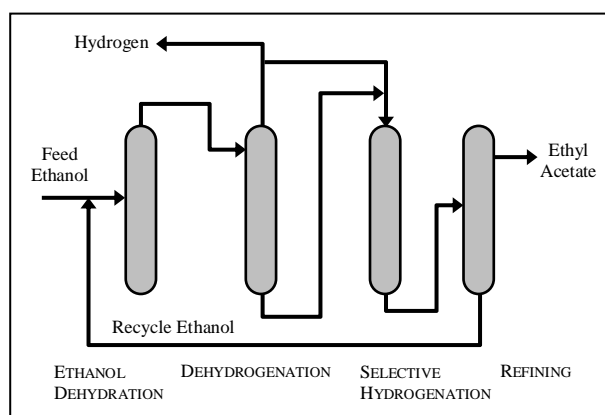


Figure 3. Learning Task for Activity on “Role of Chemical Reaction Engineering in Sustainable Development”

The learning task was designed in a manner to ensure alignment between learning outcomes, learning strategy and assessment, as shown in Figure 4. Some of the relevant learning outcomes are shown in Table 3, notably the ability to demonstrate competency in information literacy, in the context of sustainable development. They are also expected to use critical thinking skills in evaluating the information obtained.

Students then work together cooperatively to complete the task. As can be seen in Table 2, we also integrated other CDIO skills such as designing a communication strategy to convey their findings, in this case, a PowerPoint presentation to the company’s senior management.

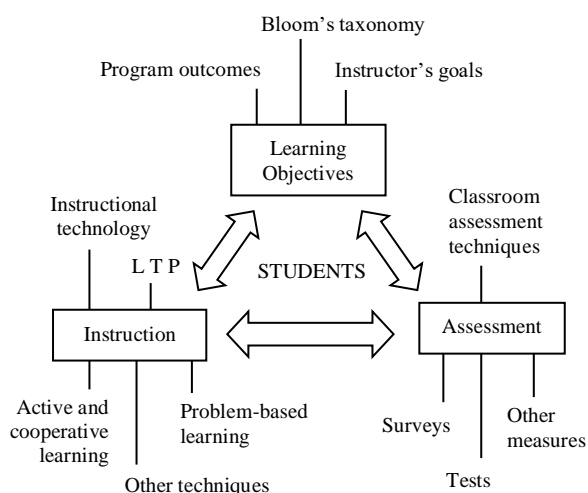


Figure 4. Curriculum alignment model for integrated learning task

Table 3. Selected Learning Outcomes

<p>(a). Demonstrate information literacy in searching, evaluating and organizing data</p> <p>(b). Compare and contrast different chemical processes to produce a given product (in this case, ethyl acetate)</p> <p>(c). Assess the sustainability of chosen process</p> <p>•</p> <p>•</p> <p>(f). Apply the good communication principles in the design of PowerPoint slides</p>
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Goodwin (2003) argues that assessment driven students are more likely to develop their information literacy skills. In this case, we assessed the students for the quality of their submission and discern from their answers (in their evaluation of sustainability of different processes) if they are able to process and evaluate the information gathered. They are also required to submit individual reflective journal to help them review their information literacy. This is shown in Table 4.

### Evaluation of Student Learning Experience

We conducted a simple survey to ascertain students' perceived usefulness of the information literacy framework. We use a 5-point Likert scale ranging from '5' for 'Strongly Agree' to '1' for 'Strongly Disagree'; for the following questions:

1. The Information Literacy Framework is easy to understand and use
2. The guidelines given in the Information Literacy Framework is useful to me in getting to the information that I needed
3. I can use the Information Literacy Framework to help me in other assignments in my course of study
4. Overall, the Information Literacy framework is useful in helping me complete my assignment.

Table 4. Selected Assessment for Learning Task

#### **PowerPoint Presentation** – Technical Content

Evaluation of the ethanol dehydration-dehydrogenation method with other different method(s) of ethyl acetate production, from sustainability point of view. Include any relevant chemical reaction equations and flow diagram, if available. (8 marks)

**NOTE:** Refer to the *CDIO Learning Guide* for more information on "Digital Literacies" to help you filter out and decide on what information to include in your answer.

#### **Reflective Journal:**

##### **Managing Learning (incl. Digital Literacies)**

(Reminder: This is an *individual* submission, by uploading to the module Blackboard site) (16 marks)

For this part of the assessment, you are to reflect on how you have managed your own learning to complete this activity, whereby the topic is probably new and not explicitly taught to you. In *no more than two A4 pages* (Arial, 12-point font), appraise how well you have managed your learning in terms of the following:

- The role of played by chemical reaction engineering in sustainable development
- Set goals, worked with team members and managed time
- Strategies and resources used to support learning
- Monitored learning (including information literacy) and made changes where necessary
- Improvements to managing learning that you could make in future

You are encouraged to support your claims made in the journal with specific relevant examples from the activity.

As the students worked on the learning task in turns, with one group of 4-5 students every alternative week, we administer the survey immediately at the conclusion of their lab session. At the time of this paper submission, the lessons are still continuing; and 4 groups of students had completed the learning task, with a total of 16 students surveyed.

### Results and Discussion

Results from our survey shows that majority of the students (80.0% Agree or Strongly Agree) found the information literacy framework useful as indicated in Figure 5. However, not all the students who reported that the framework is useful agreed that the guidelines given are useful, as shown in Figure 6. Here the percentage of students who felt neutral about this statement is significant at 35.7%. Despite this, many (78.5% Agree or Strongly Agree) felt that they can use the framework for other assignments in their study, as shown in Figure 7. Overall, 71.4% of the students are satisfied with the information literacy framework. This percentage is not as high as we expected, indicating that there are areas of improvement that we need to undertake to improve the framework and/or the learning experience.

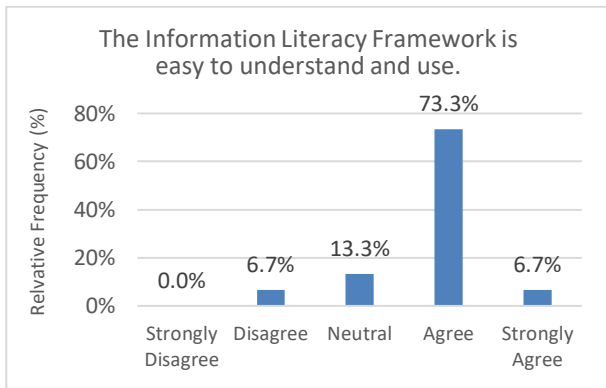


Figure 5. Usefulness of Information Literacy Framework

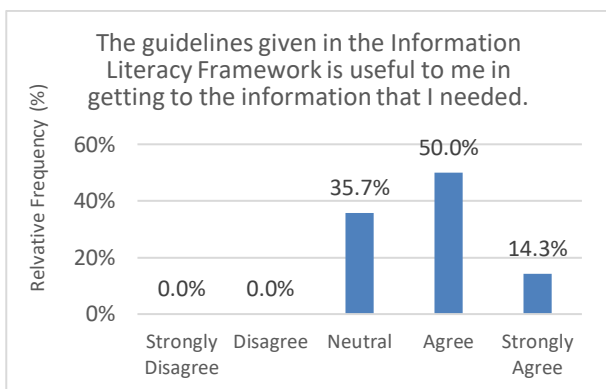


Figure 6. Usefulness of Underpinning Knowledge

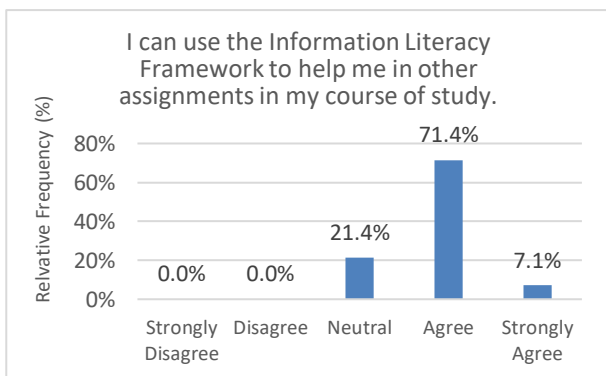


Figure 7. Confidence in using Framework

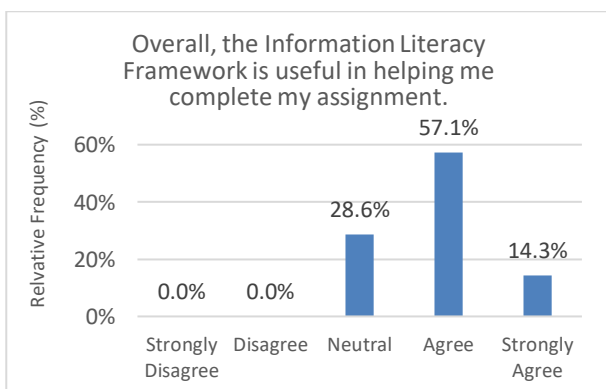


Figure 8. Overall Usefulness of Framework

As these are preliminary results only, we will do another update when all students had completed the activity. Among other things, we hope to be able to identify the students who feedback negatively about the framework and/or learning experience with the view of addressing any shortcomings in the framework and/or learning task. This can be done through a focus group discussion, whereby we seek for volunteers especially those who replied “Neutral” or “Disagree” in their responses. The challenge is to convince these students that their final module grades will not be compromised, or else we carry out the focus group discussion after the examinations.

Also, from the reflective journals submitted we can see that the students are able to appreciate the usefulness of the framework. For example, one student noted that: “The framework provides general steps to take when you are trying to look up for certain information. In summary, I need to firstly search and sort the obtained information. Secondly, I need to evaluate the information whether they are relevant to what I needed. Lastly, organize the information I have gotten and save the source for easy retrieval.” However, we also noted that the students can do better in terms of writing the learning points in the journals.

Next, from the 4 sets of PowerPoint slides received from the students thus far, we have somewhat mixed results. Some groups had clearly have demonstrated that they were able to evaluate the methods of production from sustainability point of view by comparing the feedstock used, the submissions from others obviously have some room for improvements.

Lastly, we identified several areas of improvement that can be carried out to further improve the framework and learning task:

- (1) Use of rubrics for assessment: we need to introduce suitable rubrics to ensure consistency in the marking process as administered by different lecturers taking the different classes. The rubrics also communicate to students our expectations.
- (2) To introduce in other Year 3 modules learning tasks that require the use of information literacy without explicitly linking this to the framework, to evaluate if the students can effectively use it and demonstrate the same level of competence, if not higher.
- (3) To expand the range of examples in the underpinning knowledge: we plan to add more examples to the key underpinning knowledge in the information literacy so that students can easily use it for other core modules such as rotating equipment, heat transfer and equipment, etc.
- (4) To share the model with other lecturers and to work with them to introduce the model to students especially at the earlier years of study, preferably from Year 1.
- (5) Depending on our evaluation of the remaining submissions from the rest of the students, we need to explore ways to improve their competency in making in-depth analysis of the information obtained.

## Conclusions

This paper presented our initial effort at integrating information literacy into a core module of our chemical engineering curriculum. Initial results from students' responses to the survey indicated that students possess sufficient Information Literacy skills to carry out learning tasks required. For example, one student noted in the reflective journal that "not all the resources can be trusted. We need to have enough probes and compare different resources to check on the validity of a particular information. In this activity, we did examine our results by looking on different resources. We need to have enough knowledge so that any wrong statement on the website can be eliminated in our work."

In addition to searching information from the internet, students also use other online platforms and tools, such as Google Drive and Skype to share information with each other to complete the learning tasks. This does not eliminate the fact that the students still meet face-to-face at least once before the final submission is made.

However, it remains questionable whether the students are able to contextualise the information that they search from the internet to the questions that they need to complete in an assignment. This is evident when the students submit their work where some of the answers indicate surface understanding only. This indicates that they still lack in-depth analysis and capacity to use information effectively. This also means that the integration of information literacy into core modules of our chemical engineering curriculum must be done in a meaningful way so that students learn to seek for more in-depth knowledge and understanding.

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## LEARNING TOGETHER OR KAGAN STRUCTURES? A COMPARISON OF BOTH APPROACHES IN A POLYTECHNIC CONTEXT

Tang U-Liang

School of Mathematics and Science, Singapore Polytechnic, Singapore

Email: tang\_u\_liang@sp.edu.sg

### Abstract

This paper is a report of a comparative study of two approaches or philosophies of cooperative learning in the context of mathematics education. Here we define cooperative learning as the instructional use of small groups so that students work together to maximize their own and each other's learning. While there are many approaches to cooperative learning, we will focus on two broad based ideas given the scope and limitations of this study. These two approaches which we are looking into will be termed Learning Together and Kagan structures. Learning Together is advocated by David and Roger Johnson while Kagan structures is another approach pioneered by Spencer Kagan. These two ideas have a rich history of both practise and research. Thus, it is the intention of the author to assess the suitability in implementing the ideas of these two philosophies in developing a cooperative classroom environment in the context of Singapore Polytechnic. Our method was to implement and execute activities aligned with each of these philosophies one semester at a time. Data comprising test results, student feedback and classroom observations were collected and these compared with each another. We have completed the first phase which comprised of planning and running Learning Together activities. These are classroom activities where students are assigned a group and told to work together to achieve a predetermined goal which is crucial for their learning. The second phase of the study is comprised of implementing Kagan structures in the course of normal classroom instruction. This consists of adapting and implementing one structure per lesson during the course of the semester. These structures are not developed from scratch but adapted from a list of structures available online and from books. We will assess and compare Learning Together and Kagan structures based on four criteria which are relevant to the polytechnic context. These three criteria for suitability are how it impacts

1) student performance in their written assessments, 2) feedback of students and the 3) challenges faced in implementing each framework in the classroom. Our recommendations will be based on outcomes from the two phases of implementations.

**Keywords:** *Cooperative learning, Kagan structures, team based learning, student cooperation, productive class discussions*

### Introduction

A common experience when a teacher asks an open ended question to the entire classroom is that students do not actively volunteer an answer but remain silent waiting for somebody else or the lecturer to answer the question.

This comparative study was motivated by a desire to find out ways in which one can encourage students to be more proactive in answering and thinking about questions asked in a math class. One possible solution to overcome this challenge was to get students to discuss the matter together instead of thinking about the question alone. This led to the author's exposure to two frameworks to develop a cooperative classroom, one where students would initiate consultation with their peers on questions asked and where they were not afraid to air their views.

These two approaches were developed by David and Roger Johnson-known as Learning Together-and Spencer Kagan. While both frameworks have substantial overlaps, there are important differences which we will describe as we go on in the paper. While these are not the only approaches to cooperative learning available-for instance (Michaelsen & Sweet, 2008)-we choose to focus this study on comparing these two because they do not require too much overhead in terms of resources and classroom organization. In a paper (Slavin, 1989), it was noted that

“There is ample evidence that cooperative methods are instructionally effective in grades

2-9, but relatively few studies examine grades 10-12.”

This study was also motivated to address this gap and to see whether cooperative methods continue to be effective for older adolescents.

A study was carried out from the period of October 2013 to September 2014 to investigate the following question

*Which framework is better suited for developing a cooperative classroom in the context of Singapore Polytechnic?*

### Methods and pedagogy

In order to answer this question, we need to define a set of criteria by so that we know what we mean by “better suited”. These criteria are effects on student performance in written assessments, how students felt about the pedagogy feedback and the author’s personal observations on the challenges faced in implementing each framework in the classroom. The first two criteria were evaluated quantitatively while the third is a qualitative assessment.

The duration of the study covered two semesters: Semester 2 of the 2013/14 academic year and Semester 1 of the 2014/15 academic year. In the former semester, a series of Learning Together lessons was planned and executed and in the latter semester, Kagan structures was used to organize learning. Results and feedback was collated and comparison made between these two approaches. This paper presents results, evaluation and recommendations.

While highly similar in their broad intentions, Johnson and Johnson and Kagan approach the concept of cooperation from two quite different philosophies. Both Kagan and Johnson and Johnson agree that cooperative in contrast to competitive or individualistic oriented classrooms leads to better outcomes academically, improved quality of relationships amongst peers and promoted overall psychological well-being of students (Johnson, Johnson, & Stanne, Cooperative Learning Methods: A meta-analysis, 2000).

However, there are differences between the two approaches to cooperative learning. The most important difference is in the implementation of structures. The Kagan model:

“...defines over 150 repeatable, step-by-step, content-free ways to structure the interaction of students with each other, the curriculum and the teacher.” (Kagan, Kagan Structures and Learning Together-What is the difference? , Summer 2001)

One should not confuse “structures” with “activities”.

“To illustrate, teacher can design many excellent cooperative activities, such as making a team mural or a quilt, such activities almost always have a specific content-bound objective....In contrast, structures may be used repeatedly with almost any subject matter, at a wide range of grade levels, and at various points in a lesson plan...” (Kagan, The structural approach to cooperative learning, Dec 1989)

Structures are not bound to any one goal, academic or pedagogical, but instead are a way of organizing interaction amongst student-to-student, or student-to-teacher. This equation summarizes what a structure is in distinction with what activities are.

Structure + Content = Activity

Johnson and Johnson (Johnson, Johnson, & Stanne, Cooperative Learning Methods: A meta-analysis, 2000) describes a continuum of cooperative learning methods ranging from conceptual cooperating learning methods on one end to direct cooperative learning methods. Here we may put Kagan structures on the direct end of the scale. It is very procedural and consists of predetermined steps which the instructor follows in lockstep fashion.

Learning Together is placed on the conceptual end of the scale. The focus of Learning Together is on the lesson and how it is designed to incorporate elements of cooperation in learning.

Johnson and Johnson define cooperative learning as

“..the instructional use of small groups so that students work together to maximize their own and each other’s learning...” (Johnson & Johnson, An Overview of Cooperative Learning, n.d.)

A cooperative learning lesson is one where the goal of instruction is not only competence and mastery in the subject area, but also specifies that these academic goals are to be achieved through cooperation. This requires special planning, materials and reorganization of the class away from normal lecture.

This is illustrated by an example taken from (Kagan, Kagan Structures and Learning Together-What is the difference? , Summer 2001).

Students are to make a list. In Kagan’s approach, he would use a structure called RoundTable, where each student takes turns in adding items to the list. In Learning Together,



students are told to make a list cooperatively. This is structured into the lesson by explicitly assigning “roles” for each student to play-one student may be a Gatekeeper (enforcer of equal participation) while another Encourages.

this pedagogical aim. Johnson and Johnson achieve the same ends by in exactly the opposite manner. They develop social skills by explicitly calling attention to this activity.

We could say that Kagan’s approach develops social skills without explicitly calling attention to

Table 1: Description of treatment classes

	Class name	Year	Course	Math ability	Class size	Math module	Student selection
<b>Learning Together</b>	Class A1	1	Chemical Engineering	Average to high	16	Engineering math	Compulsory module
	Class B1	1	Chemical Engineering	Average to high	21	Engineering math	Compulsory module
	Class C1	2	Computer Engineering	High	16	Advanced math	Specially selected
<b>Kagan Structures</b>	Class A2	2 + 3	Biomedical	Average	25	Statistics	Compulsory module
	Class B2	2	Chemical Engineering	High	10*	Advanced math	Specially selected
	Class C2	1	Mechanical Engineering	Average to High	33	Advanced math	Specially selected

\*Original class size was 21

The treatments were administered intensively in the first term of both semesters of this study. In both semesters, we implemented the treatment to three classes with students from various backgrounds. See Table 1.

We briefly mention some activities under the umbrella of learning together: a team based investigative activity into the topic of mathematic induction, peer teaching, role-playing based problem solving, gallery walks and a two week project based activity where students got together to develop posters for a poster exhibition in class.

In the second phase of the study carried out during the first term of the first semester of the 2014/15 academic year involved the administration of Kagan structures into the lesson. Amongst some of the structures implemented were Rotating Review/Rotating Feedback, ThinkPad brainstorming, Think-pair-share, 4-2-1 problem solving and Send a problem.

Table 2: Description of Kagan some structures

Kagan structures	Brief description of structure	Used for
<b>Rotating Review/Rotating Feedback</b>	Teams take turns to fill steps in a solution to a math problem, rotating among teams.	Recapitulation and reinforcing procedures
<b>ThinkPad brainstorming</b>	Students brainstorm ideas by writing in post-it-notes and pasting it on a surface	Getting students to generate own ideas and classify them.

<b>Think-pair-share</b>	Students pair up, discuss and write consensus on a flash card	Ensuring all students participate in thinking about a question asked to the class
<b>4-2-1 problem solving</b>	Students solve a problem in fours, then in pairs and finally alone.	Engaging students in higher order problem solving through discussion with peers.
<b>Send a problem</b>	Student teams create problems and send it to other teams to solve.	Generating intra-group discussions.

In this study, what distinguishes the implementation of Learning Together activities and Kagan structure is the amount of time dedicated to the activity and the degree to which the lesson deviated from traditional lecture format. Learning Together activities typically did away with lectures and instead relied on the activities to accomplish learning objectives. Much time was spent implementing such activities, some of them spanning two weeks. Kagan structures was used to supplement lectures, either as a lead in to the lecture or as an activity to wrap up the lesson. There wasn’t a heavy time commitment and lectures was still the main delivery tool.

### Results and Discussion

This section is organized as follows: 1) We report assessment data collected from all six treatment groups, 2) student feedback towards Learning Together activities and Kagan structured lesson and 3) challenges faced in implementation.

We assessed the effect of Learning Together and Kagan structures on students' performance in written assessment by comparing students in treatment groups against a control group comprising of students who were took the same module and in the same year of study.

**Table 3: Comparison of Learning Together treatment with control groups Mid-Semester Test results.**

Class	Learning Together activities implemented	N	Average MST result (Standard Deviation)
A1	Role-playing, jigsaw lesson, gallery walk, Peer teaching	16	61.69 (14.23)
B1	Role-playing by random assignment, Peer teaching	21	69.81 (15.95)
Control	None	20	69.65 (10.26)
Probability Test: $F = 1.99, p = 0.147$			
C1	Investigative activities, gallery walks, Proof reconstruction, poster exhibition.	15	54.2* (17.6)
Control	None	20	68.5 (12.7)
Probability Test (one- tailed): $t = 2.81, p = 0.004$			

\* Students who obtained < 50 marks had an option to retake the assessment capped at 50 marks. This average also includes students who *did not* choose to take the test.

The data indicates a significant reduction in assessment scores in the treatment group C1 compared to control. However, we cannot yet exclude the possibility that this is due to the inability of students to translate deep learning into written responses on a test as opposed to students failing to learn anything from the activity itself. This result seems to contradict in light of prior research done by (Johnson, Johnson, & Stanne, Cooperative Learning Methods: A meta-analysis, 2000) where they recorded significant gains in student achievement when Learning Together activities were implemented. However we note the difference in educational context and background of polytechnic students.

In terms of student feedback, quantitative data on how students' felt about the activity were not directly available. However, from the investigator's own personal observations students were fully engaged in the task, asking questions and having a good time interacting with the lecturer and their peers provided the task and the math involved was

sufficiently complex. If the task was a matter of working together to reinforce learning of a procedure, they chose to do the work individually, giving the impression that cooperation was somewhat redundant to their learning. Student preference was also varied, some willingly enjoying the activities while some still preferred normal lectures. There were few issues with participation, and more problems with students understanding and executing complex tasks in the cooperative activity.

While creating collaterals and organizing Learning Together activities took a lot time to prepare, the main challenge is actually implementing the lesson in class. Students tended not to respond well to activities that required students to take on certain predetermined roles. Furthermore as was noted already, if the task was too easy, they much preferred to work alone especially when the task called for solving math problems. To them, working together meant working on the problem alone and then comparing answers. However, students would exhibit teamwork if the task involved something other than solving math problems like working on a poster or writing up discussion points on a flipchart paper. Students also tended to approach open ended tasks somewhat confusedly, repeatedly querying the lecturer on what the lecturer "wanted".

Turning now to treatment groups who had Kagan structures embedded in typical lecture sessions we see that there are no evidence of significant differences between treatment and control groups except for the case of Class B2.

**Table 4: Comparison of Kagan structures treatment with control groups**

Class	Exposure to Kagan structure	N	Average MST result (Standard Deviation)
A2	ThinkPad brainstorming, 4-2-1 problem solving, Think-Pair-Share	25	71.1 (17.1)
Control	None	34	76.1 (12.1)
Probability Test (two-tailed): $t = 1.38, p = 0.172$			
B2	Rotation Review, Send a problem	10	78.80 (9.98)
Control	None	20	69.1 (10.20)
Probability Test (one-tailed): $t = 2.47, p = 0.01$			
C2	Rotation Review, Think-Pair-share	33	65.9 (12.68)

Control	None	143	66.9 (16.78)
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Probability Test (two-tailed):  $t = 0.31, p = 0.754$

Each treatment group is compared with a control group comprising of students taking the same module and in the same course of study.

However we believe that the significant increase is due to a strong selection bias present in the group. Majority of students in the class pulled out of the module due citing inability to manage second year workload. This left behind students with high math ability and this may explain the significant increase in average scores over the control group.

Student feedback was collected via a paper survey and the results are given in Table 5. This survey was administered after the mid-term holidays. The questionnaire asked students to indicate whether they had remembered anything distinct about the lectures. These averages were computed based on those students who answered yes to this question.

Table 5: Average survey responses

	Class A2	Class B2	Class C2*
<b>Q1:Did you enjoy the activity</b>	3.87	3.88	3.33
<b>Q2:Do you feel that your understanding has been deepened by participation in the activities</b>	3.91	3.38	3.11
<b>Q3:Do you prefer if math is taught this way</b>	3.87	4.00	3.11

Prob. Test  $F(6,70) = 2.285, \text{Wilks' } \Lambda = 0.699, p = 0.045$

Responses were graded on a scale of 1 to 5, 1 being most unfavourable to 5 being most favourable.

\* Quite a low proportion of students (36%) from Class C2 actually recalled the activities when surveyed.

The survey data generally showed that favourable responses came from the statistics course (Class A2). This is partly due to the fact that the type of structures used were more discussion based, and hence lent themselves well to the teaching of statistics where interpreting data is a key learning objective. However, there is a significant drop in favourability going to Class C2 who felt that the use of structures in the teaching of pure mathematics did not benefit their understanding positively or felt maths should be taught in this manner. The tendency for first year students to be more concerned about problem solving procedures in pure mathematics may explain the neutral responses.

Kagan structures are widely available and this saves instructors from creating structures from scratch. The challenge was to adapt these structures to meet the learning objectives and take into account student behaviour. Kagan structures are meant to be “bite-sized” activities e.g. a 3 to 5

minute discussion in pairs. Therefore it was important that ways were found to keep students accountable to the task. The use of flashcards where student teams wrote down discussion points which were subsequently handed in proved to be generally effective in ensuring participation. As alluded to in the previous paragraph discussing survey results, it was hard finding suitable structures which would gel effectively with learning objectives for pure mathematics. As it turns out from the investigator’s own personal observation students felt that the use of structures to help reinforce procedures in problem solving was generally redundant.

### Conclusions

Learning together and Kagan structures represent different ways of how cooperative learning objectives, beyond mere syllabus mastery, may be achieved. On one hand, Learning Together recommends thorough reorganization of the classroom to achieve the aims of cooperative learning. However, based on assessment data this approach is risky when applied to the teaching of highly technical mathematics. One cannot merely rely on peer teaching and group dynamics to make up for expertise and experience provided by a competent lecturer. However, we concede that students enjoy these activities more than classroom lectures provided these activities are engaging and relevant to the course. It must be emphasized that Learning Together does facilitates cooperation among peers and deep interaction with the lecturer, something which students love.

On the other hand, Kagan structures, while not showing any evidence that it can improve assessment outcomes, has proven that it can be embedded seamlessly into a lecture so that student learning can be fortified with group discussions, critical and interpretative thinking skills while yet leaving room for ensuring students are prepared technically. Student reactions to this are somewhat mixed. Since Kagan structures are meant to facilitate cooperative skills through small scale activities, there is a tendency for students, especially older adolescents to feel a certain sense of artificiality in the execution of the lesson. This depends on subject taught. Use of Kagan structures did not seem to help improve understanding in the context of mastering procedural skills. However, it works very well as a tool to nurture discussions and higher order reasoning when the interpretive aspect of mathematics is emphasized e.g. in statistics. Finally, Kagan structures does work to ensure that students, who otherwise might not participate if a question is simply asked to the class, actually think about the question and contribute their ideas.

In conclusion then, we see that both Learning Together and Kagan Structures face the same issues of implementation in the classroom. Also, Kagan structures, when implemented correctly, achieves much of what Learning Together activities can do too. But because the former does not consume copious amounts of curriculum time, there can be an exposure to higher order knowledge skills without sacrificing the time needed to ensure that students also acquire necessary technical skills. Therefore, we believe Kagan structures are better suited to develop a cooperative classroom the context of Singapore Polytechnic.

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## USING MULTIMEDIA TO UNDERSTAND SHIP DESIGN

Captain Ashok Mulloth, Mr Prakash Xavier  
Singapore Polytechnic/Singapore Maritime Academy, Singapore

\*amulloth@sp.edu.sg

### Abstract

**This paper demonstrates that multimedia is a highly effective tool to illustrate ship design. An interactive multimedia web based animation programme has been developed at Singapore Maritime Academy using 2D and 3D animation for CoC (Deck & Engine) students. The programme ‘Understanding Ship Design’ was developed to help students understand key ship design concepts using both 2D and 3D animation and enhanced graphics. The programme does this in a linear fashion by first explaining the basic ship design concepts and then illustrating design features of several ship types using both 2 and 3D animation.**

**Feedback obtained from Class (1) and (2) Deck students studying at the academy indicates that the ship design programme has been well designed and has therefore enhanced classroom teaching, thereby accelerating the learning process.**

**Keywords:** *Ship Framing systems, Fore and aft structure, double bottoms, midship construction, decks*

### Introduction

The Singapore Maritime Academy (SMA) has been training students for Class 1, 2 & 3 Certificate of Competencies (Deck) for over 35 years. Most of the training is done either in the classroom or in a laboratory using traditional teaching methods and multimedia. The academy has a ship handling simulator.

### Problem Definition

Traditional classroom teaching methods could be made more effective when combined with a web based multimedia presentation that has text, graphics & animation. This is especially so for topics where concepts are difficult to explain.

Ship design concepts are difficult to explain as most text books show ship profiles diagrams in 2D. A programme that allows the lecturer to zoom and revolve the ship profile will make learning easier. This is because the content of a multimedia programme will draw more attention than similar material presented in a traditional form (Gayeski 1993).

The programme presents the content in an uncluttered and organised manner illustrating key structural members of a vessel with easy to read labels. Using real ship profiles as is done for several mid-ship

profiles of several ship designs gives the user an enriching experience. (Brandt 1988).

Moreover a web based application allows the user to learn at his own pace after he has attended the lecture. It also allows for a repetition of the concept over and over again until it is clearly understood. This is user dependent.

3D graphics of mid-ship sections of several ship design types that can be rotated and zoomed illustrating key structural members of a vessel allows for greater retention and provides a clearer understanding. This is evidenced through a survey conducted on students who have used the ship design application. Details of the survey findings are given at the end of this paper.

### The Programme

SMA has developed a programme on ‘Ship Design’ for marine engineering and nautical students, studying at the academy. The programme is designed taking into consideration what the teacher requires to teach in relation to a prescribed syllabus, as this is one of the most important concepts in developing a multimedia application for teaching. The program has been designed with the teacher in mind as the role of the teacher as a facilitator remains crucial in a learning process (Feith 2008).

The screen shot below captures the menu path of the the programme.

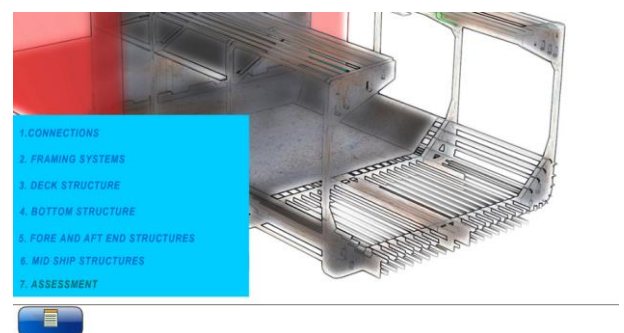


Figure 1

### Ship Design

The Ship design programme has been conceived and designed in a linear fashion and has used text, hyper-text, 2D and 3D animation. The program starts on basic concepts and builds on these gradually in a linear fashion. This is evidenced by the topics that

make up the programme, namely, key connections, framing systems, deck construction, double bottom construction, fore and aft end structures and finally mid-ship profiles of several ship design types.  
*Key Connections*

The programme starts with 3D graphics of key structural connections in ship construction. Connections illustrated include the connection between the frame and a beam, insert plates and the requirement of a faceplate at an opening on deck.

*Framing systems*

The three main ship framing systems are illustrated in this topic, namely the transverse framing system, the composite framing system and the longitudinal framing system.

A screen of a transverse framing system is as below:

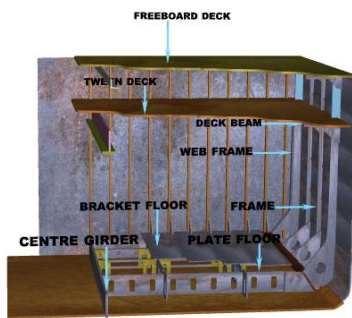


Figure 2

*Deck and Bottom construction*

Constructional aspects of both the deck and bottom construction showing the key structural members of a ship's deck and bottom are illustrated in this topic. Both longitudinally framed and transversely framed decks and double bottoms are shown.

*Fore and aft end structures*

The structural members of both a vessel's fore and aft structures are clearly illustrated using 2 and 3D graphics.

*Mid-ship structures*

As there are several ship types, key features mid-ship structures of the key ship types are illustrated in this topic. The mid-ship section of the chemical tanker is illustrated below.

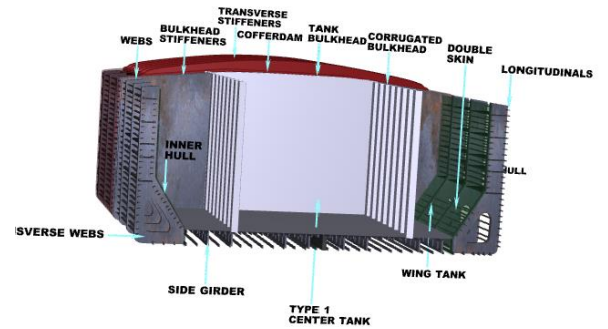


Figure 3

*Assessment*

An assessment is provided for at the end of the programme.

A screenshot of one of the assessments is as below:

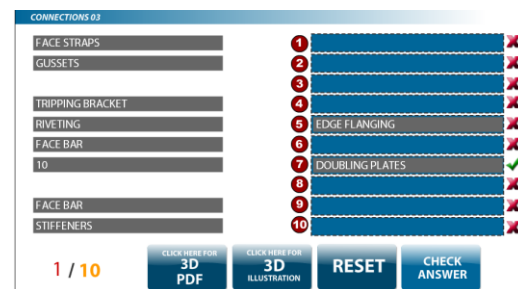


Figure 4

**User Profile**

Users are seafarers (Singaporean and foreign) aspiring for the various certificates of competency issued by the Maritime and Port Authority of Singapore.

**Development Tools**

Several programmes were used to develop the programme, and in this regard, 3D Studio Max was used for 3D Modelling and animation, Tetra4D was used to create 3D PDF files for interactive 3D viewing of Ship Models and Flash was used for Authoring.

Learning outcomes developed using Flash are suitable for uploading to the web. Programmes developed using 'Flash' can be used in a Client – Server network, where the client accesses the programme using a User ID and a password.

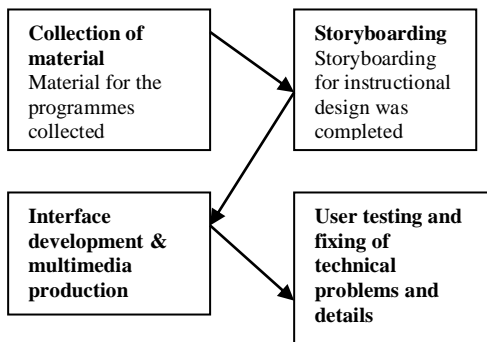
**Interface Design**

The user interfaces have been designed to make them user friendly. Navigational buttons are clear and a user need not be a computer expert to navigate through the programmes.

2 Help functions in the programmes will help the user to navigate through the programme. This will familiarise the user with the different User Interface Buttons and sections.

### Development Method

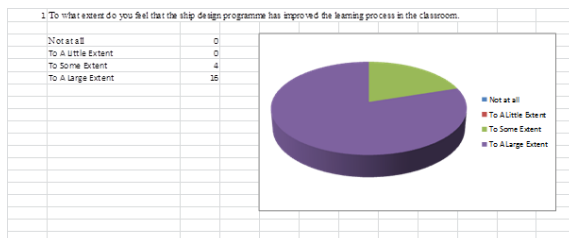
The development method was as follows:



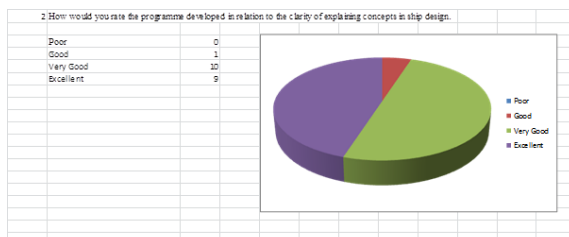
### Survey

A survey was conducted among Class 1 (deck) students to help gauge the programme developed. Results of the survey are as below:

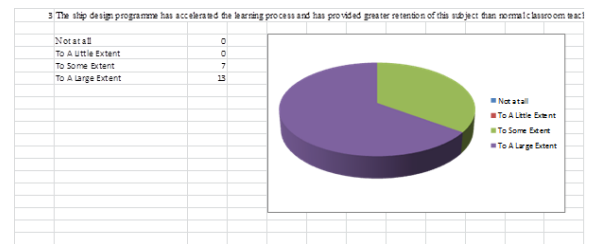
Question 1 – To what extent do you feel that the ship design programme has improved the learning process in the classroom



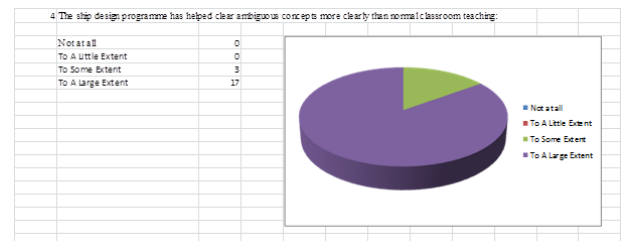
Question 2 – How would you rate the programme in relation to enhancing concepts in ship design



Question 3 – The ship design programme has accelerated the learning process and provided for greater retention than normal classroom teaching



Question 4 - The ship design programme helped clear ambiguous concepts more clearly than classroom teaching



### Conclusion

The ship design programme developed has used innovative solutions to help a learner grasp key ship design concepts. The learner can learn at his own pace and can view the various aspects of ship design using interactive 3D viewing.

Based on feedback received from users it is evident that helped student get a better grasp of ship design. Therefore it can be used to an advantage to help clarify difficult concepts in ship design which are not easy to explain in traditional classroom teaching.

Assessment's provided help a learner assess his knowledge gained. This provides immediate feedback and is essential in any learning process. This is one of the key concepts in multimedia instruction as the users' experience depends on the way the programme handles their responses to questions or options (Oblinger 1996).

Finally, the survey results so far, as documented in the previous section, are very positive in terms of the response of students to the programme. It is readily apparent that it has contributed significantly to the enhancement of important aspects of learning ship design.

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## DESIGNING NEW MODULE IN CHEMICAL ENGINEERING USING CDIO: GENERAL APPROACH

Sin-Moh Cheah and Hong-Wee Koh

School of Chemical & Life Sciences, Singapore Polytechnic, Singapore

[smcheah@sp.edu.sg](mailto:smcheah@sp.edu.sg)

### Abstract

The CDIO Initiative ([www.cdio.org](http://www.cdio.org)) is an innovative educational framework for producing the next generation of engineers. Throughout the world, collaborators have adopted CDIO as the framework of their curricular planning and continual improvement of their educational programs. In SP, the DCHE Course Management Team (CMT) had used the 12 CDIO Standards in a self-evaluation process aim at identifying areas of improvement in the curriculum.

This paper is the first part of a 2-part submission for ISATE2014 in which we outline and present a general approach used by the Diploma in Chemical Engineering (DCHE) of Singapore Polytechnic (SP) to designing a new module using the CDIO approach. It built on our earlier effort in aligning the 12 CDIO Standards to SP's existing Academic Quality Management System (AQMS), which is based on the same Plan-Do-Check-Act (PDCA) principles of ISO9001. We used the CDIO Standards for a self-evaluation process aimed that identifying key areas of improvement in the DCHE curriculum.

In this paper, we argued that that there are much similarities between the goal of CDIO Framework for re-designing curriculum, which is to “conceive, design, implement, and operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products” and that of introducing a new module into the curriculum; in this case, with the new module being a “product”. We showed how Part 4 of the CDIO syllabus corresponded with different stages of module design and development, delivery and evaluation in the AQMS. We henceforth suggested that one can also use the Standards for module-level development work, specifically in designing a new module. We offered our interpretation of the 12 CDIO Standards in the context of new module design and development; which can serve as a checklist to guide a lecturer in the process. An added feature is that our approach can also help the lecturer in pinpointing the right skills and competency needed to deliver the module he/she prepared. A separate paper (second part of this 2-

part submission) will demonstrate the application of the above approach with a case study.

**Keywords:** *CDIO, module design, continual improvement, chemical engineering*

### Introduction

The CDIO Initiative ([www.cdio.org](http://www.cdio.org)) is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving, Designing, Implementing, Operating real-world systems and products. Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment, which is based on a 4-part CDIO Syllabus and 12 CDIO Standards.

CDIO provides a comprehensive and detailed codification of the goals of engineering education, with particular emphasis on various engineering skills such as teamwork, communication, critical and creative thinking etc. The main role of the 12 CDIO Standards is to serve as tool for program adoption, evaluation, and continual improvement. The 12 CDIO Standards:

- Define the distinguishing features of a CDIO program;
- Serve as guidelines for educational program reform and evaluation;
- Create benchmarks and goals with worldwide application; and
- Provide a framework for continuous improvement.

In a nutshell, the 12 CDIO Standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12).

In Singapore Polytechnic (SP), the Diploma in Chemical Engineering (DCHE) adopted CDIO in 2006 as the basis to revamp its curriculum. Over the years, various CDIO skills such as teamwork and communication, personal skills and attitudes (e.g.

critical and creative thinking, managing learning, holding multiple perspectives) have been integrated into the curriculum. Skills relating to conceiving, designing, implementing and operating a process, product or system using relevant principles had also been introduced (Cheah, Phua & Ng, 2013). As part of the effort to continually improving the DCHE curriculum, we have also used the 12 CDIO Standards to carry out self-evaluation of our diploma identify areas of improvement (Cheah, Koh & Ng, 2013).

We now take the process one step further in using the very same standards to guide us in our design of the new modules. This paper covers the effort by the DCHE Course Management Team (CMT) in using the CDIO framework to formulate an approach whereby the 12 standards can serve as a checklist for a lecturer who had been tasked to design and develop a new module, as well as an aid in identifying his/her training needs in delivering the new module that he/she developed.

### CDIO Standards and Quality Management

SP's generic product is education and training, which in turn translates into the different diploma courses that it offers to its students. A "course" is defined as a "series of planned learning experiences in a field of study that is integrated and made coherent by a common set of aims". A course is composed of many modules; which is defined as the "basic unit or component of courses offered by the school" with its own set of aims, intended learning outcomes, instructional strategies and assessment scheme. A course is made up of 34-38 modules offered over a period of 3 years, comprising a mix of mostly course-specific modules (core and electives), basic mathematics and sciences, and institutional modules.

The relevance of any diploma course in SP is governed by the Academic Quality Management System (AQMS), which is based on the same Plan-Do-Check-Act (PDCA) principles of ISO9001. The AQMS is shown in Figure 1.

Also shown in Figure 1 is the Staff Development Plan (SDP) which is an important component of lecturer competency building under the People Developer System (PDS). The PDS is a mark conferred by a government agency in Singapore, which, through a certification process, gives recognition to organizations that invest in their people and have a comprehensive system to manage the effective development of their people. Our quality systems, PDS along with its environmental management system are all subjected to external audit by independent assessors.

Cheah, Koh & Ng (2013) had shown that the processes and outcomes of the AQMS and PDS can be mapped directly to the 12 CDIO Standards as shown in Table 1, and henceforth argued that these CDIO Standards can be used to review the diploma (at the course-level) for areas of improvement, to satisfy the requirement of maintaining a quality product, i.e. the DCHE course, under the AQMS.

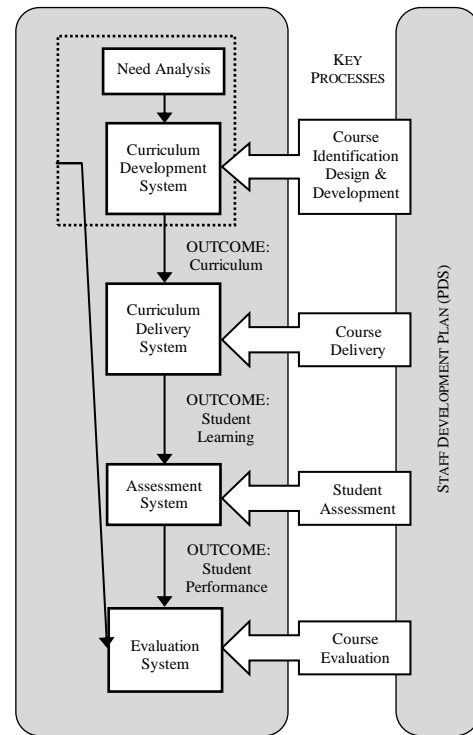


Figure 1. Relationship of Singapore Polytechnic AQMS Framework and Key Product Realisation Processes Supported by PDS

Table 1. CDIO Standards aligned with AQMS-PDS

SP Framework	Description	CDIO Standard(s) Mapped
AQMS	Need Analysis	1 CDIO as Context
	Curriculum Development System	2 CDIO Syllabus Outcomes
	Outcome: Curriculum	3 Integrated Curriculum 4 Introduction to Engineering 5 Design-Implement Experiences
	Curriculum Delivery System	6 CDIO Workspaces 8 Active Learning
	Outcome: Student Learning	7 Integrated Learning Experiences
	Assessment System	11 CDIO Skills Assessment
	Outcome: Student Performance	
	Evaluation System	12 CDIO Program Evaluation
PDS	Capability Building	9 Enhancement of Faculty CDIO Skills
		10 Enhancement of Faculty Teaching

		Competence
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### Module Design and Development in SP

The process shown in Figure 1 at the course level can also be used at the module level. For example, instead of analysing the needs for a new course to serve a particular industry, we use the same system to analyse new developments or changes in the industry to ascertain if there is a need for new knowledge or skills that the industry requires. This can be achieved via several mechanisms, including for example via Advisory Panel, industry focus group discussion, or industry survey. When a need is confirmed, a new module is then developed, and is added to the basket of modules in the existing curriculum after its approval by the relevant authorities consistent with the institutional guidelines. During the module development process, the module coordinator also discusses with his/her reporting officer any training needs and submits the training plan as part of his/her SDP.

After the new module is introduced into the curriculum, it is subjected to the same monitoring and tracking process as other existing modules. Special interest is usually placed on this module in terms of its feedback from students as well as the module coordinator. Module evaluation will be covered in later section.

### Correspondence with C-D-I-O

In this paper we use the term “C-D-I-O” to refer to the process of conceiving, designing, implementing and operating a product or systems; to distinguish it from the broader term of “CDIO” skills which is taken to mean competencies in communication, teamwork, critical and creative thinking, etc. When we compare the C-D-I-O process with the module design and development process, we can see close correspondence between the two. Likewise, Lynch et al (2007) compared the CDIO Standards against a number of contemporary theories of teaching and learning such as constructivism and problem-based learning, and concluded that the CDIO approach correlates well with these educational paradigms.

Table 2 compares and contrasts between Sections 4.3 to 4.6 of Part 4 of the SP-customized CDIO syllabus “Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context” which is most relevant to this work and that of module design and development typical in any curriculum work.

### Module-level Design and Development using CDIO Standards - General Approach

With the close matching between module design and development and C-D-I-O; we henceforth propose that we can use the same CDIO Standards to assist the lecturer in designing a new module. This should not be surprising, since a course is made up of many modules, arranged in a proper sequence to deliver the desired

graduate attributes articulated by an education institution. The existing 12 CDIO Standards initially formulated for course-level evaluation is shown in Table 3. Figure 2 shows the application of the CDIO Standards at both course-level and module-level. As mentioned previously, the former had been covered elsewhere and the latter is the focus of this paper.

Table 2. Correspondence between C-D-I-O processes and module design and development

Stage	Relevant Section of SP-CDIO Syllabus	Module Design and Development
CONCEIVE	Identify market needs and opportunities Define Function, Concept and Architecture Model System to Verify Goals Develop Project plan	Need analysis (from environmental scans) Develop module aims Prepare learning outcomes Identify module needs (equipment, facility, etc)
DESIGN	Formulate the Design Plan the Design Process and Approaches Apply Disciplinary Knowledge and Skills Evaluate design/prototype to achieve multiple objectives	Formulate module structure (L:T:P) and assessment types Draft module syllabus Prepare proposal for management approval Prepare Design integrated learning tasks
IMPLEMENT	Plant the Implementation Process Plan for Hardware Realization Planning for Software Implementing Process Planning for Hardware Software Integration Testing, Verifying, Validating, and Certifying Managing Implementation	Prepare roll-out plan, module materials (lecture notes, tutorial, PPT, assignments, etc) Prepare lab manuals and test run activities / experiments, recurrent budgets Prepare lessons timetable and lab schedule Training for other lecturers who co-teach the module
OPERATE	Planning Training and Operation procedures Managing Operations Supporting the Product Lifecycle	Introduce new module Track student learning (e.g. MST, assignments) Conduct module review, e.g. student feedback Prepare module review report and

		follow-up on action items
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Table 3. The twelve CDIO Standards

CDIO Standard	Brief Description of Standard for a Course
Standard 1 CDIO as Context	Adoption of the principle that product and system lifecycle development and deployment - Conceiving, Designing, Implementing and Operating - are the context for engineering education
Standard 2 CDIO Syllabus Outcomes	Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders
Standard 3 Integrated Curriculum	A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills
Standard 4 Introduction to Engineering	An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills
Standard 5 Design-Implement Experiences	A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level
Standard 6 CDIO Workspaces	Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning
Standard 7 Integrated Learning Experiences	Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills
Standard 8 Active Learning	Teaching and learning based on active experiential learning methods
Standard 9 Enhancement of Faculty CDIO Skills	Actions that enhance faculty competence in personal, interpersonal, and product and system building skills
Standard 10 Enhancement of Faculty Teaching Skills	Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning
Standard 11 CDIO Skills Assessment	Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge
Standard 12 CDIO	A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other

Program Evaluation	stakeholders for the purposes of continuous improvement
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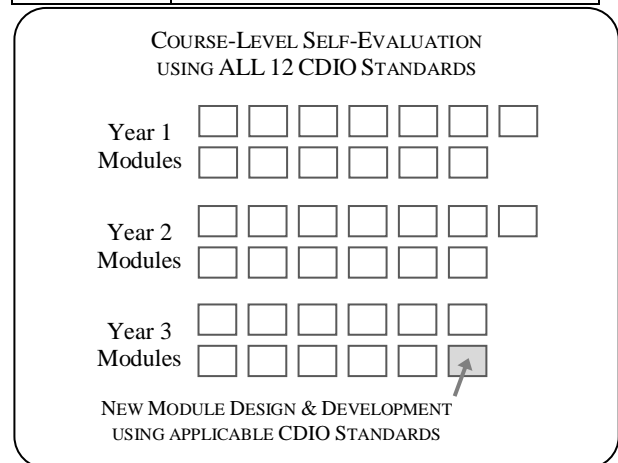


Figure 2. Application of CDIO Standards at Course-level (for Self-Evaluation) and Module-level (for new design and development)

With this as starting point, we proceed to interpret the Standards in terms of their applicability in new module design and development. The outcome is shown in Table 4.

Table 4. The CDIO Standards in relation to New Module Design and Development

CDIO Standard	Interpretation in SP DCHE Context for New Module Design and Development
Standard 1 CDIO as Context	The context under which the technical content are presented should be consistent with the overall approach for the course as a whole, i.e. CDIO as the context for engineering education, i.e. based on engineering practice, or simulated real-world learning tasks.
Standard 2 CDIO Syllabus Outcomes	The syllabus for the new module shall capture as intended learning outcomes the requirements from stakeholders, e.g. chemical processing industry; and aligned to DCHE Course Aims, i.e. that they must contribute to the development of the desired graduate attributes.
Standard 3 Integrated Curriculum	The new module must be linked to other existing core DCHE modules in terms of its technical content; as well as incorporating various CDIO skills as appropriate, and pegged at the right level of proficiency.
Standard 4 Introduction to Engineering	This standard is NOT APPLICABLE to new module, as it is already addressed in Year 1 module <i>Introduction to Chemical Engineering</i> which also featured a basic level design-implement experience in the form of a mini-project.
Standard 5 Design-	The new module may contain a mini-project if deemed appropriate, pegged at

Implement Experiences	intermediate level to complement existing offerings.
Standard 6 CDIO Workspaces	A review of the new module shall include any laboratory space requirements to support the above-mentioned design-implement experience as well as additional needs for new equipment along with the necessary operating costs, maintenance needs, etc. This may include virtual space including simulation softwares.
Standard 7 Integrated Learning Experiences	This is not restricted to lab-based activities, but all other forms of learning tasks such as out-of-classroom assignments, homework, especially for a new module without a laboratory component. It include the use of e-learning to support student learning.
Standard 8 Active Learning	The new module should include active and experiential learning to support student learning, especially for lecture and tutorial components, more so if it does not have a laboratory component.
Standard 9 Enhancement of Faculty CDIO Skills	The lecturer teaching the module and the teaching team (if applicable) supporting the module must be familiar with teaching and assessing using the CDIO approach, as mentioned in the Standards.
Standard 10 Enhancement of Faculty Teaching Skills	
Standard 11 CDIO Skills Assessment	The design of assessment components for the new module must be aligned to the intended learning outcomes and various learning tasks.
Standard 12 CDIO Program Evaluation	The new module will be subjected to the same existing review processes. Action items arising from the review will be captured in the existing module review report.

### Evaluation of New Module

At the SP-level, it is mandatory that all modules and all lecturers be subjected to module and teaching feedback from students, as part of the AQMS. For module feedback, students were asked the following questions as shown in Table 5; while for teaching feedback, the questions are shown in Table 6. All feedbacks are administered online using the Blackboard course management system. Additional feedback can be obtained via teaching observation of lecturer by his/her reporting officer, and student dialogue session with the School Director.

Feedback obtained from both Teaching Feedback and Module Feedback will be discussed at the CMT. Actionable items from the feedback exercises will be

captured in the module review for proper follow-up by the module coordinator and his/her module team.

Table 5. Questions for Module Feedback

Mandatory Questions	
Q1	This module was well taught.
Q2	The course materials in this module were of high quality.
Q3	The workload in this module was manageable.
Q4	Requirements for completing the <b>assessment</b> tasks in this module were clear.
Q5	The <b>library</b> resources met my needs for this module.
Q6	The <b>online</b> teaching and resources in this module enhanced my learning experience.
Q7	Overall, how would you rate this module?
Q8	What aspects of your module were most in need of improvement?
Q9	What were the best aspects of your module?
Additional questions on tutorials and workshops	
Q10	The tutorials were relevant to the aims of the module.
Q11	The tutorials were well taught.
Q12	The tutorials extended my understanding of the subject matter.
Q13	The workshops were relevant to the aims of the module.
Q14	The workshops offered sufficient opportunity to improve my practice of the subject matter.
Q15	The workshops extended my understanding of the subject matter.

Table 6. Questions for Teaching Feedback

Q1	The lecturer organises the lessons well.
Q2	The lecturer explains and illustrates lessons clearly and makes them easy for me to understand.
Q3	I feel the lecturer knows the subject matter well.
Q4	The lecturer keeps the classroom environment positive for learning (e.g. does not allow sleeping, using the mobile phone, talking unnecessarily, etc.).
Q5	I feel the lecturer is concerned for my learning (e.g. approachable, check our understanding).

In addition, in DCHE, the module coordinator is encouraged, in his/her discretion, to work with Academic Mentor to obtain additional feedback from students, over and above those from student feedback from teaching and student feedback on modules. This usually involves designing module-specific survey questionnaires to explore student learning experience in specific classroom- and/or laboratory-based activities; identifying areas that pose challenges to students, and also obtaining input for areas of improvements. This is often supplemented by focus group discussion with selected student representatives. The outcome of the

module review is captured in the online module review and follow-up actions are then carried out.

## Discussions

Although it is desired that all the 12 CDIO Standards be used for self-evaluation at the course-level, not all standards are applicable to individual new module design and development. As mentioned in earlier section, a course (in this case, a diploma) is made of up many modules as its constituents. In the design of a new module, the considerations shown in Figure 3 are typical:

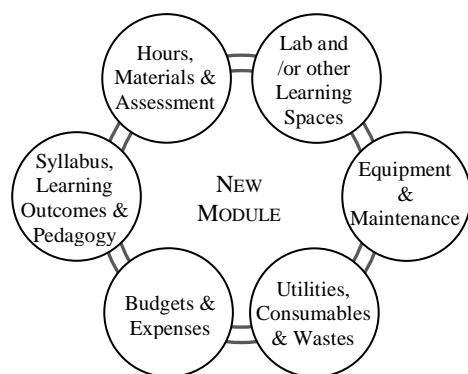


Figure 3. Considerations in new design and development`

Of special note is Standard 1, which requires that the new module be designed in the same context of chemical engineering education as the rest of the modules making up the diploma course; and Standard 2, which mandates the alignment of learning outcomes stipulated in a new module with the desired graduate attributes articulated in the diploma. This is to ensure that the overall learning outcomes of DCHE education is consistent with the requirements of all key stakeholders, most notably the chemical processing industry that the diploma serves.

Standard 4 is somewhat “exclusively” devoted to an “introductory” engineering module, which is met by a core module in Year 1 *Introduction to Chemical Engineering*. As such, it is almost certain that this standard will not be required anymore in design and development of any new module.

Likewise, not all modules in DCHE have a laboratory component. Interpreting Standard 6 strictly in terms of physical workspace will severely limit the applicability of this standard to new module design and development. Here we have widened the scope of this standard to include virtual workspaces, such as those based on dynamic simulation or 3-D plant layout designs. Also noteworthy is Standard 5, which provides for additional design-implement experiences over and above those already covered at the basic-level (in the module *Introduction to Chemical Engineering*) and advanced-level (in the capstone *Final Year Project*).

The rest of the standards are applicable to any new module design and development. The usage is similar to

that of course-level self-evaluation and hence not covered in this paper.

## Conclusions

This paper has presented a general approach that a lecturer tasked with designing a new module can take using the 12 CDIO Standards. It builds on the premise that a module can be treated as a product that is subjected to the same process of Conceiving, Designing, Implementing and Operating an engineering product, process or systems in the CDIO Framework. It shares our interpretation of the Standards in terms of module design and development and offers advice on areas that a lecturer should focus on when tasked with coming up with a new module. A separate paper will provide a case study on how this approach is applied (Koh & Cheah, 2014).

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## INTRODUCING NEW MODULE IN CHEMICAL ENGINEERING USING CDIO: CASE STUDY

Hong-Wee Koh and Sin-Moh Cheah

School of Chemical & Life Sciences, Singapore Polytechnic, Singapore

koh\_hong\_wee@sp.edu.sg

### Abstract

The CDIO Initiative ([www.cdio.org](http://www.cdio.org)) is an innovative educational framework for producing the next generation of engineers. Throughout the world, collaborators have adopted CDIO as the framework of their curricular planning and continual improvement of their educational programs. In SP, the DCHE Course Management Team (CMT) had used the 12 CDIO Standards in a self-evaluation process aim at identifying areas of improvement in the curriculum. This paper is the second part of a 2-part submission for ISATE2014 in which we outlined and present a case study used by the Diploma in Chemical Engineering (DCHE) of Singapore Polytechnic (SP) in designing a new Year 3 free elective module entitled *Chemical Process Operations and Troubleshooting* using the CDIO approach. In this paper, we illustrates how Part 4 of the CDIO syllabus corresponds with different stages of module development, its benefits and how the 12 CDIO standards supplements the existing guidance documents in Singapore Polytechnic's (SP) existing Academic Quality Management System (AQMS) from the stages of module development to module delivery, evaluation and improvement. The module feedback and semestral results obtained from the pilot run of the module suggests that the CDIO way of module design and development fits well with our AQMS, that the focused and systematic way of designing and delivering the module had enhanced students' learning experiences, which makes learning of an engineering module enjoyable, meaningful and at the same time allowing them to score excellent semestral results. Lastly, this paper also highlights how the CDIO standards have guided the module team in pinpointing the right skills and competencies needed to deliver the module prepared so as to ensure that students continue to be well prepared and equipped with the relevant knowledge and skills in addition to the critical C-D-I-O and CDIO skills to be work, life and world ready in the constantly changing global climate.

**Keywords:** *CDIO, module design, continual improvement, chemical engineering*

### Introduction

Cheah & Koh (2014) have shown the close matching between module design and development and C-D-I-O (i.e. Conceive – Design – Implement – Operate), and that the same CDIO standards can be used to assist lecturers in designing a new module. In the case of *Chemical Process Operations and Troubleshooting*, the DCHE Course Management Team (CMT) recognized from the results of its scan of external environment (namely feedback from the chemical processing industry and graduates working in these industries) that its present coverage of troubleshooting skills is inadequate. There is a cohort of 20-30 students who did not further their studies and are working as process technicians in the chemical processing industries. Having worked as chemical engineers in the past, we can quite readily pen down the intended learning outcomes for process operations and troubleshooting. We also identified the necessary skill set needed, including teamwork, communication, problem-solving and critical thinking.

An internal scan of the curriculum showed that although the fundamental knowledge and skills in process troubleshooting are covered throughout the course, they are scattered among individual core modules and are hence "tagged" to those modules. Although the students received 6-weeks industrial internship training at the Chemical Process Technology Centre (CPTC) on Jurong Island during their second year vacation; there is room to further enhance students' competencies in process operations and troubleshooting. What we needed is an integrated pilot plant that can aid students in acquiring these learning outcomes. We also noted that most process operations training needed by the industry require potentially hazardous, costly and bulky equipment beyond the affordance of SP, the team ascertained that the best method to build our students' competency in these areas is via dynamic simulations of integrated industrial processes. The CMT therefore decided that a new module is needed to be offered as free elective to this cohort of students. The next step is to design the module proper.

## Module Design Using CDIO Standards

Cheah, Koh & Ng (2013) had earlier reported on the use of the 12 CDIO Standards for reviewing the DCHE course for continual improvement. We now take the process one step further in using the very same standards to guide us in our design of the new 60-hour module *Chemical Process Operations and Troubleshooting*. Table 1 shows how the 12 CDIO Standards are applied in the design on this new module.

Table 1. Application of CDIO Standards in module design

CDIO Standard	Application of standard in designing <i>Chemical Process Operations and Troubleshooting</i>
Standard 1 CDIO as Context	This content of this module is very relevant to the chemical processing industry, with the learning tasks centered on mainly on the “I” and “O” aspects. The tasks are designed to mimic real-world working environment encountered by a chemical engineering technologist.
Standard 2 CDIO Syllabus Outcomes	The module aims focus on attainment of specific skills identified in the “need analysis” mentioned earlier, Cheah and Koh (2014). They are also are consistent with the overall DCHE Course Aims; which in turn are aligned to the SP Holistic Education graduate attributes in being work-ready.
Standard 3 Integrated Curriculum	Lecture is kept to a minimum of 1 hour per week (hpw), and tutorials (2 hpw) are designed to be highly interactive using cooperative learning strategy. On the technical aspects, this module integrates knowledge from other DCHE core modules such as <i>Heat Transfer &amp; Equipment, Separation Processes, Process Instrumentation &amp; Control, Plant Safety &amp; Loss Prevention and Workplace Safety &amp; Health for Chemical Engineers</i> , etc. Various CDIO skills are integrated as well, especially in the laboratory-based learning tasks.
Standard 4 Introduction to Engineering	Not applicable for this module.
Standard 5 Design-Implement Experiences	Not applicable for this module.

Standard 6 CDIO Workspaces	A new integrated pilot plant specifically designed by the first author was acquired, and relevant lab space allocated. Virtual workspace will also be utilized in the form of dynamic simulation of chemical processes.
Standard 7 Integrated Learning Experiences	Four laboratory-based learning tasks were designed to support the integrated curriculum mentioned above. Two are based on an integrated pilot plant and another two are based on virtual chemical plants in the EnVision dynamic simulation system.
Standard 8 Active Learning	All the learning tasks mentioned above uses active and experiential learning, using scenario-based learning widely adopted in various DCHE core modules.
Standard 9 Enhancement of Faculty CDIO Skills	The first author who is the module coordinator of this module had been mentored by the second author when he first joined the service; and had introduced CDIO in another module that he coordinated earlier. They had earlier published a joint paper in the 2013 International CDIO Conference. The teaching team supporting this module also consists of staff already familiar with the DCHE “CDIO-way” of training students.
Standard 10 Enhancement of Faculty Teaching Skills	
Standard 11 CDIO Skills Assessment	The assessment (both CDIO skills and chemical engineering knowledge) is part of the integrated learning experiences mentioned above.
Standard 12 CDIO Program Evaluation	The module was reviewed after one semester of its introduction in Semester 2 AY2013/14.

### Discussion on Work Done

To facilitate active and experiential learning of the new module, four learning tasks were developed as follows:

1. Prepare process equipment for maintenance work (planning phase)
2. Prepare process equipment for maintenance work (execution phase)
3. Operate and Troubleshoot a Natural Draft Furnace System
4. Operate and Troubleshoot an Amine Treating Unit



Tasks 1 and 2 are based on a new integrated pilot plant that was designed by the first author and purchased using F&E funding. Task 1 is intended to expose students to the real-world work of process technicians in readying the plant for shutdown and maintenance work (planning of isolation, shutdown, purging procedures, preparing all necessary paperwork like permit to work, isolation and blind lists, risk assessment, toolbox talk, etc); while Task 2 is a follow-up from Task 1 whereby students will execute their planned procedures in Task 1 to safely shut down and prepare the plant for maintenance work. Tasks 3 and 4 use virtual chemical plant based on the EnVision dynamic simulation system (see Figure 1) which was purchased earlier. These tasks simulates the real-world operation of chemical plants and offer students opportunity in dealing with plant start-up, shutdown, steady state operations and process upsets. Both simulation models were chosen because firstly, they are common processes in chemical process operations which they may likely operate in the future. Secondly, both processes are generally easy to comprehend yet at the same time they provide students with sufficient challenge and opportunities to troubleshoot process changes and upsets, thus honing their problem solving and troubleshooting skills.

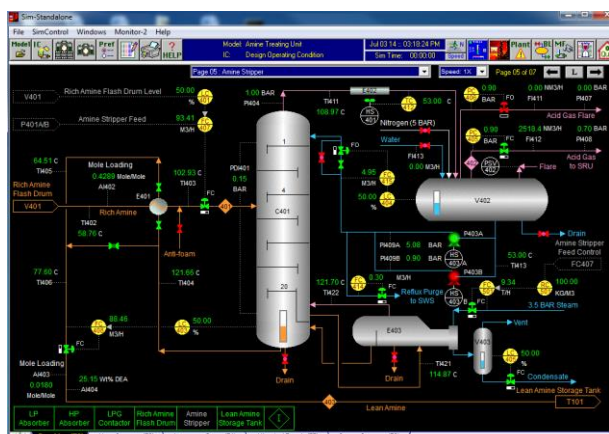


Figure 1. Dynamic simulation model for Amine Treating Unit (ATU) showing the Amine Stripper

## Results and Discussion

The module was first piloted as a free elective to Year 3 students in Semester 2, Academic Year 2013/2014. A total of 49 students took this module. Feedback on the module was conducted to obtain students input on their learning experience. Students were asked to evaluate the following:

- Q1. This module was **well taught**.
- Q2. The course **materials** in this module were of high quality.
- Q3. The **workload** in this module was manageable.
- Q4. Requirements for completing the **assessment** tasks in this module were clear.
- Q5. This module has better prepared me to work in the chemical process **industry**.

- Q6. I will **recommend** this module to my juniors and peers.
- Q7. Overall, how would you **rate** this module?
- C8. What were the **best** aspects of this module?
- C9. What aspects of this module were most in need of **improvement**?

The results for the quantitative feedback components (Q1 to Q7) on a scale from 1 (lowest) to 10 (highest) are shown in Table 2. Each of the scores were analysed to assist the module teaching team in identifying the key areas which were done well, evaluate the outcomes of module design using CDIO standards, and to identify the areas for improvement (Standard 12).

Table 2. Module feedback for pilot run of *Chemical Process Operations and Troubleshooting*

Question	Max Score	Score obtained
1	10	9.10
2		7.96
3		8.64
4		8.76
5		8.86
6		9.20
7		8.64
<b>Average score</b>		<b>8.74</b>

The high score of 9.10 that the module was well taught is an indication that the teaching and assessment of the module using CDIO approach (Standard 9) was well received by the students. This conclusion was echoed in a separate teaching feedback of this module on the module coordinator/ lecturer that was conducted on the same group of students and a similar score of 9.18 was obtained. This module was able to integrate knowledge across multiple DCHE modules (Standard 3), including various CDIO skills (Standard 7). Students were given opportunities to experience the integration of process operations and troubleshooting with other DCHE modules like *Chemical Reaction Engineering*, *Workplace Safety and Health for Chemical Engineers*, *Plant Safety and Loss Prevention*, *Process Instrumentation and Control* and *Separation Processes*, etc. This allows students to sum up and apply the underpinning knowledge learnt from previous modules to operate integrated chemical processes. The integrated curriculum and learning experiences as well as the application of CDIO approach in teaching and assessment have produced excellent semestral results in the pilot run of the module with 87.8 % of students scoring quality grades of Distinction, A and B+.

One aspect to highlight in the teaching and learning of this module was that even though greater emphasis were placed on the demonstration of the module's performance criteria, students were ironically given "opportunities to fail" in the practical tasks both during lab and simulation works. Bearing in mind that there are often "no unique solutions" in chemical process

operations and troubleshooting, students were given chances to stretch their thinking and apply basic underpinning knowledge acquired to actively experiment different techniques and strategies, for example, to prepare process equipment for maintenance work. No “model answers” were given to the students, but rather, any feasible answer or proposal will be accepted (even though there might be imperfections). Hence, feedback was provided to the students on each lesson to help them identify these imperfections in their proposed solutions (if any) and how they can be improved, all of which are done with no penalty imposed, mainly with the intention to help them learn from their mistakes. While students were given the “opportunity to fail”, we are mindful that when students make mistakes when performing their tasks (especially when it is safety, conduct related due to negligence or lack of due diligence), students will still be penalized. However, when such penalties were given, students were made to reflect on the reasons why they were penalized and in most cases, students were able to identify and accept the penalty for their own mistakes. Through such reflections, we also aim to help students integrate their knowledge and skills in the areas of workplace safety and health, cooperative learning, teamwork and CDIO skills, etc during the learning of daily tasks as a chemical engineer. A picture showing students performing a utility-tie-in connection using piping and fitting assembled by themselves is shown in Figure 2.

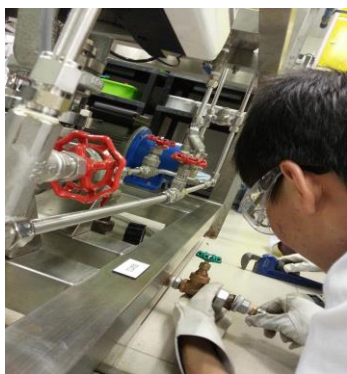


Figure 2. Students performing utility-tie-in using piping and fitting assembled by themselves

The course materials were developed with the intention to mimic as close as possible to the industry practices in process operations and troubleshooting. The new integrated pilot plant and simulation software utilized aimed to provide CDIO workspaces to enhance the integrated learning experiences of the students (Standards 6 and 7). However, it was noted that students' feedback on the quality of teaching materials had comparatively received the lowest score among all module feedback components. One observation made by the first author when teaching this module was that students, being less experienced, require more guidance than expected to comprehend the key concepts of the module, especially in the areas of understanding the

rationale behind the process control techniques during operation and troubleshooting scenarios. As a result, more time and effort were dedicated to provide students with opportunities to actively experiment the cause and effects of different control actions (Standard 8). The learning materials were also revised concurrently when teaching the module as oral feedback were collected from students on a regular basis on their learning experiences (via interaction during and beyond lesson time), and adjustments were then made to suit the students' learning pace and capabilities. Students, knowing that the module was piloted for the first time, were generally open to provide honest feedback, and they understood that the truthful feedback provided was a win-win situation for them and the subsequent batches of students to improve their learning experiences in the module. However, it was inevitable and noticed that the revision of the learning materials when the module is ongoing might have resulted in confusion and frustration (at times) in some students from the unlearning and relearning of several concepts. The module team takes the comparatively lower feedback score for this component positively, as it highlights the key areas of improvement for the module, which will be discussed in the next section.

The workload of this module is generally manageable by the students. Being a practical based module, the aim of this module is to mimic real world working environment encountered by a chemical engineering technologist to better prepare our graduates to be work ready (Standard 2). Thus, in contrast to traditional DCHE module which is weighted heavily on written tests and examinations, a greater assessment weightage was allocated to lab work and practical test ( $\approx 50\%$ ). To sustain interest and motivation in the module, no “homework” was given to the students. Instead, formative assessments in the form of mini weekly quizzes were given to the students at the end of each lesson. The main objective of the mini quizzes was to reinforce the key concepts learnt in each lesson, and questions were mainly in the form of multiple choice, short structured, fill in the blanks and true/false. To encourage students' participation in the quizzes, a weightage of 10% to the final grade was allocated. To close the learning loop, feedback was provided to the students on each question in the quizzes so that they were able to learn from their mistakes (if any). The results of the mini quizzes were encouraging with the cohort scoring an average of 90.4%. Being motivated to learn the module contents and to score in the quizzes, this module also received excellent punctuality and attendance records with 86.0% of students having perfect punctuality and attendance in the entire semester. Oral feedback was also obtained from the students during the course of the semester and the feedback provided was consistent with the module feedback results that the workload is manageable by the students. The excellent semestral results obtained also suggest that the module's performance criteria were attainable.

In the area of clear communication of assessment requirements, the score of 8.74 achieved could be attributed to the following factors: firstly, there was clear explanation of the assessment criteria of the module from Day One, with constant reminders and reinforcement that students are assessed not just on technical knowledge, but also on CDIO skills (Standard 11). Secondly, the weekly mini quizzes help students develop clearer understanding of the key concepts in the module, both in the written and practical assessments. Thirdly, there are detailed learning outcomes, assessment rubrics and guidelines provided; this is especially helpful in the area of practical assessment. To better prepare students for the practical test, assessment rubrics which clearly indicate the assessment components and weightages for each performance criteria were specified to the students. The feedback obtained from students was that the given assessment components provided them with clearer learning checkpoints to better assist them in the revision process. These are in line with Standards 1, 2, 8 and 11.

In terms of whether the students find that they were better prepared to work in the industry after reading the module and whether they will recommend the module to their peers and juniors, the high scores of 8.86 and 9.20 respectively was an encouraging sign that this module has met its primary objective to equip students with the key competencies and confidence to work in the industry (Standard 2). The overall module feedback average score of 8.74 suggests that the students have excellent overall impression of the module and its learning experiences. Some positive comments (extracted from the module feedback) provided by the students include:

*“It is a more hands on module rather than a theoretical module which is great as it tests us students on our practical knowledge and how well we understand the system rather than pure memorizing”*

*“The best aspect of this module is that it is very relevant to the chemical process industry. It can help us to connect the concept and theory learnt in other modules to the operation of a chemical plant. Also, this allow student to experience how a chemical process technician handle problem, upset or emergency situation in a process plant. Personally, I feel that this module will benefit the students in the long run.”*

*“Students are able to learn and experience what a chemical engineer does in their daily life. Learning the theory isn't enough, one must understand what they are doing to be able to understand why they are learning other modules. If a chemical engineer doesn't know how the plant works, he won't be able to improve the plant.”*

Based on the quantitative module feedback scores and qualitative feedback obtained, we are encouraged and hence daringly conclude that the success of this module's pilot run is attributed to the integrated curriculum and learning experiences (Standards 3 and 7), CDIO spaces (Standard 6), and that this module has

helped students prepare for real world challenges as a chemical engineer to be work ready (Standards 1 and 2) via active learning (Standard 8).

### Recommendations for Future Work

While we were encouraged that the pilot run of Chemical Process Operations and Troubleshooting module yielded excellent module and teaching feedback scores, we recognize that there are areas for improvement based on feedback by the teaching team and students' module feedback (Standard 12). The key comments highlighted in the students' module feedback were as follows:

1. Increase the time duration spent on learning the simulation to perform start-up, shut down and troubleshooting exercises.
2. Increase the module hours as there are a lot of simulation exercises for students to try.
3. Students who lacked plant experience during internship at CPTC might require more help in class and more detailed explanation on the equipment and utilities.
4. The notes are not really that useful as this is a module that requires more understanding.

The feedback to increase the module hours or time spent on learning the simulation was the most common feedback provided by the students. One observation made when teaching the module was that students were generally able to keep up with the pace during the earlier chapters which were less practically intensive and students might have some prior exposure when they attended internship at CPTC. However, when the module progresses to the simulation activities, the lesson pace became slower than expected as it was initially presumed that CPTC training has provided students with sufficient foundation knowledge in plant operations to enable students to apply them to grasp the skills in process troubleshooting with greater ease. This gap between the expected and actual presumed knowledge and skills levels had caused some hiccups during the lesson delivery. The learning materials were hence revised along the way to suit the learning needs of the students.

Rather than increasing the hours for the module, one possible suggestion to resolve points (1), (2) and (3) is to consider merging and integrating chemical process operations and troubleshooting with existing DCHE modules. One possibility is to merge it with *Process Instrumentation and Control*. As operation and troubleshooting of integrated processes requires knowledge and skills in process instrumentation and control, merging the two modules may be able to exploit the synergy between them to achieve the desired learning outcomes in both modules in a shorter total duration in contrast with teaching both subject areas as separate modules. In order to get a stronger affirmation whether this is a feasible direction, it is recommended to run the module on a second batch of students to confirm

the similar observation and findings before deliberating this at DCHE CMT for further discussions.

The module coordinator (who is also the first author) agrees that the quality of the teaching and learning materials can be further improved. It was mentioned in the previous section that improvements were made to the teaching and learning materials during the course of study when the module was piloted. While the teaching team agrees with the student's module feedback that because of the practical nature of this module which places more emphasis on understanding rather than memory work, the lecture notes might be perceived by the students to be lacking in detailed explanations. This lack of detailed explanations, or we put it across as spoon feeding, is compensated to the students in the tutorial and lab exercises where students were made to demonstrate the learning outcomes of the modules by performing actual lab and simulation tasks as opposed to regurgitating model answers from lecture notes in most "traditional" theoretical modules. While we recognize that improving teaching and learning materials is an ongoing process and new learning strategies might be developed for different batches of students, we are also mindful that it is critical to set the right mind-set among the students' right from day one. The mind-set that there could have no "model answers to memorize" must be strongly brought across to the students right from the start, that the purpose of the lecture notes and tutorial materials is to merely serve as a tool or guide to help students to grasp the key underpinning knowledge before they could apply them to different plant operating scenarios. The learning materials should not be regarded as a secret manual for them to memorize to excel in the module.

Lastly, while the pilot run of the module has yielded successful students results and module feedback, the sustained success of the module and its relevance to the industry can only be achieved if the teaching team continues to "sharpen its saw" to stay current with the current industry processes and practices, namely in the areas of new emerging processes like green engineering, workplace safety and health practices, permit to work systems, utility tie in techniques and equipment. Staff industrial attachments to local or overseas process facilities at least once every three to five years will be advantageous for the teaching team to stay current with these practices to ensure that students continue to be well prepared and equipped with the relevant knowledge and skills in addition to the critical C-D-I-O and CDIO skills to be work, life and world ready in the constantly changing global climate.

## Conclusions

We shared our approach in using the CDIO Standards to guide us in designing a new free elective module, *Chemical Process Operations and Troubleshooting* for DCHE. We felt that using this approach offers 2 benefits: (1) Focused: The 12 CDIO Standards supplements the existing guidance documents in AQMS by providing specific guidance in core areas,

for example module development (e.g. integrated curriculum), delivery (active learning), assessment and evaluation; and (2) Systematic: The 12 CDIO Standards allows the module to be developed in a systematic fashion according to the Conceive, Design, Implement and Operate stages, namely in the areas of module development to module delivery and finally module evaluation and improvement. The module feedback and semester results obtained suggest that the CDIO way of module design and development fits well with our AQMS. It also serves as a checklist to guide the lecturer in the process, and that this focused and systematic way of designing and delivering the module had enhanced students' learning experiences, which makes learning of an engineering module enjoyable and meaningful. Finally it helps the module team pinpoint the right skills and competencies needed to deliver the module contents prepared.

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## FLIPPING THE CLASSROOM FOR DIGITAL ELECTRONICS

Christopher Teoh and Mark Wan

School of Electrical and Electronic Engineering  
Singapore Polytechnic, Singapore

[cteoh@sp.edu.sg](mailto:cteoh@sp.edu.sg); [markwan@sp.edu.sg](mailto:markwan@sp.edu.sg)

### Abstract

This paper describes a pilot implementation of flipped classroom teaching for a first year class in Digital Electronics in the Common Engineering Course. While most practitioners implement a 2-stage flipped classroom (pre-classroom and the face to face classroom phase), we implemented in a 3<sup>rd</sup> post-classroom phase advocated by some. Customized lesson plans were constructed and delivered for each stage. To improve the learning experience, particular effort was made to connect with students during the 2 out-of-classroom stages (the pre- and post- stages) through the strategic use of technology. The pre-classroom phase included learning activities like watching specially recorded micro-videos, surfing selected websites, reading specially prepared or existing material etc. These were carefully calibrated in terms of difficulty level and time required for students to learn. The face to face lesson was then conducted where the lecturer now has more time for an active lesson which may include clearing of misconceptions, formative quizzes, teaching of more difficult topics, challenging students with more difficult problems, doing peer learning activities etc. Because the lecturer now takes on a facilitator role, greater attention can be given to weaker students. The face to face lesson typically ends with an exit poll or/and a post lesson survey which then forms the basis of the post classroom session. This session seeks to clarify any remaining doubts and misconceptions which the students may have on the topics covered. The learning activities here mirror the pre-lesson stage but is customized to address concerns raised by students. Technology (our LMS, Whatsapp, video recording software, Socrative classroom response system etc.) is heavily leveraged on to provide a seamless learning experience for the students. Preliminary surveys conducted suggests that students respond well to this pilot implementation. In particular, they told us to continue with flipped teaching because they learnt better this way. Results from the mid-semester tests also seem to indicate that the class that underwent flipped teaching lessons did better than those that did not.

**Keywords:** *flip teaching, pre-lesson plan, post-lesson plan, active learning, education technology, micro videos*

### Introduction

The first goal in the CDIO framework is that engineering graduates should obtain a deep working knowledge of technical fundamentals (Crawley, 2007). The National Research Council Commission (2000) says as much when it reported that a deep understanding of factual knowledge and the ability to organise knowledge within the context of a conceptual framework in ways that facilitate retrieval and application is key to successful learning.

The prevailing method of lesson delivery – through lectures, tutorials and laboratory sessions – and classroom practice in Singapore Polytechnic does not, however, seem to support this goal. More often than not, content is taught passively, and in silos, and students are left to connect the dots themselves to see the bigger picture. Students tend to memorise content, and regurgitate it during examinations.

Teachers should, instead, adopt a more active learning approach and through it help students to understand knowledge deeply and apply it. There is a wealth of literature supporting the merits of active learning and how it contributes to deep learning. Crawley (2007) argued that, among other approaches, active and experiential learning is fundamental to achieving deep learning. It also led to students' being better able to achieve intended learning outcomes, and in the process gained more satisfaction with their education. Chickering and Gameson (1987) says as much when they observed that learning is not a spectator sport where students just sit in class and listen to teachers, memorizing pre-packaged assignments, and then spitting out the answers. Rather, they must make what they learn part of themselves by talking and writing about it, relating it to past experiences, and applying it to their daily lives. Biggs (2003) emphasised that students who were actively involved in their own learning made better connections, both with past learning, as well as with new concepts. This invariably led to a deep learning.

But an active learning lesson necessarily requires more time to conduct. How does one find time in a

curriculum structured to be delivered in an economically efficient way (e.g. through lectures in the least amount of time to most number of students) to practice active teaching consistently? The answer may lie in taking a flipped approach to teaching.

## Methods and Pedagogy

### THE CASE FOR FLIPPED TEACHING

Bergmann and Sams at Woodland Park are credited as the first practitioners of the flipped classroom (White, 2011). In flipped teaching, students spend time before the lesson to learn fundamental knowledge on their own. This can be in the form of watching video clips, or doing required learning from notes, books or web resources. The time freed up because of this prior learning can then allow for classroom learning where explanation and discussion of theory, problem solving, and case study etc. can take place. The teacher can now take on the role of a coach with enough time to help students achieve higher learning outcomes. Norrman (2014) proposes that among the success factors in flipped teaching is one where it involves 3 distinct stages: before, during and after classroom activities. All parties involved must recognise each phase, and understand the purpose and concept of each of them. Findlay-Thompson & Mombourquette (2013) also notes that it is crucial that all parties involved understands and cooperates with the purpose of the different components of flipped teaching. It is not just the launching of some videos. The teacher must be able to create engagement within the group and use the full concept.

From the perspective of revised Bloom's Taxonomy (Anderson, 2001), flipped teaching makes sense. Students tackle lower levels of cognitive work which typically involves learning new factual knowledge (remembering, understanding) on their own, so that higher levels of cognitive work (applying, analysing, evaluating and creating) can be done in class where they have the learning support of the lecturer and peers. Pre-classroom learning, however, needs to be carefully constructed, and students need to feel that they are never alone in their learning journey. Otherwise the temptation to give up can be great. After the classroom session, post-classroom activities is necessary to ensure learning support of those who may not have been able to learn as quickly.

### IMPLEMENTATION

All first year students in the School of Electrical and Electronic Engineering (EEE) study Digital Electronics (ET1003). It is a fundamental module on which more advanced ones like Microcontroller Applications are built on. Topics covered include number systems, basic logic gates, combinational logic circuits, Boolean algebra, Karnaugh Maps (K-Maps) and simple sequential logic circuits like flip flops and counters. The traditional class consists of 60 hours of instruction per semester of 15 weeks; divided into 30 hours (2

hours per week) of lectures, and 15 hours each of tutorial and laboratory sessions (2 hours per fortnight of alternating tutorial and laboratory lessons).

Because students come from different backgrounds and have different learning styles and abilities, one on-going problem is to cater to a wide band of student abilities. Weaker students tended to be left behind, because there was no time to pay close attention to them. Another challenge was to get students to think more deeply about the subject matter and perhaps see its application in the real world. They tended to treat the module like Mathematics – i.e. as a series of challenging theoretical problems to be solved with new theory learnt, without understanding deeply how the knowledge could be applied in the real world. Through a series of competency tests done by the School of EEE in 2012 and 2013, it had been found that knowledge learnt in ET1003 in particular was very quickly forgotten, suggesting that learning tended to be shallow.

To improve the situation, we sought to create more time within the ET1003 contact hours where deeper learning could take place. The lesson could revolve around the higher levels of cognitive work as described by Bloom (Anderson, 2001), and take place in an active learning environment. The premise is that active learning typically leads to deeper learning. If possible, some lesson plans involving real applications of ET1003 could be developed. In such a lesson, it was envisaged that the lecturer becomes a facilitator (guide at the side) rather than a source of knowledge (sage on the stage). Weaker students will be able to get the attention they need.

A pilot run of flipped teaching was implemented for ET1003 in 2 Common Engineering Program (CEP) classes. CEP is one of 7 courses offered by the EEE School. The cohort size for CEP is 8 classes. Altogether, 36 students were involved in this pilot run.

### METHODOLOGY

The flipped teaching lesson plan in ET1003 was clearly and distinctly divided into 3 parts:

- The pre-classroom phase
- The classroom phase
- The post-classroom phase

Each of these 3 parts are linked to each other, but were designed to be separate and distinct learning experiences in their own right.

#### *The Pre-Classroom Phase*

The pre-classroom phase was one where students are required to learn some fundamental knowledge on their own before coming to class. Norrman (2014) advocates that ideally this should be a smorgasbord of readings, films and downloadable exercises dedicated to different learning styles. But perhaps this was too ambitious for this pilot run. Several authors have described this phase as one where learning takes place using a video. Sellens (2014) noted in his study on what aspects of a micro-video was deemed most important to students found that the videos should be not more than

10 minutes in length, be voiced by the lecturer teaching the class, and taught in whiteboard style (where notes were written as the presentation went forward, like a chalk and talk session). He also notes that students did not value slick productions and top notch video and sound quality. As long as the videos are watchable and the sound was audible, it was good enough. We took heart of these observations because the learning curve to produce top quality videos can indeed be very steep.

For this pilot run, we made use of a simple and free software called Screencast-o-matic to produce the pre-classroom videos. The module learning objectives were carefully studied, and topics which were deemed simple enough for students to learn on their own were identified. Short videos of about 10-15 minutes in length were then made using the camera and microphone embedded in the PC, using the principles recommended by Sellens (2014). The videos were then uploaded to our Learning Management System (LMS), Blackboard. To embrace the idea of a “smorgasbord” of learning material advocated by Norrman (2014), we did not just use custom-made videos all the time. Cartoons, short videos sourced from Youtube, customised reading material, and Powerpoint presentations with voice-over were also used to add variety to learning.

We thought it crucial that the lecturer kept in close touch with the students especially in this pre-classroom phase so that they would not feel alone in their learning journey. The messenger software WhatsApp was used for this purpose. A WhatsApp group was formed with the class so that the lecturer could inform the students when new material was uploaded, and the deadlines to complete them. A simple summary of the learning material, and the learning outcomes expected could also be communicated. Doing this personally through instant messaging imparted the feeling that there was personal touch involved.

We also thought it important to poll the students on their learning before they came to class. A smart-student response system called Socrative was used for this purpose. Socrative was designed to be a classroom polling tool. But since it makes use of wifi or 3G for connectivity, it didn't matter if the students were not physically in the same place. A series of multiple choice and short questions was sent to students at a pre-determined time, and the poll will be left open for an extended period (say 8 hours). At the end of the poll, we would have a good idea about what the students have managed to learn, and whether there had been any gaps in the learning. The lesson plan of the face-to-face lesson can then be adjusted based on the poll results.

#### *The Face to Face Classroom Phase*

The classroom phase pre-supposes that students had done their “homework” and now have some prior knowledge of the subject material. The Socrative classroom poll done during the pre-classroom phase would have told us if any student had not been participative. It would also indicate to us if students had difficulty with the learning material. If so, time will be set aside to address these difficulties.

More importantly, however, classroom time has been freed up for us to plan lessons that are more active and interesting. E.g. more challenging and intriguing problems can be posed and students can work collaboratively to solve them. Or students can be formed into groups to investigate different problems and then present their proposed solutions to each other. Or they can be asked to use simulation software like MultiSIM to learn and verify that their solutions are correct. Because the lecturer is now a facilitator and is free to walk around and interact with students, weaker students can get the attention they require. Weaker students also get the support of peers when they are tasked to work in groups.

It is important in active learning classroom sessions that some form of summing up be done periodically. Each student tends to make sense of what is going on in their own way and learning could become divergent. Summing up sessions or mini-lectures were conducted at every session. Occasionally, a short quiz is conducted using the Socrative polling App to test understanding.

At the end of every session, we thought it was crucial for students to tell us what they had found difficult. This is a “muddiest point” poll of sorts. Instead of asking them to write this down before they left the class, we thought it would be more insightful if we polled them electronically and gave them an extended amount of time to respond. Socrative was used again. Exit poll would be activated soon after the lesson, and left active for about 8 hours. WhatsApp was used to remind them to respond. The responses will then be analysed and will form the basis of the post-classroom phase.

#### *The Post-Classroom Phase*

The classroom phase will always end with an exit poll of students to uncover their “muddiest point” in the lesson. This serves to find out if there were any part of the lesson they found difficult to understand. Polling students electronically for this information encourages even the normally silent and reticent students to give feedback. Based on the poll results, and depending on the number of students who were confused about a particular topic, different forms of remedial action can be designed.

In more extreme cases, where there were widespread and fundamental difficulties on a particular topic, a short home-made video was made and uploaded to the LMS to clarify the topic. With Screencast-o-matic, these videos are easily made without too much investment of time on the part of the lecturer.

Difficulties which were not as serious, would be addressed in passing in the next pre-classroom phase of learning. Or they could be addressed the next time students and lecturers meet during the classroom phase.

#### *Uniqueness of our Flipped Teaching Pilot run*

While implementing flipped teaching in ET1003, we had attempted to learn from the best practices of other practitioners, and added in what we thought was

important in our context. This included continuously engaging students in conversation at every stage (either through WhatsApp or the Socrative polling software), closing the learning loop as soon as we could with a post-classroom phase (through formative quizzes at the different stages and instruction videos to clarify muddy points if necessary) and making pervasive use of IT that is very much a part of the everyday lives of students.

### Student Feedback and Performance

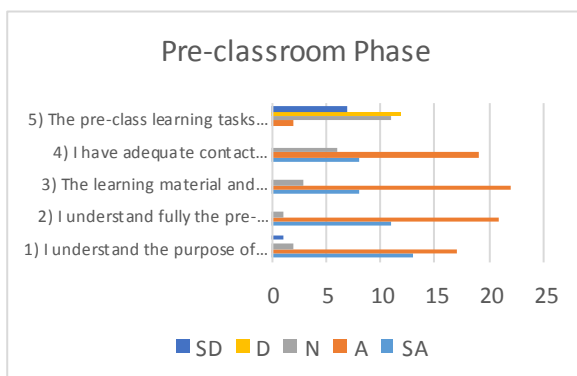
#### STUDENT FEEDBACK

After 9 weeks of implementation, a student survey was conducted to gauge the level of student satisfaction and support for this pilot run. The survey was also designed to detect problems the students may have in learning the flipped teaching way, and what they liked or disliked about it. Students were asked to respond to questions about each distinct learning phase and also give their overall opinion of flipped teaching.

Altogether 33 students (out of 36) responded to the survey. Most of the questions were on a 5 point Likert scale where students responded whether they Strongly Disagreed (SD), Disagreed (D), were Neutral (N), Agreed (A) or Strongly Agreed (SA) with a statement. To calculate the mean response to a question, a score of 1-5 was given to the 5 responses SD-SA. There was also a free response question at the end of every section for students to give their comments and views freely.

#### The Pre-classroom Phase

- 1) I understand the purpose of the pre-class learning activities in Digital Electronics (mean = 4.24)
- 2) I understand fully the pre-class tasks that I have to do each week (mean = 4.30)
- 3) The learning material and videos produced are adequate for me to understand the material covered (mean = 4.15)
- 4) I have adequate contact with my lecturer, and support during this pre-class phase (mean = 4.06)
- 5) The pre-class learning tasks were too difficult & take too long to complete (inverse scale; mean: 2.25)



Comments:

*"Videos to be shorter, focus on the main point. Maybe split into multiple videos on each main idea"*

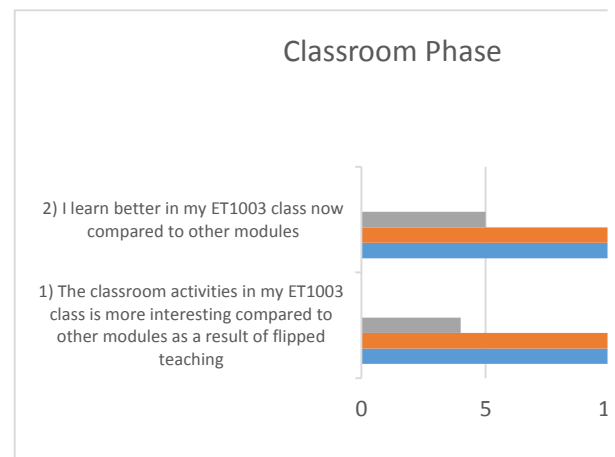
*"..... In my opinion, the pre class stage can only help the lesson proceed smoothly as we have a small understanding of the chapter already, thus not everything has to be explained in class allowing the lecturer to proceed at a slightly faster pace."*

*"Please post videos 2 days before lessons. Thk you"*

The overwhelmingly positive response in this phase surprised us. We had thought we had fallen short in terms of quality of video production and the variety of pre-classroom tasks. Nevertheless, the free response comments uncovered some operational shortcomings. Because we had produced videos on the fly, they were often longer in duration than we had planned, and were often only posted the day before the scheduled lesson.

#### The Classroom Phase

- 1) The classroom activities in my DE class is more interesting compared to other modules as a result of flipped teaching (mean = 4.32)
- 2) I learn better in my DE class now compared to other modules (mean = 4.28)



Comments:

*"Good job clarifying doubts we don't understand in the video"*

*"More questions could be answered by the lecturer compared to before as we know what we don't understand"*

*"Sometimes lecturer goes through what has been covered during pre-class phase and it makes the pre-class phase redundant."*

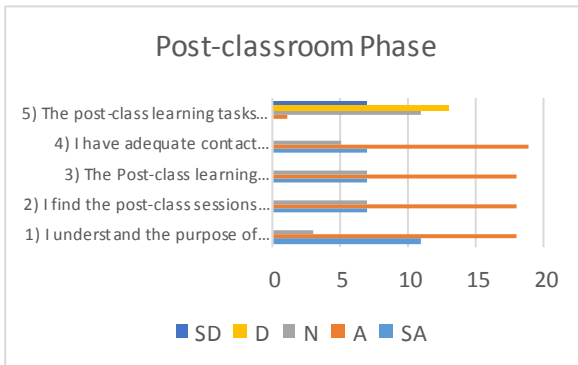
We had anticipated that since we now had more time to design and deliver more varied and active lessons, that we would get positive feedback regarding the classroom phase. In the comments, there was a useful reminder for us to shed our old teaching habits and not to lecture to student what we had assigned as homework.

#### The Post-classroom Phase

- 1) I understand the purpose of the post-class learning activities in DE (mean = 4.25)
- 2) I find the post-class sessions in DE useful in addressing my doubts arising from the lesson in class (mean = 4.00)



- 3) The Post-class learning material and videos produced are adequate for me to clarify my doubts if any (mean = 4.00)
- 4) I have adequate contact with my lecturer, and support during this post-class phase (mean = 4.06)
- 5) The post-class learning tasks are too difficult and take too long to complete (inverse scale; mean: 2.19)



Comments:

*"We are able to consult the lecturer about our doubts better compare to our other modules"*

*"Will be better if Lecturer can summarize up and recap on the current lesson before ending the class"*

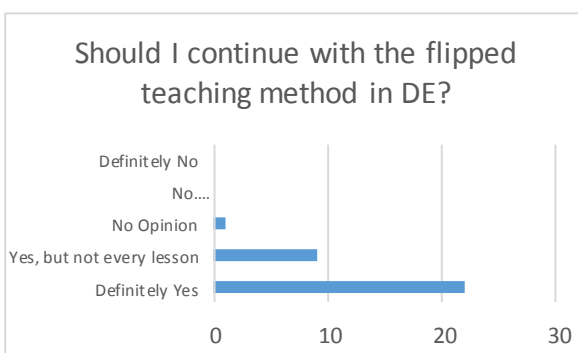
*"Teacher is thorough in addressing all doubts related to the class and if a suggestion is made regarding delivery of content he makes an effort to implement it. Credit given when it's due"*

Many flipped classroom implementation do not have a post-classroom phase. We thought that this was important because it helped us close the learning loop quickly with students before the next lesson. We were glad that students validated our efforts in this phase although there is room to improve on the quality of the material in terms of its ability to clarify doubts.

Overall

Should I continue with the flipped teaching method in DE? (Mean = 4.66)

- 1) Most definitely no. It take too much time and effort
- 2) No, but it could be used sparingly in some lessons
- 3) No opinion
- 4) Yes, but perhaps not every lesson
- 5) Most definitely yes. I learn better this way



Comments:

*"This method is very effective for me"*

*"You can be more detailed in explanation on the video"*

*"Would like to see this being implemented but with improvements and some changes to it"*

*"Flipped teaching is useful but it would mean that student will have to do more work at home by watching and understanding the video. It's like another form of homework."*

*"Try it out with another module"*

The number of students who answered "definitely yes" without any qualification surprised us. We had expected a higher proportion of the responses to be more guarded. The comment about a heavier workload as a result of flipped teaching was noted. We had consciously tried to limit the amount of self-learning material and activities to a minimum.

STUDENT PERFORMANCE

Notwithstanding what the students told us about their learning journey, we also wanted to find out if flipped teaching had an impact on their test performance. Students taking ET1003 sit for a mid-semester test (MST) in the middle of the semester. This is a 1½ hour written paper consisting of multiple choice, short and long questions. The results for ET1003 for the 2 classes on the flipped teaching pilot were analysed and compared against the CEP cohort.

MST Results (ET1003, DE)

Flipped class mean = 90.17

Cohort mean = 74.72

Cohort Standard Deviation (s.d.) = 10.65

Outperformance of Flipped Class = 1.5 s.d.

The results astonished us. It appeared too good to be true. So we investigated and found out that unknown to us, the course management team had done some amount of banding on the classes. The 2 pilot classes contained students who had done well in "O" level Additional Mathematics, and can be deemed as better students within their cohort.

To find out whether the outperformance in ET1003 was within expected norms or better, we analysed the MST results of a similar but different module taken by the same cohort of CEP students. This module was ET1005 Principles of Electrical and Electronic Engineering (PEEE). In PEEE, all classes were taught in the same way – using lectures, tutorials and laboratory sessions. The PEEE results was meant to give us a baseline of outperformance by the 2 classes involved in the ET1003 flipped classroom pilot.

MST Results (ET1005, PEEE)

Mean of class involved in ET1003 pilot = 86.86

Cohort mean = 81.88

Cohort Standard Deviation (s.d.) = 3.83

Outperformance of class involved in pilot = 1.3 s.d.

It appeared that flipped teaching in ET1003 had a small, positive impact on test results. The out-performance in the module was slightly better than the baseline. While this out-performance may not be very significant, we found it re-assuring that at least we did not harm students' performance. This could happen because the tests could have been optimised around traditional teaching methods. In any case, the student seemed to have a more enjoyable journey with ET1003 – which is a good thing

### Discussion

Both student feedback on the flipped teaching experience and the MST performance of the class were positive. This was edifying for the lecturers, and validated to some extent all the extra work put in. Nevertheless, several important questions remained. E.g. does flipped teaching work better with better students? What about weaker classes? Would they have the motivation to do extra work required in the pre- and post- classroom phases? Is the success of flipped teaching lecturer dependent? Would we get similar results if we “recruit” a wider range of lecturers for the pilot?

It also remains to be determined if students' can actually demonstrate higher order learning objectives like better levels of knowledge retention and higher order skills like critical thinking, transfer of knowledge etc. because they had the opportunity to learn in a more active manner. This will be a subject of future investigation

### Conclusions

Based on initial feedback and a preliminary analysis of the mid-semester test performance, we are cautiously optimistic that this flipped teaching pilot run was worthwhile from the pedagogic perspective. Notwithstanding the extra work required in coming up with almost "real time" teaching responses to end of classroom feedback, it appears that we were justified in paying attention the post-classroom phase in flipped teaching. This approach addresses students' learning needs as they arise and are dealt with with some immediacy.

While the flipped teaching approach has its merits, it remains to be seen if students can cope with the increased out of classroom workload should several modules within a study stage also employ flipped teaching. For if more modules shift what was previously taught in class to outside of it, in order to create more time in class for more meaningful learning activities, it may cause burn-out in students who will need to spend more time on the learning task overall.

### Acknowledgements

Special thanks to Mr Andy Ngai for planting the initial idea of flipped teaching into our minds. And to

our colleagues from the Singapore Polytechnic's Education Development Unit (EDU), especially Ms Cheryl Wee and Ms Chong Siew Kee for working so hard and closely with us to provide help and advice regarding lesson plans and teaching & learning strategies suitable for this project. You were the fly on the wall during some lessons. The experience would have been much less rich without you.

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## THE ROAD LESS TRAVELLED – FACULTY DEVELOPMENT TO PROMOTE ACTIVE LEARNING

Safura Anwar\* and Christopher Teoh E.L.

School of Electrical & Electronic Engineering, Singapore Polytechnic, Singapore

Email: \* safura@sp.edu.sg

### Abstract

Singapore Polytechnic, as an educational institution, constantly changes to meet the needs of industry and also to better prepare students for the workplace, specifically in engineering. It is also one of about 90 institutions around the globe that has adopted the CDIO (Conceive-Design- Implement-Operate) engineering education model. The framework comprises of 12 standards, which amongst others, defines key characteristics and provides guidelines for continuous educational improvement. Within Singapore Polytechnic, the School of Electrical & Electronic as the largest engineering school with about 3000 full-time students and teaching faculty of about 150 in Singapore Polytechnic (SP), adopts the CDIO framework for all its diploma courses. All six compulsory standards out of the 12 CDIO standards are manifested in some form in the curricula of the diploma courses that the School offers. While most of the modules taught in the School are delivered in combinations of lectures, tutorials and lab sessions, there is room to implement active learning (CDIO Standard 8), in particular for the lectures conducted for the students. This potentially not only helps students in their learning, but also compels teaching staff to re-examine their teaching practice, that is, align with Enhancement of Faculty Teaching Competence (CDIO Standard 10). This paper describes the journey undertaken by the School in the area of faculty development, especially amongst the more senior and experienced teaching staff, to adopt active learning in their teaching practice. Since 2011, an active learning plan has been rolled out across the School. This paper describes further the measures taken to bring about the change. These include the provision of training, resources, the use of virtual learner response system and the opportunity arising from the mandatory annual staff work plan to include teaching innovation. It describes also the current stage of active learning implementation within the school where the culture of faculty sharing their teaching practices, whether

through presentations and reports is beginning to take root.

**Keywords:** *Active learning, staff development, engineering, traditional lectures, student response system*

### Introduction

*“If we teach today’s students as we taught yesterday’s, we rob them of tomorrow,” John Dewey.*

The School Electrical & Electrical Engineering (SEEE) has the largest student enrolment of some 3000 full-time students, pursuing six three-year-long full-time diploma courses, with a 150-strong teaching faculty, amongst the nine academic schools that make up Singapore Polytechnic (SP).

A few years ago, a study carried out within the school revealed that the median age of the teaching faculty was in the early 50s, with about three-quarters of staff aged above 50. Essentially the majority of the teaching staff were born in the 50s with a significant number also comprising those born in the 60s. Since then, there have been some faculty turnover in terms of retirements, resignations and new staff recruitment. However in terms of the median age of teaching staff, this has remained relatively unchanged.

Contrast this with the students who are enrolled in the School each year. The overwhelming majority are admitted based on their GCE O levels, having completed 10 to 11 years of secondary education. Most of these students will be around 16 to 17 years age when they are first enrolled in the School.

The situation in the School mirrors that described by Jonas-Dwyer, et al (2004) of the characteristics of the changing student body of the Australian universities, comprising of millennials and their accompanying changing needs and expectations on the one hand, and on the other, the makeup of the teaching faculty of the same institutions, who comprises mostly of baby boomers and generation X, those born in the 50s and 60s. The implication of these is that there is a need to propose academic or faculty development that

promotes student-centred approaches to meet the changing demands of the millennial students.

This paper looks at the faculty development that has taken place within SEEE to promote active learning as one such student-centred approach in order to meet the changing expectations and needs of its own students.

## Background

As with most schools that offer engineering diploma courses, SEEE offers, for five of its full-time diploma courses, an engineering curriculum that are mostly carried out through a combination of lectures, tutorials and practical (L,T,P). These tend to be the fundamental and core engineering subjects or modules.

Lectures for first-year students are carried out in class sizes of 40 students, comprising two different classes of about 20 students each. For tutorials and practical, the typical class size of 20 students applies. For second and third-year lectures, the class sizes can range from a size of 20 students (one class) to 120 students six classes), although typically 60 to 80 students would be the norm. The class size of lectures for first-year students are kept at 40. This is so that they will have an easier time adjusting to the new lecture-tutorial system which for most, they are experiencing the first time, having come from the secondary schools where such a system is not practised.

Teaching faculty of SEEE are well-qualified with most having masters' qualifications, and even some with PhDs, and industrial experience. Upon recruitment as lecturers, those without teaching experience are required to undertake training course on teaching (originally called Teaching Methods Course (TMC) and later replaced by the Certificate in Teaching Course) conducted by the Department of Educational and Staff Development. As most of the teaching faculty are long-serving lecturers, some of whom having been with SP for 10 years or more, such a teaching course would have been done in their first year upon joining SP, and it would have been quite some time since they have undertaken training related to pedagogy, although there are courses regularly run related to the use of technology and software for teaching and administration-related work.

Arguably, a somewhat apt description of the SEEE teaching faculty is as that described on the CDIO website, "*Engineering professors and lecturers are very strong in their fields and discipline ... They teach the way they have been taught ... (they) have a clear idea of how to teach a course or deliver a lecture but they do not necessarily think in pedagogic terms.*" It can be expected then, that teaching faculty as lecturers, true to their designation, essentially *lectures* and consider this as their main task in their lecture classes.

In the classes, teaching faculty face not only the millennial students with their changing needs and expectations, but there is also the real challenge of students who need not necessarily have been admitted into the diploma course of their choice, and hence less

motivated in their studies, and perhaps less engaged in their learning. A common refrain amongst teaching faculty is that the current students are "different" from those whom they taught years back. It is perhaps unrealistic to expect that recent cohorts of students to be like those of the past with similar characteristics where learning attitudes are concerned. A more plausible approach perhaps is for teaching faculty to re-examine their teaching practice in order to better engage the current students and help them in their learning, capitalising still on their wealth of technical and industrial expertise and knowledge.

## Active Learning – getting students to do more than just listening

Jonas-Dwyer, et al (2004) made the case that the millennials, the new generation of students having been exposed to technology from relatively young age, would expect on-going use of technology in the classes they attend from the teaching faculty. However beyond the teaching faculty making use of technology in their classes, the authors propose adopting teaching and learning approaches and strategies that will meet the emerging learning expectations of the millennial students. These suggest that teaching and learning strategies include the opportunities for experiential and authentic learning activities, collaborative work and providing frequent feedback, amongst others to feature in the classes.

Within the engineering curriculum, such opportunities present themselves when students are attending tutorials and practical for all three years of their course of studies, and when they are undertaking their final-year projects. These usually involve problem solving, group work on hands-on experiments and lab sessions of class size of about 20 students each. The small size of these allows more of the student-centred strategies mentioned before. However in lecture classes, it would be expected that there is less room for such student-centred activities as described earlier where content coverage in particular is usually the overriding concern of the teaching staff.

The work to introduce active learning within SEEE drew its inspiration from MIT's Department of Aeronautics and Astronautics' adoption of active learning for lecture-based multidisciplinary course which started in 1996 as reported in Hall, et al (2002). Over a period of five years, active learning implementation was carried out for five disciplines, each with 40 lecturers in this case. The cohort size was rather small. For example, for one year, the cohort size was only 60. Juxtapose this with the annual cohort size of the SEEE, with close to 3000 full-time students.

Despite this, the MIT case serves as an exemplar in active learning as it took place within an engineering setting that SEEE faculty could identify with, notwithstanding the vast difference in academic calibre perhaps of MIT students and SEEE students. However, this marked difference serves to support the move. If it was thought necessary that students with

supposedly much better academic standing ought to be exposed to active learning, then perhaps arguably, it would be worthwhile to adopt active learning for students with lesser qualifications, as in the case of the polytechnic students. As discussed in Prince (2004), his study *“has found support for all forms of active learning examined. Some of the findings, such as the benefits of student engagement, are unlikely to be controversial.”*

SP has adopted the CDIO (Conceive-Design-Implement-Operate) framework to drive the engineering curriculum with its 12 standards. Of these, *“Teaching and Learning based on active and experiential learning methods”* is espoused as CDIO Standard 8 on Active Learning, (CDIO website). In Crawley, et al (2007), active learning methods are described as those that *“engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information and more emphasis on engaging students in manipulating, applying, analysing, and evaluating ideas. Active learning is considered experiential when students take on roles that simulate professional engineering practice, for example, design-build projects, simulations, and case studies.”*

Felder (2009) describes active learning as *“... anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes.”* These definitions of active learning provide broad guidelines and are suggestive, rather than prescriptive of the different approaches and strategies that teaching faculty could adopt and adapt to suit their teaching context and their comfort level, in order to move away from the monologues in lecture classes.

In the implementation of faculty development, Weimer (2010) outlines some factors for professional growth in pedagogy which are worth consideration. These include the following: *“Improvement is an opportunity; isn't always easy; involves risks; directed at more and better learning for students; improvements begins and ends with you; set realistic expectations for success; teaching excellence is a quest.”*

These serve as main considerations in introducing educational changes. For instance, the principle on *“directed at more and better learning for students”* makes it imperative that the aim of the faculty development within SEEE is explicitly targeted at better student engagement and learning, and not at turning faculty into better lecturers or teaching staff per se. The latter is likely to repel faculty members as this raise questions on their teaching capabilities. It is also worth bearing in mind that implementing change for such a large number of teaching staff is not without its challenges. Lane (2007) reports that *“modification of behaviour or teaching practice is challenging”* and *“(the) particularly conservative characteristics of faculty in the “hard” scientific disciplines ... (and)...Because of the long-prevailing paradigms in both content and pedagogy, faculty members are often teaching as they were taught and any challenge to the method may be perceived as challenging the credibility*

*of their own training and their previous teaching efforts.”*

### **Implementation of Active Learning at School level (Phase One)**

Recognising the need for faculty to re-examine their teaching practice in order to better engage the students, it was decided to roll out the active learning initiative across the School. This was also driven in part by the need for teaching faculty to include a teaching innovation and technology-related goal in the staff annual work plan (Performance Management Programme (PMP) as it is called in SP) for teaching staff of a certain lecturer grade or higher. This applies to a significant number of the experienced teaching staff within SEEE.

To acquaint teaching staff with the initiative, a series of short workshops, training courses, introduction of the use of mobile devices, community of practice sessions and sharing sessions were held in the initial early stage.

To start off teaching members on their active learning journey, two half-day workshops at different times in 2011, were organised for staff. The sessions were conducted by facilitation using the jigsaw method on the topic of active learning itself. In a sense, an approach to active learning was modelled to the participants while exposing the area of active learning to them. To advocate the possibility of incorporating such an approach in their classes, a colleague from another engineering school was asked to share her own teaching experience using the jigsaw method on blueprint drawings of engineering structures for her structural engineering classes.

There were two main considerations for having a colleague from another engineering school to contribute to the workshop. First, it was to impress on the staff that active learning approaches were already taking place within campus, albeit in another engineering school, and thus, this was something that teaching faculty could possibly identify with and attempt as well. Second, the sharing by the teaching faculty served as a precursor that teaching staff could similarly share their own teaching and learning strategies on similar or other platforms further down the road. A simple approach called “I SEED” to start staff on thinking and writing about their own teaching strategies on active learning (AL) was also shared (see Figure 1).

To have teaching faculty to talk openly about their teaching practice in a formal setting, away from casual canteen talk, requires some getting used to. As with other educational institutions, teaching faculty do not openly share their teaching practice and this is echoed by Lane (2007) that *“open discussion of teaching practice can be perceived as dangerous, as if any attempt to learn from others is seen as inadequacy.”*

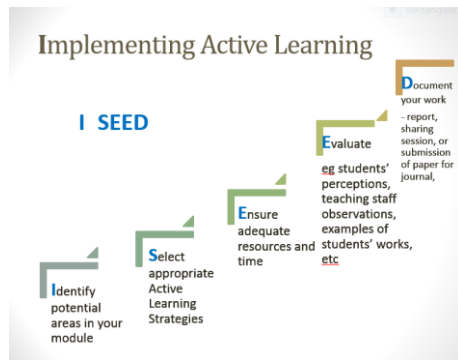


Figure 1. I SEED - A start to AL

Subsequent to that, two first-year modules were specifically targeted as these involved practically almost all Year 1 SEEE students. Due to the relatively small class size of 40 and also because these students were new to the polytechnic system, they would be more open to different learning approaches. Year 2 and Year 3 SEEE students could be less open, and might expect to be taught and to learn in the more traditional ways they were used to. The teaching members of these two modules attended a training workshop by an external consultant to incorporate active learning in these two modules. For the second day of the workshop, the teaching members who participated, proposed and presented lesson plans using the techniques and knowledge gained from the first day of training. The choice of the external consultant was rather deliberate. His background in the hard science, Physics, coupled with his teaching experience of teaching students of almost the same age of the polytechnic students, and that also of teaching budding teachers-in-training, lent him the credence which could perhaps make it possible for the more experienced teaching faculty to be receptive and accepting of the approaches he suggested.

Other training courses organised for staff involving external trainers included Facilitation Skills for Teaching, and also Being a Reflective Practitioner; the former as teaching staff would be expected to be more of a coach, doing less of transmitting knowledge but more of guiding and facilitating, so that students could be more actively engaged in their own learning. The latter course was conducted with the aim so that teaching staff would continually reflect on their teaching practice as part of their ongoing professional development.

As an additional option for lecturers who wished to embark on active learning, iPads were available for loan for staff to bring to class for their student usage. Teaching staff could plan an active learning class session making use of the iPads as a learning tool, draw out the iPads for the duration of the lesson, and then return them when they were done. Alternatively, they could re-schedule their class to the teaching facility holding the iPads, and conduct their lessons there. Examples of lesson plans where iPads could be used include launching Apps that could simulate circuits, or reading and discussing online

material and then working out problems and posting solutions online, or making a video or audio recording of a demonstration or presentation and submitting it for assessment etc. With iPads, the lessons could also take place out of the classroom location. This option was to give teaching staff a new dimension of options from which to consider.

Beyond training courses and workshops, support for teaching staff in the implementation of active learning also took the form of sharing session of active learning classes by a group of three lecturers which was undertaken as part of a lesson study pilot.

There were also community of practice (COP) sessions held which were non-compulsory. These sessions, conducted in informal, collegial and supportive mode saw about 10 to 15 staff participating, and with some sharing of what they have done for active learning implementation in their own teaching practice. The explicit reminder here was that participants were to drop their reporting officer roles so that the teaching staff could freely suggest and propose what worked and what could be improved of fellow participants' approaches.

At the school level, staff sharing of their practices were done over a few sessions. Such sessions were opened to the whole SEEE. Such a large-scale sharing was perhaps a first, perhaps at least in the area of active learning. Through these sessions, not only were the success stories showcased, approaches and strategies that did not work as well were also shared so that together these were useful examples which teaching staff could learn from. There were also different interpretations of active learning as seen through teaching faculty perspectives, the expected usual challenges to active learning implementation voiced by teaching staff such as the extra time and effort needed for the both preparation and implementation of active learning approaches, and hence less time to cover the syllabus, amongst others.

### Implementation of Active Learning at School level (Phase Two)

The subsequent year of active learning implementation within the School saw its introduction and implementation through the use of student response system for teaching faculty to use with their classes. For lecture classes, the use of virtual clickers were spelt out rather explicitly as there was the continuing challenge to better engage students in the lecture setting. As the use of mobile devices and smartphones were already prevalent amongst the students, the use of virtual clickers rather than physical clickers were considered and preferred, having studied the pros and cons of the use of each type. The choice of the virtual clickers was also preferred as a few years previous to that, physical clickers acquired found few takers as these required staff to borrow the clickers, distribute amongst students, collect them again and return the physical clickers after use. The logistics of its use rather than the potential pedagogic benefits could have turned off teaching

faculty from its use. Implementing the use of physical clickers school-wide was not an option as it would have required massive initial investment in cost which would be hard to justify, given the large number of students.

While there were several options of virtual clickers systems available, it was decided to focus on one specific virtual clickers as the particular system used offered more than just multiple choice and true and false options when posing questions through the student response system, apart from other considerations. This way, teaching faculty could explore more options in gathering responses and feedback from their students. Students were able to download the free app on their smartphones, or if they did not have one, they could access the internet on their own pc laptop as long as the wireless network is available. The School paid for a limited number of licenses so that at different times, teaching staff could use the virtual student response system as long as they had presenter accounts needed to start such sessions. Teaching staff involved underwent introductory training course on its use, in particular the technical aspects and were also supported through subsequent clinic sessions where staff could seek further help on its use. While the use of virtual clickers was introduced and on-going, faculty could continue to seek and explore active learning approaches that would fit their module and teaching context better.

So that teaching staff approaches could also be referred to at other times, other than during the school-wide sessions, teaching staff were also required to submit their active learning implementation in the forms of reports. The use of a standard template (see Figure 2) was suggested to not only help busy teaching faculty to document their work, but also in a standardised format so these could be more readable for other teaching staff to refer to, and learn from. The reports submitted were uploaded to online platform (in this Blackboard) for interested staff to access.

For the school-level sharing session, those selected to present had undergone an initial first round of sharing amongst their own teaching group. Being selected to present at the School-level serves as a measure of the quality and degree of innovativeness that were displayed in the teaching members' work. The sharing sessions within the teaching module level showed that teaching staff were using the virtual clickers at testing factual knowledge, and some were using the virtual clickers to pose concept questions in conjunction with peer teaching and discussion. The test of concepts through the use of clickers was strongly suggested by Felder (2009) that is "...focus on the hard stuff—the things students always have trouble with on assignments and exams." However there is somewhat a dearth of concept questions related to the field of electrical engineering and this somewhat hampered the more widespread use of the virtual clickers in testing concepts. This is echoed by Laxman (2011) who pointed out that "there are few (if any) collections of good clicker questions available for most fields of educational study."

USING ACTIVE LEARNING METHOD IN A LECTURE-BASED LESSON

Active Learning Method (can be any known method or new method invented)
A) Module:  Topic:
B) Outcome Students will learn: 1) 2) 3)
C) Aims:  Explain what you aim to achieve
D) Activity  Describe how the activity is implemented (attach handouts or document used in the activity, if any). State clearly how this is different from your previous teaching practice.  Provide two or more sources of relevant research or references.
E) Feedback 1. Methodology of data collection  2. Feedback Action Plan  I will discuss feedback with student or group of students/ co-lecturers/ others (* delete appropriately)  Name of students or group/co-lecturers/ others: _____  Date of discussion : _____
F) Post-implementation - Discussion Summary
G) Other information

Figure 2. Template for report on AL implementation

### Lessons from school-wide active learning implementation

While the benefits of active learning in engaging students were reaped to some extent, there were concerns and issues which were common to most active learning implementation. These included not having enough time to cover the syllabus, the tricky measurement of students' real learning, the need to spend extra time on preparation, the extra resources and support to implement in large classes, etc. These were real issues that needed to be tackled head-on and not avoided.

Chief amongst these issues perhaps was to do with the extra time needed in order to conduct an active learning class. Given the limited time in the lectures, the flipped approach to teaching has been piloted for a few modules within the School since 2013, as it offers perhaps a more efficient way to facilitate active learning potentially. With this approach, students spend time outside the lectures to learn some basic and fundamental concepts on their own before the lecture classes. Resources such as video clips, reference texts and/or web resources are accessed by students themselves. During the actual lessons, because of the freed up time spent on prior learning by the students, the teaching staff can take on the role of a coach and facilitator to engage students perhaps on the "hard stuff" that Felder alluded to, and these could include further discourse on concepts, including explanation and discussion, problem solving and others.

## Conclusion

The first steps on faculty development to get staff to continually examine their teaching practice to better engage students and help students to learn better have been taken. Training, support and resources were expended to get these started and on-going. That active learning was suggested was because offered a wide and broad enough approach for staff to explore possibilities to move away from the usual lecture transmission mode. Weimer (2010) points out that “*teaching excellence is a quest; it’s about the journey, not the destination.*” This serves as a reminder that perhaps educational changes and initiatives are never easy undertakings, and especially when it involves such a large school with many teaching staff and students.

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## A GIFT OF DRINKING WATER: A CHEMICAL ENGINEERING CDIO PROJECT

Ai Ye Oh and Katerina Yang

School of Chemical & Life Sciences, Singapore Polytechnic, Singapore

Email: oh\_ai\_ye@sp.edu.sg

### Abstract

A group of staff and students from the School of Chemical & Life Sciences at Singapore Polytechnic embarked on an overseas community service project with the local community at Nagarkot, Nepal since 2012. The project, led by the staff and students from the Diploma in Chemical Engineering, aims to improve the infrastructure at a village school, named Shree Janakalyan Lower Secondary School, at Nagarkot with water scarcity issue due to seasonal changes. This paper shares the work done by the staff and students, using the CDIO Framework, to conceive and design a system to provide clean and sustainable source of water all year round that is suitable to be implemented and operated to meet the needs of the rural community in Nagarkot.

First, the paper provides some background information on the situation of the village school at Nagarkot and its community. Then, it describes the application of Design Thinking methodology to understand the lifestyle and ergonomics of the community. Through empathy studies, interviews and living with the local community, our students conceptualised several designs to provide clean and sustainable source of water to improve their sanitation condition. The learning activities that enabled the students to design a sustainable rainwater harvesting system and its outcome are discussed in details. In early 2013, the students returned to Nagarkot to build and implement the rainwater harvesting system that they had designed, with the aid of the local community. Upon harnessing the rainwater, further test on site were also conducted to establish the water quality and thus suitability for drinking purposes.

In addition to the rainwater harvesting system, it came to realisation that bacteria growth is evident in water stored over long periods of time. As such, a follow-on project was conceived in 2013 to explore various water purification technologies that meet the needs of the community. At the time of this abstract submission, the optimisation of solar disinfection is still on-going. The results will be discussed in the full paper.

**Keywords:** *chemical engineering, sustainable solution, CDIO, social responsibility, design thinking*

### Introduction

Nagarkot is located on a mountainous region about 1900 meters above sea level, in the hilly regions of Nepal where ground water is scarce. The main source of water originates from rainfall and piped spring water from higher grounds. As a result, the community experiences seasonal changes which greatly affect the supply of water or even no supply of water during dry season.

This project aims to provide clean and sustainable source of water to a village school in Nagarkot, named Shree Janakalyan Lower Secondary School. The village school has about 300 children and teachers. The children are aged between 4 and 14. The school has minimal amenities because funding from the local government is limited. Prior to the commencement of this project, there is a water tank which stores 7000 litres of piped spring water. It is the only source of water in the school. Typically, everyone drinks from the tank and the community is susceptible to the contamination of spring water upstream as shown in Figure 1. Moreover, the supply of water is insufficient to provide for everyone in the school particularly during the dry seasons. Thus, this project embarked on harnessing excess rainfall during the wet season and store it for the dry season.

The project is carried out in two parts, namely the rainwater harvesting system and thereafter water purification technology.



Figure 1. 7000L water tank which was the only source of drinking water in the village at that time

## Design Thinking Methodology

Design Thinking is used by global consultancy company IDEO which has over 1000 patents since 1978 and has worked collaboratively with fortune 100 companies such as Microsoft, PepsiCo, Procter & Gamble and Steelcase. The Design Thinking approach focuses on three mutually supporting elements. They are user empathy, technical feasibility and business viability as shown in Figure 2 (Brown, 2009).

The key to the Design Thinking process was the user research that the students were tasked to do. As noted by Kumar and Whitney (2007), Design Thinking is about "... looking at activities that surround the product, rather than getting reactions to the product (and related distribution, promotion and price) leads to breakthrough ideas that are grounded in how people are living."

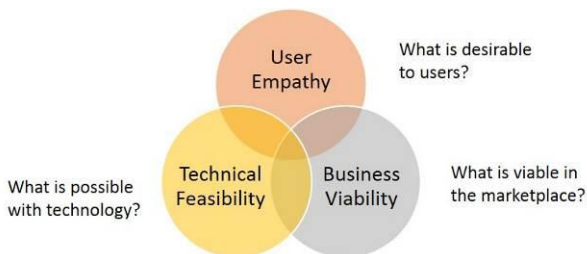


Figure 2. The Design Thinking Framework

## Designing a Sustainable Rainwater Harvesting System

The conceiving and designing of the rainwater harvesting system involves a group of staff and students who visited the village school to first understand the topography of the area and lifestyle of the villagers. They interviewed the villagers and local partner so that they can fully comprehend the issue at the heart of the community. Through empathy studies, they also identified the needs of the local community and better appreciate the importance of creating a solution that took into consideration of their lifestyles. Eventually, the team ideated a solution which is to build a rainwater harvesting system that is unique to the terrain at the village school.

One important observation made was the unavailability of electricity in the village school. Classrooms were ventilated through the windows and lit using natural lighting during the day. While the school is connected to the grid, electricity supply is interrupted, intermittent and unpredictable.

The team of students realised that without consistent supply of electricity, the installation of any electrical device will end up as a white elephant eventually. The students also observed that the school is surrounded by slopes and terraces. With a unique terrain in the area, a pump-less design was selected and to be implemented for the rainwater harvesting system.

The location of the storage tanks was carefully selected to maximise the rainwater catchment. This was done by tapping on the natural gradient available where water was collected from the roof of the building and directed into the storage tanks. As part of the design, the location of the water storage tanks were slightly elevated from the level where the toilets are so that the water can also be used for cleaning and flushing purposes. As part of the design, a portion of the water collected in a 1000-litre storage tank was diverted for sanitation purposes, and some to be further purified for drinking purposes. Figure 3 illustrates the preliminary design of the rainwater harvesting system which was constructed in 2012 as a pilot unit.

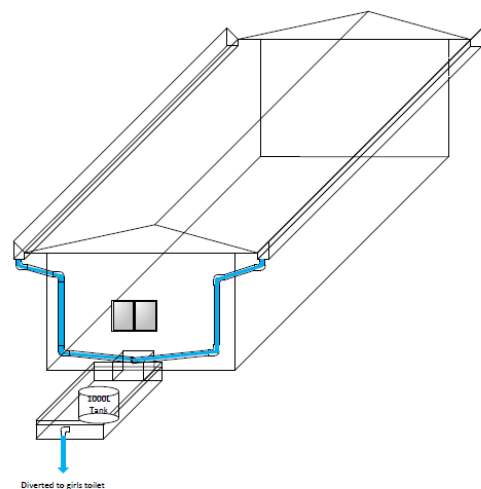


Figure 3. Design of the Rainwater Harvesting System

While the students undertook a Year 2 module, named *Product Design and Development*, the students used "Parts-Whole Relationship" approach to identify the role that each component plays and its importance to the functioning of the whole system. In this learning activity, the students used the following guiding questions to construct a "Parts-Whole Relationships" diagram.

- What smaller things make up the whole?
- What is the function of each part?
- For each part, what would happen if it was missing?
- How do the parts work together to make the whole what it is or operate as it does?

This learning activity requires the academic staff to act as a facilitator to enable the students to examine the components and relationships of the system and source for relevant information so that the students understand the purpose of each component in the system. At the end of this learning activity, the students created a "Parts-Whole Relationships" diagram and it is illustrated in Figure 4. The diagram allows the students to see the big picture as well as the relationship between

each component and identify developments required for specific components.

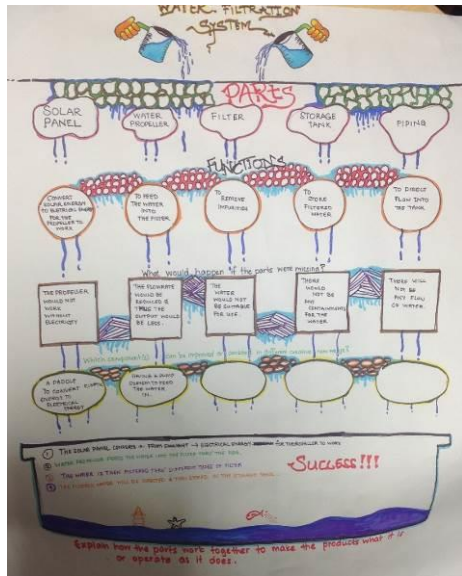


Figure 4. Example of Parts-Whole Relationships Diagram

### Solar Disinfection as Water Purification

The aim of exploring each purification method is to ensure that the water collected is free from chemical and biological contaminants and its quality is in accordance to World Health Organisation's (WHO) standards for drinking water (2008).

Many tests were carry out to establish the water quality harvested using the Rainwater Harvesting System. Figure 5 shows the location in which the water sample was taken and a student carrying out a water quality test. The main objective of the test is to determine the suitability of the water for drinking purposes.



Figure 5. Collection and testing of harvested rainwater by a student while in Nepal

It came to realisation that bacteria growth is evident in water stored over long periods of time. As such, a follow-on project was conceived to explore various water purification technologies to meet the needs of the community. Solar disinfection was selected to purify the water due to the abundance of solar energy available at Nagarkot where it is geographically located at an elevated terrain. According to Kevin et. al. (2012),

solar disinfection has been proven to be effective in more than 50 countries in Asia, Latin America and Africa. More than 5 million people disinfect their drinking water with solar disinfection (SODIS) technique.

SODIS is a simple, environmentally sustainable, low-cost solution to treat microbiologically contaminated water to potable water for household purposes. SODIS uses solar radiation to destroy pathogenic microorganisms that causes water borne diseases and therewith improving the quality of drinking water.

### Results and Discussion

According to SANDEC (2002), turbidity of water will affect solar disinfection efficiency. Water with turbidity of more than 30 NTU cannot be used for SODIS. Based on studies of the collected rainwater, it was discovered that the rainwater has low turbidity, thus only a small buffer tank was built upstream of the storage tank to filter out large particulates such as leaves and sand that may be captured together with the rainwater as shown in Figure 6.



Figure 6. A student measuring the dimensions of the buffer tank upstream to the storage tank

With the buffer tank placed upstream, water that is stored in the downstream water storage tank could be immediately disinfected using SODIS. The downstream water tank has a capacity of 8000 litres.

Portable water test kits were brought from Singapore to Nagarkot to establish the presence of chemical contaminants and amount of biological contaminants in the rainwater. The test kit is shown in Figure 7.

The test results indicated the absence of significant amount of chemical contaminants such as nitrates, nitrite, phosphate and ammonia in the collected rainwater. In addition, the rainwater samples were brought back to Singapore so that other tests can be carried out to establish the presence and quantity of other chemical contaminants that could not be tested by the portable test kits. The rainwater samples were tested

using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The ICP-OES tests revealed that only copper and lead were present in the rainwater sample. The quantities present were well within WHO guidelines for drinking water. This indicates that the rainwater sample meets the WHO guidelines for drinking water for its chemical properties.



Figure 7: Chemical and biological test kit used at Nagarkot

After establishing the water quality of the collected rainwater and expansion of the rainwater harvesting system in Nagarkot, the students continued to pursue through their Final Year Project and ideated on the use of a continuous SODIS system for the village school. While the students undertook their Final Year Project in Singapore, they designed and constructed a prototype to test the feasibility of using it in Nagarkot.

After many rounds of design and ideation, the students finally selected the prototype shown in Figure 8. This prototype was selected because it is compact and provides large surface area for exposure to solar radiation.

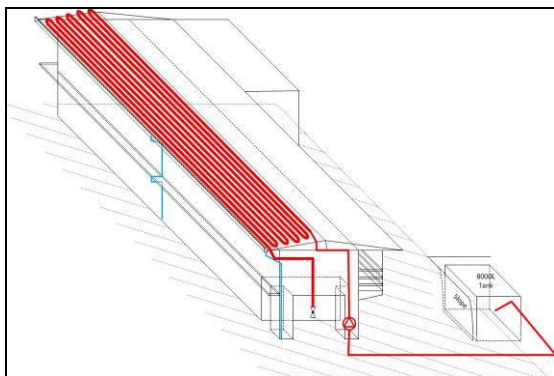


Figure 8: Design of the prototype

Figure 9 shows the final prototype that was constructed in this project. The prototype is made of transparent polyvinyl chloride pipe material so that solar radiation can penetrate to destroy the pathogens in the water sample. It is also relatively light-weight because it needs to be carried and moved to a place where there is maximum sunlight to study the effectiveness of SODIS and kept in the workshop when it is not in use.

In order to study the effectiveness of SODIS in the prototype, the students first filled the prototype with the rainwater samples. The water-filled prototype is left

under the full sunlight for approximately 4 hours per day. This is to simulate the actual condition at Nagarkot.

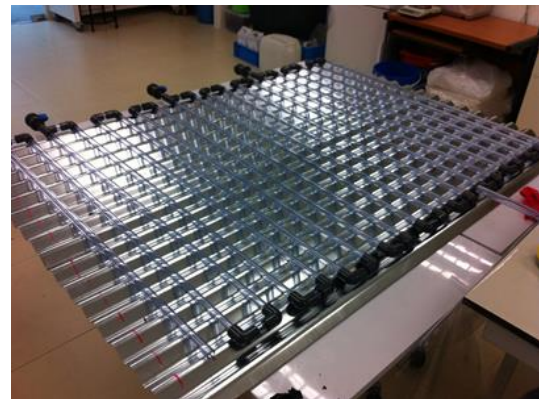


Figure 9: Prototype designed and built by students to test the feasibility of adopting continuous SODIS at Nagarkot

The prototype consists of 3 water sample points where water samples can be drawn to test for the water quality after certain amount of residence time. As the purpose of this prototype is to use solar radiation to destroy water borne pathogens, only the presence of coliform was tested. Coliform is commonly used as bacterial indicator of sanitary quality of water.

Prior to SODIS, the water sample had 200 cfu of coliform count. After the water had travelled for 6.4 meters from the inlet, the coliform count reduced drastically to 6.7 cfu as shown in Figure 10. This is a reduction of 96.65% in coliform count. Subsequent samples that were collected 13 meters and 20 meters from the inlet had reduction in coliform count but the SODIS technique was not as effective. With the water sample passing through the prototype's maximum length of 26.1 m, the final coliform count of the water sample was 2 cfu. This is a reduction of 99% in coliform count.

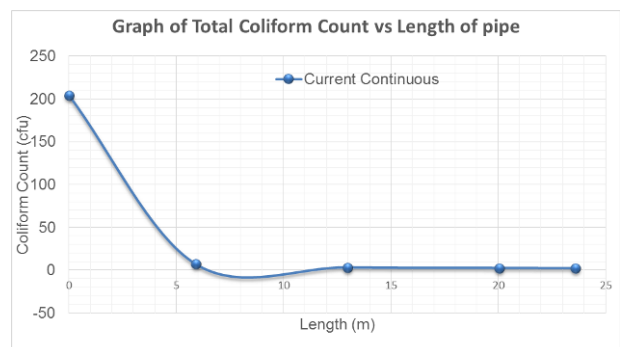


Figure 10: Total coliform count versus length of pipe travelled by water

Based on the WHO guidelines for drinking water, the coliform count is zero to ensure the absence of *Escherichia Coli* in drinking water. This preliminary test result is inconclusive because the test for the

presence of *Escherichia Coli* was not carried out. This is an on-going study that is being executed currently.

Based on this project, an increase in the length of pipe reduces the coliform count. However, the effectiveness of SODIS seemed to be less with the increase in length of pipe. Thus, further studies are in progress to investigate the optimal length of pipe with respect to the inactivation rate of coliform in the water.

### Conclusions

When the rainwater harvesting system was adopted for the first time at Shree Janakalyan Lower Secondary School, it has vastly benefitted the school community and improved its sanitation. With the breaking ground of this rainwater harvesting system, there are hopes that the younger generation who are educated on this concept will influence their families to adopt similar systems that can help them tide through the dry seasons. In future, it could also possibly help them in their agriculture productivity.

The usage of SODIS on the prototype designed and built by the students were proven to be effective in removing water borne pathogen.

### Acknowledgements

The authors would like to acknowledge the support received from the Mr Deepak Shrestha and Mr Dhruba Thakuri from Divine International Explore & Treks (S) Pte Ltd who have made the travel arrangements and contact with the principal of Shree Janakalyan Lower Secondary School, Mr Pertam Bahadur Tamang. The authors would also like to thank the local community at Nagarkot who played hosts and accommodated our students and staff during their visit and stay there.

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## A REVIEW ON THE IMPLEMENTATION OF FLIPPED CLASSROOM IN SECOND YEAR ENGINEERING MODULE

Frank Lo Cheong Wah, Yue Pik Kong\*, Rosa Tan-Wong Ah Hoon, Low Kok Hee, Kwa Teck Poey, Rodney Dorville and Christopher Teoh Eng Leong

School of Electrical & Electronic Engineering, Singapore Polytechnic, Singapore

\*yue@sp.edu.sg

### Abstract

**This paper presents the motivation and the implementation of flipped classroom in the teaching of Network Systems Design, a second year engineering module for the Diploma of Computer Engineering in Singapore Polytechnic. The result of two student surveys, one conducted at the beginning and another conducted at the end of the semester that provided feedback on the students' acceptance is analysed. Some retrospective observations and insights in the implementation of flipped classroom are also presented.**

**Keywords:** *flipped classroom, engineering module, Bloom's Revised Taxonomy, Learning Autonomy, Student Feedback.*

### Background

Network Systems Design (ET0717) is a second year engineering module of the Diploma of Computer Engineering in Singapore Polytechnic. The aim of the module is to teach the students how to design, implement and troubleshoot a computer network. In the first 6 years that the module was conducted, teaching was carried out with the basic networking concepts taught in a series of lectures with worked examples and tutorial discussion. The theoretical knowledge learnt was then put into practice during laboratory lessons with a standard set of experiments. Instructional hours consist of 30 hours of lecture and 60 hours of tutorial, laboratory experiments and project works. The module started its pioneer run in 2006 and has been running for 14 semesters and into its 8 years in 2014.

The biggest challenge in the teaching of the module lies in the delivery of theoretical content through lectures. Engaging students with 2 hours of lecture weekly as a primary mechanism for the delivery of technical and theoretical content is an uphill challenge. Students come from a diversity of educational background and disparity in intellectual aptitude and attitude. It is difficult to find a right balance and right pace that are satisfactory to all using traditional one size fit all lecture approach in the teaching of the module.

To overcome the problem and improve the situation, the course management team adopted flipped classroom as a new pedagogical model in the teaching of the module. Braine (2013) stated that the flipped classroom describes a reversal of traditional teaching where students gain first exposure to new material outside of class, usually via reading or lecture videos, and then use the class hour do the harder work of assimilating that knowledge through strategies such as problem-solving, discussion or debates. The purpose of flipping the classroom is to shift from passive learning in lecture room to active learning and to put back the autonomy of learning to the students whereby students take more responsibility for their own learning according to Larsen J. (2013). In flipped classroom students study core content either individually or in groups before class and then apply knowledge and skills to a range of activities using higher order thinking. With the adoption of flipped classroom model in Network System Design, it is hoped that students will become self-motivated and learn the core concepts at a pace comfortable to them at home before turning up in classroom to take part in activities that reinforce the learning outcome.

### Implementation



Figure 1. Bloom's Revised Taxonomy of Learning

In terms of Bloom's revised taxonomy by Anderson & Krathwohl (2001), flipped classroom means that students are doing the lower levels of cognitive work (gaining knowledge and comprehension) outside of class, while the higher levels of cognitive work (application, analysis, synthesis, and/or evaluation) are focused in class, where the students have the support of their peers and instructor. This model contrasts with the traditional model in which "first exposure" occurs via

lecture in class, with students assimilating knowledge through homework.

There is no single model for the implementation of flipped classroom. In its simplest form, the term is widely used to describe almost any class structure that requires students to do simple textbook reading or pre-recorded lectures viewing prior to in-class exercises and discussions. In our opinion, such a simple approach does not offer any significant enhancement to learning compared with the traditional lecture/tutorial/laboratory approach, other than the benefit that it frees up the lecturer's time for activities that involve higher level of learning and the advantage that students can watch the lecture at their own pace with the possibility of pausing, replaying, or skipping segments of the recorded lecture. There is not much of active learning in "first exposure" phase.

Educational technologies provide exciting possibilities in implementing flipped classroom. Not only can new technologies be used to present the course content online for students to access at their own convenience and at any time to suit their pace of learning (e.g., lecture material, pre-recorded lecture video, readings, interactive multimedia), new technologies like interactive multimedia technology that respond to the user's actions in presenting content such as text, graphics, animation, video, audio, games, etc. makes learning an engaging experience.

The flipped classroom was implemented in the teaching of Network Systems Design module in 2013 using a model presented by Leggett A. (2013) that divides learning into 3 distinct phases, namely concept exploration, meaning making and demonstration / application.

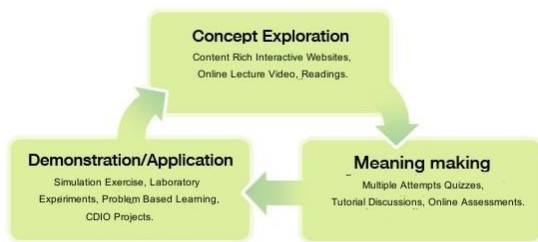


Figure 2. Learning Through Flipped Classroom

### Concept Exploration Phase

In flipped classroom, students take more responsibility for their own learning and study core content either individually or in groups before class. The responsibility of the instructor is to make the content interesting and engaging; in addition to making the student accountable to go through the concept exploration before the class. In our implementation, concept exploration was implemented using content rich interactive websites, online pre-recorded lecture video and suggested reading materials.

Mindful of our limited resources to implement a full fledged interactive multimedia course content website, we decided to make the best use of available

educational resources on the Internet. Cisco, a company that designs, manufactures and sells networking equipment runs a very successful international educational portal called Cisco Networking Academy that provides ICT training and certification. The CCNA Discovery and CCNA Exploration curriculum of Cisco Networking Academy provide general networking theory and comprehensive coverage of networking topics from fundamentals to advanced applications. Many chapters in CCNA Discovery and Exploration curriculum overlaps significantly with the topics taught in the Network Systems Design module. We enrolled all students taking the Network Systems Design module to Cisco Networking Academy. As a minimum requirement for concept exploration, students are required to go through chapters in CCNA Discovery and Exploration that are identified to be relevant to the topic to be taught in the week.

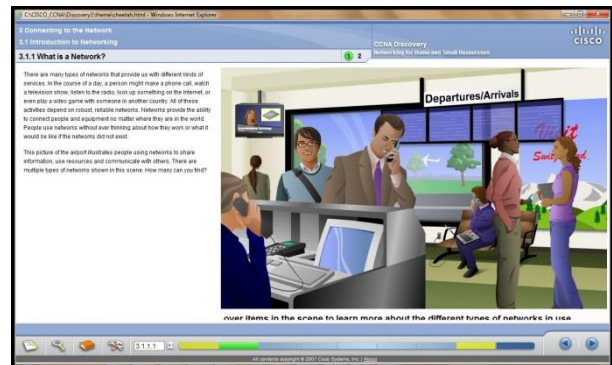


Figure 3. Cisco CCNA Discovery

In addition to Cisco Networking Academy website, voice over lecture slides in PowerPoint format and pre-recorded lectures are also made available in the eLearning portal of Singapore Polytechnic. The lecture slides and pre-recorded lecture video can be used as optional reinforcement to learning and also as a guide to the scope of the syllabus of the module.



Figure 4. Pre-recorded Lecture Video on SP eLearning Portal

In addition, links to relevant video on YouTube and other portals are provided as well. Reading materials and references are also provided in the eLearning portal and study guide to students.



Figure 5. Links to Relevant Video on YouTube

As far as possible, we try to present learning materials in a variety of formats to suit different learner styles (e.g. text, videos, audio, multi-media), however, we also do not want the students to be bogged down by heavy load of self-study. As a minimum requirement, the students are required at least to go through the chapters in Cisco Networking Academy that are identified to be relevant to the topic to be taught in each week.

### Meaning Making Phase

Classroom teaching in the flipped classroom model focuses more on facilitation and moderation than lecturing. Significant higher level of learning outcome can be gained through facilitating active learning, engaging students, guiding learning, correcting misunderstandings and providing timely feedback using a variety of activities,

In our implementation, the first activity to engage the students in the classroom is to conduct the online quiz for the chapter in CCNA Discovery and Exploration that the student have gone through before the class. The quiz in each chapter of CCNA Discovery and Exploration typically consists of 20 multiple choice, multiple answers or graphical drag and drop questions. Students who have difficulty in understanding or have questions on certain concepts can go through the content and discuss with their peers or seek clarification from the instructor. The quiz is made multiple attempts so that students can repeatedly improve their score. The quiz provides immediate feedback for instructor and students to signal revision points, difficult concepts and also captures data about students to analyse their progress and identify weak students.

The second activity is tutorial discussion. Tutorial questions for each topic of the week are given to the students beforehand in their study guide. During classroom hour, the instructor and students go through the questions one by one and present their answers and solutions. Tutorial discussion is another attempt to provide opportunities for discourse, interaction and

feedback whereby the instructor and students can gauge the students' understanding on various concepts on the topic of the week. Some questions require the students to work in group and do their research using the Internet,

Lastly, assessments in the form of single attempt online quiz with a weightage of 5% of the total assessment marks of the module are conducted twice in the semester to motivate the students to study and to provide a means to measure the overall progress of the students' study.

### Demonstration/Application Phase

The knowledge learnt has to be applied and demonstrated to solve real life problems. These skills are the higher levels of learning in Bloom's Taxonomy. In our implementation, these aspects of learning are achieved through simulation exercises, laboratory experiments and a CDIO (Conceive, Design, Implement and Operate) project.

Each chapter in CCNA Discovery and Exploration comes with several simulation exercises using its Packet Tracer simulation program. Cisco Packet Tracer is a powerful network simulation program that allows students to experiment with network behaviour. The program provides realistic simulation of various networking equipment like workstations, servers, hubs, switches, routers, etc. whereby students can connect together to form a network using a wide variety of different media. The students can also configure each of the networking devices.

During classroom hour, the better students are encouraged to go through some of the simulation exercises in each chapter and demonstrate the simulation to other students. The weaker students are encouraged to go through the same simulation exercises at home after they have fully understood the concepts in each topic.

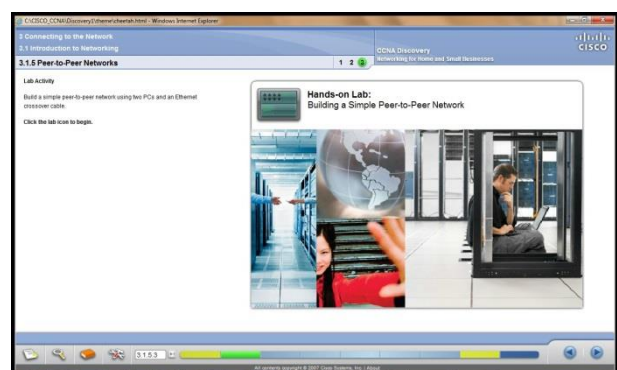


Figure 6. Simulation Exercise in CCNA Discovery

In addition to simulation exercises, a series of laboratory experiments using hardware equipment were designed to provide the opportunities for the students to apply their knowledge in real life situations. The experiments range from cable making, cable testing, network troubleshooting, implementing Local Area Network using switches and routers, implementing



WAN connection, setting up various servers, implementing network security, etc.

Students are also required to form in a group of 4 or 5 students to work on a CDIO project to conceive interesting project ideas, for example, network design for home, school, hospital, commercial building and shopping centre, which they will then design and build. Students will be expected to identify the network design requirements, perform site survey, develop logical and physical designs, conduct traffic analysis, perform material cost calculation, configure switches and routers, allocate IP addresses and perform network troubleshooting to get the projects working. The students are also expected to demonstrate soft skills such as good team work, initiative, resourcefulness, perseverance, ingenuity, time management skills, communication skills and critical thinking skills during the project. At the end of the project, each group of students will have to submit a project report and make a presentation to the class.

In the implementation of flipped classroom in the Network Systems Design module, we have tried to provide the key elements that facilitate flipped learning. In the concept exploration phase, we provided the opportunity for students to gain first exposure prior to class in a wide variety of format. We also provided the incentive for students to prepare for class with engaging interactive multimedia delivery. In the meaning making phase, we provided various mechanisms for the teacher and students to assess students' understanding. We also provide various learning activities for the students to clarify their understanding on various concepts and achieve deeper understanding. Lastly, in the demonstration/application phase, we provided in-class activities that focus on higher level cognitive activities.

### Student Feedback

Student survey were conducted twice; one at the beginning of the semester, another towards the end of the semester, to gauge the students' acceptance and feedback on the flipped classroom model in the teaching of the Network Systems Design module. The survey were in the form of questionnaire with four questions. Three of the questions were multiple choice questions, while another is an open-ended question.

Two of the questions asked in the survey were directly related to students' acceptance of the teaching of Network Systems Design module using flipped classroom.

The first question was "How are you feeling about the way that the module is conducted?" with four possible answers as listed below to select from.

- A. I love it.
- B. I like it most of the time.
- C. I don't like it most of the time.
- D. I hate it.

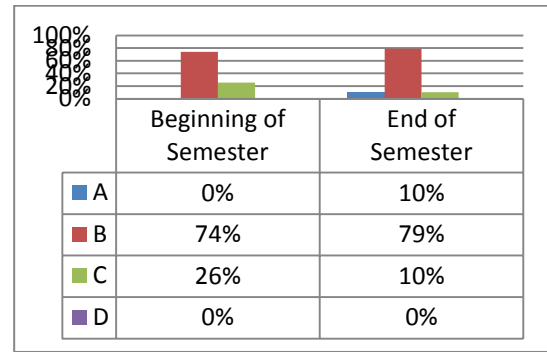


Figure 7. Student Response to the Survey Question "How are you feeling about the way that the module is conducted?"

Response at the beginning of the semester was mild. None of the student responded with either "I love it!" or "I hate it!" at both end of the extreme. Overall, more than three quarter of the students like flipped classroom teaching. At the beginning of the semester, there was one quarter of the students who were not convinced. However, the trend improved towards the end of the semester at which point only 10% of the students who still do not like the flipped classroom. 10% of the students became fully convinced and love flipped classroom.

Another question posed was "How does the method used in the module help you in learning the material?" with five possible answers as listed below to select from.

- A. Much better than traditional
- B. Better than traditional
- C. The same as traditional
- D. Worse than traditional
- E. Much worse than traditional

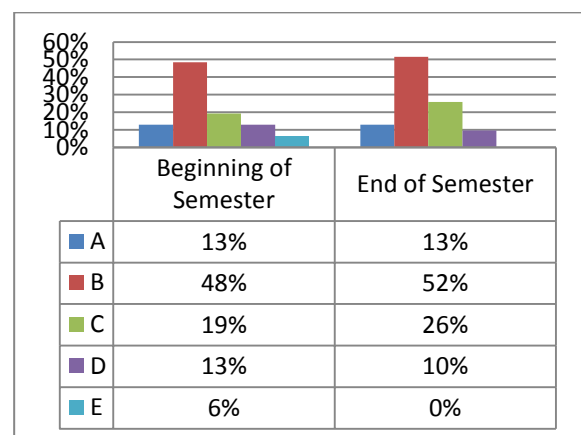


Figure 8. Student Response to Survey Question "How does the method used in the module help you in learning the material?"

Interestingly, there is not much fluctuation in the response to this question, showing only marginal improvement towards the end of the semester. More than 60% of the students feel that the flipped classroom

is better than traditional method. 20% of the students do not see any difference in how the flipped classroom could help them in their learning, 10% of the students think flipped classroom is worse than traditional lecture method of teaching.

The third question posed was “Describe your effort in the module Network Systems Design and explain.” with 6 possible answers, namely

- A. I feel like I give 100% effort every day.
- B. I feel like I try my hardest, even when I don't seem to like it.
- C. I feel like I am pretty lazy most of the time.
- D. I feel like I am lazy all the time.
- E. I feel like I really want to try, but I get so distracted by everything else around me.
- F. I feel like I really want to try, but I am so busy that it doesn't always work that way.

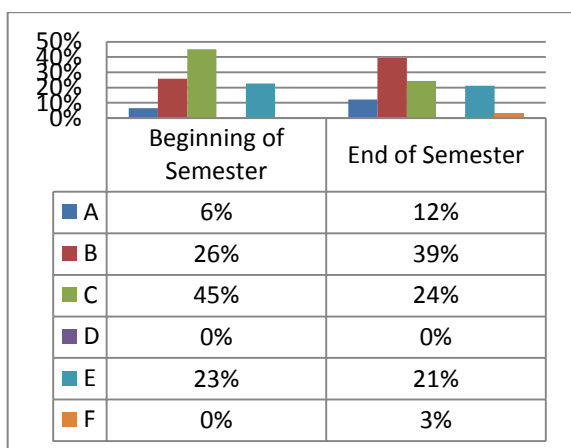


Figure 9. Student Response to Survey Question “Describe your effort in the module Network System Design and explain.”

The result shows that students were not so motivated in the beginning of the semester with 45% of them confessing that they feel lazy most of the time. The situation improved towards the end of the semester, with 50% of the students saying they are trying hard. 20% of the students said they are distracted in their study.

The last question in the survey was an open-ended question, “What could be done to make the module better?” The students who responded mentioned that the interactive multimedia content is exciting and engaging. On the other hand, there are also students who said that they prefer lecture, lecture should be conducted first and complained that the interactive multimedia content is boring. Others mentioned that more quizzes should be conducted for them to practice before the final examination.

Overall, based on the feedback, students are favourable and positive about flipped classroom. More than 75% of the students like the lesson conducted in flipped classroom and 60% of the students think that it

is better than traditional method. The motivation of the students improved after going through a semester of learning with flipped classroom.

### In Retrospect

Flipped classroom is a relatively new pedagogical method. The theoretical framework and methodology are not fully developed according to Bishop J.L & Verleger, M.A. (2013). Our implementation is self-taught based on the reading of references and Internet resources. The role of the instructor as a facilitator significantly differs from the role of lecturer and tutor in the traditional method. In addition, curriculum development for a flipped classroom module definitely is not the same as the development of module taught using traditional method. Development of course material should focus on the self-learning aspect of the flipped classroom. Formal training on flipped classroom would be useful for staff embarking of flipping the teaching of any module.

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## TEACHING WORK-READY CLOUD COMPUTING USING THE DEVOPS APPROACH

Ji Pengxiang and Peter Leong

School of Digital Media and Infocomm Technology,  
Singapore Polytechnic, Singapore

jipx@sp.edu.sg, peterleong@sp.edu.sg

### Abstract

The paper surveys the current state-of-art for cloud computing technology, and analyses the wanted skill sets that the industry needs in the area cloud computing. This identifies the gaps in the current polytechnic cloud computing curriculum. A gap analysis is presented in the paper to identify the core cloud computing knowledge and useful skills sets to help polytechnic graduates to be work-ready.

Although Cloud Computing technology had been introduced to the student in the existing polytechnic computing curriculum, to the best of our knowledge, this is the first time an approach is used to teach polytechnic students industry-sought cloud computing, hybrid skill set using a development-operations (DevOps) approach.

The key attribute identified is a set of hybrid skills for students: 1) having “problem finding skills” to find the business problems to solve, 2) propose and design information technology (IT) solutions, and 3) operationalize or deploy the solution to the cloud. The paper proposes an implementation strategy to prepare the students with the hybrid skill sets with an integrated approach. It brings students a learning experience for the salient basic knowledge and skills in the cloud computing, hands-on experience in building, configuring, managing a small-scale cloud computing platform, developing cloud applications with web service, and managing cloud security, which fills the gap for the current polytechnic computing curriculum to meet the emerging industry needs.

A detailed sample set up for the aforementioned strategy is described in the paper, where the students are given the opportunity to use the tools like virtual machine hypervisors to set up and manage a typical three tier application, with browser, web server and database server in a virtualized environment. This is followed by the activities to install open source content management software on the virtualized environment. Changes need to be made by the students in the open source software as well as operational environment to meet the new functional and/or performance requirements for the client. The

**key learning objectives could be achieved through this agile DevOps cycle.**

**Keywords:** *cloud computing, hybrid skills, authentic learning, problem finding skills, problem solving skills, operationalize, deployment, DevOps, computing curriculum*

### Introduction

Cloud computing is an orchestration of various technologies enabling, but not limited to, multi-tenancy, automated provisioning and usage accounting, the Internet and other connectivity technologies to realize the vision of computing delivered as a public utility. In the long term, IT agility enabled by cloud computing will transform the business landscape.

As the term cloud computing covers a wide swathe of technologies, we need a fine-grained characterization of what cloud computing encompasses. The National Institute for Standards and Technology (NIST) of the U.S. Department of Commerce has provided one of the earliest characterizations of cloud computing (Peter Mell & Timothy Grance, 2014). We discuss this briefly below. NIST defines cloud computing based on 5 essentials characteristics, 3 service models and 4 deployment models.

The 5 essential characteristics are listed below.

- On demand self-service: Computing capabilities are accessible to consumers on demand and can be self-provisioned without the need to interact with a human.
- Broad network access: A wide-variety of client-side platforms can be used to access computing capabilities remotely over a network.
- Resource pooling: A computing capability service provider is able to pool its resources and offer it to multiple customers, with often-times a single physical server being shared between multiple customers.
- Rapid elasticity: Computing capabilities can be scaled-up and scaled-down automatically depending on customers' need.
- Measured service: Ability to provide a pay-as-you (or) pay-for-what-you-use) model for computing capabilities much like electric utility.

The 3 service models are listed below.

- Infrastructure as a Service (IaaS): In IaaS, the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls)
- Software as a Service (SaaS): In SaaS, various applications are provided as a service instead of a standalone desktop application. The client platform should be able to access these services using standard tools such as a web browser.
- Platform as a Service (PaaS): PaaS provides layered enhancements to IaaS and provides it as a service that can be used to build software that can utilize IaaS benefits. For example, specific application development platforms such as Ruby on Rails can be configured on computing infrastructure and offered as a service.

The 4 deployment models are:

- Public Cloud: In this deployment, the underlying computing infrastructure provided by the service provider is shared by multiple clients. This is by far the most economical deployment but clearly has a number of privacy concerns from the customers' perspective.
- Private Cloud: In this deployment model, the underlying computing infrastructure provided by the service provider is not shared by different clients. Each client has exclusive access to the resources. This could be more expensive but clearly has the least privacy concerns from the customers' perspective. Note that the physical location of the computing infrastructure might be at the service provider owned facility or within customer premises.
- Community Cloud: In this deployment model, the underlying cloud infrastructure can be shared between a community of clients that share similar concerns.
- Hybrid Cloud: In this deployment model, the underlying cloud infrastructure can be deployed using more than one deployment model above.

### **Cloud Computing Skill Sets in Different Service Domains**

The IDA 2012 handbook (IDA, 2012) provides an executive summary of the nine technology themes in Singapore's Infocomm Technology Roadmap 2012 — cloud computing is one of the nine technology themes. These cloud services may be offered in the public, private or hybrid deployment model. Google, Amazon, Salesforce, and Microsoft Azure are some well-known cloud vendors (Jack M., 2013).

With the new computing paradigm, there is also a fundamental shift in the skill sets required from IT staff. HEA, 2014 reports that strong demand is anticipated for

IT staff with skills to leverage on the new cloud and advanced online platforms. Cloud computing has been introduced into the polytechnic curriculum for a few years, however the new cloud computing environment is resulting in the demand for hybrid skill sets or DevOps. DevOps is a portmanteau of developer and IT operations. The term DevOps arise out of a need for developers who traditionally only focused on creating the code to also expand their responsibilities to include getting the code to be deployed and working for the final consumers. There has been a push for coders not just to “code over the wall into IT operations”. DevOps is a software development method that stresses communication, collaboration and integration between software developers and information technology (IT) operations professionals.

The adoption of DevOps is being driven by:

- Wide availability of virtualized and cloud infrastructure from internal and external providers
- Increased usage of data center/infrastructure automation and configuration management tools
- Demand for faster, more frequent production software releases from stakeholders
- Use of agile and other development processes and methodologies

Anecdotal evidence from industry news, trade press and industry analyst suggests that this trend is already underway. “The hardware market — and the demand for people that support it — is declining rapidly. There is a strong possibility that the storage and server admins that held systems together for decades may require new skills to adapt to the cloud computing world” (David B., 2013; Ried, S. & Kisker H., 2011). David B. (2013) said that “Clients want multi-skilled people, because everything is now integrated, as every resource is service which could be managed programmatically.” “IT professionals cannot rest on their existing knowledge and must actively learn about cloud in all its dimensions” (Brett W. & David B., 2013). Gartner (2012) says the advent of the cloud for servicing individual users opens a whole new level of opportunity. Every user can now have a scalable and nearly infinite set of resources available for whatever they need to do.

Concurrently, the demand for people with Hybrid Skill Sets and DevOps skills is growing rapidly. Amazon's CTO Werner Vogels (ACM QUEUE, 2006), said in an interview that when developers take on more responsibility for operations, both technology and service to customers improve.

A list of core DevOps attributes (Aliza E, 2013):

- ability to use a wide variety of open source technologies and tools
- Ability to code and script
- Experience with systems and IT operations
- Comfort with frequent, incremental code testing and deployment
- Strong grasp of automation tools
- Data management skills
- A strong focus on business outcomes

- Comfort with collaboration, open communication and reaching across functional borders

Table 1 Service Domain Knowledge

Service User	Service Domain	Domain Knowledge
End User	<b>SaaS.</b> Operating environment agnostic. Fully functional applications e.g. email, CRM.	Cloud Applications (E.g. Google Apps, CRM, Analytics, BigData)
Application Developer	<b>PaaS.</b> Operating environment deployed e.g. J2EE, .Net. For web/mobile developers to deploy apps.	Cloud Architecture. Cloud App Development. Cloud Storage & Database.
Network Architect	<b>IaaS.</b> Virtualized platform on which environment and applications are deployed.	Virtualization and Data Centre (DC) Management
Cross Service		Cloud Security

The new working experience that would be encountered by our graduating polytechnic students has been vividly described (Jeremy S, 2013) – “They write programs to glue together these tools with APIs from other vendors like VMware, Amazon, Google, or from other software they download from the open source community. These sysadmins, who were not formally trained software engineers, picked up new programming skills and began focusing on automation as a key business driver, and as a personal asset. They use open APIs and open software. They collaborate. They innovate. They are driving the success of their business. They can (and will) become key influencers in deciding which vendor is deployed in the network.”

Table 2 Mapping of the Critical Skill Sets in Different Service Domain Knowledge

Service User	Critical Skill Sets
Application Developer (PaaS)	<b>Cloud Integration</b> A key skill as organisations deploy applications in the cloud will be the ability to use APIs to bridge or integrate data between disparate systems. Cloud customers will need to also work out automated ways of exposing data hosted in one hosted system in another.

	<b>Full Stack Developers</b> Software developers will need to program applications to be aware of the distributed architecture on which they now reside. They will need to be as aware of infrastructure issues - latency, redundancy, security - as they are of the latest development tools and platforms, have to understand “scalable applications” – both from a development and an infrastructure perspective.
Network Architect (IaaS)	<b>DevOps and the new “Infrastructure as Code” paradigm</b> The merging of Development and Operations will see more software skills required by infrastructure people.  <b>Automation</b> "The top three skills for a cloud work is automation, automation and automation ..." IT staff will need to get a handle on auto-scaling - the ability to spin up and pull down infrastructure resources on-demand. Staff will need to know what is required for the application to auto-scale smoothly. (Brett W & David B, 2013)
Cross Service (e.g. Security, QoS)	<b>Cloud Vendor Management</b> Organisations going to the cloud are going to spend more time on the contract architecture than the IT architecture. Cloud contracts require careful negotiation and constant monitoring;

This new environment provides both challenges and opportunities for our polytechnic students, as API hides the details of the service implementation (Wesley C., 2012), as traditional hardware and networking skills sets become programmable devices which could be managed, programmed, and integrated as services to meet the needs of business in an ever changing environment. These developments have given rise to the notion of “Programmable Infrastructure” or “Infrastructure as Code” (Chris Riley, 2014; Patrick Debois, 2013). Internet software companies such as Facebook are hiring “Full Stack Developers” (Laurence Gellert, 2012; Mike Loukides, 2014) who are equipped with the DevOps skills to leverage these new APIs and Programmable Infrastructure.

### Implementation Strategy for Development of Hybrid Skills

Gordon Cawelt (1990) of The Association for Supervision and Curriculum Development (ASCD) offered these principles to guide course planning.

- Offer a balanced core of learning in each course.

- Adopt the belief that in-depth study of a limited number of important topics will have a more lasting effect than a course that tries to cover too many disconnected bits and pieces of information.
- Design course outcomes to focus on results, with multiple indicators (assessments) of performance.
- Design authentic assessments that will encourage originality, insightfulness, and problem-solving, along with master of important information.
- Design courses to encourage active involvement.
- Get students "doing" early in the course rather than studying all the principles and basics prior to performing.

Our polytechnic cloud computing module introduces the fundamentals of virtualization, and provides hands-on experience in creating and managing virtual machines, configuring connectivity and application services. Hands-on sessions also provide the students opportunities to deploy and configure an open source appliance service on the established cloud platform. The module will conclude with the issues such as performance, availability, scalability, reliability, security for the application service running on the virtualized platform. It gives the students the skills required to design, code, test, and integrate services based on cloud platform and web platform.

The Activity-based approach may get students to be actively involved in the learning experience (Gordon Cawelt, 1990), especially for the Year one students. Activities starts with creating and configuring virtual machines for different client and server platforms, followed by deploying the open source Content Management System (CMS) appliance to the virtual machines. The approach gives the students' opportunity to have a real working environment combining the virtual platform as well as the applications running on the platform, and get students "doing" early in the course rather than studying all the principles and basics prior to performing (Gordon Cawelt, 1990).

It also addresses the hybrid skill set of operation of infrastructure and development perspective. The deployed applications will be used by students to post their reflection journal. This brings the developers, operators closer to the end user's experience (ACM QUEUE, 2006), which help students to address the real life challenges, such as performance, availability, scalability, reliability, security for the application service running on the virtualized platform, and learning more in the more challenging activities and group assignment.

Virtualization technology is a key enabler of cloud computing technology. In particular, rapid elasticity would be infeasible without virtualization. The goal of these modules is to introduce virtualization to students using standard tools available such as Xen, KVM or VirtualBox. VirtualBox is a powerful x86 and AMD64/Intel64 virtualization product for enterprise as well as home use. Not only is VirtualBox an extremely feature rich, high performance product for enterprise customers, it is also the only professional solution that is freely available as an Open Source Software under the

terms of the GNU General Public License (GPL) version 2 (Oracle VirtualBox, 2013).

We setup a lab environment by using open-source products such as OpenStack (OpenStack, 2013) CloudStack (CloudStack, 2014), OpenNebula (OpenNebula, 2014), Eucalyptus (Eucalyptus, 2013), and oVirt (oVirt, 2014). Eucalyptus is an open source private cloud software for building private and hybrid clouds that are compatible with AWS APIs. With AWS-compatibility, the open source software pools together existing virtualized infrastructure to create private or hybrid cloud resources for computing, networking, and storage. The lab setting provides an opportunity to explore SaaS for big data in the future.

### Detailed Example of Setup for the Implementation Strategy

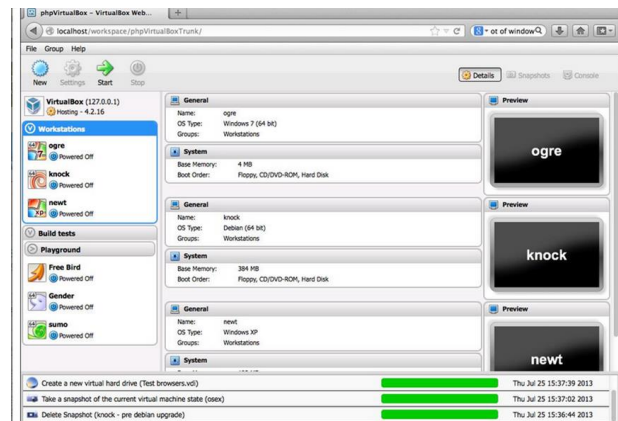


Figure 1 Virtual Box VMs to emulate multiple hosts and servers

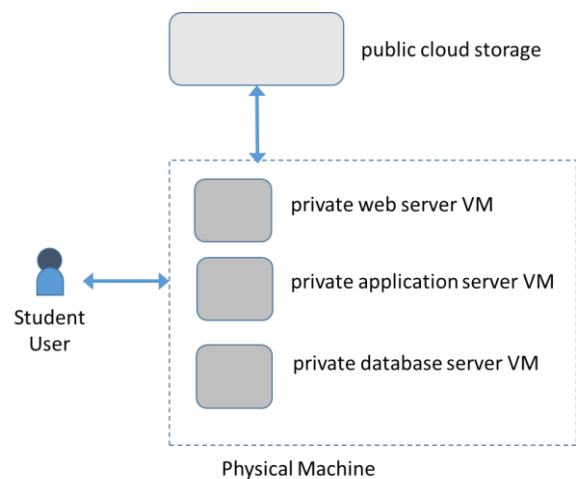


Figure 2 Virtual Box VMs to emulate servers and public cloud storage

Figure 1 and Figure 2 illustrate the use of multiple virtual machines (VM) to implement the virtualized environments for our students to practice their hybrid skill. The main hypervisor we are using is Virtual Box (Oracle VirtualBox, 2013). The VMs are setup to

emulate the “Full Stack” developer’s environment of having a web server, application server and database server.

Public cloud services such as Amazon Web Services (AWS) require the students to register and also verify their accounts with a 16-digit credit card number. This posed issues for our students as many of them do not possess a credit card number. In the end, we decided to use Google Drive, Dropbox or other cloud storage providers that have a free account available for the students.

## Results and Discussion

The current cloud computing module has evolved from traditional client server computing, to Service Oriented Architecture using XML and Web service technologies. SaaS, PaaS, and IaaS has been introduced to cover the basic introduction to cloud computing, with greater focus on developing cloud applications on Microsoft Azure platform.

The strong foundation, for the cloud computing module, in Service Oriented Architecture (SOA) and Web services has been well aligned with the industry. Behind Amazon’s successful evolution from retailer to technology platform is its SOA, which broke new technological ground and proved that SOAs can deliver on their promises. As users visit the home page from Amazon.com's gateway, 100 services has been invoked from the backend to collect data and construct for you (ACM QUEUE, 2006). Joe M. (2011) describes the situation in the following words – “The bottom line is without SOA, it’s very difficult to get to cloud. Beyond the IT stack there is a challenge on which many organizations haven’t yet focused: rethink its business as a collection of services, and ‘services thinking’ approach to business problems.”. As the cloud is inherently service-oriented, it is a right move to accommodate and integrate cloud computing in the module with the focus in PaaS.

Our ultimate goal is to create an end-to-end toolchain that would facilitate automation of the entire DevOps workflow. To facilitate practice with infrastructure automation, we can use the Salt Stack (Salt Stack, 2014). This an open source Infrastructure automation and management system ( <https://github.com/saltstack/salt>). An alternative tool for infrastructure automation is Ansible (Ansible, 2014). Standardized container APIs for application development environment also makes it easier to develop and deploy applications rapidly. The Vagrant development environment (Vagrant, 2014) and Docker container environment (Docker, 2014) can be used for application development and deployment virtualization environments.

Docker is an open-source project that automates the deployment of applications inside software containers. Docker extends a common container format called Linux Containers (LXC), with a high-level API providing lightweight virtualization that runs processes in isolation. Docker can be integrated into various

infrastructure tools, including Vagrant, Salt Stack and Ansible. Vagrant is an open-source software for creating and configuring virtual development environments. It can be considered a wrapper around virtualization software such as VirtualBox.

Microsoft Windows is the main host operating students used by the students; thus, we need to configure our setup to run on Windows. The Docker Engine uses Linux-specific kernel features, so to run it on Windows we need to use a lightweight virtual machine (VM). The Docker for Windows Installer, when it is executed, will install VirtualBox, MSYS-git, the boot2docker Linux ISO, and the Boot2Docker management tool. boot2docker (Boot2Docker, 2014) is a lightweight Linux distribution made specifically to run Docker containers. It runs completely from RAM, weighs about 27MB and boots within 5s.

## Conclusions

The core knowledge and hybrid skill sets for cloud computing can be incorporated in a traditional polytechnic cloud computing curriculum and get students ready for the industry. With Activity based approach, the students are equipped with the skills to learn by themselves and solve problem by themselves. It is especially critical for Information Technology students to catch up the new technology where the cloud computing technology landscapes are changing rapidly.

Future works includes experimentation on how the following could be introduced in the future curriculum:

- Laboratory setup with Cloud Architecture and Security
- Service Patterns for Cloud Computing
- Introduction of new the modules to other diploma course.
- Incorporating these modules to part-time course, such as Specialist Diploma in Mobile Applications Development.

## Acknowledgements

We wish to acknowledge the support of the School of DMIT, Singapore Polytechnic management team for the research work.

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## FLIPPING A CAD CLASSROOM

NG GEOK LING

School of Architecture & the Built Environment, Singapore Polytechnic, Singapore

Email: ngl@sp.edu.sg

### Abstract

“Teach less Learn more”, a phrase when introduced to many will focus on the words “Teach less” and take it to mean simply less teaching. Those who are in the teaching profession will know “Teach less Learn more” does not literally mean less teaching to learn more as advocated in Ministry of Education (MOE) Singapore website, is about teaching better, to engage our learners and prepare them for life, rather than teaching more, for tests and examinations. To accomplish better teaching, active learning strategies in the classroom are used to support an impactful activity to be done in the classroom facilitated by the lecturer. These impactful activities are designed to involve the use of ‘constructivist’ teaching methods to create deep learning. This is discussed in, “Evidence-Based Teaching – A Practical Approach”, Geoff Petty. (2009).

Often a change in teaching strategies (e.g. impactful activities incorporated) does not necessarily result in an increase in curriculum hours. Lecturers after focusing on delivering the basic content knowledge would find no extra time in the classroom to include these impactful activities. Project work and assignment, which can be impactful to students’ learning, were usually planned for students to do outside the classroom time.

Flipped classroom, a pedagogical model that changes the typical way of how students learn has the lecture and homework components of a module swapped so that class time with the lecturer is used for impactful activities with the students. This has the right structure to overcome the problem of insufficient time in the classroom for impactful activities.

This paper looks into the practical reasons on why CAD classroom is the most suitable to flip, its benefits and eventually a good way to nurture good habit into students that will lead to excellence in learning new knowledge in CAD. The paper then describes the tools and approaches used in flipping a CAD classroom. It also identified the challenges faced by students and lecturers and discusses the initial solution and an improved solution in the

**implementation. Feedback from students on this approach has been very positive.**

**Keywords:** *Flipped, classroom, CAD, habit, active, learning*

### Introduction

“Teach less Learn more”, a phrase often misinterprets to mean simply less teaching or less hours of teaching. Those who are in the teaching profession will know “Teach less Learn more” does not literally mean less teaching to learn more as advocated in Ministry of Education (MOE) Singapore website, is about teaching better, to engage our learners and prepare them for life, rather than teaching more, for tests and examinations.

To accomplish better teaching, active learning strategies are infused into the teaching and learning for better students’ engagement and achievement. Active learning supports deep approach to learning, which means that learners intend to understand the concepts instead of simply reproducing the information on an exam. This is discussed in, “Rethinking Engineering Education – The CDIO Approach”, Crawley et al. (2007). Thus teach less is definitely not a reduction in curriculum hours or content, rather curriculum hours may increase in order to teach better with activities to engage our learners directly in thinking and problem solving. However, in reality curriculum hours often do not increase with changing teaching strategies or delivery methods. These engaging activities needs extra class time and may indirectly cause a cut in curriculum hours to deliver content knowledge. The best strategy to overcome this problem is to flip the classroom by letting the students learn the basic knowledge content at home and then add the detail later by facilitating the engaging activities in the classroom.

### The Challenge

The conventional way of teaching CAD comprises a series of step-by-step demonstration of the tool and independent lectures and tutorials on visualization (i.e. orthographic projections and isometric drawing) and reading of symbols (blueprint reading) and views on a

2-dimensional drawing. Tutorials on orthographic projections and isometric drawings are usually in the form of sketches. Tutorials on reading blueprints are usually in the form of questionnaire. Assignments and projects are set as homework for students to tell us their integrated application knowledge.

Teaching CAD has becoming more challenging with the new paradigm in the world of CAD – BIM (Building information Model) and the integration of more applied context. The applied context offers to shift the focus of instruction to encouraging strategic and motivated students to sustain students' interest in learning. A quick overview of exhibitions and conferences shows an enormous advancement in software in the world of CAD. CAD software changes frequently at almost yearly to improve the efficiency of drafting process in the construction industry. To provide graduates to meet the industry needs has thus becoming even more challenging.

### The Flipped Classroom

One of the ways to meet these challenges is to assimilate (incorporate into one's thinking) the underlying concepts of the tools. Consequently, the emphasis in training is on understanding through concepts, analysis and design rather than concentrating on the operation of the application. Another way is to build a structure such as high order of learning activities, to connect the knowledge concepts and CAD tool so that students can easily grasp it, also supported by Bruner (1965) that such activity and strategies have a significant impact on education and on the understanding of the learning process. Active learning also helps to facilitate the application of knowledge to new problem or task as Crawley et al. (2007) make this distinction. However, when time is allowed for such high order of learning activities, there is less time to deliver the details. Often delivering of the content will be cut to the bare minimum. In order not to compromise the delivering of the content, flipped classroom has just the right structure to replace the step-by-step demonstration delivery method, which is a weak constructivist teaching method as advocated by Geoff Petty (2009). This new way of classroom would force students to build up a habit of independent learning in picking up steps in operating the tool and offers time in the classroom for higher order of learning activities.

Flipped classroom as described in EDUCAUSE, a non-profit membership association created to support those who lead, manage, and use information technology to benefit higher education, is a change in the typical way of how students learn. It is a pedagogical model in which the lecture and homework components of a module are swapped. In another words, students learn and comprehend independently on the knowledge through video lectures before the lesson time, while tutorials, projects or discussion are carried

out in the classroom with the lecturer. Lecturer can now implement their engaging activities without compromising the content knowledge.

Figure 1 show the lecturer spending time in the class focusing on the higher order thinking skills rather than spending time in the classroom focusing in the basement of the taxonomy on rote and basic teaching. This change will put more of the responsibility of learning on the students and giving them more opportunity to inquire about lecture content, learning their skills in applying knowledge and interact with their peers in the classroom. For the better students who can help their peers, get an opportunity to see new problems and searching for new solutions, encouraging them to reassess their own understandings without a lecturer actually 'telling' them. Lecturers now function as facilitators, bringing students into the higher order of learning in the Bloom's taxonomy by challenging their basic knowledge in CAD tools learned before the lesson so as to encourage them to 'reach' for deeper level of understanding in using the tools on the same or new problem

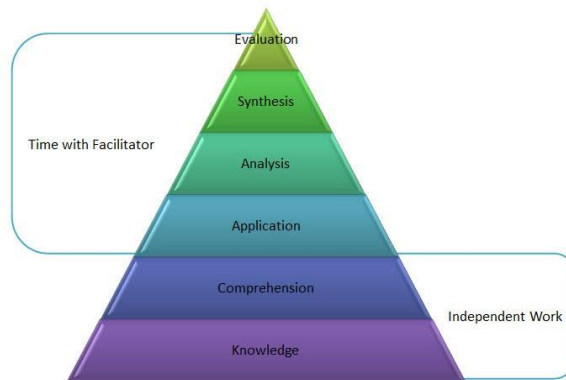


Figure 1. The Flipped Classroom Bloom's (extracted from Leighanne's learning notes)

### Learning CAD

Figure 2 shows part of the integrated training pyramid for a first year module in Diploma in Civil Engineering, CAD with BIM, in the School of Architecture and the Built Environment.

Starting with a two-dimensional (2D) and three-dimensional (3D) base of CAD knowledge upon which the visualization and blueprint reading and skills build upon.

To engage students in learning visualization and blueprints reading skills with CAD, a series of active learning strategies were used in the classroom to motivate students. When students are motivated, they need little push to accomplish a task and learning will become self-directed. This will also help sustain their interest in learning as they advance through the course.

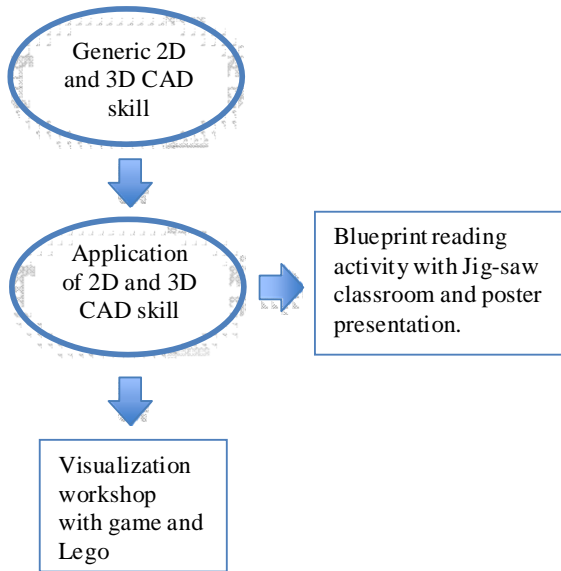


Figure 2: Integrated teaching plan for CAD module

The challenging reasoning task of applying the 3D CAD skill to model the blueprint into a 3D digital model which is used to be set as a homework assignment or as a Mini Project is now possible to be set in the classroom with Flipped classroom as shown in Figure 3.

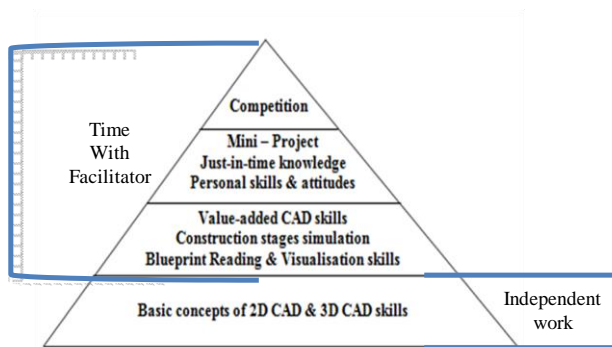


Figure 3: Integrated teaching plan for Blueprints Reading in a Flipped Classroom

The step-by-step demonstration of CAD skills is set as homework for students to go through before the lesson. Thus there is now time in the classroom for application skills learning such as advanced tutorial, assignment or project. To ensure that students watch and learn from the video, a short readiness test is conducted in the classroom.

## Flipped Classroom Tool and Approach

### Pre-recorded lecture & Sampling

Video lectures were sourced and selected from YouTube to match the lecture delivery. A sample group of 39 students (Two Year 1 DCEB lecture and practical session, each class size of about 19-20 students) was used for this research project. Using the flipped classroom pedagogy model, CAD lecture, which consist of step-by-step demonstration of CAD tools operation, is swapped with project work (usually a completed real-life building). A readiness test was conducted to test if students have watched the video lecture.

### 1<sup>st</sup> Attempt Method

Flipped classroom was implemented over a period of a term with video lecture uploaded in BB for students to watch and learn before the lesson. This was implemented after students have undergone 2 terms of conventional classroom.

- Pre-Flipped week: students were informed to watch and learn from the video lecture in BB. They were briefed on the purpose of flipping the classroom. It is important that students see why they are learning in this way. Geoff Petty (2009) discussed this point in his book as one of the seven principles common to high-quality learning and achievement.
- 1<sup>st</sup> flipped week: video lecture focus on basic drawing skills. Readiness test was conducted to check on students' skill as a class. Content of the tests was based on the video watched. Students that did not pass the readiness test were to watch and learn from the video again in class while the rest work on their tutorial.
- 2<sup>nd</sup> flipped week: video lecture still focus on more basic drawing skills. 2<sup>nd</sup> readiness test was conducted. More students were expected to pass and project work/tutorial were given to student to work in class.
- The rest of the flipped weeks : once project work has started, video lecture focus on value-added skill or tricks and tips or applied specific skill related to the project work.

### 2<sup>nd</sup> Attempt - Improved Method

The revised method has the following changes:

- Flipped classroom was implemented right at the start of the course in year 1 over a period of a term with video lecture uploaded in BB for students to watch and learn before the lesson. This revision offers no option for students to choose.

- 1% weightage is awarded to those who has watched the video before coming to class. Students were expected to contact lecturer (through email or any social media) when they encountered problem with the video content.
- Students that did not pass the readiness test were awarded 0% for that week and were expected to pick up the skills from peers during the tutorial session.
- Extended hours of tutorials each week after the readiness test provide students an opportunity to learn more in the classroom with the lecturer.

## Results and Discussion

### Students' Feedback

A survey was conducted at the end of the term to gauge the likes, dislikes and relevancy of flipped classroom from the students who have experienced the flipped classroom. They were asked to respond to questionnaires with ratings of 1(poor) to 5(excellent). Following two areas were surveyed to rate flipped classroom in:

- using the in-class time to help students' learning in the classroom / do homework or tutorial in the classroom
- shaping students to be an independent and responsible learner

Thirty-six out of thirty-nine responded in 1<sup>st</sup> attempt and thirty-seven out of thirty-nine responded in the 2<sup>nd</sup> attempt. Responses were summarized and shown in the pie chart in Figure 5 and 6. In the 1<sup>st</sup> attempt, 86% of the students rated using the in-class time for their learning in the classroom as good. 78% of the students rated flipped classroom as a good way in shaping them to be a more independent and responsible learner. In the 2<sup>nd</sup> attempt with the improved method, 90% of the students rated using the in-class time for their learning in the classroom as good. 84% of the students rated flipped classroom as a good way in shaping them to be a more independent and responsible learner.

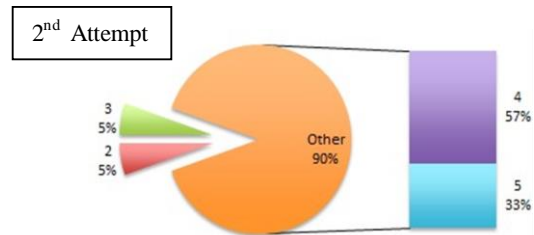
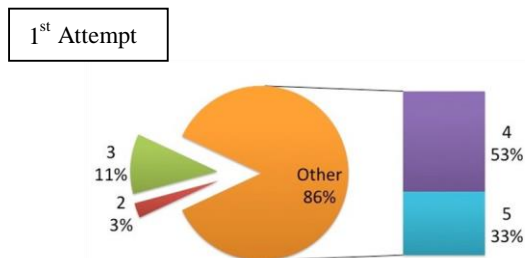


Figure 5: Rating for using in-class time to help student's learning in the classroom

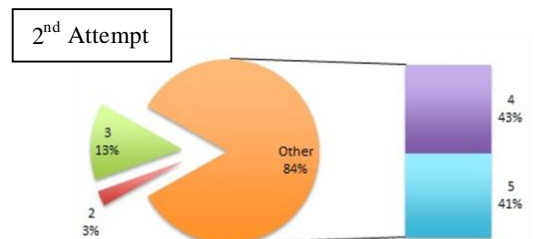
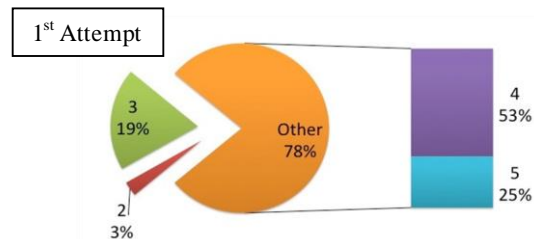


Figure 6: Rating for Shaping Student to be an Independent and Responsible Learner

The 1st attempt ratings indicated that students recognized that they have benefited from flipping the classroom in their learning and in nurturing them to be an independent and responsible learner. The 2nd attempt ratings indicated more students recognized the benefits from flipped classroom.

The open-ended questionnaires (Q2, Q3) focus on the likes and dislikes. Their responses were summarized and listed below:

One thing that they like most about flipped classroom were:

- More 1-1 lecturer's time with them to learn more
- Able to repeat watching of video lecture
- Able to adjust own learning pace and learn more independently
- Opportunity to practice in class and corrected on the spot
- Receiving help in doing real-life project work
- Sense of achievement for learning more
- Able to continue learning at home and clear doubts in class
- More time in class to solve more complicated problem

One thing that they don't like about flipped classroom were:

- Video lecture cannot respond to their queries
- Don't like video lecture; prefer traditional class teaching
- Video lecture too long; low video quality
- Difficult to find and download the video lecture
- Have doubts and do not understand the video lecture.

## **Discussion**

The greatest challenge in teaching CAD in a flipped classroom is when students came to classroom without watching the video lecture. These are students who do not like unfamiliar learning styles or learning style that needed effort and responsibilities. Professor Frank Coffield and others (2004) conducted a very extensive research on learning styles has advised that it is important to encourage students to use unfamiliar styles, even if they do not like them at first and teach them how to use these.

One strategy, in the 1st attempt, is to make them watch the video lecture at one corner while the others carried on with the high order-thinking task with the lecturer. Lecturer has to be firm not to give any teaching to those who did not do their task at home. As a result, lecturer may get bad feedback for not teaching in the class. Lecturer also has to be cautious in identifying weak students who have done their task at home but still could not grasp the basic content knowledge demonstrated in the video lecture. Giving them a readiness test as described in the flipped classroom method above, would be a good way to identify such students and to give proper help to clear their misconception.

Another strategy, which is implemented in the 2nd attempt, is to award students a small percentage of marks for their learning at home verified by a readiness test in the class. However, there are still some students who just don't like changes. For this reason, it is therefore good to integrate flipped classroom approach right from the start of the course to build up their habit of independent learning which would lead them to excellent in life long learning. This has been found to concur with two of the six principles that foster strong academic growth while focusing on character building in "An Integrated Approach to Character Education", edited by Timothy Rusnak (1998).

In both strategies, the readiness test is important. This test offers lecturer to find out what the students already know (learn from the video or other means including students' prior knowledge) and their misconceptions.

## **Conclusions**

Flipping a classroom depend extensively on the video lectures. This resource preparation task required much time investment from lecturers. CAD video lecture which is easily available on Youtube, usually uploaded free by CAD software vendor, thus is a good resource centre for lecturers to get started with flipped classroom. Once they have experienced the benefits from flipped classroom, time can then be invested to improve or add on more applied related video lecture.

Adopting the flipped classroom approach has not only overcome the problem of insufficient time for higher order thinking task in the class but has at the same time become an approach to nurture students to become an independent learner. A quote by Aristotle, "We are what we repeatedly do. Excellence, therefore, is not a skill but a habit". Flipped Classroom is therefore not only a skill but also a good habit to instill in our students that will lead to excellent. It is thus believed that if students are repeatedly trained in this approach will lead them to be an excellent independent learner.

The pedagogy change in a flipped classroom is thus allowing higher order thinking task to be done in the classroom and character building. In summary, besides the known benefit of flipped classroom, it is:

- 1) A way to provide an excellent environment to nurture independent and responsible learners.
- 2) A springboard to prepare students and lecturers for home-based learning.
- 3) A good habit to be repeated in students for excellence in life-long learning.

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## ENGINEERING INVENTIONS: DESIGN OF A PROJECT BASED INTEGRATED COURSE

M. Fikret Ercan <sup>\*,a</sup> and David Tan Soon Ling<sup>b</sup>

<sup>a</sup> Singapore Polytechnic, School of Electrical and Electronic Engineering, Singapore

<sup>b</sup> Singapore Polytechnic, School of Mechanical and Aeronautical Engineering, Singapore

\*mfercan@sp.edu.sg

### Abstract

In engineering education integrative methods helps students to establish link between various engineering topics as well as make them discover the relevance of the material being taught. This approach also provides many avenues for experimentation, as well as practicing engineering design and application. Consequently, learning becomes more experiential which enables students to comprehend, retain and apply the knowledge better.

In this paper, we present an integrated project based module namely “Engineering inventions” which is offered as an enrichment course to second year electrical and mechanical engineering students at diploma level. This course is primarily designed to help students in establishing the link between math, science and different disciplines of engineering by using the history of Asian engineering as a theme to connect them. Learning takes place in a studio environment and it’s conducted by a team of faculty from four different departments. As a project, students design and build engineering artefacts by taking inspirations from the history of Asian engineering and inventions. During the implementation, teaching team also use the same subject for practical examples and activities to explain some of the engineering principles. In addition to our pedagogical objectives, we hope to inculcate research skills in our students as well as widen their horizon. We believe it is important for our students’ to acquire knowledge from fields other than engineering to broaden their view. Therefore, students are expected to do an in depth analysis and demonstrate a good understanding of the needs resulted in these inventions and their impacts in various areas such as society, economy, agriculture, military, and so on.

This paper will present the development and application of this integrated course together with our preliminary evaluation results and observations.

**Keywords:** *Integrated curriculum, project based learning, curriculum design, student motivation.*

### Introduction

The skills required from engineers, working in today’s industrial environment, are a lot more demanding. A significant attribute is being able to integrate various disciplines since every engineering field is now highly dependent on other disciplines such as biology, medicine, physics, chemistry, design, business, and so on. Students need to be familiar with other disciplines in addition to their core discipline of study. Therefore, there is an increasing emphasis on developing integrated curriculum that aims to build links between disciplines which are traditionally distinct. There are many initiatives reported earlier in the literature for developing integrated curriculum. For instance, McCowan (2002-a) and McCowan (2002-b) show developing an integrated curriculum where students can develop effective communication skills, the ability to perform well in teams, managerial skills, lifelong learning skills, in addition to a good understanding of engineering theory and practice. Linder et al. (2001) and Froyd et al. (2005) discuss the need for integrating engineering, science and various other disciplines in the engineering curriculum extensively. Ford and Riley (2003) demonstrated integrating communication across engineering programs as this is one of the shortcoming of conventional engineering courses. In summary, integration plays an important role in engineering education.

Another major challenge for engineering graduates is the greater expectation of innovation and creativity from them. With fast prototyping and manufacturing tools, such as 3D printing, becoming available, future of engineering and manufacturing is highly dynamic and innovative. Consequently, it is important to inculcate a culture of innovation and making in our students. Traditionally, engineering education is mainly concerned with engineering science. The curriculum is heavily based on math and science leaving little room for developing hands-on and practical skills. There are many initiatives to overcome this shortcoming such as capstone projects (Dutson et al (1997)), project based learning (Du et al. (2009)), CDIO initiative (Crawley et

al. (2014)) and introducing design principles into engineering (Dym et al (2005)).

Considering current trend and expectation of real world environment from engineering graduates, it is necessary to rethink engineering education. In our institution, we now intend to enhance not only the technical skills of our students but also other key attributes in order to prepare them for the challenges ahead. Based on our observations and experience, we have identified four key areas that we need to strengthen. They are autonomy, integration, hands-on skills, teamwork and communication skills.

An autonomy supporting curriculum provides plenty of opportunity for student to make decision and determine their learning. This, in turn, encourages better engagement, personal satisfaction and intrinsic motivation (Iyengar (1999)).

As mentioned earlier, integration is one of the key elements in our curricular change with the intention that our graduates will have a better understanding of engineering and how it is interlinked with other disciplines.

The industry demands engineers with hands on skills who can fit into work force rapidly. Hence, by involving our students into project work and be familiar with various prototyping tools and devices from the very beginning of their study, we try to give an understanding of what engineers do and inculcate a culture of making.

Finally, we would like to develop team work and communication skills of our students since modern engineers need to use all means of communication effectively and be a team player.

Considering all these factors discussed above, the most practical way to implement our pedagogical objectives was to design an integrated and project based enrichment course. The course is offered to second year electrical and mechanical engineering students who already have some engineering fundamentals and some hands on experience through introduction to engineering (or similar) courses. As the name of the course suggest, history of Asian engineering is used as a means to establish the link between various disciplines. Learning takes place in a studio environment and conducted by a team of faculty from four different departments. As a project, students design and build engineering artefacts by taking inspirations from the history of Asian engineering and inventions. Students work as a team and experience plenty of communication opportunities.

### **Details of the course**

As mentioned above, the theme Asian engineering inventions are used as a medium to integrate the four disciplines namely Mechanical, Electrical and Electronics, Engineering Mathematics and Chemical Engineering. Teaching team also use this theme for designing learning activities and to explain some of the engineering principles. This theme also enable us to inculcate research skills in our students as they have to do an in depth analysis of the invention they pick and

understand the needs resulted in these inventions, their impact in society, economy, culture, and so on. This enabled students to correlate how engineering principles contributed to the advancement of civilizations. By doing so, we hope to achieve an appreciation of engineering, broaden students view, create awareness on the impact of engineering, stimulate lively discussions, instigate a research need that will lead students to crave for knowledge that is available beyond their text book.

*Content:* During the 15 weeks, students are introduced to various engineering topics which are carefully chosen from four disciplines and presented with plenty of examples from engineering history. Moreover, the chosen topics not only demonstrate integration of various disciplines but also beneficial to students in their project work. The topics are thought employing active learning approach that engaged the students, improve their practical skills and provide a deep impact to their learning experience. Through the activities, students are able to correlate the fundamentals to design optimizations and applications.

Mechanical Engineering introduces systematic approach in engineering design, gears, spring, lever, cam and force analysis. Systematic approach in engineering design covers topics such as Function Analysis and Morphological chart that guides the student to analyse complex systems and generate alternative concepts. Students learn about mechanical advantage of using gears, design cams based on desired actuations, calculate lever force and spring load. In one of the activities, students are required to build a simple crossbow to calculate the trigger force mechanism. They are required to conduct experiment to obtain coefficient of friction and solved the calculations using law of lever.

Electrical Engineering introduces sensors and electro-mechanical actuators. Students build a temperature sensor circuit, analyze the function of the components, and perform calibration. Students also learn the basic principles of actuators and the physical laws that cause the electro-mechanical motion. Students construct control circuits for DC and Servo motors and program the motions. Students employ their electrical engineering knowledge in their project in various ways. For instance, they use actuators to simulate a motion source and sensors for experiments and data collection.

In Engineering Mathematics, students are thought about vector and linear regression. For instance, using vectors, students are able to determine the collision path of two moving objects which is the basic principle of the projectile weapons used in hunting or military in the ancient time.

Chemical Engineering introduces chemical reactions and biofuel concepts. In chemical reaction, students perform experiments to determine the impact of the reaction with different concentration and mass of the starting material. The activity uses common household chemical such as vinegar and baking soda. In biofuel, students create bioethanol fuel of different organic material using fermentation process. They evaluate the



quality of the fuel through measurement of the energy density.

**Schedule:** Engineering Inventions is delivered in four hours lesson every week. All the lessons are scheduled to complete within the first three quarters of the semester and the last quarter is solely reserved for the students to troubleshoot and complete the project. Students are required to submit the concepts generated from the morphological chart by the 5th week. First project review is set on the mid-semester to review the progress of the projects, experiment results, mechanisms prototype and calculations. The last week of the semester is the final presentation and demonstration of the project. During the lessons, the students are posted with questions to set them thinking on how to use the engineering topics they have learned from the lessons to apply on their project.

**Examples activities:** A fundamental component of the class activity is to choose examples form engineering inventions that can not only engage our students, but also enable lecturers to impart necessary technical knowledge.

**Case 1: A crossbow-trigger mechanism.**

In this example, we use a crossbow as one of the class activity where students build a crossbow, analyze and calculate the triggering force. A crossbow, in particular repeating crossbow, provided significant advantage during ancient wars. This subject easily grabs student's attention since they are able to see engineering in action. By completing the activity, the students learn and apply the engineering fundamentals such as Hooke's law, Lever law and Coefficient of friction in the analysis of crossbow trigger mechanism.

The activity uses scaffolding technique to guide the students to learn and research about the above mentioned engineering fundamentals. Some of the activities use jig saw approach to split the task to smaller subgroups. Jig saw technique could help to reduce the time to fit within the four hours and increases the engagement of the students within each groups.

The activity starts by researching different crossbow triggering mechanisms. Students are required to gather the information on two different triggering mechanisms, identify the parts and functions of the mechanism. They sketch and describe the parts and mechanisms functions.

In the second phase of the activity, each group is divided into two subgroups where one subgroup research on the topic related to spring (Hooks' Law) while the other group research on the topics related to Lever Law and coefficient of friction. The research is guided with a series of questions that consists of basic definitions, formula and experiment methodology. To validate their understanding, the students are required to conduct a simple experiment to obtain the spring constant of an elastic object and the coefficient of friction between two surfaces. The values obtained through the experiment are required in the final activity.

In the third phase, students calculate the trigger force of a given mechanism. Figure 1 shows students' working the trigger mechanism problem. Solution requires a collective effort and a sharing of research

findings from both subgroups. To complete third phase, students need to share their knowledge from the jig saw learning made in the second phase.

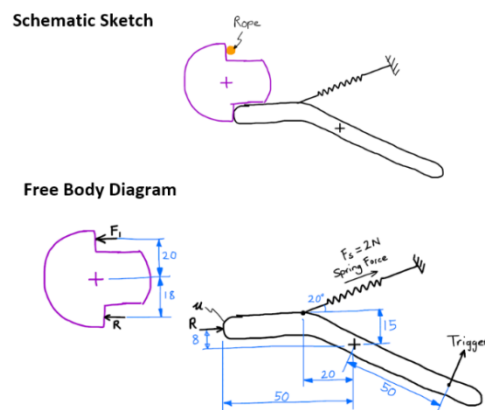


Figure 1: Example of students' working on the trigger mechanism.

The final stage of the activity is the application of knowledge. Students are provided with necessary materials to build a simple crossbow and are required to calculate the trigger mechanisms based on their prototype. They are required to use the experimental data obtained in the second phase and the calculation methods in the third phase to deliver the solution required in their own prototype. Figure 2 shows a crossbow build by students at the end of the activity.



Figure 2: Sample prototype of a crossbow and triggering mechanism.

The example activity described above is designed to infuse engineering knowledge while guiding students to their final project. The activity naturally embraces research, analysis and experimentation elements. It also engages the students with active discussions, problem solving while constructing their own prototype.

**Case 2: Mechanical hoisting device.**

This is another example activity which exposes students to the concept of gears. Gears can be used in many applications that require the control of relative speed and provide mechanical advantage. There are plenty of examples from ancient Asian engineering that can be representative of the topic. For instance, Zhang Heng (AD78-139), a Chinese inventor, well-versed in the fields of mechanics and gears, used gearwheels in water-powered armillary sphere to represent astronomical observations. Other examples of successful application of gears in the past include South

pointing chariot, odometers and water mills (Needham (1954)).

Spawning from these examples, a lesson is taught to the students on the application of gears to reduce the effort in mechanical hoisting devices. In the first half of the four hours lesson, the students are taught about the fundamentals of gears, calculation of gear ratio for simple and compound gear arrangements. On the second half of the lesson, they are required to complete an activity to build a hoisting device using gears provided. As shown in Figure 3, the design requirements of the hoisting device are provided together with a series of guided questions to solve the problem.

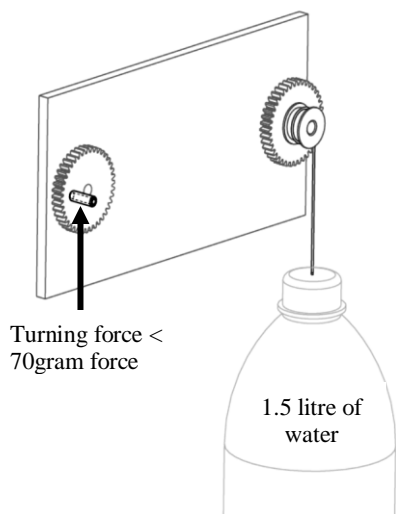


Figure 3: Schematic sketch of the hoisting requirements

The activity will require students to calculate the desired gear ratio based on the given requirements. Subsequently, they need to determine the combination of the gears to achieve the desired ratio. Plenty of gears provided for this activity so that it will result in few possible solutions. Finally, the students are required to construct the prototype in the same arrangement as their layout and calculations. Figure 4 shows one of the prototypes built by students. By constructing a prototype, students validate their solutions. Additional questions are posted to the students to reflect the quality of the construction and possible improvements in their prototype.



Figure 4: Student's solution to mechanical hoisting problem.

*The Project:* Students working in groups are required to develop a project based on an ancient engineering artefact that inspired them. The project can be developed in various ways. It can be a rebuilding (or scaled model) of the invention, a modern version of the invention using current technology, or a computer simulation where students are able to demonstrate their understanding of the subject, analytical and thought process. The students, formed in groups of 4 to 5 members, are given the autonomy to choose project topic and submit at least three proposals. The lecturers assist the students in finalizing their project selection by evaluating the feasibility and complexity of the all the proposals, primarily considering the allocated time frame for this course.

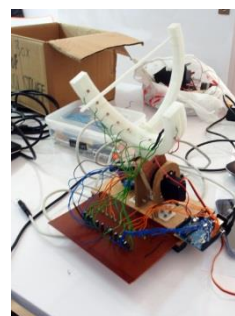
In the mid-semester, a progress review is conducted with each group to evaluate the design of low resolution prototypes, experiments and mathematical analysis. Using low resolution prototypes, students are able to demonstrate the key function of the project and increase their confidence and success rate in completing the project. During realization of the project, student use modern fabrication and prototyping tools such as 3D printers and laser cutters. Figure 5 shows some example student projects.



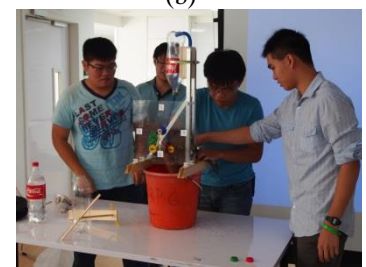
(a)



(b)



(c)



(d)

Figure 5. Example student projects (a) Chinese repeating cross bow (b) Crescograph with electronic plotting mechanism (c) an Indian sun-dial with LED indicators to illustrate time (d) Chinese water clock.

*Assessment:* During the course of this module students are assessed for various components. These assessment components can be broadly categorized as individual and team work. The final grade of a student is determined by 60 per cent of his/her individual work and 40 per cent of his/her teamwork. There are two

formative (mainly for the purposes of improvement) component during the term and a summative component at the end of the project. There are four main areas that students are assessed. They are the research process, quizzes and assignments, presentations, and final project work. Individual contributions to the team are assessed via research process as well as peer assessment. For assessing teamwork, students need to produce tangible evidence of learning as a team. During the presentations of the final project work, we try to observe aspects of student's teamwork activity and individual contributions.

**Results and Discussion**

A feedback session was conducted for the Engineering Inventions module focusing primarily on the course impact on the four core competency areas identified prior. As shown in Figure 6, 60% of the students agreed (8% strongly agreed) that the teaching approach supported autonomy. There was 0% disagreement in this area. Figure 7 shows students rating on the question of integration where 64% of the students agreed (12% strongly agreed) that the integrated approach made it easier to make connection among various fields of engineering. A minority 8% disagreed. From the survey we found that, a significant 72 % agreed (28 % strongly agreed) that they are able take different perspectives for the solution of a problem. This hints that students are now more conscious about other engineering fields and will be able to seek solutions other than their core discipline. When we examine the ratings on practical skills and the development of a culture of making (Figure 8), we observe a significant positive impact since 84% agreed (32% strongly agreed) that they are now more fluent in using tools for prototyping/fabricating engineering projects. Our concern was on team work and communication skills. Our classroom observations during the delivery of the module were positive and this is supported with students' response to the questionnaire as well. As shown in Figure 9, 64% (24% strongly agreed) agreed that they can work effectively with different personalities when doing team-based projects. A minority 4% disagreed.

From the comments made in the survey as well as during the interview sessions, we see that in general students enjoyed the experience and gained significantly from this module. However, the students also commented that module content is intense, workload is heavy, and schedules are tight. Furthermore, after hour access to lab space is limited. Further improvements may be necessary to address these minor issues which basically demands better time management by students and faculty.

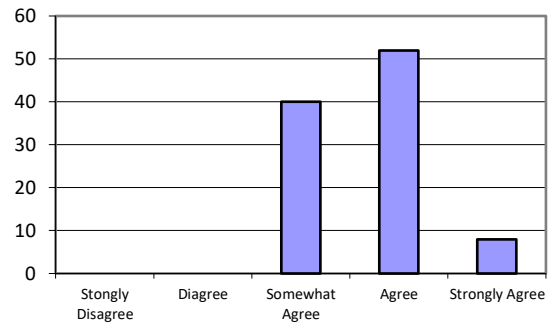


Figure 6. Students' view on the modules support for autonomy.

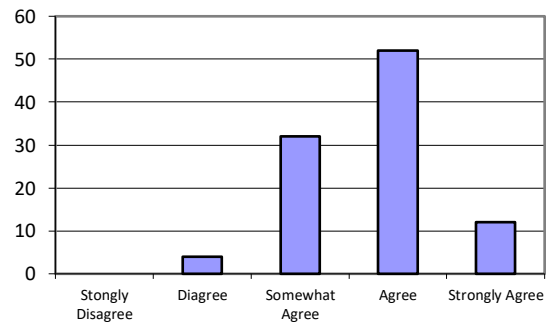


Figure 7. Students view on modules' help understanding connection among various fields of engineering.

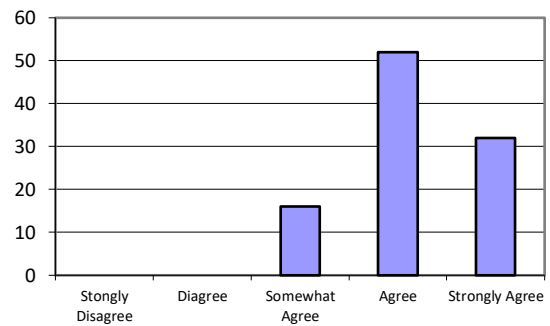


Figure 8. Students view on the confidence in using various tools for prototyping and fabrication.

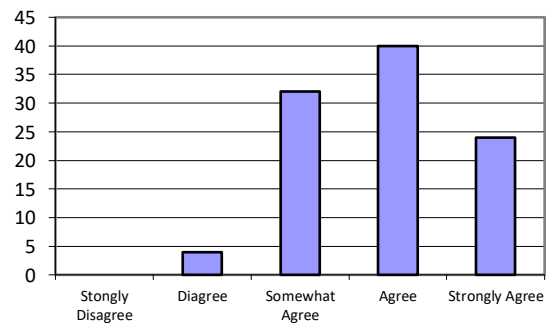


Figure 9. Students view on modules' help in developing students' ability to do teamwork.

## Conclusions

This paper presented our initiative for designing an integrated project based module. A major challenge was to choose a right theme, or project, where integration can naturally be part of the learning experience. Furthermore, studio based pedagogy is employed to support active learning and team work. Similar programs can be an effective approach to adapt to the needs of modern engineering education, especially when making drastic changes in the curriculum may not be so straightforward.

## Acknowledgement

The authors are grateful to colleagues Dr Noel Kristian and Soh Ying Ying in preparation and implementation of this course.

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