PEDAGOGY FOR EVIDENCE-BASED FLIPPED CLASSROOM – PART 2: CASE STUDY

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ABSTRACT

This paper shows how a pedagogical framework for designing a flipped classroom using an evidence-based approach supported by creative use of info-communication technologies (ICTs) tools in being applied to a Year 3 core module in an engineering curriculum, *Plant Safety and Loss Prevention* from the Diploma in Chemical Engineering, Singapore Polytechnic. The paper firstly presents a brief introduction of the module and its learning outcomes; and the use of a chemical process plant lifecycle approach in teaching the module. Next, the pedagogy for flipped classroom is introduced, with detailed explanation on how the key elements in the flipped classroom framework (introduced in Part 1) is translated in practice to the designing and sequencing of learning tasks into pre-class activities and in-class activities. This serves as the basis in planning the entire student learning experience, which is achieved using the core principles of learning embodied in the flipped classroom framework. This include the consideration of what students already know, what else they need to know, what can they do to acquire the requisite knowledge, and what do they to do in class, the kind of evidence to be collected to demonstrate their learning, the opportunity for formative assessment (feedback), and the choice of ICT tools most suitable for the task at hand. Unique features of the approach to teaching chemical process safety and how an engaging in-class learning environment is created are shared, including approaches to scaffolding student learning via mock assignment, self- and peer marking using rubric and score sheet. Various approaches to create positive learning environment for students are also presented. The last part of the paper presents the first author's reflections on the key learning points from the flipped classroom initiative followed by a discussion of areas of improvement to teaching the module. (295 words)

KEYWORDS

Flipped Classroom, Evidence-based Approach, Chemical Engineering, CDIO Standards 8 and 12

FLIPPED CLASSROOM FOR TEACHING CHEMICAL PROCESS SAFETY

The application of flipped classroom in higher education had been adopted in various disciplines and had been broadly presented by Cheah and Sale (2017). This paper presents a case study on the work done in teaching chemical process safety (entitled *Plant Safety and Loss Prevention*) using a flipped classroom approach, using the framework suggested by Sale and Cheah (2017), as shown in Figure 1.

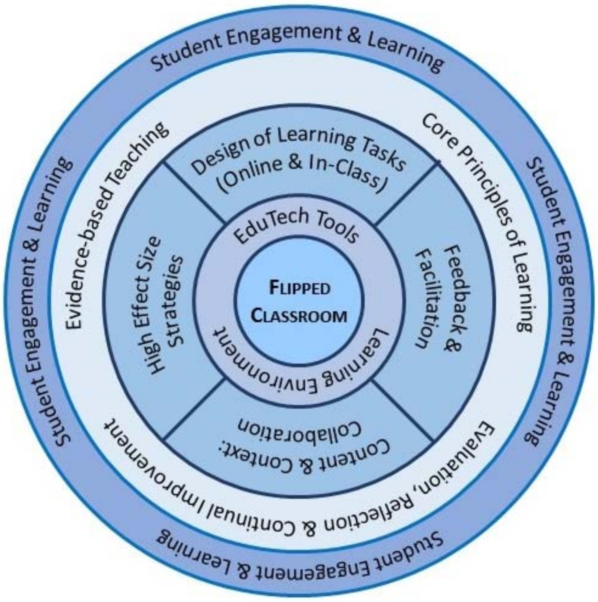

Figure 1. Framework for Evidence-based Flipped Classroom

The module is a Year 3 Diploma in Chemical Engineering core module (60 hours, fully in-course assessment, i.e. no examinations) taught to all 120 students in Semester 1 of an academic year. The module is taught over a period of 15 weeks using case study as the core pedagogic method. Contact hours are 4 hours per week which is devoted to classroom activities designed to engage students in applying the concepts learned during the online components. The main learning outcomes from the module, which frame the type of assessment evidence to be derived from the various student activities, are:

1. Identify from the assigned cases the correct safety issues at the proper stage of the chemical plant lifecycle
2. Infer and interpret probable causes that can lead to deviation from safe operating conditions and predict likely consequences or damages
3. Apply the correct preventive or mitigation strategies to prevent the occurrence or minimize the impact of any occurrence of a chemical process hazard
4. Transfer key concepts and principles from analysis of earlier cases to new cases presented at a later part of the semester

The teaching of the module uses a chemical plant lifecycle approach as shown in Figure 2 (Cheah, Lee & Sale, 2016).

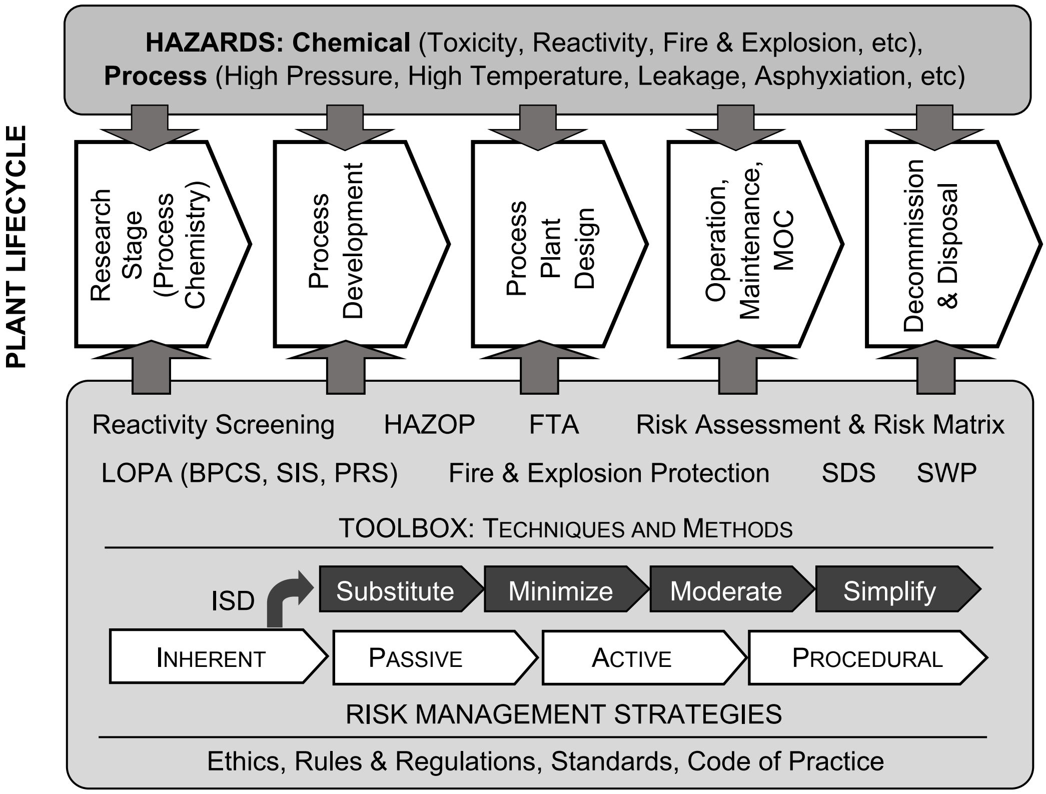

Figure 2. Lifecycle Approach to Teaching Chemical Process Safety

The lifecycle approach is adapted from the one used by the American Institute of Chemical Engineers, AIChE (Hendershot, 2011), which shows that a typical chemical plant goes through 5 key stages from its inception during R&D and process development, through to design and operation, and end with its eventual retirement and disposal. Added to the lifecycle diagram are chemical and process hazards shown above the lifecycle, and the loss prevention measures available to identify the hazards, evaluate the risks associated with the hazards, and preventive measures that can be taken to minimize the risks. A key theme that ran across the entire plant lifecycle is the emphasis on inherently safer design (Kletz, 1991).

PEDAGOGY FOR FLIPPED CLASSROOM USING EVIDENCE-BASED APPROACH

With Figure 2 setting the overall “direction” of teaching chemical process safety, we use the framework as shown in Figure 1 to design the flipped classroom for the entire 15-week duration of the module. Broadly, the outcome can be represented by the approach shown in Figure 3. The first and second columns show the 2 components of flipped classroom – the pre-class preparation and in-class activities, while the third column shows the assessment approaches to gather evidence of learning, and the last column show the role of EduTech tools that support the learning process.

Pre-Class Activity

As shown in column 1 of Figure 3, students gain disciplinary knowledge outside of classroom (as Pre-Class Activity) needed for in-class discussion by watching online videos of the lecture materials, supplemented by resources from the web site of the U.S. Chemical Safety

Board. Students can also engage in other pre-class activities such as reading of selected journals, information curated by the lecturers, or do actual visit for selected laboratory/workshop. Students get to assess their own learning by answering a series of self-evaluation questions – usually a combination of true/false and multiple choice questions (MCQs). These are shown in column 3 of Figure 3, and is formative in nature – the assessment is not graded, and students get immediate feedback on their effort, with short notes providing explanation on the selected response regardless of whether a correct or wrong answer is given. The ICT tools used are shown in column 4 of Figure 3, for example, the online videos are created using PowerPoint with narratives, and the self-evaluation questions are created using Socrative. Socrative is able to compile the necessary statistics that capture as evidence how well students grasped the content of their pre-class preparation. The lecturer can view these submissions before class, and accordingly address any issues that may surface.

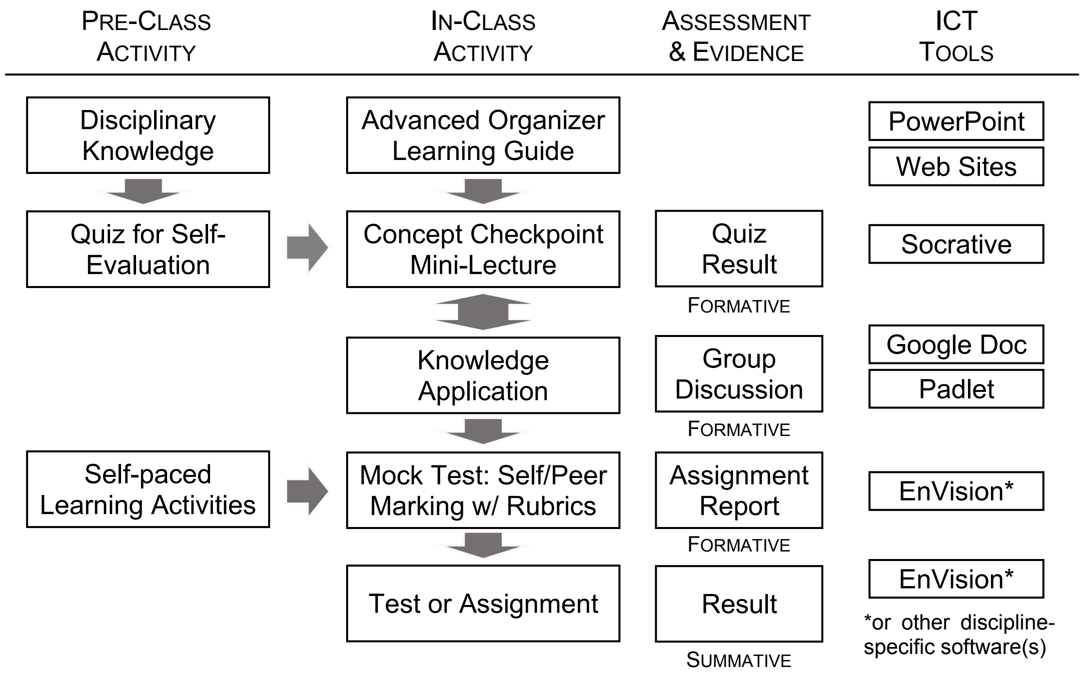

Figure 3. Pedagogy for Flipped Classroom using Evidence-based Approach

Approach to Learning Chemical Process Safety

Before proceeding, it is worth mentioning that we used case studies as the method of choice in teaching chemical process safety, which had been identified by many educators as an effective method (Shallcross, 2013). In our approach, we use the Bhopal Gas Tragedy of December 1984 as the “anchor” case study, supported by several other high-profile accidents (e.g. Piper Alpha, BP Texas) to demonstrate how hazards may arise at different stages of the chemical plant lifecycle, and how the techniques taught in the module can be applied to mitigate the risks associated with the hazards. Students are then required to apply what they learnt from the Bhopal and these other cases to other case studies. As these high-profile' incidents are already very well documented, it is relatively easy for students to go to Google to look for model answers if we used the traditional “Learning from Accidents” approach to teaching chemical process safety, such as discussion of the chain of events that occurred, the key lessons learnt, and recommendations to avoid future occurrence.

Instead, by using the plant lifecycle approach, we make it more challenging for students as they had to first analysed a case to pinpoint the specific stage of the plant lifecycle when the accident occurred, the specific hazards that existed, and how the risk could have been reduced had proper measures been taken not only at that given stage, but in earlier stages where there are more opportunities for implementing an inherently safer design. In this manner, we ensure there is a better transfer of what is learnt in earlier lessons to later ones. With this, we wish to avoid the pitfall noted by Pitt (2012): "The official 'lessons learned' can be pasted in or even memorized for the exam but not applied elsewhere."

In addition, we also prepared our own cases, based on a fairly common chemical process available in all refineries – the amine treating system, used for removing sulfur compounds in kerosene and diesel products. The chemical processing industry is known for its adoption of advanced technologies, many of which are proprietary. We firmly believe that learning chemical process safety needs to be done in the suitable context, and as such students need to know in sufficient detail a typical chemical process, and amine treating, in the judgment of the first author, fits the requirement nicely. The layout and equipment is very similar in all companies, so it can provide a good foundation on which students can study how chemical process safety is applied throughout the different stages of the plant lifecycle. Of course it is also very real-world focused. Another added advantage is that, epitomised by what the first author told students: “This is one case whereby you cannot find answers by ‘googling’. You need to really understand the process and my lessons in order to apply the knowledge gained.”

In-Class Activity

When students come to class (column 2 of Figure 3), they are reminded on how the day’s topic fit into the overall picture as depicted in the advanced organizer (based on Figure 2), and shown the learning guide which provide a summary of the week’s lessons. The learning guides are made available in advance to students as part of pre-class online viewing of the recorded video. The lecturer, who would have previewed the students attempts at the self-evaluation questions, may conduct a mini lecture not more than 10 minutes addressing key challenges or misconceptions identified and may also administer a concept test (consisting of several MCQs using Socrative) to further ascertained that students fully understand the underlying concepts.

For in-class learning experiences, several high effect size strategies (Hattie, 2009) are adopted, including mass practice (effect size 0.60), feedback (effect size 0.73), classroom discussion (effect size 0.82), etc. Next, we plan out the in-class learning tasks. This is where the core principles of learning embodied in the Framework of Figure 1 is useful in guiding us in the design of learning tasks. For our evidence-based teaching (EBT) approach, we use the framework as shown in Figure 1 for planning the contents to be covered based on what students need to know, what they already know, what they need to do in class to demonstrate that knowledge, the kind of evidence to be collected to demonstrate learning, and the choice of info-communication technologies (ICTs) tools most suitable for the task at hand. In this manner, the students’ learning can be appropriately scaffolded and timely feedback can be delivered. As can be seen in Figure 3, the ICT tools of choice are Google Doc and Padlet. Google Doc allows online collaboration among team members and a jointly reasoned response is then presented. Padlet is akin to a digital Post-It Note and allows individual students to share his/her thoughts regarding the case being analysed. Students’ responses are captured and shown in real-time in class. This serves as evidence to the students understanding of the topics covered and allows the lecturer to immediately point out any misconceptions or rectify any deficiencies in understanding. With good reflective practice, it also enables the lecturer to review his own teaching of the topics and make improvements. Feedback is also given in real-time based on the students' contributions to the discussion. In this manner, students continually build up their knowledge base and competency in applying them. This is supported, over the week(s), by self-paced learning tasks outside of classroom, as well as mass practices and also a mock assignment

Lastly, as shown in Figure 3, a "milestone" is reached where a summative assessment is administered. Figure 4 shows a more concrete example of the work done for the module, in this case, a 6-week lesson plan using this approach is shown in Figure 4.

	FLIPPED CLASSROOM	IN-CLASS ACTIVITIES	
Week 1		What is Flipped Classroom, How to Learn this Module, Expectations + Learning Guide; Principles of Loss Prevention	Flixborough Incident, Chemical Process Plant Lifecycle as Advance Organizer Bhopal as "Anchor" Case
Week 2	Inherently Safer Design (ISD), Management of Change (MOC) + Selected Journal Articles e.g. AIChE	Bhopal & Piper Alpha ISD & MOC; Introduction to Amine Treating Unit (ATU) Process Flow Description (PFD)	Jigsaw: Q&A on ATU PFD, ATU Dynamic Simulation Exercise + ATU Piping & Instrumentation (P&IDs)
Week 3	Layer of Protection Analysis: Basic Process Control System, Alarms & Intervention, Safety Instrumented System	LOPA: BPCS, Alarms & Intervention, SIS – Discussion on Bhopal, application for Distillation Pilot Plant (DPP)	Google Doc: Discussion on ATU BPCS + SIS Peer Marking of Mock Assignment w/ Rubrics
Week 3 (cont'd)	Self-learning: Extra ATU Steady-state Dynamic Simulation (SSDS) Exercises + Mock Assignment Report	ATU Concept Checkpoint on BPCS & SIS Discussion: BPCS & SIS to ATU HP Absorber	Mock Assignment + Self-Guided Marking Exercise Application: BPCS & SIS to ATU LP Absorber
Week 4	Layer of Protection Analysis: Pressure Relief System Site visit to W318 DPP PRS Indept Learn: Relief Sizing	LOPA: PRS – Discussion on Bhopal Relief Scenarios + Extras Exercises: Piper Alpha, BP Texas, Chemical Reactor	Apply PRS to ATU HP Absorber, Introduction: Self-Learning ATU Malfunction Exercises, SSDS Peer Marking
Week 5	Hazard & Operability Study (HAZOP), Self-Learning ATU Malfunction Exercises	HAZOP: Discussion on Bhopal, Piper Alpha, BP Texas, Application to DPP	HAZOP for ATU: Mock Study for LP Absorber + Briefing on Rubrics for HAZOP Study
Week 6	Continue HAZOP Continue Self-Learning ATU Malfunction Exercises, and peer sharing on findings	Using HAZOP for MOC: Case of ATU HP Absorber Release of CA1 (20%): HAZOP Assignment	Mock HAZOP Peer Marking w/ Rubrics for LP Absorber Interim Module Summary Briefing on Week 7 MST

Figure 4. Sample 6-week Lesson Plan

Continuing the discussion, now using Figure 4 as example, in-class discussion is carried out with the lecturer using the Bhopal and other cases to highlight safety issues relevant to the day's lesson and engage students in discussing how to resolve the issues using what they had learnt online prior to class. The discussion then moved to more in-class activities where new cases are introduced. Students working in teams get to apply their knowledge to these new cases by discussing the issues and/or offer solutions as dictated by the design of each case.

Creating Supportive In-Class Learning Environment

This can be created in several ways using the core principles of learning. One is through scaffolding and careful sequencing of the topics to be learnt. As noted above, one of the biggest challenges in this module is the students' lack of real-world experience working in a chemical plant. The system we used is the Amine Treating Unit (ATU) from EnVision, a dynamic simulation software used for the training of process technicians and engineers. We devote 2 weeks for students to learn the process, its control and safety systems, as well as operating the plant – virtually. However, even the ATU can be intimidating for one who had not worked before in a chemical plant. We therefore used the "chunking" approach to break the ATU up into smaller work units, each with its own set of self-assessment questions, and staggered the learning tasks to spread over several lessons, as shown in Figure 4. In a similar manner, topics in chemical process safety are also logically sequenced so that latter topics build on the earlier ones. Such "chunking" and sequencing help to reduce the cognitive load on students, making learning the topic manageable and meaningful (Mayer, 2002).

Each activity will require students to activate their prior knowledge gained in earlier activities. In this manner, the students are continually engaged in thinking critically about what they had learnt, hence promoting good understanding and mastery of the subject matter. And to strengthen students' appreciation of the topics learnt, the lecturer introduced several "Let's Get Real" segments in the classroom by means of picture collages showing various real-world safety protective systems.

Supportive learning environment is also created by providing the students learning with clear and yet challenging goals, and providing them with ample opportunities for practice. Using the EnVision dynamic simulation system, we created many optional self-paced learning exercises for students to practice on. They can learn the ATU process at their own pace – before the next in-class lesson that is – thus creating a sense of flexibility in managing their own learning. As seen in Figure 4, students are given several mock assignments, which allow them to understand the performance standard expected of them. The assignments come complete with marking rubrics, which were explained to students. They also went through a sample marking exercise using comprehensive assessment rubrics, guided by the lecturer. For the mock assignments, students get to mark their own scripts, as well as practising peer marking on another student's scripts. They are also given custom designed score sheer, so that they can learn to give feedback to each other.

Supportive learning environment can also be created by using formative assessment to guide students towards the learning goals. In the current educational setting, there will be one or more summative (i.e. graded) assessment along the way, and this module is no exception. The assessment scheme for this module is shown in Table 1. With our evidence-based approach, feedback and 'learning checklist' are used regularly and consistently as formative assessment so that students can monitor their own learning. As can be seen in Figure 2, lessons are organized so that they progress toward the stage where a graded test or assignment (summative assessment) is due. For the subject *Plant Safety & Loss Prevention*, the students need to take a 1-hour mid-semester test (individually graded, worth 20% of total coursework) and submit a HAZOP study report (group work, worth another 20% of total coursework).

Table 1. Assessment for *Plant Safety & Loss Prevention*

Assessment	Percentage of Total Grade	Type	Week Due / Administered
Mid-Semester Test	20	Individual	7
HAZOP Assignment	20	Group	9
Independent Study Assignment	15	Group	11
Presentation on Engineering Ethics	15	Group	14
End-of-Semester Test	30	Individual	15

Before rounding off this section, mention needs to be made regarding the proposed pedagogy for evidence-based flipped classroom. The approach in Figure 3 is meant to provide a systematic way of planning the flipped classroom taking into consideration the topics to be learnt, the assessment evidence to be collected, and the choice of ICT tools to be used to gather such evidence. It is applicable to any duration of study – and not restricted to a 6-week lesson plan as we shared above. The duration needed should be based on the level of difficulty of topics to be covered, and the lecturer would be the best person to adjust it to suit his/her teaching needs. A short topic may only need 2-3 weeks, while a challenging one, like the one for *Plant Safety & Loss Prevention* above, required up to 6 weeks to so that students develop sufficient understanding to tackle the HAZOP assignment.

REFLECTION AND LEARNING POINTS ON FLIPPED CLASSROOM

This is the second time the module is taught via flipped classroom approach by the first author. In terms of being able to engage students in their learning, the author opined that this approach is successful. As noted by Sale & Cheah (2017) earlier, today's students – the Net Generation, i.e. the millennials – are different from students of yesteryears, and as such cannot be engage using the same methods. Lecturers need to change the way they teach to suit the way these millennials learn (Skiba & Barton, 2006). As aptly pointed out by Oblinger & Oblinger (2005): "Whether the Net Generation is purely a generational phenomenon or whether it is associated with technology use, there are a number of implications for colleges and universities. Most stem from the dichotomy between a NetGen mindset and that of most faculty, staff and administrators". On this regard, it is important for lecturers – typically from the Baby Boomers and Generation X – to change their mindset, especially in the way one teaches: not least of all, in using ICT tools to aid in one's teaching. Vaughan (2014) opined that "the integration of technology into the higher education classroom presents an opportunity to transform traditional pedagogy so that it reaches millennial learners". Ironically, it is also the use of technology that many lecturers – the 'Digital Immigrants" (Prensky, 2001) – are most apprehensive about. It would appear that lecturers are lacked the knowledge regarding the affordance of ICT tools and overly worried about having to learn new skills in computer technology, the approach of which is very different from the way they were once educated. Many lecturers are worried that they need to spent time – which they do not have – to develop new teaching materials from scratch. As well, many are also intimidated by the myriad of ICT tools available – over issues such as not sure which tool to use for which purpose, required learning curves, and support from school or department. This fear is aptly captured by Ross, Morrison & Lowther (2010) who noted that "the more options teachers have for improving lesson quality, the greater the demands for organizing or 'orchestrating' many diverse instructional activities".

Lecturers' mindset towards ICT tools need to change, and the first step is to recognize that "educational technology is not a homogeneous 'intervention' but a broad variety of modalities, tools, and strategies for learning". Its effectiveness, therefore, depends on how well it helps teachers and students achieve the desired instructional goals (Ross, Morrison & Lowther, 2010). In our own experience with flipped classroom, we recommend one to start with professional development programs from one's own institution (such as that offered by the Department of Educational Development or equivalent) if these are available. Otherwise, one can choose to enrol in one of the introductory online courses on using Web 2.0 Tools such as Coursera, Edutopia, Udemy, or others. Rounding up several like-minded colleagues will provide the added momentum and "peer-pressure" to complete the programme.

Another mindset change needed on the lecturer is to get accustomed to the new role as facilitator of learning. Lecturers need to learn to "let go" of the perceived control they have in a flipped classroom. Lecturers must learn to be more situational and be able to respond to questions beyond "standard textbook answers". More importantly, lecturers must have the humility to acknowledge that he/she does not have all the answers. The most important reply then is to give the student credit for asking a good question, and be sure to get back to the student with an answer as soon as practical, preferably by the next class. Bates & Galloway (2012) described the payoff for this approach as "the potential for an inclusive and participatory classroom atmosphere". We may be increasingly moving towards what Fullan (2013) called the "new pedagogy" where students and teachers are now partners in learning. Organising a community of practice for professional sharing can be a way to encourage more lecturers to change their way of teaching.

The introduction of any new strategy requires a shift in the minds of students as well. Talbert (2012) suggested that students who come from an educational background where lecturing and rote work is the norm may experience a great deal of culture shock at the flipped classroom and resist taking on the responsibility for learning that the method entails, feeling that they are being abandoned to learn the material on their own. To address this, the lecturer need to be prepared to gather lots of formative assessment data to watch for places where students may not be learning and to convince students that they are learning when appropriate. The first author certainly agreed with the advice offered by Silverthorn (2006) that the lecturer should tell students what he/she is doing and the rationale behind flipped classroom, and to periodically keep revisiting with students so that they truly understand the intention.

The flipped classrooms require students to assume more responsibility for their individual learning experience. An often raised concern is to get students coming to class prepared – they should have watched the recorded lectures, did the necessary reading, etc. Williams & Williams (2011) noted that "very little if any learning can occur unless students are motivated on a consistent basis"; and identify five ingredients as key to student motivation: the student themselves, teacher, content, method/process and environment. Indeed, the very success of flipped classroom depends a great deal on student motivation to prepare themselves before coming to class. Given our experience in this flipped classroom journey, the first author feels that the team had done sufficiently well in using the framework in Figure 1 in addressing the in-class component of flipped classroom. The second author's classroom observation of lessons by the first author seems to support this. A key area that needs improvement is the online component. The team feels that this is the area where student motivation is still lacking. More will be elaborated in the next section on how the viewing of lectures can be incentivized (Gannod, Burge & Helmick, 2009).

Equally important, as reported by McCallum, et al (2015), students themselves expressed concerns “about the increased self-discipline required for participating in a flipped classroom.” This is indeed the comments the first author received from some students, especially on the week where there is another assignment due from another module, for example. In this case, the students tend to “optimize” their available time based on the perceived relative importance of competing requirements from different modules.

In any case, the first author suggests that the lecturer stands firm on not repeating the lecture in class. It may be frustrating at first if we have to go on with lessons with half the class (or more!) not prepared, but if we persist, the whole class will soon “get it”.

Lastly, from the first author’s perspective, although implementing flipped classroom is time-consuming in terms of the preparatory work required (e.g. video-recording, designing in-class activities, including various rubrics), the experience had been more enriching and rewarding. In today’s world where the often quoted reasons for not carrying out the long overdue curriculum revamp is that there is insufficient time to cover all the materials that students need to learn; flipped classroom actually permits freed up precious classroom time. The key is not to make use of the available classroom time to teach more content, but to engage students in applying what they learnt, and hence deepening their learning – the stuff that really matters. As noted by Bates & Galloway (2012): “It is an exhilarating feeling to be freed from the tyranny of content coverage to be able to have the time and space to focus on what really matters…. Furthermore, this understanding did not come with a price of ‘covering’ less material: we are convinced that, largely through the students’ efforts outside class, we covered as much content but uncovered a great deal more understanding”. This is especially satisfying for lecturers who viewed themselves as “designers of learning” (Friesen, 2009) in influencing student learning. These lecturers are able to design better learning experiences for their students in part because they conceive of teaching as fostering learning (Bain, 2004).

Overall, the experience in implementing flipped classroom had been very rewarding, as there was as much learning for the lecturers, as we research for resources to curate the resources needed for in-class activities and designing them.

RECOMMENDATIONS FOR FUTURE WORK

We conducted an evaluation of the evidence-based flipped classroom. The findings detailed elsewhere (Cheah & Sale, 2017). Suffice to note that our experience indicated that students are sufficiently engaged during in-class activities. This section focuses on the ideas for improvement in teaching the module. One of the feedbacks we obtained from students is that the video-recording can be boring at times. This is hardly surprising – a video recording of a lecture is still a lecture! As we transitioned from the usual lecture to flipped classroom, a priority of our initial emphasis is on designing meaningful classroom activities. These are more time-consuming than expected, so we chose the easiest approach for the lecture component and prepared recorded narratives within PowerPoint itself.

Now, after 2 semesters of teaching with the flipped format, and even though we still came up with a sizeable “punch list” of areas of improvement, we felt the time is due for a relook at how to make the online lecture component more engaging for students. As noted by Svinicki & McKeachie (2011): “In most courses students spend at least as much time studying out of class as they do in class. Thus, you need to focus as much on what you expect students to do outside class as on what goes on in class". Baepler, et al (2014) suggested that the pre-class assignments served as the structure needed to engage with course content more deliberately, hence careful planning is needed. Likewise, Gross, et al (2015) argued that student success in flipped classroom results from the close coupling of in-class activities to online course content.

Our current practice is to supplement the recorded lectures with some reading of journals, additional videos from U.S. Chemical and Safety Board (www.csb.gov), YouTube, etc. Students then engage in activities during class time. We did not provide the questions for students to prepare before coming to class. Heiner, et al (2014) suggested that we be specific in our approach; for example, in required reading – by directing students to look at specific figures and/or pages. The authors also suggested that any quizzes given should be graded if possible, and that this is best done online and not during class. At the moment, the questions we posed using Socrative is meant for self-evaluation by students, not as a mean of assessment or grading, and as such were not graded. Initially we are rather hesitant to award marks that contributes toward final grading, as this seems like a form of extrinsic motivation. However, in this case, the reward may be justified, as noted by Pink (2011), as it "can provide a small motivational booster shot without the harmful side effects."

Next, we plan to replace the recorded lessons with microlectures. A microlecture is short recorded audio or video presentation on a single, tightly defined topic" (EDUCAUSE, 2012). Sweet (2014) noted that microlectures are generally comprised of a lecture or demonstration, a narrated slideshow, or a screencast accompanied by a voiceover; are useful for flipped classroom, for example, by providing students with small chunks of new information necessary before in-class discussions, or to pique student's curiosity and interest for a new topic prior to introducing it in class.

Lastly, there is also a need to evaluate the effectiveness of the learning designs of the online component: the pre-recorded lectures. Various authors had written about the usefulness of recorded lectures as supplementary to their usual lectures, for example in allowing students to catch up on missed lessons, and to study for examinations (e.g. Whatley & Ahmad, 2007; Gorissen, et al, 2012). Gysbers, et al (2011) reported that students will attend lectures despite the availability of online recording because they value the learning environment afforded by live lectures. Students consider attendance at lectures as value-adding and provide the required discipline in their study program; and consider live lectures as integral part of the contemporary university community experience. However, the use of recorded lectures in flipped classroom, where students are required to first view and learn the contents prior to coming to class, is a relatively new phenomenon and is not yet widely studied. Anecdotal evidence from this work suggested that some students managed to "get by" during some of the in-class activities. These students appear to only use the online materials for revision before the mid-semester or end-semester tests. It will be of interest to investigate the efficacy of the microlectures used in the flipped classroom context. A possible approach is to use scholarly framework such as the SAMR Model (Romrell, et al, 2014) as suggested by Mazur, et al (2015).

CONCLUSION

This paper provided a case study how a framework for evidence-based flipped classroom is being applied to a core module in the Diploma in Chemical Engineering. A structure for organizing the online and in-class components, along with the choice of ICT tools that best deliver the needed evidence to demonstrate student learning is provided. Examples of lesson plan and how scaffolding is systematically applied is shared. Based on reflections on work done, we would like to suggest that the approach shared in this paper is a viable way to engage students in learning about chemical process safety; and that the same approach can be extended to higher level of learning (undergraduate and beyond) to develop competent safety professionals that meet the needs of the chemical processing industries. The evidence-based flipped classroom approach had enabled the required learning to take place, and the framework used in its design allows for continual improvement.

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