CURRICULUM INTEGRATION: TWINNING OF A CORE CHEMICAL ENGINEERING MODULE WITH A TEAMWORK & COMMUNICATION MODULE

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ABSTRACT

Teaching in the Diploma in Chemical Engineering (DCHE) of Singapore Polytechnic largely follows the traditional way of covering various technical disciplines in modular format, taught by faculty with relevant working experience in the chemical and process industries. The teaching is supported by various “soft skills” such as inter-personal communication, report writing and presentation taught separately by faculty from the School of Communication, Arts and Social Sciences (CASS).

Since its adoption of CDIO in 2007, the DCHE Course Management Team (CMT) had directed its efforts at integrating various CDIO skills into suitable core modules in the curriculum. One such module is *Introduction to Chemical Thermodynamics*, taught to Year 1 students where CDIO skills such as teamwork and communication, personal skills and attitudes (e.g. critical and creative thinking) had been integrated. Subsequent evaluation of the module had shown that, although students generally benefitted in learning about CDIO skills in the module, there is a strong need to further integrate the module with key concepts underpinning teamwork and communication. As a result, the various “soft skills” modules are consolidated into a new module entitled *Teamwork and Communication Toolbox*, to be taught in such a way that it “twins” with the CDIO-infused *Introduction to Chemical Thermodynamics* module.

The CMT works closely with CASS in designing the syllabus and learning outcomes for the *Teamwork and Communication Toolbox* module. CASS faculty retains the responsibility for teaching the *Teamwork and Communication Toolbox* module, while DCHE faculty handles the teaching of the *Introduction to Chemical Thermodynamics* module. Student learning is achieved via carefully designed “twinning” activities that requires them to integrate the knowledge gained in both modules.

The paper shares the work done in the “twinning” initiative (including active learning experiences) and compares the impact on student learning before and after the “twinning”. The challenges faced, and future recommendations to further improve the “twinning” process will also be discussed.

(NOTE: Singapore Polytechnic uses the word "course" to describe its education "programs". A "course" in the Diploma in Chemical Engineering consists of many subjects that are termed "modules"; which in the universities contexts are often called “courses”.)

KEYWORDS – Curriculum integration, twinning, chemical engineering, CDIO skills, program evaluation

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) course in Singapore Polytechnic is one of the 49 courses available to students. The teaching is largely modular in nature, whereby students are required to complete a suite of up to 6 modules each semester, over 6 semesters in a 3-year period. Such modular teaching can result in compartmentalization of knowledge by students, unless the faculty actively make a conscious effort to integrate the various chemical engineering disciplines.

Curriculum integration is therefore of utmost importance in linking together the various knowledge and skill components taught in these separate subject modules. This is clearly captured in CDIO Standard 3 “Integrated Curriculum” which stated that a curriculum should be “designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process and system building skills.” (Crawley, et al, p.35 [1]).

DCHE had adopted CDIO as the basis of revamping its curriculum since 2007 (Cheah [2]), and had integrated specific CDIO skills into its various core modules. The emphasis of the integration effort is mainly directed at creating active learning experiences for students in practicing CDIO skills. However, due to an already-packed curriculum, there had been little opportunity to adequately cover the underpinning knowledge of the CDIO skills in the core modules. Hence, the teaching of these “soft skills” is still covered in separate standalone modules, and taught by faculty from the School of Communication, Arts and Social Sciences (CASS).

This paper presents an initiative by the DCHE Course Management Team (CMT) to further strengthen the curriculum integration effort by “twinning” a core chemical engineering entitled CP5067 *Introduction to Chemical Thermodynamics* and a “soft skill” module entitled LC0236 *Teamwork and Communication Toolbox*. Both modules are offered to Year 1 students in the same semester of study.

DESCRIPTION OF WORK DONE

This section will firstly outline the learning designs for *Introduction to Chemical Thermodynamics*, a Year 1 core chemical engineering module; before the “twinning” initiative that require students to practice CDIO skills. It then discusses the results of a student survey that, although confirming the usefulness of active learning, also highlighted concerns among students that they needed more understanding of the key concepts underlying teamwork and communication. This is followed by a discussion of the “twinning” initiative and explanations on modifications made to improve student learning. Lastly, a new survey result is presented, which compares the impact on student learning of such “twinning” mode of teaching.

Active Learning Activities

The curriculum re-design effort followed the “standard” approach taken by the DCHE CMT as outlined by Sale and Cheah [3], Cheah [4], and Cheah and Sale [5]. and Drawing on the requirements as spelt out in CDIO Standard 8 “Active Learning”, we used the student-centred approach to curriculum design by Felder and Brent [6] (see Figure 1) to introduce various CDIO skills into the module.

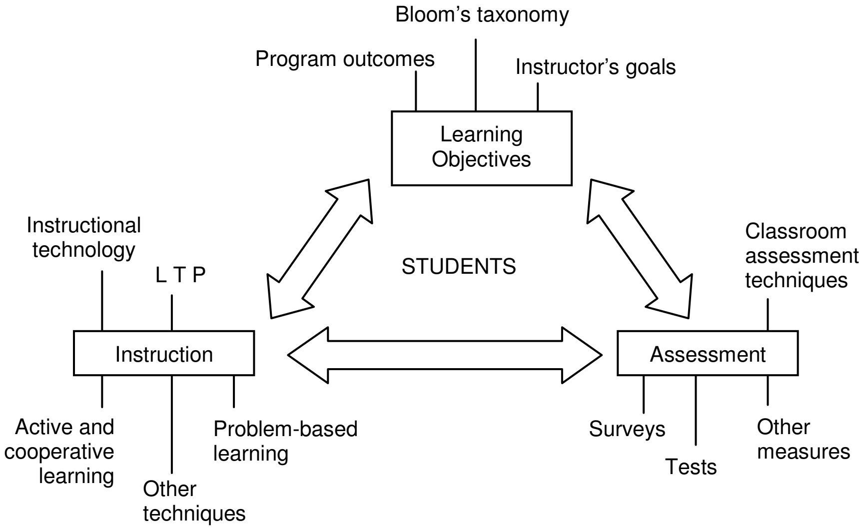

Figure 1. Student-centred approach to curriculum design

The basis for the approach in designing active learning activities for the module is derived from extensive research that students learn best when they perceived a clear need to know the material being taught (Felder [7]). It is also clear that the best opportunity lies not in the classroom but in the laboratory, where students work in small teams. Hence, all five laboratory activities of the module were designed using real-world work scenarios that contextualize the learning environment so that students can experience the needs to master the various CDIO soft skills. Emphasis is placed on three selected CDIO skills of teamwork, communication and personal skills and attitudes (focusing namely on thinking, and managing learning).

Table 1 shows the laboratory sessions for the module *Introduction to Chemical Thermodynamics* and the selected CDIO skills covered.

Table 1.
Selected CDIO skills infused into each activity

Activity S/N and Name	CDIO Skill Infused			
	Teamwork	Com-munication	Thinking Process	Manage Learning
1. Size Analysis & Energy Requirement in Grinding	√		√	√
2. Study of Gas PVT Relationship		√	√	√
3. Thermodynamics of Steady-State Flow System			√	
4. Energy Efficiency of a Fuel Cell			√	√
5. Study of Vapour-Liquid Equilibrium for a Binary Mixture	√	√		√

The underpinning knowledge of these CDIO skills is made available in the laboratory manual, which also contains detailed descriptions for each activity. The instruction for each laboratory activity is divided into several sections, i.e. learning objectives, theory, pre-experiment assessment, conduct of experiment, post-experiment assessment, results and calculations, discussion, and/or independent learning.

For example, in Activity 1 “Size Analysis & Energy Requirement in Grinding”, students are required to analyze the task to be performed and divide key task components to team members. The basis of task allocation and impact of the role on team performance must be justified and presented to the faculty-in-charge. The activity helps students to demonstrate teamwork skill through the practice of job delegation in order to perform a group work effectively.

Both written and oral communication skill are infused in all laboratory activities through report writing and presentation of answers orally during in-class assessment. However, communication skill is particularly emphasized in two activities. Students are tasked as an assistant engineer in a chemical company in Activity 5. Given a work scenario to conduct training on “distillation principles” to a group of plant operators, students are required to practice their oral communication skill in a technical context.

Other CDIO skills such as “Apply Thinking Process” and “Manage Learning” are also embedded into the laboratory activities.

As the module is taught to students in the first semester in their first year of study, most if not all of them, had barely knew each other, and have little understanding of what constituted CDIO skills. The grouping for laboratory activity was done by the faculty in an arbitrary manner. A briefing was conducted in the first week of the semester, prior to the commencement of the laboratory in the following week. The purpose is to explain the underpinning knowledge of the CDIO skills, in particular the key components and attributes of a successful team. Students were asked to discuss with their assigned team members and complete a “Pre-Experiment Exercise”. In this exercise, students are required to identify the strengths and weaknesses of each team member, goal of the team, situations whereby failure of a member can adversely affect the team performance, and set ground rules for the team. A sample worksheet for the “Pre-Experiment Exercise” is shown in Appendix 1.

The laboratory activities were conducted on a twice-weekly basis. Each week, one group of students will work on one activity, taking turns on a rotation basis, to work on another activity two weeks later. This continues for the entire semester (15 weeks) until all activities are completed. During the conduct of the laboratory sessions, one faculty served as facilitator and assessor for the entire 3-hour duration of each activity. An additional faculty served as a first-hour assistance to the faculty, so that all five groups can start-off on their tasks as soon as possible, i.e. by meeting all the requirements of the Pre-Experiment Assessment (detailed in following sections).

Assessment

Assessment is perhaps the most powerful curriculum component in terms of shaping student’s approaches to their learning (Edstrom et al, [8]). In fact, Ramsden [9] points out that:

> from our students’ point of view, assessment always defines the actual curriculum …. Assessment sends messages about the standard and amount of work required, and what aspects of the syllabus are most important. (pp.187-188)

Detailed planning went into the design of assessment questions in these laboratory activities. A customized assessment scheme is prepared for each activity. Detailed breakdown for each assessment scheme is provided in the instruction manual. A sample of this is shown in Figure 2.

The assessment can be broadly classified as In-Class Assessment and Report Assessment. The In-Class Assessments were carried out at two key points in time: first at the beginning of class (the so-called "Pre-Experiment Assessment" and later during debrief at the end of class – "Post Experiment Assessment". Students were also assessment on their overall conduct of the experiment. The pre-experiment assessments are introduced to test students' understanding prior to allowing them to start the experiment. Students are encouraged to practice teamwork by preparing for each activity before the actual date of the activity. During such preparation work, students need to learn how to manage their own learning, as certain topics may yet to be taught in class at the time of the activity in the laboratory.

		ASSESSMENT SCHEME	Weightage	Individual	Group
In-Class Assessment					
I	Pre-Experiment Assessment				
	A.	Understanding Theory Hazard Identification and Safety Precaution	25%	√	
II	Conduct of Experiment				
	A.	Punctuality and Display of Positive Learning Attitude	5%	√	
	B.	Safety Practice and Housekeeping	5%	√	
III	Post-Experiment Assessment				
	A.	Questions for Practical	10%	√	√
Report Assessment					
	A.	Results and Calculations	13%		√
	B.	Discussions	17%		√
	C.	Independent Learning	15%		√
	D.	References	5%		√
	E.	Overall Presentation	5%		√
	TOTAL MARKS		**100%**		
	Penalty for Lateness (–5% / day)				

Figure 2. Sample Assessment Scheme for Laboratory Activity

On the other hand, the aim of post-experiment assessments can be broader. In addition to testing students on their observations of the conduct of the activity, they may be assessed on other knowledge and skill areas, depending on the specific learning outcomes of each activity. This may include understanding the rationale of the way the steps are sequenced, testing of hypotheses formulated by students, etc. Questions were also designed for students to integrate what they learnt in other modules such as *Introduction to Chemical Engineering*; into what they learnt in this module; for example, unit conversion and unit consistency when performing engineering calculations.

Students are given two weeks to submit a group written report. Guidelines for report writing are communicated to students during the briefing. A wrap-up session on all the laboratory activities is conducted at the end of the semester to give overall feedback on the report and to highlight the common mistakes made, as well as clarify any doubts over the technical concepts.

Program Evaluation: Obtaining Student Feedback

The methods utilised to collect the feedback from students on the effectiveness of the active learning activities embedded with CDIO skills are consistent with the approach adopted for DCHE [4]. We engage six students (two from each class) to serve as "co-participants" (Lincoln, [10]), who regularly blog regarding their learning experiences in an online journal. Students are typically presented with a range of questions relating to the learning tasks, and asked to provide specific examples to support their responses. These student co-participants also took part in a focus group interview at the end of the semester. Both blogging and focus group discussion are facilitated by education advisors from the Department of Educational Development (EDU), in absence of faculty participation. We also used questionnaire for mass survey of all students, again at the end of the semester and administered by EDU staff.

Evaluation of Student Feedback (before "Twinning")

In summary, a questionnaire was administered to all students taking the module at the end of semester. The total respondent is 57 out of 61 and the response rate was about 93%. Some of the notable findings are presented below.

Firstly, the results of student survey confirmed the usefulness of active learning in facilitating learning of the module, and showed high appreciation for the importance of teamwork and communication skills. However, students also expressed concern over the long waiting time for consultation with the faculty, especially after the departure of the first-hour assistant. The insufficient engagement and contact time with the group may cause difficulty in assessment of teamwork and other skills in each group. Some students suggested peer assessment for a fairer assessment on teamwork skill among group member.

Secondly, students also highlighted another concern that they had not learned communication skill in their first semester, hence faced difficulties in demonstrating effective communication skill, in both written and oral forms. Some were unable to see connections between the underpinning knowledge briefed earlier and the tasks they were asked to perform in a given activity.

Thirdly, students informed that they generally understand the characteristics of being a good thinker and agreed on the importance of having good thinking skill. However, they found some of the tasks challenging and expressed concern about their competency in using a range of critical and creative thinking skills to perform these tasks. They cited lack of knowledge on how to approach the thinking process and acquire the necessary thinking skill. Table 2 below summarizes students' perception and the context of CDIO skill on "Good Thinking".

Table 2.
Comparison of student perception and CDIO context of "Good Thinking"

Students' perception on "Good Thinking"	CDIO context of "Good Thinking"
▪ Have good foundations of knowledge ▪ Able to resolve problems ▪ Have innovative ideas and solutions ▪ Understand the questions posted ▪ Analysis what had learnt and use it logically and practically, and then create more methods for solutions	▪ Use ranges of critical thinking skills ▪ Use ranges of creative thinking tools and techniques ▪ Identify contradictory perspectives and underlying assumption ▪ Reframe and take a range of different perspectives ▪ Use meta-cognition in monitoring the quality of personal thinking

Faculty Personal Reflections and Review of Implementation

Overall, the main author (as the faculty teaching the module) generally found that students are motivated, coming to the laboratory sufficiently prepared and able to manage their learning more independently out of classroom. Facilitating the activities also helped deepen faculty understanding of the CDIO skills, leading to strong internalization, and build up faculty CDIO competency.

The author's shared students' concern of insufficient time for more engagement during these laboratory sessions. This is especially challenging during the last hour where the faculty had to conduct debriefs for all the five groups; performing a multitude of tasks which include reviewing the students' experimental data, conducting post-experiment assessment, etc.

Faculty also empathised with students' comments on lack on synchronization between the independent teachings of communication skills and technical subjects in the current arrangement. A case in point is the teaching of the module *Report Writing and Presentation*, which is only taught to Year 1 students in Semester 2. In addition, the faculty also realised that teamwork need to be explicitly taught to students. There is insufficient time during the first-week briefing for more in-depth exercises to adequately prepare students for applying teamwork skills. These factors points to a strong need to align the teaching of soft skills and teamwork, and served as strong motivation to revise the DCHE Year 1 course structure.

The explicit development of thinking skills is another area which needs further faculty development. This is presently being addressed; the approach and results are presented in a separate paper [11].

Improvement Made: The "Twinning" Initiative

Several improvements were made on the module after incorporating students' feedback and the faculty's self-reflection and review. A major recommendation that was adopted by the CMT is to introduce a new module entitled *Teamwork and Communication Toolbox* to support student learning of these core CDIO skills. The new module is created by merging and streamlining two existing modules: *Report Writing and Presentation* (as mentioned previously), and a Year 2 module *Effective Interpersonal Communication*. Overlapping topics and contents were rationalized to allow the introduction of topics on teamwork. The new module hence provides a platform for students to learn both teamwork and communication skills (oral and written) in a more structured and systematic approach. A sample of learning objectives is provided in Figure 3.

S/N	Learning Outcomes
A	**TEAMWORK AND INTERPERSONAL COMMUNICATION**
1	**Understand What Makes an Effective Team**
1.1	Identify components of an effective team.
1.2	Explain team roles and their impact on team performance.
1.3	Analyse the strengths and weaknesses of a team.
2	**Understand the Relationship Between Teamwork and Communication**
2.1	Identify types of verbal and non-verbal communication.
2.2	State causes of verbal and non-verbal miscommunication.
2.3	Explain how verbal and/or non-verbal communication affects teamwork.
C	**ORAL COMMUNICATION**
7	**Understand the Basic Principles of Oral Presentation**
7.1	Define the purpose, the audience and the context (PAC) of a presentation
7.2	Identify the essential elements (verbal and non-verbal) of a good presentation
7.3	State the delivery strategies for an effective oral presentation
8	**Prepare for the Presentation**
8.1	Plan the speech by determining the audience, purpose and context (PAC) required
8.2	Decide on a presentation strategy for the team
8.3	Select suitable delivery strategies for the presentation
8.4	Select appropriate visuals e.g. PPT slides for the presentation
8.5	Anticipate questions and prepare answers for the Q & A

Figure 3. Sample learning objectives in *Teamwork and Communication Toolbox*

Also, by introducing *Teamwork and Communication Toolbox* in first semester, together with *Introduction to Chemical Thermodynamics* in the same semester, we can proceed with our "Twinning" effort that allows students to simultaneously learn and apply teamwork and communication skills in a relevant chemical engineering context.

The key feature of twinning the two modules is to align the learning activities and assessments in both modules. The authors (from DCHE) worked closely with CASS faculty to redesign the learning activities in the *Introduction to Chemical Thermodynamics* module which also serves as assignments in the *Teamwork and Communication Toolbox* module. In that way, students are taught and assessed for both technical and soft skills in a coordinated manner. In addition, the role of the first-hour helper has now been converted to a full three-hour support.

As an example, students are given a real-world work scenario in which they need to conduct a training lesson in distillation principles to a group of plant operators using PowerPoint. In this activity, the CASS faculty will focus on teaching oral presentation skill, providing guidance in presentation slides preparation and delivery of group presentation. On the other hand, the DCHE faculty (i.e. the main author) provides guidance on technical contents of the presentation. Both faculty then jointly assess the students on their competency in both the technical domain and CDIO skills. The same practice applies to written communication skill when students are required to submit a scientific report using one of the laboratory activities to both faculty. Figure 4 shows the workflow of the integrated assessment in scientific report writing.

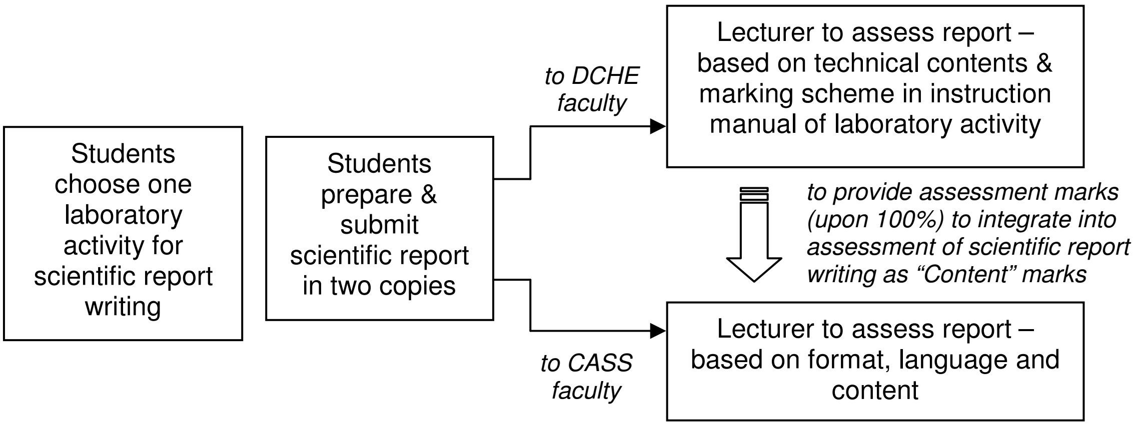

Figure 4. Workflow for integrated assessment in scientific report writing under the Twinning Initiative

Faculty from both CASS and DCHE also decided to improve the "Pre-Experiment Exercise" on teamwork mentioned previously, in order to sustain the development of students' teamwork skill throughout the semester. This is achieved via the introduction of a reflection component on the "Pre-Experiment Exercise" during mid-semester, which serves as a mid-point check. In this group reflection exercise, students review their strengths and weaknesses, team's goals, ground rules and performance that are stated in the "Pre-Experiment Exercise". If required, students can make changes to their ground rules in order to achieve the team goals.

At the end of the semester, a "Team Effectiveness and Peer Evaluation Form" is administered to all students. Students will rate individual contributions as well as team performance; and record any conflicts that arose in the course of carrying out the activities for the module *Introduction to Chemical Thermodynamics*. The results of the peer assessment will serve as input of an assessment activity in the module *Teamwork and Communication Toolbox*.

Figure 5 shows the workflow of administering the integrated activities related to teamwork skill for both modules.

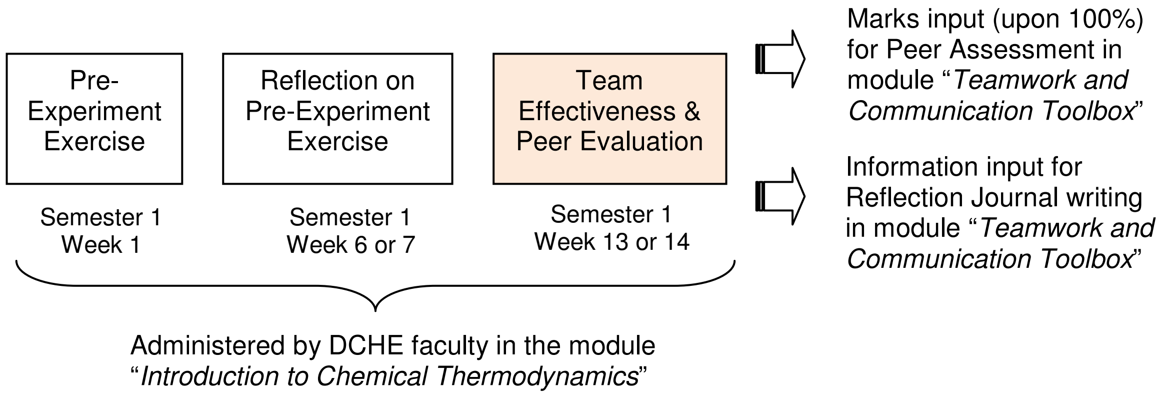

Figure 5. Administration workflow for integrated activities under the "Twinning" Initiative

Any real conflicts that may have arisen during the course of the semester, will be summarised by DCHE faculty and shared with the CASS faculty. The CASS faculty will use the findings as input to facilitate discussion of applying conflict resolution strategies teamwork and interpersonal communication.

Evaluation of Student Feedback (after "Twinning")

A new round of survey was conducted for students who have gone through an integrated learning activity, i.e. oral presentation and joint-assessment from both core chemical engineering module and teamwork and communication module. The total number of respondents is 60 (out of 63), giving a response rate of 95%.

Students are asked of their learning experience in activities that integrates assessment from both perspectives. Specifically, they are asked to indicate on a 4-point Likert Scale, the extent to which they agree disagree with the following statements (1 being Strongly Disagree and 4 being Strongly Agree):

<u>Merits of Twinning on Learning Oral Presentation</u> (see Figure 6 for responses)

Q.1 *The twinning assignment allows me to have a better understanding of the importance of oral communication skill in the job scope of a technologist or an engineer*.

Q.2 *With the twinning assignment, I am able to apply what I learnt in LC0236 to actual oral presentation in technical context, more so than if the two modules are taught and assessed independently*.

Q.3 *With the twinning assignment, I am more mindful of the importance of both technical contents and delivery strategy for oral presentation*.

<u>Joint-Assessment of Oral Presentation</u> (see Figure 7 for responses)

Q.1 *I feel comfortable for both lecturers from LC0236 and CP5067 to conduct the assessment of oral presentation due to their competency in different aspects*.

Q.2 *It is appropriate and fair for CP5067 lecturer to assess the "content" of the oral presentation as the lecturer understands the technical content the most and gives better judgement on the contents, more so than the "content" is assessed by LC0236 lecturer*.

Q.3 *It is appropriate and fair for both LC0236 and CP5067 lecturers to assess the "Management of Q&A" as they could have better judgement on the clarity and relevancy of the answers given by students respectively*.

Q.4 *The feedback from LC0236 and CP5067 lecturers on my oral presentation gives me more ideas for improvement in both technical contents and oral communication skills*.

Q.5 *I would prefer the co-assessment in twinning mode, i.e. by both LC0236 and CP5067 lecturers, more so than the assessment is done independently in two modules*.

The result from this survey is very positive; with more than 90% of the students indicating preference for the "twinning mode" of teaching; as compared to learning technical and soft skills in separate standalone modules.

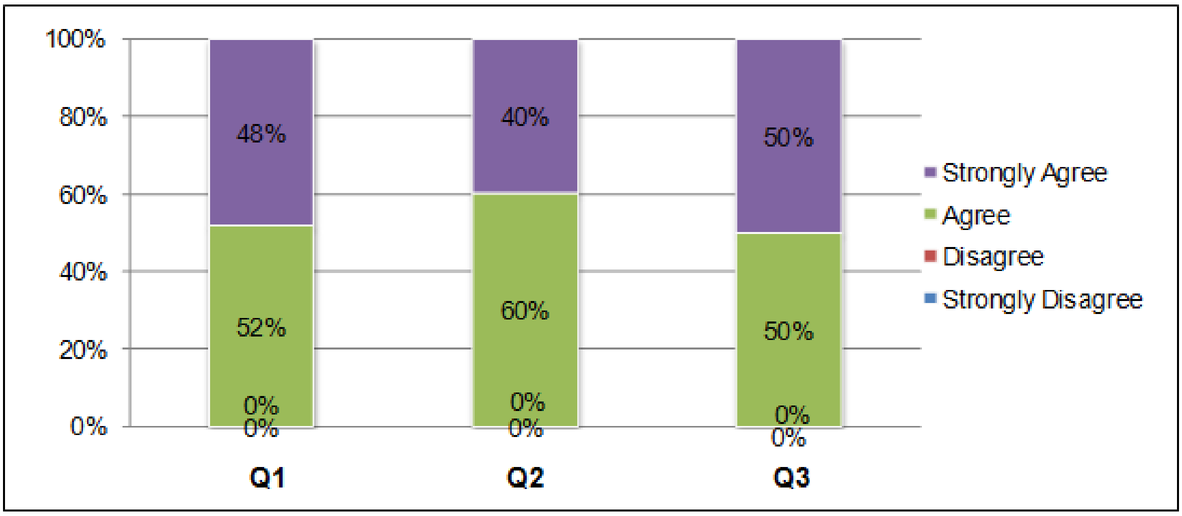

Figure 6. Students' response on integrated learning activity for oral presentation

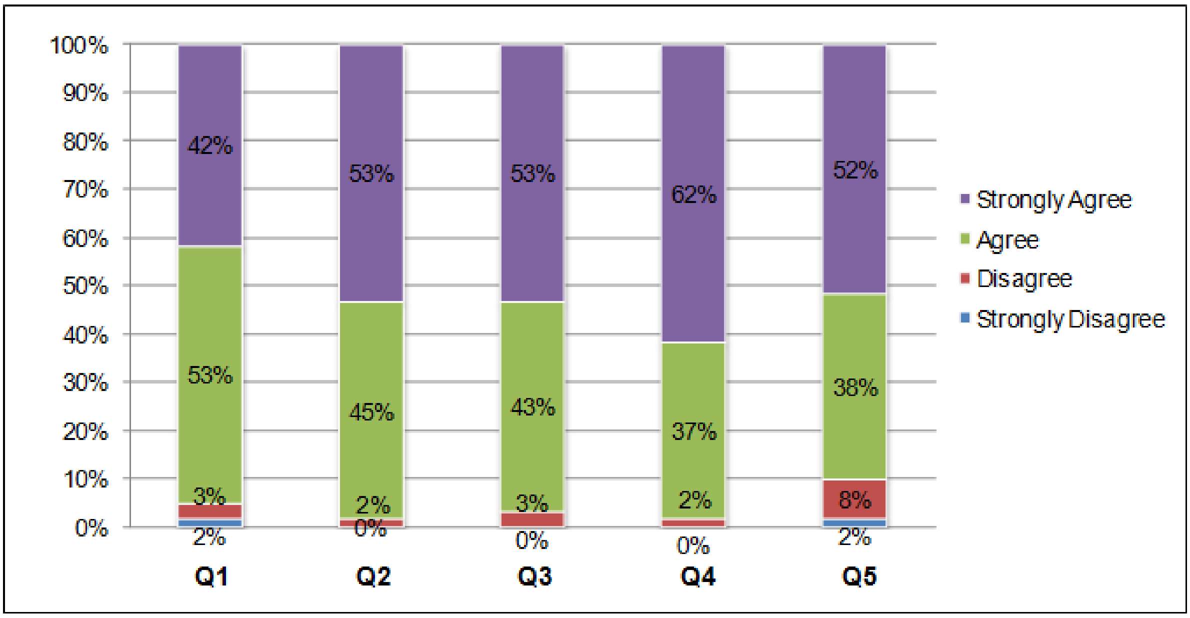

Figure 7. Students' response on joint-assessment by both DCHE and CASS faculty

From these results as well as their journal entries, we ascertained that students liked the "twinning mode" of learning activity. Some responses were as follows:

> *"It is good to have comments from lecturer on our presentation contents, especially to clear our misconception; as such we could learn from mistakes and rectify them."*
>
> *"I could feel the team's synergy in this learning activity. Everyone is taking initiative during discussion, and we use interesting analogy to deliver the technical contents. It is good to integrate what we have learnt in two modules."*
>
> *"The presentation gave me clear picture of having good strategies in preparation of PowerPoint slides and in communication skills such as using the right and appropriate terms of language, put relevant pictures in PPT slides."*

Overall, students also commented that it was a great learning experience as lecturers gave them feedback and suggestions on how to improve their oral presentation skills; along with technical knowledge and concepts at the same time. The oral presentation in such work scenarios gave them a more authentic understanding of a real work context and the importance of good presentation skills along with the appropriate technical content.

ISSUES AND CHALLENGES

The faculty encountered several issues and challenges in conducting such twinning mode of teaching. These centred around the coordination of teaching and assessment in the two modules. Both faculty need to work closely as the "twinning" learning activities and joint-assessment requires a lot of coordination, particularly in lesson planning and administration.

Scheduling of joint-assessment also posed a challenge as both faculty have their individual teaching timetable done separately at the respective school level; and both need to find common time slots that also match with students' timetables. This usually ended up outside of the formal teaching hours. From the faculty's perspective, these are additional time commitments over and above their own scheduled teaching hours; which is not captured in the computation of teaching load. As for students, they sometimes have to meet up with faculty late in the evening, even though their classes may have ended earlier, as that is the only time both faculty are available. However, we were relieved to learn from students that the workload is manageable and that many understand the rationale for rigor and demand of the chemical engineering diploma.

A similar challenge emerged concerning faculty giving feedback to students on their scientific written report in a timely manner. The current practice requires student to submit one report to DCHE faculty and another duplicate copy to CASS faculty. After marking the report, both faculty give feedback on technical contents and CDIO skills respectively. However, again due to coordination difficulties, we are not able to provide a joint feedback. Often, each faculty will make separate arrangement that is convenient, e.g. after lecture or during tutorial. In fact, the DCHE faculty is only able to give feedback during the wrap-up session held at the end of the semester.

KEY LEARNING POINTS AND RECOMMENDATIONS

The key learning point from this "Twinning" initiative is that a lot of effort was required from both faculty to successfully integrate the learning activities and assessment in both modules; more so on the following-up debrief, assessment and feedback. The motivation from both

DCHE and CASS faculty in piloting with this initiative is the unwavering belief that we can make a difference in students' learning. The good rapport between both faculty can be considered the deciding factor in such partnership. We are greatly encouraged with the student feedback that such integration had proven beneficial to them, and we see evidence improvement in their written reports. Both faculty will continue to fine-tune this integration effort, in subsequent semesters.

The author felt that a key factor that can help to sustain the integration effort is to have a common timeslot for both faculty to conduct a joint debrief and feedback session. The author, together with her CASS counterpart, will explore such possibility with their respective management, whose support is crucial. However, we recognized that this may or may not be possible due to various timetabling constraints for which the faculty may not be aware. Both faculty will continue with the current form of collaboration and enhanced it via regular communications. The DCHE faculty will also leverage on our current module review system, which include the DCHE faculty as the module coordinator and a few other DCHE colleagues that serve as module team members. We will now include the CASS faculty in the module review team, so that the team can more effectively fine-tune the integration effort. In this manner, other module team members will also learn about the way we organized and integrated the various learning activities and assessment.

Another key learning point for the DCHE faculty is the realization that teaching of teamwork and communication skills are not that difficult as previously perceived. While the full range of teamwork and communication skills are covered by the CASS faculty, the author now feels comfortable teaching aspects of these skills in the engineering context.

Hence, we believe that once engineering faculty fully understand what is involved and the importance of these skills for student learning, they will be less resistant to the idea that they might need to teach such skills within the engineering context. Most significantly, as all faculty are experienced engineering professionals turned academic, they will quickly appreciate that much of the underpinning knowledge for teamwork and communication is, in fact, quite familiar to them. Such knowledge is what Polanyi [12] referred to as tacit knowledge, as opposed to explicit knowledge. This is further elaborated by Sale [13]:

> Through the provision of key underpinning knowledge for CDIO Skills, it is possible to bring such tacit knowledge to a more explicit and practical focus. Faculty can then see that they actually possess such knowledge and competence. It is then much easier for them to make direct connections to where and when in the curriculum such skills can be naturally and effectively integrated. (p.16)

As for future development in this area, we have the following recommendations:

Teamwork and communication skills should be sustained and further enhanced in Year-2 and Year-3 chemical engineering curriculum so students could develop, demonstrate and eventually master the skills to become effective at work as well as in life. The faculty will share the guidelines on scientific report writing that was developed under this initiative with all DCHE faculty so that we can have a consistent approach in assessing students' reports throughout their 3-year study.

We can also leverage on conflicts – potential or real – at the moment they arise, as teachable moments instead of relying on students report in the "Team Effectiveness and Peer Assessment" survey. Faculty could make use of "live" opportunity that presents itself to teach students' in applying conflict strategies to resolve conflicts. Reflection journal on conflict resolution is then a supplementary good tool for students to re-examine their values and identify the causes of conflict, or to suggest actions to avoid the conflict in the first place.

They could learn how to accept different personalities and team role capabilities of their team members, and hence learn to work more effectively with different people.

Explicit teaching of thinking skills can be included in the module *Introduction to Chemical Thermodynamics*, to bridge the gap identified in student surveys earlier. To this end, we can adopt a suitable model of thinking (see [9]), and fine-tune introducing it into the laboratory activities. We can also continue our "Twinning Initiative" with CASS faculty in considering using writing as a form of assessment for critical thinking (see for example, Gunnick et al [13]). Lastly, the curriculum integration could be further extended to mathematics module so students could apply their mathematical skills to solve problem in chemical engineering context. At the time of this paper, the main author is currently participating in an action research project with faculty from the School of Mathematics and Science to integrate mathematics in DCHE curriculum using problem-based learning.

It is also recommended to have a common session for DCHE and CASS faculty to give feedback to students on their written skill and technical contents during the mid-semester. This would result in students having more time to rectify their common mistakes and improve their report writing skill after the feedback session. To facilitate this, a common block-off for both faculties timetable would be desirable. Faculty could work more effectively and provide feedback in time for students to improve their skills. However, we do recognize the practical challenges this may demand in practice.

CONCLUSIONS

The "Twinning" initiative formulated as part of the DCHE curriculum revamp using the CDIO framework has indeed benefited students in their learning experience. Despite the challenges mentioned above; both faculty felt that the results were well worth the efforts; as they had made chemical engineering education more interesting. The feedback from students and faculty were used to drive improvements in the engineering curriculum, especially in the design of learning activities and assessment. The specific areas for improvement have been presented to the DCHE CMT who is supportive of our continuous improvement efforts.

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Sin-Moh Cheah is a chemical engineer turned academic. He is the Deputy Director in Singapore Polytechnic, overseeing various applied sciences diploma, including the Diploma in Chemical Engineering. He has lectured on various topics including chemical engineering principles, separation processes, heat transfer and equipment, and chemical reaction engineering. His current portfolios include curriculum revamp, academic coaching and mentoring, and using ICT in education. His current scholarly interests are learning pedagogy, curriculum re-design and program evaluation. He held various positions in Mobil Oil Singapore Pte Ltd (now part of ExxonMobil) prior to joining Singapore Polytechnic.

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Appendix 1 Sample worksheet for “Pre-Experiment Exercise”

Diploma in Chemical Engineering

Semester 1, Academic Year 2010 / 2011

PRE-EXPERIMENT EXERCISE

Module Code :
Module Name :
Members : ___________________________

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Work in the pre-assigned group as briefed by the lecturer, and discuss as a group and provide the group’s consensus to the following questions:

1. List some strengths and weaknesses of each team member:

S/N	Name	Strengths	Weaknesses
1			
2			
3			
4			
5			

2. List down the top 3 goals for your team

(1). ____

(2). ____

(3). ____

3. Identify 3 situations whereby failure or non-performance of a member can adversely affect the team performance.

(1). ____

(2). ____

(3). ____

4. Set some ground rules for the team to serve as guidelines on how the team will conduct itself over the duration of the laboratory sessions (.e.g. arrangement for meeting, free-riding or non-contributing, disagreement over division of task, etc)

(1). ____

(2). ____

(3). ____

(4). ____

5. Decide how the team will handle any conflict that may arise.

6. Provide information of members' contact details as follows:

S/N	Name	Handphone No.	Constraints – If Any
1			
2			
3			
4			
5			

Return the Completed Form to the Lecturer who will keep it for future reference