ASSESSMENT OF CDIO SKILLS FOR STUDENT FINAL YEAR (CAPSTONE) PROJECTS OF DIFFERENT GENRES

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ABSTRACT

Part of the curriculum revamp effort for the Diploma in Chemical Engineering offered at the Singapore Polytechnic is to use the CDIO framework as the basis to introduce chemical product design to our students. Our curriculum requires students to complete a 30-week capstone project work in their third (and final) year of study. Students completed a variety of projects, which can vary greatly from fundamental research to pilot plant operation; reflecting the multiple initiatives that the polytechnic as a whole is pursuing, including strengthening industrial links and promoting creativity, innovation and enterprising spirits among students. This diversity presents a challenge to the existing one-size-fits-all assessment scheme to provide a fair evaluation of the students' work.

This paper explores the challenges faced in executing final year projects (FYPs) in the Diploma in Chemical Engineering, and discusses the approach taken to address them. It first briefly traces the nature and evolution of FYP execution, and explains the rationales for introducing projects of different genres. Detailed study of FYP assessment system vis-à-vis the CDIO framework is carried out. While several skills such as teamwork and communication, as well as personal skills and attributes etc can be common assessment components, in the context of our students' FYPs the same cannot be said of skills such as Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context. This paper then discusses the review of FYPs from three different genres, namely research, engineering and multimedia; and explores the feasibility of assessing CDIO skills. We argued that while this is plausible, it is necessary to customize the assessment tools, which posed several execution and administrative challenges.

Lastly, this paper presents the assessment tools specific to the different project genres. Results from a trial run using these assessment tools in parallel with the existing assessment tool was carried out and the feedback of the assessors were discussed. The paper concludes with valuable lessons learnt.

KEYWORDS

Chemical engineering, CDIO skills, final year project, assessment

INTRODUCTION

All students from the Diploma in Chemical Engineering need to complete a *Final Year Project* in order to graduate. Historically, majority of projects were proposed by lecturers, while some are so-called external projects, involving collaboration with external research institutions and local universities such as the Institute of Chemical Engineering and Science (ICES), National University of Singapore (NUS) and Nanyang Technological Universities (NTU), as well as some small and medium enterprises. It is desirable to have these collaborations as there is a strong need to remain in touch and in support of the chemical industry. Especially in recent years, we had seen an increase in such collaborations, with the projects of pure research genre starting to populate the project list.

However, by their nature, these projects usually lack the CDIO components of "conceive" and/or "design" components as the project objectives had been largely determined by the company sponsoring the projects. Often students are enlisted to help in conducting experiments on behalf of post-graduate students or company R&D personnel. The intended learning outcomes for such projects are also different from in-house projects proposed by our own lecturers. In research projects supervised by post-graduates or doctorate students, for example, tend to receive more attention from the respective supervisor, especially those with a dissertation at stake. Similarly, for industry-sponsored projects, industry partners obviously had a different attitudes and expectations toward project outcomes, e.g. tangible benefits.

With the introduction of *Product Design and Development*, we hoped to have more students proposing their own projects in Year 3 by leveraging on the work done in Year 2. However, we also recognized that not all ideas and proposed solutions from *Product Design and Development* may be feasible or implementable. As such, a fall-back measure is needed to ensure that all students have a project to work on, using either external projects or having lecturers proposing their own projects to make up for the shortfall.

Projects proposed by lecturers ranged widely from basic applied research to design and construction of pilot plants, covering areas in plant operation and optimization, occupational safety and health, alternative fuels, etc; reflecting the broad-based nature of our chemical engineering curriculum. In addition, with greater emphasis on the use of laptops at the institutional level and the availability of simple-to-use software have also encourage staffs to propose software based final year student projects such as Flash-based e-learning packages, or computer-based optimization studies.

Although some of the learning outcomes for students undergoing the final year student projects can be argued to be generically the same, with the emergence of projects of vastly different nature, the current one-size-fits-all assessment criteria becomes increasingly difficult to use. The current *Final Year Project assessment* scheme is shown in Table 1.

Table 1
Existing Assessment Scheme for Final Year Project

S/N	Description	Weigh (%)
1	PRELIMINARY WORK	
	Carry out literature search to meet the scope of the project	5
	Plan and organise work schedule logically & independently	5
2	KNOWLEDGE & SKILLS	
	Carry out methodology effectively to meet project objectives	5
	Demonstrate competency, independence and initiative in carrying out tasks	5
	Demonstrate creativity, innovation and good problem solving skills	10
	Practice good housekeeping & observe good lab safety practices	5
	Work as an effective team member	5
3	LOG BOOK	
	Plan and revise work schedule	5
	Record work progress clearly	5
4	REPORT	
	Summarise project scope and major findings concisely	5
	Analyse and discuss results logically	10
	Make realistic suggestions for further work /Identify avenues for enterprise	5
	Present a neat and scientific report	5
5	PRESENTATION	
	Demonstrate good grasp of principles of project through effective delivery	10
	Demonstrate learning outcomes effectively and answer questions in a clear and logical manner	15

To better reflect the nature of work carried out by students, it is important that they are assessed based on different criteria relevant to the nature of the project. We broadly grouped our final year projects into three different genres of final year projects: (1) Research-based project, (2) Engineering project, and (3) E-learning project. All three project genres will be assessed based on the following five categories:

1. Organisation and Planning 10%
2. Process and/or Product 30%
3. Report and Presentation (Mid-Term) 10%
4. Work Attributes 25%
5. Report and Presentation (Final) 25%

The percentage weightings follow the original five categories of the original project assessment scheme of Table 1. This is due to the need to retain the existing format of online project assessment system for other diplomas that had not adopted the CDIO Framework.

In general, we found that while project genres can differ greatly, several skills such as teamwork and communication, as outline in Section 3 as well as skills defined in Section 2 in the CDIO Syllabus such as time and resource management are of central importance to all these projects and hence can be common components in the assessment of projects of different project genres. With this observation, the three categories of "Organization and Planning", "Report and Presentation (Mid-Term)" and "Report and Presentation (Final)" all have the same sub-criteria as shown in Table 2 capturing CDIO skills of Personal and Professional Skills and Attributes and Communication. The category "Work Attributes" shown in Table 3, captures the all important interpersonal skill of teamwork and as well as personal attributes and qualities.

Table 2
Proposed Assessment Scheme for Final Year Project – Common Categories

S/N	Description	Weigh (%)
1	ORGANIZATIONG AND PLANNING	
	Time management and resource planning	5
	Risk management (includes initiatives and willingness to take risk)	5
3	REPORT AND PRESENTATION (MID-TERM)	
	Plan and revise work schedule (Gantt chart and other tools)	5
	Record work progress clearly in the project Logbook	5
5	REPORT AND PRESENTATION (FINAL)	
	Written Report	10
	Oral Presentation	15

Table 3
Proposed Assessment Scheme for Final Year Project of Different Genres:
Work Attributes

Research and Engineering-based	E-learning	Weigh (%)
Teamwork	Teamwork	5
Personal Attributes and Qualities (e.g. perseverance)	Personal Attributes and Qualities	10
Safety Consciousness & Housekeeping	Customer Satisfaction	5
Troubleshooting	Troubleshooting (Debugging)	5

Under Work Attributes, the category, “Personal Attributes and Qualities” is included to enable vital soft skills such as profession ethics and integrity to be assessed and serves to emphasize their importance to an engineer in the real world setting. Assessment of soft skills are however subjective, hence, to overcome this, a breakdown of the Personal Attributes and Qualities sub-criterion was done and showed in Table 4. Besides having the project supervisors to assess the students in these areas, every project student is also required to carry out a self appraisal as well as for all fellow members in the team using an appraisal form developed based on Table 4. Project supervisor can use the students’ appraisal forms as a reference for adjusting their scores for the students for “Personal Attributes and Qualities” sub-criterion.

For Table 3, apart from teamwork and personal attributes which are common for all project genres, two other customized sub-criteria were also included. This again arose from the needs to adhere to the format of the online assessment system. With reference to Table 1, under the category of “Knowledge and Skill”, housekeeping and observation of safety practices are assessment items already in the existing scheme. For e-learning projects which are computer-based, safety consciousness and housekeeping however, are of lesser concern and customization is hence called for. Customer Satisfaction takes the place of Safety Consciousness & Housekeeping for e-learning projects. In including customer satisfaction as a sub-criterion, it is hope that students would think more deeply and more holistically about the needs of the customer.

Table 4
Proposed Assessment Scheme for Final Year Project of Different Genres:
Personal Attributes and Qualities

Personal Attributes and Qualities 10%	Professional Ethics, Integrity, Responsibility and Accountability	3
	Interpersonal Skill	3
	Attitude towards Work- Professional Behavior	2
	Stress Management - Perseverance and Flexibility	2

Process takes on different meaning for different project genres. Research projects do not usually end up with products and E-learning projects do not need to consider the selection and sizing of equipment unlike engineering projects. Different sub-criteria for the category of “Process and/or Product” are hence defined differently for different project genres. The weightings of each sub-criteria, are however, designed to be the same so as to facilitate the compilation and entry of marks into digital format. The differences are as shown in Tables 5.

Table 5
Proposed Assessment Scheme for Final Year Project of Different Genres: Process and/or Product

Research-based	Engineering	E-learning	Weigh (%)
Evidence of understanding of rational and significance of the study and justification for the study	Application of Theoretical Knowledge	Application of Theoretical Knowledge	5
Literature Review Part 1: Evidence of an extensive review of research literature and elicit the links between the review and area of study – analysis of supporting / opposing evidence	Cost and Quality Consciousness	Design Procedure	5
Literature Review Part 2: Own interpretation put in the context of other interpretations – showing awareness of understanding of assumptions underlying own interpretations	Design Procedure	Interactive, engaging and overall Aesthetic quality	10
Experiment design and sampling plan	Commission and Testing	Maintenance and Accessibility	5
Experimentation – skills and proficiency	Materials Consideration	Compatibility and ease of Use	5

For a research project, experimentation is usually repetitive in nature in order to establish the reliability and repeatability of the findings. This, although is of vital importance to any research work, has little element of design or innovation apart from the initial experiment design. The emphasis for research projects would hence be on knowledge discovery, in particular, the survey of print and electronic literatures. A high weighting of 15% was assigned to literature review. Literature review reflects the depth of the students in the understanding of the research topic. This literature review was split into two sub-categories. The first part focused on understanding the works done and findings made by other researchers working on the same area while the second part of the literature review emphasized on the students' ability to internalize these works and findings and to develop their own interpretations and hence the research direction and approach to the research topic.

For engineering project involving the fabrication of a pilot plant or system, CDIO elements of conceive, design, implement and operate were evidentially present and can be assessed. The emphasis would hence be different to that of research work. Engineering projects that were in collaboration with external institutions and industry or projects proposed by lecturers would most probably have the problem identification and formulation process done. Students working on such projects would nevertheless still have the opportunity to use their engineering reasoning and problem solving skilling in developing the solutions and recommendation. Student initiated projects, which could be an extension of the works by the students from the *Chemicals Product Design* module that they had taken in their second year

or projects that the students wished to embark on, would also most likely belong to this engineering genre. For these projects, the assessment focus would be on working knowledge of the technical fundamentals through the application of engineering concepts in the design of system, selection of equipment and materials and the adequate sizing of equipment (e.g. pumps).

For e-learning project the focus is the end-user. For such project, aesthetic appeal is more important that functionality. Assessment will be based on the ability of the students to develop projects that not only achieve the objectives but are appealing to the senses, engaging and interactive. Issues such as compatibility with current computer operating system, scalability of the program are also to be considered.

ROLLOUT PLANS

Prior to rolling out this new genre specific assessment scheme, a parallel run was conducted for the current batch of students. Out of a total of 37 final year project groups, 19 project groups were selected for their strong inclination towards a particular project genre. The breakdown of these 19 projects is as below:

Engineering projects	:	8
Research projects	:	7
E-learning projects	:	4

As each lecturer under the Diploma in Chemical Engineering has to supervise 2 to 3 projects, the number of supervisors that participated in the survey was 12 from a team of 18 lecturers. After the project supervisors have finished assessing their students using the existing assessment scheme, they were asked to answer the first three questions of the survey. The genre specific assessment was then introduced to them and they were requested to re-assess the same group of students using the new assessment scheme and thereafter to continue and complete the survey form.

We used a series of questions to solicit response from these lecturers. Lecturers have to mark their response on a Likert scale. An open question was included to gather suggestions from the respondents to further fine-tune the new assessment scheme.

The following questions were asked in the survey:

1. I usually assess the students closely according to the assessment items on the existing assessment form.

2. I have little problem when assessing the students according to 5 assessment indicators on the existing assessment form.
   - Preliminary Work
   - Knowledge & Skills
   - Log Book
   - Report
   - Presentation

3. I find the present assessment form adequate for all types of projects

4. I find the assessment of personal attributes such as Independence, Interpersonal skill, Attitude towards work and Coping with stress relevant and important for FYP.

5. I feel that assessment criteria should be different for different project genres.

6. I find that with the new form, I can better assess the students.

7. The following areas need further improvement
   - Organization and Planning
   - Product and/or Process
   - Report and Presentation (Mid Term)
   - Work Attributes
   - Report and Presentation (Final)

8. My suggestions are _____

The first question was to understand how the lecturer assessed the students. The final year project spans over a period of more than 30 weeks and supervisors would generally have developed a certain impression of the students under their supervisions. This may result in some lecturers adopting a "work backwards" approach towards assessment. That is, the lecturer would first determine the grade to award a student and then worked with the numbers in the assessment form so as to arrive at that grade. For such cases, the design of the assessment scheme would hence be of little importance.

75% responded with a score of 4 while 25% responded with a score of 5. This indicates that lecturers assess the students closely to the assessment criteria laid out in the form.

The second and the third questions aimed to gather the respondents' view towards the existing assessment scheme. For Question 2, most respondents awarded scores of 4 or 5 for four of the sub-criteria. A glaring low average score of 3.67 was however awarded for the sub-criterion "Knowledge & Skills". This indicated that lecturers have some hesitations or difficulties when assess the students in this area. For Question 3, the average score was only 3 with 25% of the respondents expressing dissatisfaction over the existing assessment scheme give a score of 2.

Questions 4 to 6 were designed to gather the feedback of the respondents after using the new assessment scheme. The average scores for the three questions were 4.25, 4.1 and 3.9. These sent a strong signal that a genre specific assessment scheme is preferred over a one-size-fits-all scheme. The lower score for Question 6 however suggested that much work is still needed on the proposed new assessment scheme. From Question 7 and 8, the area requiring further fine-tuning was, not surprisingly, Product and/or Process. Suggestions for improvement in general revolved around the weighting assigned for a particular sub-criterion.

CONCLUSIONS

In this paper, it was shown that despites vast differences in project genres, several skills such as those outlined in Section 2 and Section 3 in the CDIO Syllabus are of central importance and can be common components in the assessment of projects of different project genres. While assessing these sections of the CDIO syllabus is plausible for different project genres, customization must be carried out to the assessment scheme as different project genres emphasize different CDIO skills.

Customization, although is a mammoth task, not only due to the very varied projects but also the need to satisfy administrative requirement such as project mark entry into the school computer software system for grading purposes, is a worthwhile endeavor to ensure a fair assessment of the students' work.

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Biographical Information

Kok-Eng Ting is a chemical engineer turned academic. Prior to joining the teaching profession, Ting held both technical and management positions with a multinational manufacturing company with responsibilities ranging from providing technical support to affiliated companies around the Southeast Asia regions to managing a team of engineers and technicians to achieve manufacturing and cost-saving targets. His current research interest is in water-related projects. His current works include applying the reflux-recycle concept from distillation to reverse osmosis and using nanosize semiconductor materials for photocatalytic degradation of persistent toxic chemicals.

Sin-Moh Cheah is a chemical engineer turned academic. He is the former Course Chairman for the Diploma in Chemical Engineering in Singapore Polytechnic. His current portfolio includes course promotion and outreach, as well as current student and alumni relations. His current scholarly interests are curriculum re-design and program evaluation. He has lectured on various topics including chemical engineering principles, separation processes, heat transfer and equipment, and chemical reaction engineering. He held various positions in Mobil Oil Singapore Pte Ltd (now part of ExxonMobil) prior to joining Singapore Polytechnic.

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Appendix A: Existing Form for assessment of final year projects.

Form B

SINGAPORE POLYTECHNIC SCHOOL OF CHEMICAL AND LIFE SCIENCES

FINAL YEAR STUDENT PROJECT ASSESSMENT (Weightage: 100%) YEAR _____

Name of Supervisor: _____ **Signature:** _____
Name of Co-examiner: _____ **Signature:** _____
Project Title : _____ **Course:** _____ **Date:** _____

	Assessment Indicator (%)	Name: Adm No:		Name: Adm No:		Name: Adm No:	
		(S)	(C)	(S)	(C)	(S)	(C)
1	**PRELIMINARY WORK (S) (10%)**						
1.1	Carry out literature search to meet the scope of the project (5%)						
1.2	Plan and organise work schedule logically & independently (5%)						
2	**KNOWLEDGE & SKILLS (S+C) (30%)**						
2.1	Carry out methodology effectively to meet project objectives (5%)						
2.2	Demonstrate competency, independence and initiative in carrying out tasks (5%)						
2.3	Demonstrate creativity, innovation and good problem solving skills (10%)						
2.4	Practice good housekeeping & observe good lab safety practices (5%)						
2.5	Work as an effective team member (5%)						
3	**LOG BOOK (C) (10%)**						
3.1	Plan and revise work schedule (5%)						
3.2	Record work progress clearly (5%)						
4	**REPORT (S+C) (25%)**						
4.1	Summarise project scope and major findings concisely (5%)						
4.2	Analyse and discuss results logically (10%)						
4.3	Make realistic suggestions for further work /Identify avenues for enterprise (5%)						
4.4	Present a neat and scientific report (5%)						
5	**PRESENTATION (S+C) (25%)**						
5.1	Demonstrate good grasp of principles of project through effective delivery (10%)						
5.2	Demonstrate learning outcomes effectively and answer questions in a clear and logical manner (15%)						
	Total Average Marks (as in project database)						
	Marks Deduction Due to Late Submission of Report (2 marks/day)						
	Final Total Average Mark (to be entered into SAS, rounded to whole no.)						