EFFECT OF REFLECTIVE ASSESSMENT ON INTERNALISATION OF CDIO PRINCIPLES

Mushtak Al-Atabi and Wong Yee Wan

School of Engineering, Taylor's University, Malaysia

ABSTRACT

CDIO initiative aims at creating engineers who can engineer through the use of a product life cycle as an educational framework. CDIO's Standard 11 which refers to the CDIO Skills Assessment focuses on the assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge. This paper presents an assessment rubric for a Multidisciplinary Engineering Design module in which the students are required to explicitly reflect on when did they Conceive, Design, Implement and Operate while working in a multidisciplinary team on a given project. To assess the effectiveness of the reflective component of the assessment, two groups of students were surveyed; the first group was assessed on the achievement of their learning outcomes, quality of the project submitted and the interpersonal skills while the second group was asked to reflect on the CDIO process frequently during the semester. The initial results show that asking the students to intentionally analyse their learning experience through the prism of CDIO creates more awareness of the CDIO as a process which can lead to internalisation of the process as a thinking and problem solving technique that can be used when learning other modules that are not design and build by nature.

Keywords – assessment rubric, thinking process, CDIO standards, graduate capabilities

INTRODUCTION

In order to prepare graduates to be ready for the global challenges ahead, Taylor's University (Malaysia) identified a set of capabilities and named them the Taylor's Graduate Capabilities (TGC). These capabilities encompass discipline specific knowledge, cognitive capabilities and soft skills and they are mapped against the syllabus of all prgrammes offered by Taylor's University [1]. Project Based Learning is widely accepted as an effective technique for engineering and technology education as it provides students with avenues to develop both their technical and non-technical skills while integrating knowledge acquired into its practical contexts [2, 3] and hence, Project Based Learning is identified as the technique the School of Engineering at Taylor's is using to instil Taylor's Graduate Capabilities. Since joining the Conceive, Design, Implement and Operate (CDIO) initiative, the School has subscribed to a Project Based Learning with a product life cycle flavour whereby students enrolled at the School are required to take a Project Based Learning module in every semester of their studies. This is to ensure that students are given enough opportunities to acquire personal, interpersonal, and product and system building skills.

It is widely accepted that one of the major challenges facing the implementation of Project Based Learning is the lack of standard assessment and evaluation rubrics [2]. In order for Project Based Learning to achieve its full potential, not only new teaching methods are required but also innovative supportive assessment and evaluation methods [4]. In this paper, a reflective assessment for a Project Based Learning module is presented with special interest of the effect of the assessment on the internalisation of the CDIO principles.

MULTIDISCIPLINARY ENGINEERING DESIGN MODULE

The Multidisciplinary Engineering Design module is offered to the second year students. In this module, interdisciplinary teams of 5 students from Electrical and Electrical (EE) Engineering and Mechanical Engineering (ME) are created to design and build a product in one semester (14 weeks). There were a total of 109 students which made up 22 teams and each team chose their respective project.

In the Multidisciplinary Engineering Design module, there are six learning outcomes. The mapping of the learning outcomes against the CDIO syllabus is shown in Table 1. The mapping of CDIO syllabus to the learning outcomes is important to show the students competency in terms of CDIO skills.

Table 1. Mapping of CDIO syllabus to learning outcomes of the Multidisciplinary Engineering Design module

Module's Learning Outcomes	CDIO Syllabus
1. Explain the principles of design for sustainable development	4.1 External and Societal Context 4.1.2 The Impact of Engineering on Society
2. Apply the principles of physics to achieve a specific engineering task or to build an engineering artefact.	1.1 Knowledge of underlying sciences
3. Evaluate different approaches to achieve a required end result.	4.5 Implementing 4.5.5 Test, Verification, Validation, and Certification
4. Appraise and defend ideas	2.2 Experimentation and knowledge discovery 2.2.4 Hypothesis Test and Defense
5. Predict outcomes of suggested approaches	2.2 Experimentation and knowledge discovery 2.2.1 Hypothesis Formulation
6. Blend visual and verbal communication using a variety of presentation tools	3.2 Communication 3.2.6 Oral Presentation and Inter-personal Communication

ASSESSMENT PLAN

The achievement of the learning outcomes and the respective CDIO syllabus was evaluated using a variety of methods. These methods included the submission of a design proposal, portfolio, written final report, oral presentation, artefact oral test, and artefact presentation. Table 2 shows the assessment methods and their respective type (whether group or individual assessment). Of all the assessment methods, students were required to self-reflect in the portfolio and oral presentation. The students were given freedom whether to reflect their learning experience in terms of CDIO lifecycle or not. At the end of the semester, these students were categorised in two groups: reflection with CDIO and reflection without CDIO. On one hand, students who were categorised in “reflection with CDIO” worked on their project and reflected their learning experience based on CDIO lifecycle. On the other hand, the other group of students worked on their project and reflected on the learning experience without considering the CDIO lifecycle.

Table 2 Assessment methods with the respective type of assessments

Assessment Methods	**Type of Assessment**
Design Proposal	Group
Final Report	Group
Artefact Presentation	Group
Portfolio	Individual
Oral Presentation	Individual
Artefact Oral Test	Individual

Design Proposal

The objectives of the design proposal were to ensure that the students understand the project and have good management for the project. Students were required to submit the design proposal which contained objective of the project, introduction to the project, bill of material, proposed budget, Gantt chart and linear responsibility chart.

Final Report

The objective of the report was to document the technical information of the project. Students were required to submit the report with the abstract, introduction, materials, methods, results and discussion, conclusion and recommendation, and references.

Artefact Presentation

The objective of this assessment was to expose students to demonstrate and explain their product to peers, lecturers, judges and visitors. The assessment was based on the overall functionality and design of the product, teamwork and ability to answer questions.

Portfolio

The objective of the portfolio is to assist students in tracking the progress of their achievement of the module’s learning outcomes through documentation of evidences and reflection. The possible evidences included photographs, journal papers, reports, coursework, technical drawing, video clips, written material, audio presentation, exams and quizzes. The evidences could be either previously graded or not. The evidences should be combined to show a clear picture of how the students related their learning experiences with the course learning outcomes as well as the CDIO stages. The self-reflection is included together with the evidence. To assist students who would like to analyse their learning experience based on CDIO lifecycle, examples of evidences for learning outcomes were suggested as shown in Table 3. Student submitted their evidences by identifying when they conceived, designed, implemented and operated. The evidence submitted would be evaluated as shown in Table 4. Students submitted one piece of evidence for each level of the five learning outcomes. The levels were categorized according to the Bloom's Taxonomy.

Table 3 Suggested evidence with respect to learning outcomes and CDIO lifecycle

LO	Lifecycle	Suggested Evidence
1	Conceive	▪ Statement and/or proposal of a project that has positive (or at least no negative) environmental impacts when it operates ▪ Statement and/or proposal of a project that provide solutions for environmental and/or energy problems
	Design	▪ BOM with material selected adhering to sustainability principles ▪ Energy audit of the project (how much energy will be used to manufacture it, operate it and maintain it- This should include the energy used to manufacture off the shelf parts)
	Implement	▪ Business plan clearly showing the Business Value (BV) and the Return on Investment (ROI) ▪ Maintain cash flow records
	Operate	▪ An account of what will happen to the different components of the project after the end of its lifecycle (e.g. if solar cells are used, will they be dumped in the environment when the project is no longer in use?) ▪ A list of the waste and/or by-products of the project's manufacturing, operation and maintenance

Table 4 Rubric for portfolio assessment

LO	Level	Mark	Question Cues	Suggested Examples for LO1
1 to 5	Level 3	1 or 2	• Evaluate, access, modify, plan, design create, invent, plan, generalize, integrate, measure, conclude, summarize, discriminate, etc.	• Design a better solution to solve problem in the project. • Evaluate the design of the project in terms of sustainable development. • Explanation is supported with clear and directly related evidences.
	Level 2	1, 2 or 3	• Apply, analyze, demonstrate, calculate, relate, experiment, change, predict, explain, compare, infer, etc.	• Analyze the problems of the project in terms of the environment impact. • Compare the possible solutions for the problem. • Analysis or explanation is supported with clear and directly related evidences.
	Level 1	1, 2 or 3	• List, define, describe, identify, show, label, collect, name, estimate, discuss, etc.	• Giving the definition of the principle of design for sustainable development. • Identify the components of the project that involve in the design of sustainable development. • May/may not give supporting evidences.
	N/A	0		Off topic

Oral Presentation

Students would have to present their digital portfolio orally to the examiners. The content should be the selected evidences for all the learning outcomes that the students had, together with the self-reflection. For those students who reflected with CDIO and without CDIO, they presented their evidences in terms of CDIO lifecycle and learning outcomes, respectively. The oral presentation was adopted to evaluate the student competency for learning outcome 6, which is the communication skill. The areas of evaluation included the content of the presentation, digital portfolio and presentation skills.

Artefact Oral Test

In this assessment, students are required to demonstrate the part of work that they involved individually in the project. The students were asked to demonstrate the artefact of the project to the assessor. The areas of evaluation included the individual contribution, depth of knowledge and quality of product design.

RESULTS & DISCUSSION

This section presents the effectiveness of the CDIO reflective component in the learning experience in the two groups of students. The first group reflected their learning experience without CDIO and the second group reflected their learning experience with CDIO. The number of students chose to reflect with CDIO was 58 whereas the number of students chose to reflect without CDIO was 51. The performance of these two groups of students was first compared using the results obtained from the individual assessments which were the portfolio, oral presentation and artefact oral test. Then the overall grade was compared.

The performance of the two groups of students in the achievement of learning outcomes in portfolio assessment is shown in Fig. 1. In the figure, LO refers to “Learning Outcome”. The result shows that students who reflected with CDIO achieved higher average marks in the five learning outcomes as compared to students who reflected without CDIO. It is important to note that the group of students who reflected with CDIO achieved an average mark of 4.6 out of 8 in LO3 to LO5 (2.2 and 4.5 in the CDIO syllabus) as compared to 3.4 out of 8 which achieved by the other group. This shows that by reflecting with CDIO, the students’ experimentation and problem solving skills were improved.

Fig. 2 illustrates the average marks of the two groups of students in the oral presentation and artefact oral test. The result shows that for the group who reflected with CDIO achieved 1.6 marks higher than the group who reflected without CDIO in average. The average marks achieved by the group who reflected with CDIO were 7.8 out of 10. Then Fig. 3 depicts the overall grade achieved by the two groups.

Although the results indicate that students who have opted to reflect upon their work through the mirror of CDIO performed better than the other group of students, more work need to be done to ascertain the role of CDIO reflection in impacting the students’ learning. Future work will include repeating the experiment with different groups of students as well as comparing the students’ performance in other modules to their performance in Project Based Learning module.

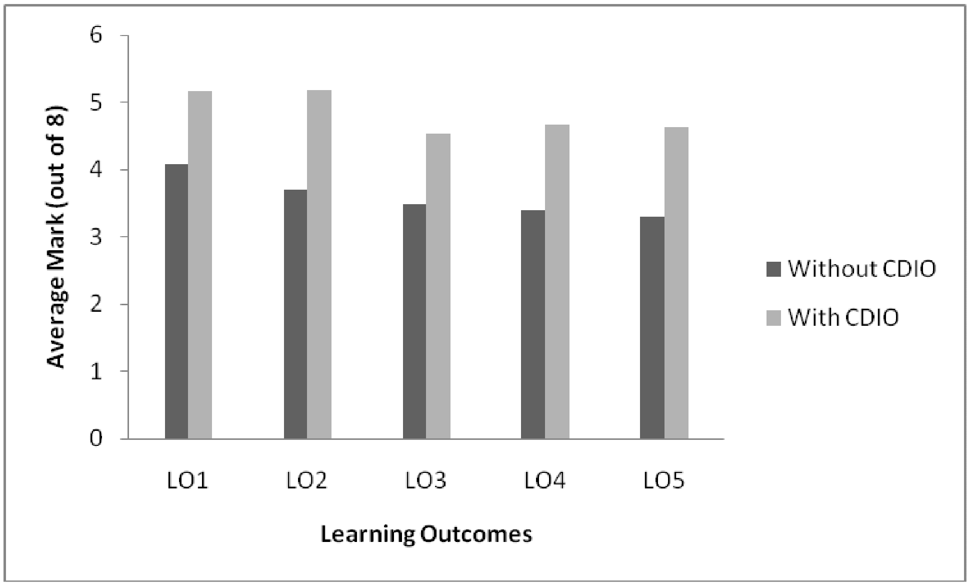

Fig. 1 Average mark against learning outcomes comparison

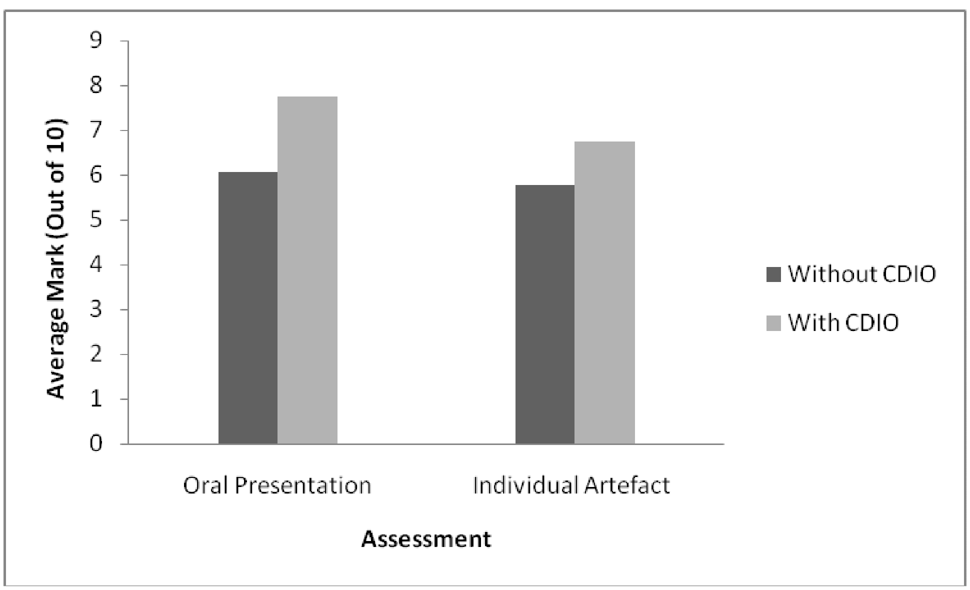

Fig. 2 Average mark comparison for oral presentation and individual artefact test

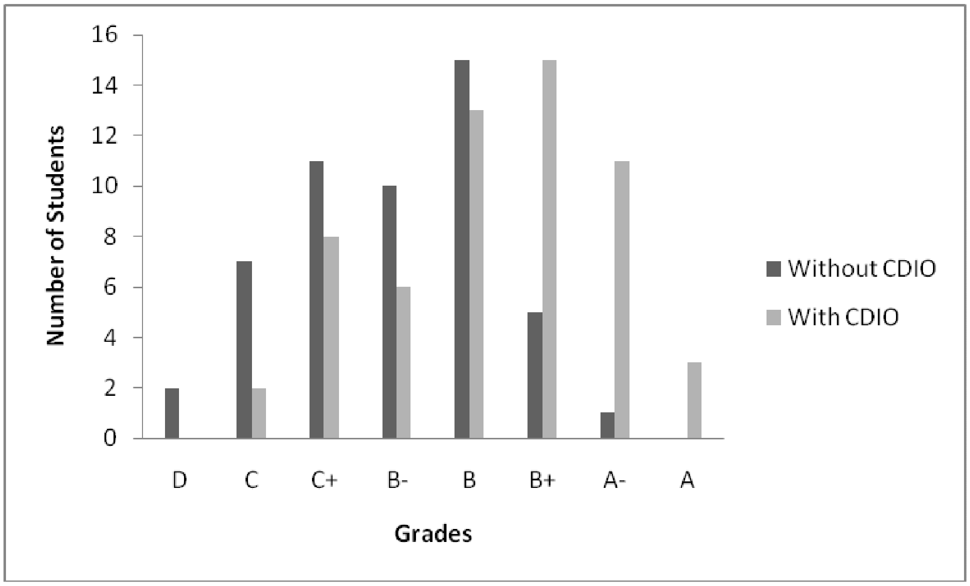

Fig. 3 Overall performance in the module

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Biographical Information

Mushtak Al-Atabi is an Associate Professor of Mechanical Engineering and the Dean of the School of Engineering at Taylor's University. His current research interests are in the areas of thermofluids and engineering education. He served as a member of the International Steering Committee of the CDIO Academy 2011.

Wong Yee Wan is a Lecturer in Electrical and Electronic Engineering at the School of Engineering of Taylor's University. Her research interests are in the areas of networking and engineering education. Currently she is the CDIO coordinator at the School of Engineering

Corresponding author
Dr Wong Yee Wan
Taylor's University
No 1, Jalan Taylor's, 47500 Subang Jaya, Selangor DE, Malaysia.
Wong.yeewan@taylors.edu.my