EVALUATING THE IMPLEMENTATION OF CDIO PROGRAMS AT SINGAPORE POLYTECHNIC: THE SECOND YEAR

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ABSTRACT:

This paper describes the evaluation of the second year of implementation of the CDIO initiative in engineering programs in 4 schools in Singapore Polytechnic. Unlike the first year where changes were made to the syllabuses to incorporate the CDIO skills to develop the students' personal and interpersonal skills and attributes, the second year focused more on the professional and system and product building skills such as conceiving user needs, visualizing, problem solving and project planning and management. A range of evaluation tools were used to collect students' perception of the new skills and their integration into the curriculum.

Preliminary findings of the evaluation showed that students were generally positive about the activities introduced as they provided them with opportunities to learn a range of skills. The students were able to integrate and transfer knowledge learnt in other courses and in the first year to the second year courses. Teamwork was consistently well rated in the courses as the design implement activities required students to work on projects and tasks collaboratively. The findings also showed that, as in the first year of implementation, the teaching of thinking skills needs improvement and that lecturers' behaviours and teaching competence were key influences of students' experience and learning.

The paper will report on the conclusions drawn from the evaluation and make comparisons with the findings of the first year of implementation. It will also discuss the support needed for further improvements to the curriculum implementation and faculty teaching.

KEYWORDS

Program evaluation, personal skills and attributes, communication skills, teamwork skills, Introduction to Engineering, integration of skills,

INTRODUCTION

The CDIO evaluation in Singapore Polytechnic was initiated to provide a structured research driven approach to monitor and review the implementation of the CDIO in Engineering Programmes. 13 engineering programmes from the Schools of Architecture and Built Environment, Chemical and Life Sciences, Electrical and Electronic

Engineering and Mechanical and Manufacturing had been revised and restructured according to the CDIO framework.

In the first year of the programmes, changes were made to the syllabuses to incorporate the CDIO skills to develop the students' personal and interpersonal skills and attributes. An Introduction to Engineering module was instituted to provide students' with the opportunity to develop the selected skills; link and integrate knowledge across the modules; and stimulate interest in, and strengthen students' motivation for, the field of engineering through real world design build activities.

The revised first year curricula were implemented in April 2008. The CDIO evaluation was initiated to provide a structured research driven approach to monitor and review the implementation of the CDIO Framework at Singapore Polytechnic. The evaluation activities were designed to address three broad research questions central to understanding the impact of key aspects of the CDIO implementation:

1. Are the learning outcomes, learning activities and assessments aligned?
2. How has the changes in the curriculum, learning activities and assessments impacted the students?
3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills (thinking, teamwork and communication) and interest in the subject?

The findings of the impact of the changes were analysed and reported (Leong-Wee et al, 2009).

EVALUATION OF THE INTEGRATION OF CDIO SKILLS IN THE SECOND YEAR CURRICULA

In the second year, curricula changes were made to integrate the skills of professional and system and product building such as conceiving user needs, visualizing, problem solving and project planning and management.

The three broad research questions used for the evaluation of the first year and the corresponding specific research questions were critically reviewed and kept as they were found to be still relevant (Table 1).

Table 1: Research questions

Broad Research Questions	Specific Research Questions
1. Are the learning outcomes, learning activities and assessments aligned?	• Are the CDIO skills sufficiently incorporated in the learning outcomes, learning activities and assessments? • Are the learning designs appropriate? • Are the assessments appropriate and valid?
2. How has the changes in the curriculum, learning activities and assessments impacted the students?	• Are the students showing competence in the CDIO skills? • Are the students more engaged and interested? • Do students find the lessons more meaningful?

3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?	• In what ways, do the activities help develop the selected CDIO skills? • In what ways do the activities encourage interest and learning? • What are the difficulties and areas for improvement?

In this second evaluation, effort was made to define and refine the constructs for the questions more clearly. This allowed for a more focused design of the student questionnaire and journal questions and analysis of the data. The constructs included students' perceptions of

- the awareness of skills integrated into the lessons
- the relevance or usefulness of the skills,
- the significant activities that enabled the learning of the skills
- the level of understanding of the skills
- the ability to apply the skills
- the ability to integrate of knowledge and skills taught, and
- the level of motivation/interest.

Data for the evaluation was collected through document checks, student co-participant journals, student surveys, and focus group interviews with students and lecturers.

METHODOLOGY

Table 2 below summarizes the data collection methods and evidence sources utilized for the various components of the evaluation. The methods were kept consistent with the first year evaluation as they were found to be appropriate and relevant to the research questions.

Table 2: Data collection methods

Broad Research Questions	**Data collection Methods (evidence sources)**
Are the learning outcomes learning activities and assessments aligned?	Examination (in collaboration with participating faculty) of a range of curriculum materials (e.g., course documents, module documents, learning plans, schemes of assessment, assessment items)
How has the changes in the curriculum, learning activities and assessments impacted the students?	Student questionnaire for all students in the sample Student journals Focus group interviews with a sample of students Student achievement in assessments (e.g., performance in learning activities/tests relating to selected CDIO skills)
What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?	Focus group interviews with faculty teaching on CDIO programmes Observation of selected lessons (e.g., those incorporating activities related to selected CDIO skills).

Examination of a range of curriculum materials
To ensure that the curriculum materials met the conditions of an aligned curriculum (e.g., Biggs, 1999) and were consistent with relevant CDIO standards (Crawley et al 2007), a close collaborative approach between the school faculty (who are the subject specialists) and Educational Development staff (who provided the pedagogic guidance) was adopted. This involved individual and team consultation on course design, writing of learning outcomes, designing learning activities and assessment items integrating the CDIO skills.

The existing learning outcomes were revised and rewritten to ensure that the selected CDIO skills were infused appropriately. Once the process of ensuring clarity and appropriateness of learning outcomes (including the infusion of selected CDIO skills) was completed, a similar process of revision of the key learning tasks and assessment activities (including the scoring systems) was undertaken. This process of collaborative work continued until the course curriculum was fully aligned and the various components appropriately designed (e.g., learning outcomes, learning designs, assessments).

Student Journals
The student journals were employed as they provided a means to obtain the students' on-going learning experiences with the revised curriculum. Students "co-participants" (a terms used by Lincoln (1990, p.78) were invited to journal their experiences of the lessons taught. The selected students were briefed on the research purpose and their role and responsibilities. They were specifically required to:

- Chat to classmates and identify some broad experiences relating to learning the selected CDIO skills and the teaching approaches used
- Make personal notes and/or journal their experiences in relation to both structured and open questions in the designated student journal
- Meet with the researchers at least once a semester for group sharing

Students are typically presented with specific questions relating to their experience of lessons that had selected CDIO skills infused, and asked to provide their responses with examples where possible. The students are also at liberty to post comments at any time if they feel this information would enhance our understanding of their learning experience in the classroom context. In a course of a semester, 4 sets of questions could be sent to the students to respond to. Altogether, there were 55 Year 1 and 58 Year 2 student co-participants.

Student Questionnaire
Questionnaires were administered online via the BlackBoard e-platform to all students in the courses at the end of each semester. The questionnaires employed a number of structured questions that were customized to the specific courses and CDIO skills adopted. It consisted of a list of statements relating to the students' experiences with the CDIO skills which were rated on a 5-point scale (where 5 represents a perception of "strongly agree" and 1 represents "strongly disagree"). Conscious attempt was also made to align the questions to the constructs identified and to ensure clarity and appropriate focus and efficiency.

It is to be noted that there are some key changes in the questions posed between the semesters, as well as between the schools and departments. For example, in the first semester, there was interest in identifying the extent to which student were aware of the

infusion of the selected CDIO. In subsequent questionnaires, the focus was more on establishing the extent of application of the skills in the module context.

Focus Groups
Focus group interview were conducted with the student co-participants and faculty teaching the courses. Focus group interviews were adopted as they provided the researchers with a more in-depth response to the research questions being investigated. Participants were able to provide elaboration of observations and insights reported in the journals and build upon the responses of other group members. Hence, richer accounts of the experiences were obtained.

Typically, the focus group interviews last between 1-2 hours depending on the number of participants involved. To provide a more structured approach to the interviews, the research constructs and student journal entries were used as the basis for the interview questions. It is generally felt that sufficient depth and exploration of key ideas were achieved in the discussions.

Altogether, there were 43 Year 1 and 38 Year 2 student co-participants participated in focused group interviews.

The staff participants in the focus groups comprise those teaching courses in which selected CDIO skills were infused. 28 staff, representing all the schools that adopted CDIO, participated in 7 focus groups sessions. In the interview sessions, faculty were asked to offer their experiences and reflections on:

- What they had been involved in doing, in terms of CDIO implementation?
- What they had specifically done and how?
- What were their perceptions of the impact of the curricular changes on student learning?

The interviews are facilitated by two members of EDU staff, one acting as main facilitator and the other doing the summary recording of key responses.

Observation of Lessons
Eight lessons taught by faculty involved in the CDIO implementation were observed. The observations helped verify the data from the student journals, questionnaires and focus group interviews through the process of triangulation. Useful insights for enhancing understanding of how students experience learning activities related to the selected CDIO skills were obtained from the observations.

DATA ANALYSIS & FINDINGS

Data analysis techniques were selected on the basis of appropriateness to the data types generated from the various collection methods. Table 3 summarizes the approaches taken.

Table 3: Data analysis approaches

Data Type	Data Analysis Approach
Curriculum Materials	Analysis of curriculum documents and materials (e.g., module documents, learning activities, learning designs, assessment schemes,

	assessment items and scoring systems) Recording of the numbers of appropriately completed (and non-completed) document/material types
Student Blog	Quantitative tabulation and analysis of responses to questions Qualitative data analysis (e.g., categorization and generation of themes)
Student Questionnaire	Quantitative tabulation and analysis of responses to questions
Focus Groups	Qualitative data analysis (e.g., categorization and generation of themes)
Observation of Lessons	Qualitative data analysis using designated recording categories (e.g., tasks relating to thinking, teamwork and communication)

Curriculum materials

Analysis of the curriculum showed that a number of modules required significant revision in terms of the writing of learning outcomes generally (e.g., rationalization, performance focus, clarity of intent, etc). However, the focus has shifted over the past academic year from the rewriting and integration of appropriate learning outcomes in module documents to the design and implementation of assessment methods and the design of learning experiences. Most module coordinators have now completed their module documents. Assessment systems (including guides and rubrics, etc) have been developed for the final year capstone project, as well as for other module based projects. Also, another shift in focus has been towards a more holistic approach to assessment across the engineering schools.

Student Questionnaire

The Student Questionnaires were designed to gather feedback from students at the end of the semester. Due to differences in implementation across schools and across semesters, different variants of the questionnaire were used. Students were required to submit their responses to the questions on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The response rate for the questionnaires were around 60% of the full student population. Table 4 shows the frequency distribution (with percentages in parenthesis) of students' responses by course for Semester 1. More than 50% agreed and 20% strongly agreed, in favour of the implementation of CDIO.

Table 4: Frequencies and percentages (in parenthesis) of students' responses for 14 courses in Semester 1

Module	1	2	3	4	5
ABE710Y (n=34)	21 (1.6)	51 (3.0)	244 (14.5)	754 (55.7)	277 (20.5)
ABE715Y (n=102)	31 (1.9)	6 (0.4)	137 (9.3)	900 (55.4)	521 (32.7)
CP5045/46 (n=46)	92 (5.8)	115 (7.2)	215 (13.4)	720 (45.0)	452 (28.3)
CP5045/47 (n=36)	54 (3.4)	97 (6.1)	157 (9.8)	777 (48.6)	518 (32.4)

CP5008 (n=30)	20 (1.7)	58 (4.8)	192 (16.0)	644 (53.7)	274 (22.8)
CP5009 (n=42)	33 (1.7)	107 (5.6)	454 (23.9)	899 (47.3)	399 (21.0)
CP5010 (n=60)	10 (0.6)	84 (4.7)	354 (19.7)	872 (48.4)	480 (26.7)
CP5015 (n=32)	12 (1.1)	49 (4.5)	313 (28.5)	679 (61.7)	45 (4.1)
CP5017 (n=39)	2 (2.3)	17 (2.1)	79 (9.9)	550 (68.8)	156 (19.5)
EEE Year 1 (n=365)	16 (1.0)	25 (1.7)	185 (12.8)	909 (56.5)	462 (27.8)
EEE (D & I) (n=150)	35 (2.2)	40 (2.5)	315 (19.7)	880 (55.0)	325 (20.3)
EEE (ASME) (n=72)	13 (0.9)	60 (4.3)	206 (14.7)	848 (60.6)	273 (19.5)
MM1028 (n=68)	13 (0.9)	60 (4.0)	244 (16.3)	834 (55.6)	338 (22.5)
MM2027 (n=59)	114 (6.7)	133 (7.8)	347 (20.4)	828 (48.7)	272 (16.0)
Overall (n=1135)	466 (2.3)	902 (4.2)	3442 (16.4)	11094 (54.4)	4858 (22.4)

Similarly, Table 5 shows students' responses for Semester 2. Although slightly lower values than those in Semester 1, nearly 45% agreed and 20% strongly agreed, in favour of the implementation of CDIO.

Table 5: Frequencies and percentages (in parenthesis) of students' responses for 17 courses in Semester 2

Module	1	2	3	4	5
ABE710Y (n=22)	1 (0.3)	34 (10.3)	102 (30.9)	151 (45.8)	42 (12.7)
ABE715Y (n=56)	61 (6.1)	109 (10.8)	175 (17.4)	470 (46.6)	193 (19.1)
ABE7208 (n=25)	8 (2.1)	7 (1.9)	41 (10.9)	227 (60.5)	92 (24.5)
ABE760Z (n=66)	0 (0)	35 (3.1)	237 (21.1)	488 (43.5)	362 (32.3)
CP5045/46 (n=30)	13 (3.1)	6 (1.4)	88 (21.0)	215 (51.2)	98 (23.3)
CP5045/47 (n=27)	1 (0.3)	21 (5.6)	131 (34.7)	162 (42.9)	63 (16.7)
CP5008 (n=54)	2 (0.3)	27 (3.8)	136 (19.4)	427 (60.8)	110 (15.7)
CP5009 (n=55)	3 (0.3)	35 (3.3)	209 (20.0)	658 (63.0)	140 (13.4)
CP5010 (n=56)	2 (0.2)	11 (1.1)	168 (16.7)	662 (65.7)	165 (16.4)

CP5015 (n=45)	16 (2.7)	6 (1.0)	122 (20.9)	338 (57.8)	103 (17.6)
CP5017 (n=47)	14 (4.3)	1 (0.3)	57 (17.3)	192 (58.4)	65 (19.8)
CP512Y (n=47)	26 (4.3)	9 (1.5)	117 (19.1)	288 (47.1)	171 (28.0)
EEE Year 1 (n=607)	304 (2.5)	566 (4.7)	3571 (29.4)	5149 (42.4)	2550 (21.0)
EEE (D & I) (n=463)	171 (2.3)	351 (4.7)	2262 (30.5)	3218 (43.4)	1406 (19.0)
EEE (ASME) (n=141)	39 (2.0)	97 (4.9)	393 (19.9)	1051 (53.2)	394 (20.0)
MM1028 (n=271)	239 (2.1)	591 (5.2)	3514 (30.9)	5149 (45.2)	1889 (16.5)
MM2027 (n=114)	199 4.2	312 6.5	1394 29.1	2042 42.6	841 17.6
Overall (n=2126)	1099 (2.4)	2218 (4.9)	12717 (27.9)	20887 (45.8)	8684 (19.0)

The following are the more generic findings:

- Students, across the academic schools, understand the usefulness of these skills in their learning and development as a technologist
- The percentage ratings overall tend to be positive (e.g., 4 and 5 combined consistently exceed 3, 2 and 1 combined). However, it is to be noted that there is a significant percentage of 3 ratings across many of the question areas relating to application of the CDIO.
- There is some variation in responses across the academic schools and between courses. This is likely to reflect the different approaches taken by the academic schools, as well as the individual faculty. This observation was made very apparent from the student focus group interviews.

Student Journals

A rich qualitative data on the impact of the curriculum changes were obtained from the student journals. The great majority of students who blogged perceived the importance of these skills as a valuable part of the curriculum. The variation in perception was low with most students agreeing that the skills are an integral part of being a good engineer as well as useful in a range of life contexts.

Majority of the students felt that the Teamwork and Communications course (TCS) covered in year 1 is beneficial to them now in 2nd year. For example, a second year Diploma in Aerospace Electronics (DACE) reported:

“Yes, the Teamwork & Communication Skills module (TCS) taught in the 1st year definitely paid off. Active listening is a crucial part of group discussion as everyone was attentive to what the other team members had to say before expressing our own views, thus ensuring everyone in the group had equal chances to contribute ideas and views.”

Second year students were able to identify linkages between the 1st year and 2nd year courses. For example, second year students in DACE found the first year courses of Digital Electronics, Principles of Electrical and Electronic Engineering, Engineering Mathematics and Structured Programme, and the second year course of Microcontroller Programming relevant to the Design and Innovation course they were learning.

On Conceiving of ideas, the students reported doing brainstorming, analysing, breaking problem into parts and decision making. Students also identified that research and gathering information is an aspect to conceiving of ideas.

Student Focus Groups
All students who participated in the focus groups felt that the selected CDIO skills (e.g., thinking, communication and teamwork) are relevant and important to learn. They reported that well designed activities were able to provoke their thinking, enhanced the application of both technical knowledge as well as personal and interpersonal skills, and prepared them for the workplace. The students highlighted teamwork in particular as the skill they found most applicable in their courses.

The students also expressed concerns about the high workload and the variation amongst practices of individual faculty. While some faculty were well versed with the objectives of the lessons and provided appropriate guidance and scaffolding, others did not.

Staff Focus Groups
As in the previous evaluation, staff across schools see the relevance of the CDIO framework (e.g., need to make engineering more practical and interesting). Students' attention and interest were enhanced as a result of the greater emphasis on real world engineering projects and activities

In the previous evaluation (2008/09), staff generally agreed that CDIO implementation resulted in an increase in workload as a result of the preparation and assessment involved, especially when cohort size is large and there are a number of assessment components. However, one year later approximately half of the staff interviewed felt this had significantly declined as much of the changes that required considerable time (e.g., rewriting module documents, designing assessment, etc) had been completed, and that they were more comfortable with the teaching approaches.

It is noted that as new faculty come into the programme, they will not have had the training and hands on experience in teaching CDIO skills. This raised the need for ensuring that appropriate training and support is made available for new faculty.

Observation of Lessons
This evaluation component has been discontinued mainly as a result of time-resource constraints. It was felt that the time invested is unlikely to result in significant new insights relating to the research questions underpinning the evaluation.

SUMMARY & RECOMMENDATIONS

The evidence from the evaluation supports the implementation of the CDIO framework in the engineering programmes in SP. The students and staff find the real-world projects and tasks introduced into the curriculum have made the learning more relevant and

engaging, and supported the development of understanding and competence. The evaluation also shows that the changes to the curriculum structures and activities supported the integration of knowledge and skills across courses. Students reported that the knowledge and skills learnt in first year were applicable and relevant to their second year courses.

The importance of effective faculty practices in the implementation of the curriculum changes was highlighted by the evaluation data. A major consideration in the success of CDIO implementation, hence, will be to ensure the necessary competence of the lecturing staff involved. It is suggested that an induction programme on the CDIO skills and standards and support for new staff, in particular, be made available, possibly using a blended learning approach.

In conclusion, this large scale longitudinal study has provided valuable information and insights on the effectiveness of existing practices under review. It is however essential that the evaluation not only retains its effectiveness but continues to contribute to new questions enhancing educational quality in the areas of focus. As we move forward to the third year of implementation of CDIO in SP, a review of the evaluation design and processes will be conducted to ensure its continued effectiveness and situational responsiveness.

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