Assessment of CDIO skills in the context of the Civil Engineering course in the School of Architecture and the Built Environment at Singapore Polytechnic

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ABSTRACT

The division of Civil Engineering in School of Architecture and the Built Environment (ABE) at Singapore Polytechnic started to adopt the CDIO initiative in May 2007. A CDIO design team was formed in July 2007 to study, design and integrate this initiative into two diploma programmes – Diploma in Civil Engineering & Management (DCEM) and Diploma in Environmental Management & Water Technology (DEWT). From literature reviews of past CDIO conference papers and articles, the team affirms that many of these engineering skills are already emphasized in the course. It is timely to recognise the gaps, document them in CDIO terminology and integrate them into the curriculum. One gap is that assessments of these skills are not clearly linked to learning outcomes and documented. The CDIO syllabus has thus provided an overall framework for developing an integrated curriculum and a guide to address our needs for the training of civil and environmental engineering technologists.

This paper describes the process of outcome assessment using rubrics to assess CDIO skills (engineering skills) of DCEM and DEWT students at Singapore Polytechnic. The resultant assessment template aims to:

a) Assess students engineering skills using rubrics linking to a learning outcome
b) Help lecturers assess students CDIO skills within their respective modules

KEYWORDS

Civil Engineering, CDIO, assessment, rubrics, CDIO skills, learning outcomes.

INTRODUCTION

The CDIO (Conceive-Design-Implement-Operation) initiative was brought into Civil Engineering division, School of Architecture and the Built Environment, two years ago. A design team was formed and found that many of the CDIO skills in the CDIO syllabus were already implemented in the course but were not clearly documented in the module syllabus [1, p257]. CDIO skills related to disciplinary or technical knowledge are not covered in this paper as these are well covered in the existing syllabuses. The other CDIO skills are personal and interpersonal skills (section 2 and 3 of CDIO syllabus), and product, process, and system building skills (section 4 of CDIO syllabus). The CDIO initiative has provided a good framework to develop and manage the integration of these skills into the existing diploma courses.

Staff and industry surveys were carried out to determine the expected proficiency level for each CDIO skill for fresh diploma graduates. Then a survey of the two diploma courses were carried out among staff to identify where we introduce, teach and use (ITU table) each of these skills. With this ITU table, an overall picture of CDIO skills for each course can be seen. Where there are gaps and overlaps, there are more apparent. From this exercise, it was discovered that assessments of CDIO skills are not linked to the module learning outcomes of the existing syllabuses. The challenge is to develop an outcome assessment to assess these skills and to reflect the integration of CDIO skills into the existing module syllabus.

INTEGRATING CDIO SKILLS INTO THE SYLLABUS

The CDIO initiative has provided a good student learning assessment process for the development and continuous improvement to teaching and learning [1, p155]. This process has guided us in deriving a model (Figure 1) which provides an approach to outcome assessment based on the CDIO syllabus and stakeholders (industries and lecturers) feedback.

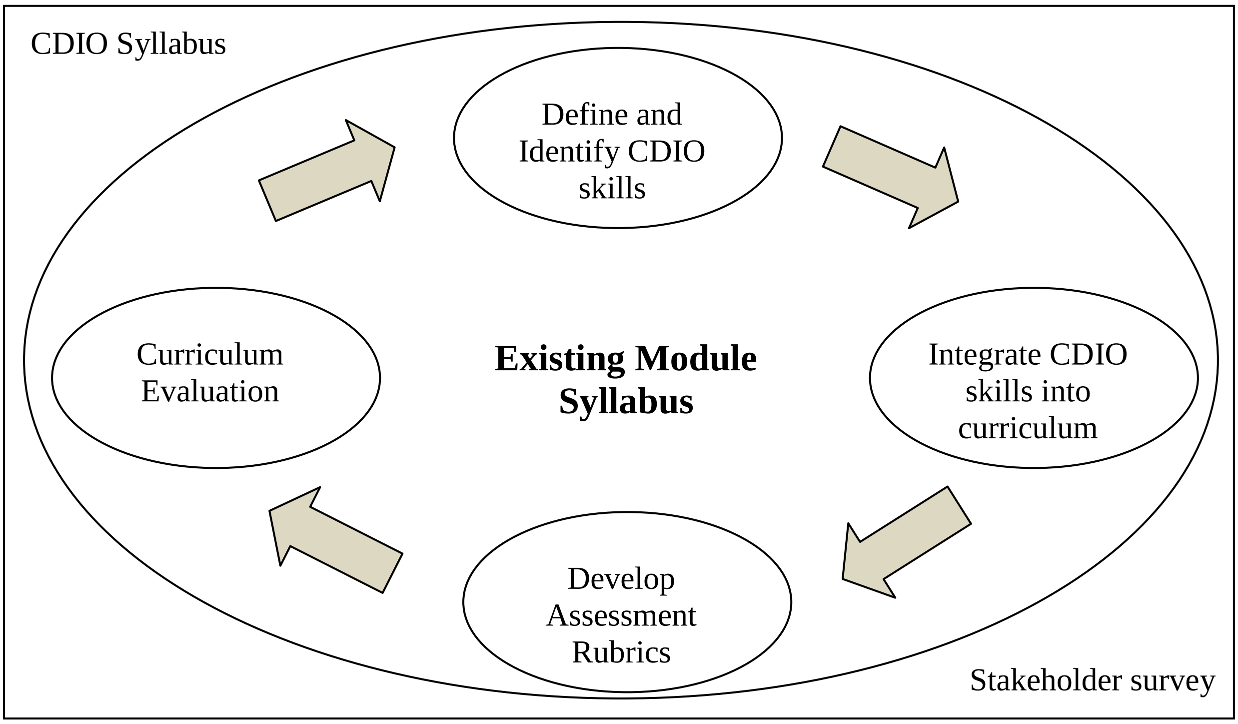


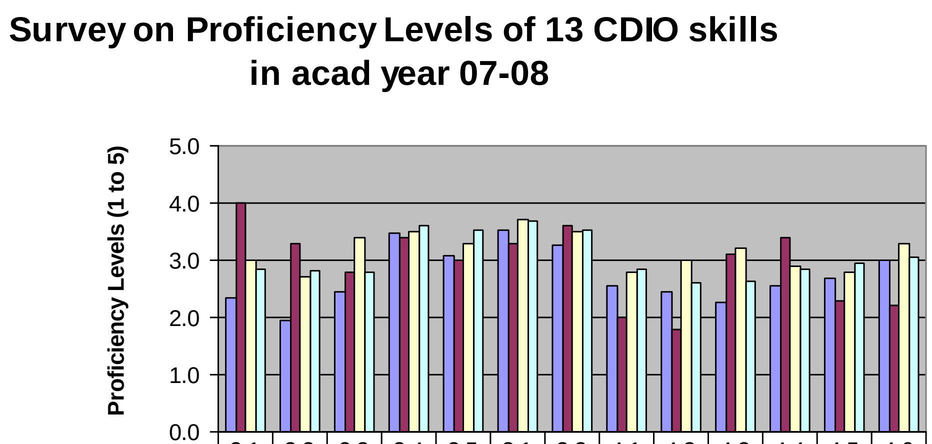
Figure 1 CDIO Skills – Outcome Assessment Model

The model in figure 1 also shows the process of integrating CDIO syllabus into our module syllabus to curriculum evaluation in four stages.

Stage 1 – Define and Identify CDIO skills

The process starts with defining and identifying CDIO skills for technologists. The CDIO design team distinguished between CDIO skills of civil engineers and civil engineering technologists. In the Singapore context, the technologists are middle-level managers in organisations. They work as technical officers, administrative officers, supervisors, assistant project managers, draftspersons, assistant engineers and sales executives upon graduation. A higher expectation of CDIO skills is in implementation and operation rather that concept and design.

Figure 2 shows the proficiency levels of 13 CDIO skills expected from Civil Engineering staff, alumni and industry in the first stakeholder survey conducted between 2007 and 2008. The results are compared with proficiency levels expected of MIT degree graduates by MIT faculty [2].



CDIO Skills	2.1	2.2	2.3	2.4	2.5	3.1	3.2	4.1	4.2	4.3	4.4	4.5	4.6
Civil Staff AVE [23 attempts]	2.3	2.0	2.4	3.5	3.1	3.5	3.3	2.6	2.4	2.3	2.6	2.7	3.0
MIT Faculty AVE	4.0	3.3	2.8	3.4	3.0	3.3	3.6	2.0	1.8	3.1	3.4	2.3	2.2
Alumni - (01 to 05) [36 attempts]	3.0	2.7	3.4	3.5	3.3	3.7	3.5	2.8	3.0	3.2	2.9	2.8	3.3
Industry 2008 [32 attempts]	2.8	2.8	2.8	3.6	3.5	3.7	3.5	2.8	2.6	2.6	2.8	2.9	3.1

Figure 2 Expected Proficiency Levels from Stakeholder Survey

The results show that the proficiency levels expected of civil engineering technologists match what are expected for them as compared to proficiency levels expected of engineers from universities, such as MIT. The plan is to conduct the industry survey annually to fine tune the expected proficiency levels.

Having defined the proficiency levels expected of civil engineering technologists, the expected skills that are covered or need to be covered are entered in the ITU table. The design team recognizes that capstone projects provide the context for development of many of the CDIO skills. Table 1 is, an ITU table showing some modules and capstone projects for year 1 of the DCEM course

Table 1
ITU Table for DCEM course

Technical Knowledge			CDIO Skill Sets												
1			2					3		4					
s/n	Module Code	Module Name	Personal and Professional Skills and Attributes					Interpersonal Skills: Teamwork & Communication		Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context					
	Year 1 - Year-long modules		2.1	2.2	2.3	2.4	2.5	3.1	3.2	4.1	4.2	4.3	4.4	4.5	4.6
1	BE 750Y	CAD Studio	I			IU		U	U						
2	BE 751Y	Building Technology & Materials			T	U	I	U	U	T		I	I	U	I
3	BE 752Y	Structural Mechanics	T	U		U				Intro: Marina Barrage;					
	Year 1 - Semester 1 modules									Capstone Prj: Trellis,					
4	MS 3440	Foundation Physics								Bungalow,					
5	SP 0101	Character Development					T	U							
	Year 1 - Semester 2 modules														
6	BE 7500	Internet Technology	I		T	U									
7	SP0102	Innovation, Design & Enterprise in Action (IDEA)	IT					U	U						
8		GEM 1													

The module team identifies and discusses the key skills that are to be included in the module. Only skills which are indicated as "T" will be taught and assessed while "I" means skills will be introduced but not assessed and "U" means skills taught in other module but may or may not be assessed [1,p87].

Stage 2 – Integrate CDIO Skills into Curriculum

Once the CDIO skills are identified, they are integrated into the curriculum by breaking down into the knowledge, skill and attitude (KSA table) component with an intended weightage distributed to each existing means of assessment as shown in Table 2. In the existing syllabus, various means of assessment are defined, such as "CA" for Class assignment;"LAB" for Lab work"; "TST" for class test or "Exam".

Table 2
KSA Table

Breakdown of Knowledge, Skill and Attitudes Weightage						
	Weightage					
	CA1	CA2	LAB1	TST1	TST2	TST3
CDIO Skills from ITU table	15%	25%	15%	15%	20%	10%
1.0 Technical skills	5%	10%	5%	15%	20%	10%
2.1 Engineering Reasoning & Problem Solving	Introduce but not assess					
2.4 Personal skills & attitudes	5%	5%	5%			
3.1 Teamwork		5%				
3.2 Communication - oral		5%				
Communication - graphical	5%		5%			

The weightages in the KSA table are limited to 5% minimum in order to be considered significant for assessment. These weightages are then transferred to the table of specification (Table 3a) where first level of disciplinary knowledge learning outcomes are defined and categorised into knowledge (K), comprehension (C), application (A) and higher than application levels (HA) of Bloom's Taxonomy in the cognitive domain. After ~~much~~ literature review on Bloom's taxonomy [2] and comparison with CDIO syllabus, the team developed a correspondence between the CDIO syllabus (technical knowledge + CDIO skills) and the Bloom's Taxonomy as shown in Table 3b.

Table 3a
Existing Table of Assessment

	Topics	Abilities (%)			Total (%)
		K	C	A/HA	
A	Introduction to environmental management and water technology	6	1	0	7
B	Organizational structure and management processes	4	2	0	6
C	Piping and valves in water conveyance	8	4	2	14
D	reading and understanding P&ID	10	8	2	20
E	Water treatment process	15	10	8	33
F	Engineering Calculation, Material and Energy Balance	10	6	4	20
	Total	53	31	16	100
Infusion of SP Core Values: Students take charge of their learning though coaching by the module lecturer. Self-discipline, Personal Integrity, Care & Concern, Openness, Responsibility and Excellence are highlighted during the lectures, tutorials and laboratory works. Marks are given for good housekeeping practices during the laboratory sessions.					

Table 3b
New Table of Assessment

Bloom CDIO skill 2 to 4

	Abilities(%)										Total
CDIO framework	1.0		2.1-2.3	*2.4	*2.5	3.1	3.2	4.5	4.6		
Bloom's Taxonomy	Cognitive Domain			Affective Domain		-	-	(only for module with capstone			
Topics	K	C	A/HA								
1. Introduction to environmental management and water technology	0	0	0		5	5					10
2. Organizational structure and management processes	0	0	0								
3. Piping and valves in water conveyance	5	0	0	10			10	10	5		80
4. Reading and understanding P&ID	10	5	0								
5. Water treatment process	15	10	0								
6. Engineering Calculation, Material and Energy Balance	5	5	0								10
Total	35	20	0	10	5	5	10	10	5		100

Stage 3 – Develop Assessment Rubrics

Rubrics and rating scales are used to assess learning outcome by observing student's performance in a task [1, p158]. At this stage, a list of rubrics is developed for each intended CDIO skills corresponding to the expected proficiency level from the stakeholder survey. Table 4 below shows an example of technical content and its assessment criteria and the rubrics for Personal skills & attitudes derived with the module team. These rubrics were used in the various assessment methods in table 5 to determine student performance.

The weightage column reflects the marks based on the percentage contribution indicated in the KSA table. For example, in table 3, the technical content contributes 10% to the total percentage of 25% for CA2 will be converted to 40 marks (100/25% x 10%) out of 100 marks for this mini-project task.

Table 4
Assessment Rubrics

Assessment Rubric for Mini Project - CA2 (25%)

	Criteria	Weightage 100
	1.0 Technical Content	40
	- Model has appropriate structure components and sizes	
	- shows sufficient development with material assignment	
	- Demonstrated application of knowledge acquired in class	
	2.4 Personal skills & attitudes	20
1	Initiative and willing to take risks	
2	Worked and learned independently	
3	Choose logical solutions	
4	Creative thinking (execute the process of invention)	

Table 5
Assessment Methods

	Assessment Methods for CDIO skills				
	1	2	3	4	5
	Written or computer practical questions (e.g. tests , exams)	Performance ratings (e.g. tutorial, lab)	Product reviews (e.g. reports, presentation)	Journals and portfolios	self-report instruments (e.g reflection)
2.1 Engineering Reasoning and Problem Solving			√	√	
2.4 Personal Skills and Attitudes			√	√	√
3.2 Graphical Communication	√	√	√		

Table 6 shows the template created to help lecturer in administering each student assessment records. Under each skill, students are given a rating based on a scale of 1 to 5 which matches the proficiency level rating scale [1,65] used in stakeholder survey, to reflect the student performance.

Table 6
Assessment Template at Work

			1-Poor 2-Fair 3-Good 4-Very Good 5-Excellent						
			CA1 (20%)						
			CDIO project model (IO), final						
			skill	mark	skill	mark	skill	mark	Total
s/n	Adm No.	Name	2.4	25	4.5	50	4.6	25	100
1			1	5	3	30	5	25	60
2				0		0		0	0
3				0		0		0	0

Rating explanation:
1- Poor : to have experienced or been exposed to
2- Fair : to be able to participate in and contribute to
3- Good : to be able to understand and explain
4- Very Good : to be skilled in the practice or implementation of
5- Excellent : to be able to lead or innovate in

Stage 4 – Curriculum Evaluation

This stage, which is also the most important in the process, is the use of assessment results to improve teaching and learning and the curriculum as a whole [1,162]. As not all of our modules have implemented stage 3 in their assessment, ratings of CDIO skill for the course cannot be obtained. However, at module level, we have obtained the average rating of 2 groups (47 students) for skill 2.4, 3.1 and 3.2 to compare with the proficiency level rating we obtained from our stakeholder survey as an example.

Table 7
Module Evaluation

CDIO skills	Average rating of 47 students	Average Expected Proficiency Level from Stakeholders
2.4	3.46	3.55
3.1	3.24	3.6
3.2	3.71	3.4

Table 7 shows the average rating of student performance in a mini-project activity of a module comparing with the expected rating from stakeholder survey. The comparison result shows a close convergence indicating how well the intended learning outcomes (i.e. rubrics) of that skill are being achieved. However, this is not conclusive until more data are collected from the other 4 groups doing this same module before we can make use of it to adjust the module curriculum where needed. Similarly, for course curriculum adjustment more data has to be collected from other modules in the course.

CONCLUSION

CDIO framework has helped to develop and manage curriculum integration with CDIO skills of two diploma courses. The approach and guidelines outlined in CDIO standard 11 is a good reference to develop the process of outcome assessment using rubrics. Staff are shown through in-house training how to adopt the assessment approach presented in this paper. The rubric will be used for the final year students in the third year of implementation.

At the stage 3 – Develop Assessment Rubric, we recognize that it would not be realistic to set the learning outcomes of a year 1 module to correspond to the expected proficiency level obtained from the stakeholder survey. It would be more realistic to achieve the expected proficiency level progressively over the three years of study in the diploma course. We have started to work on defining the three levels of expected proficiency levels for each year of study in both diploma courses. We hope to pitch the different years of learning outcomes and expectations of CDIO skills to the right level.

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