

# Development of Integrated Curricula for the Master of Engineering Programs Using the CDIO Framework

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**Abstract**—This research presents the revision of the current curriculum of the Master of Engineering program at Camarines Sur Polytechnic Colleges in the Philippines through series of consultations and focus group discussions with the faculty and students of the graduate program and industry practitioners, and the development of integrated curricula using the CDIO framework. Standards 1, 2, 3, 4 and 5 and syllabus v2.0 of the CDIO framework were used in the development of the integrated curricula. Graduate attributes were developed, and the result of the industry needs survey served as one of the bases in the integration of various skill sets in the integrated curricula for the master of engineering programs.

**Keywords**—CDIO, CDIO framework, CDIO standards, CDIO syllabus, curriculum, integrated curriculum, Master of Engineering

## 1 Introduction

The outcomes of the student learning can be determined by how well an educational institution design and to implement the entire curriculum for a specific program. The development of curriculum for educational programs can be influenced by a number of sources. The goals of the program could be defined based on the funding source, the community, government departments of education (state and federal level), or by the educator who is designing the activity [1].

CDIO is an international initiative in reforming education. CDIO framework has been the current trend, and it influences the reformation of engineering education. It is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamental set in the context of Conceiving-Designing Designing – Implementing – Operating (CDIO) real-world systems and products [2]. The current educational setup must be aligned to the current needs of the industry and skills gap is a common problem between university products and industry needs [3]. To cope in this competitive world, a well-designed curriculum must be designed to satisfy with the international standards of engineering education that focus on the attainment of the needs of the industry.

In the Philippines, CDIO was first to introduced with the partnership of Singapore Polytechnic and Temasek Foundation. One of the nine State Universities and Colleges

in the Philippines is the Camarines Sur Polytechnic Colleges that undergone series of trainings and seminars both in the Philippines and Singapore on the CDIO Framework. Six faculty members of the College of Engineering were trained to become Master Trainers that has the role of cascading CDIO not just in the college but to all Colleges and Universities in the Philippines.

Camarines Sur Polytechnic Colleges popularly known as CSPC is a state college in the Philippines. It is mandated primarily to provide higher technological, professional and vocational instruction and training in fisheries, trade and technology, arts and sciences, as well as short term technical and vocational courses, as the Board of Trustees may deem necessary, and shall promote researches in the exploration and conservation of natural resources in the province [4]. The vision of the college is to be the regional center of excellence in polytechnic education. Presently, CSPC has two campuses: the main campus in Nabua, Camarines Sur and Buhi Extension campus. In the main campus, the institution has 5 colleges, namely, College of Engineering, College of Health Care Technology, College of Management and Entrepreneurship, College of Information and Communications Technology, and College of Education, Arts and Sciences. The college offers 2 levels of educational programs in various disciplines: bachelor's degree and master's degree programs.

CSPC has been one of the leading engineering institutions in the Bicol Region. The College of Engineering puts its goals in providing quality instruction and training in engineering through the ladderized curricula in civil, electrical, mechanical and electronics engineering which are responsive and relevant to the needs and development of the service area in particular and the country in general as well as develop total quality engineers and technology researchers for industry and society to maximally contribute to sustainable national development [5].

The first master's program offered by the college in the last 20 years was the Master of Arts in Teaching Engineering Technology (MATET) and then it was changed to Master of Arts in Engineering Technology (MAET) and Master in Engineering Technology (MET). Currently, the name of the program was change in 2014 to Master of Engineering (M.Eng'g). The program offers specializations in Civil Engineering, Mechanical Engineering, Electrical Engineering and Electronics Engineering. Based on the tracer study of Barandon conducted in 2016, the graduates of the program at CSPC from 2004 to 2015 is fifty-five (55). From 2016 to present, the enrollees of the program greatly increased and in 2018, the current number of students is eighty (80).

CSPC is one of the two higher education institutions in Bicol region to offer a master's program in engineering catering engineering professionals and practitioners in the six (6) provinces of Bicol. The main objective of the study is to develop integrated curricula for the master of engineering programs using the CDIO framework guided by the current educational standards and requirements of the graduate program in engineering, and the results of industry needs survey.

## **2 Literature Review**

The following are reviews on CDIO that served as the basis in the development of the integrated curricula for the master of engineering programs.

### **2.1 CDIO and the Educational Standards and Accreditation**

The adoption of the CDIO Initiative at the School of Engineering, Nanyang Polytechnic, Singapore contributed to the ABET accreditation of the Diploma in Aerospace and Aeronautical Engineering. The CDIO played a key role in meeting the ABET criteria; the success of the accreditation within a short span of time is shaped by the strategic foundation for NY organizational excellence – Culture, Concept, Capability and Connection/Collaboration [6].

CDIO standards are accepted to be compliant with the Washington accord. With the CDIO process, the CDIO Standards and the CDIO Syllabus, many scholarly contributions have been made around cultural change, curriculum reform and learning environments. The CDIO Syllabus cast into the Australian context by mapping it to the Engineers Australia Graduate Attributes, the Washington Accord Graduate Attributes and the Queensland University of Technology Graduate Capabilities [7].

The Tomsk Polytechnic University carried out the analysis of the existing Academic Standard to understand whether it requires some changes and to identify the possibilities of its improvement. The analysis was aimed at the development of a basis for a new edition of the TPU Standard in the frame of CDIO context [8].

With these literatures, it is to note that CDIO is a worldwide accepted framework for engineering education. It conforms to various educational standards such as the Washington Accord and incorporates outcomes-based education. It is compliant to the standards of engineering education and accreditations of programs

### **2.2 CDIO standards**

The CDIO framework is consists of 12 CDIO Standards [9]. Standard 1 focused on program philosophy. Standards 2, 3 and 4 is on the curriculum development. Standards 5 and 6 are on design-build experiences and workspaces. Standards 7 and 8 are on new methods of teaching and learning. Standards 9 and 10 is on faculty development. And standards 11 and 12 is on assessment and evaluation.

### **2.3 CDIO syllabus**

The syllabus is the cornerstone of CDIO. It offers rational, complete, universal and generalizable goals for undergraduate engineering education [10]. The CDIO syllabus was developed through discussions with focus groups comprised of various stakeholders, and by reference to other documentation of the time [11]. The CDIO syllabus is composed of learning outcomes that are classified into four high-level categories, namely, technical knowledge, personal and professional attributes, interpersonal

skills, and the skills specific to the engineering profession. Table 1 shows the CDIO Syllabus v2.0 [12].

**Table 1.** CDIO Skill Sets

<b>CDIO Syllabus v2.0</b>
<b>1. Disciplinary Knowledge and Reasoning</b> 1.1 Knowledge of Underlying Mathematics and Science 1.2 Core Engineering Fundamental Knowledge 1.3 Advanced Engineering Fundamental Knowledge, Methods and Tools
<b>2. Personal and Professional Skills and Attributes</b> 2.1 Analytical Reasoning and Problem Solving 2.2 Experimentation, Investigation and Knowledge Discovery 2.3 System Thinking 2.4 Attitudes, Thought and Learning 2.5 Ethics, Equity and other Responsibilities
<b>3. Interpersonal Skills: Teamwork and Communication</b> 3.1 Multidisciplinary Teamwork 3.2 Communications 3.3 Communications in Foreign Languages
<b>4. Conceiving, Designing, Implementing, and Operating Systems in the Enterprise and Societal Contexts</b> 4.1 External, Societal and Environmental Context 4.2 Enterprise and Business Context 4.3 Conceiving, Systems Engineering and Management 4.4 Designing 4.5 Implementing 4.6 Operating

### 3 Methodology

This study was focused on the development of integrated curricula for the master of engineering programs using the CDIO framework. The Master of Engineering Programs at Camarines Sur Polytechnic Colleges, a higher education institution in the Philippines was the subject of the study. Revisions of the curricula were done through a series of consultations and FGDs with the faculty and students of the graduate program, and industry practitioners in order to obtain the most important courses and descriptions to be developed. Review of the CDIO standards and syllabus formed part in the whole processes of the development of the integrated curricula. Graduate attributes were developed, and industry needs survey on the expected proficiency of graduate students were gathered that served as inputs in the integration of the CDIO skill sets in the developed curricula. The questionnaire survey was obtained using the CDIO Syllabus v2.0. Respondents were asked to assess the expected level of proficiency, using a set of descriptors as shown in Table 2, in the range of skill sets of the CDIO syllabus [13].

**Table 2.** Expected Level of Proficiency Descriptors

1	To have experienced or been exposed to
2	To be able to participate in and contribute to
3	To be able to understand and explain
4	To be skilled in the practice or implementation
5	To be able to lead or innovate in

The participants of the study were classified into two groups. The first group is the composition of the faculty and students of the graduate program, and industry practitioners. They served as the informants to the series of consultations and FGDs in the revision of the curricula which include the course contents and descriptions. The second group of respondents is the primary engineering industries in the Bicol region, Philippines where the majority of graduate students are employed. They served as the respondents of the industry needs survey in determining the expected levels of proficiency of graduate students. Arithmetic mean and standard deviation were the statistical tools used in the analysis of data. Cronbach's Alpha was used to determine the reliability of the survey. Microsoft Excel was used in the analysis of the data.

## 4 Results and Discussions

### 4.1 Graduate Attributes

On the curriculum development process, five CDIO standards were involved. These are standards 1, 2, 3, 4 and 5 [14]. To meet standard 1, it is understood to indicate that the curriculum has adopted CDIO as a context for the master of engineering education. To meet standard 2, graduate attributes are necessary. Graduate attributes are essential factors in planning the curriculum of any university. The five themes generated represent the main areas of engineering attributes regulated by national bodies [15]. These are knowledge base, professionalism, problem solving, diverse work settings and design. These attributes were derived from the data of countries under the Washington Accord. Currently, the college doesn't have clear statements on the graduate attributes. The proposed attributes were developed and meet the global graduate attribute themes and categories as shown in Table 3. The graduate attributes conformed to the CDIO knowledge and skill sets from CDIO syllabus as shown in Table 4.

**Table 3.** Proposed CSPC Graduate Attributes

No.	Global Themes	Proposed Graduate Attributes	
1	Knowledge Base	Deep Discipline Knowledge	Graduates who have the knowledge and mastery of the fundamental and advanced concepts required for effective practice of their respective fields of disciplines.
2	Professionalism Problem Solving Design	Professional Skills and Competence	Graduates who have basic and advanced practice in their fields, able to think, design, build and solve problems to respond to the needs of the industry and community.
3	Diverse Work Settings	Personal and Interpersonal Skills	Graduates apply effective communication skills both orally and in writing, give importance to life-long learning, and work effectively in multi-disciplinary and multicultural teams.
4	Diverse Work Settings	Socially Responsible and Ethical	Graduates give importance to moral values and beliefs, and understand social and ethical responsibilities.
5	Design	Productivity	Graduates contribute to nation-building and development, and industrial innovation through creative generation of technologies.

**Table 4.** CDIO Skillsets-Future Graduate Attributes Mapping

CDIO Skill Sets based on CDIO Syllabus v.20	Desired Graduate Attributes				
	1	2	3	4	5
<b>1. Disciplinary Knowledge and Reasoning</b>					
1.1 Knowledge of Underlying Mathematics and Science					
1.2 Core Engineering Fundamental Knowledge					
1.3 Advanced Eng'g. Fundamental Knowledge, Methods & Tools					
<b>2. Personal and Professional Skills and Attributes</b>					
2.1 Analytical Reasoning and Problem Solving					
2.2 Experimentation, Investigation and Knowledge Discovery					
2.3 System Thinking					
2.4 Attitudes, Thought and Learning					
2.5 Ethics, Equity and other Responsibilities					
<b>3. Interpersonal Skills: Teamwork and Communication</b>					
3.1 Multidisciplinary Teamwork					
3.2 Communications					
3.3 Communications in Foreign Languages					
<b>4. Conceiving, Designing, Implementing, and Operating Systems in the Enterprise and Societal Contexts</b>					
4.1 External, Societal and Environmental Context					
4.2 Enterprise and Business Context					
4.3 Conceiving, Systems Engineering and Management					
4.4 Designing					
4.5 Implementing					
4.6 Operating					

## 4.2 Industry Needs Survey Results

Twenty (20) questionnaires were returned. The computed Cronbach's Alpha was 0.855 which is higher than 0.700, thus, the survey was reliable. Table 5 shows the result of the survey of the proficiency expectation from the industry. It is found that multidisciplinary teamwork, advanced engineering fundamental knowledge, methods and tools, attitudes, thought and learning, ethics, equity and other responsibilities, and communications were the top expectations. The lowest expectations are communications in foreign languages and enterprise and business context. Results show similarities of the findings of Kuptasthien [16] in 2014. Also, in the results of the study of Ercan, et al., [17], they observed that engineering as well as communication and teamwork skills of students participated in their program developed significantly, which proves that these skills must be integrated in the curriculum.

**Table 5.** Result of Industry Needs Survey

No.	Skill Sets	Mean	Std. Dev.
3.1	Multidisciplinary Teamwork	4.500	0.671
1.3	Advanced Eng'g. Fundamental Knowledge, Methods and Tools	4.250	0.829
2.4	Attitudes, Thought and Learning	4.250	0.622
2.5	Ethics, Equity and other Responsibilities	4.200	0.600
3.2	Communications	4.200	0.600
1.2	Core Engineering Fundamental Knowledge	4.150	0.572
4.4	Designing	4.150	0.654
2.1	Analytical Reasoning and Problem Solving	4.050	0.669
2.3	System Thinking	4.050	0.497
4.3	Conceiving, Systems Engineering and Management	4.000	0.548
1.1	Knowledge of Underlying Mathematics and Science	3.950	0.589
4.5	Implementing	3.850	0.853
2.2	Experimentation, Investigation and Knowledge Discovery	3.750	0.698
4.1	External, Societal and Environmental Context	3.700	0.900
4.6	Operating	3.700	0.843
3.3	Communications in Foreign Languages	3.550	0.669
4.2	Enterprise and Business Context	3.500	0.806

## 4.3 Revisions of the curriculum

The revision of the curriculum was done through a series of consultations and FGDs with the faculty and students of the graduate program, and industry practitioners. The contents of the curriculum were based on the needs of the industry and the capability of the faculty members to handle specialized courses. The faculty suggested that the major courses should only focus on one specialization in each program since the previous curriculum focuses on various specializations. In this revision, four major courses were designed in each program as shown in Table 6.

**Table 6.** Proposed Curriculum: Master of Engineering in Civil Engineering

<b>Foundation Courses (12 units)</b>			
<b>Course Code</b>	<b>Pre-Requisite /Co-Requisite</b>	<b>Course Title</b>	<b>Units</b>
ET 200	None	Engineering Research and Development	3
ET 201	None	Probability and Statistical Concepts in Engineering Planning and Design	3
ET 202	None	Computer Engineering	3
ET 203	None	Advanced Engineering Mathematics I	3
<b>Core Courses (15 units)</b>			
ET 204	ET 203	Advanced Engineering Mathematics II	3
ET 205	/ET 203 /ET 202	Numerical Methods with Computer Applications	3
ET 206	None	Production Engineering and Management	3
ET 207	ET 202	Computer-Aided Design Applications	3
ET 208	None	Environment, Energy & Technology Management	3
<b>M.Eng'g. in Civil Engineering: Structural Engineering (12 units)</b>			
CE 200	ET 204, ET 205	Advanced Structural Analysis	3
CE 201	ET 204, ET 205	Advanced Reinforced Concrete Design	3
CE 202	ET 204, ET 205	Prestressed Concrete Design	3
CE 203	ET 204, ET 205	Structural Dynamics and Earthquake Engineering	3
<b>M.Eng'g. in Mechanical Engineering: Heat Transfer, Thermodynamics and Energy Systems (12 units)</b>			
ME 200	ET 204, ET 205	Combustion Engineering	3
ME 201	ET 204, ET 205	Thermal Engineering	3
ME 202	ET 204, ET 205	Two-Phase Flow and Heat Transfer	3
ME 203	ET 204, ET 205	Thermal Science Application in Power Engineering	3
<b>M.Eng'g. in Electrical Engineering Major Courses: Power Engineering (12 units)</b>			
EE 200	ET 204, ET 205	Power System Operation & Controls	3
EE 201	ET 204, ET 205	Power Transmission and Distribution	3
EE 202	ET 204, ET 205	Computer Applications in Power Systems	3
EE 204	ET 204, ET 205	Renewable Energy Resources Design	3
<b>M.Eng'g. in Electronics Engineering: Robotics and Control Engineering (12 units)</b>			
ECE200	ET 204, ET 205	Electronic Systems and Instrumentation	3
ECE201	ET 204, ET 205	Robotics and Mechatronics Engineering	3
ECE202	ET 204, ET 205	Modern Control Systems	3
ECE203	ET 204, ET 205	Digital Control Systems	3
ET 210		140 HOURS Industry Immersion	3
		Comprehensive Exam	
ET 211		Thesis Writing	6
		<b>Total Units</b>	<b>48</b>



#### 4.4 Integrated curricula using the CDIO framework

From the results of the survey, the top five industry expectations are multidisciplinary teamwork, advanced engineering fundamental knowledge, methods and tools, attitudes, thought and learning, ethics, equity and other responsibilities, and communications. Multidisciplinary teamwork, attitudes, thought and learning, and communications were integrated into the developed curricula. Communications will be taught (T) in the course engineering research and development.

While the multidisciplinary teamwork, and attitudes, thought and learning will be used (U) and be assessed (A) in the various courses of the program as shown in the integrated curriculum. Course syllabi on these courses should be designed and incorporated the various skill-sets as presented in the curriculum.

The foundation courses serve as the fundamentals of engineering as stated in standard 4. Four major courses were incorporated in the curriculum to enhance the implementing skills along with Design & Build experience (standard 5). Figures 1 to 3 shows the gap analysis, skill map and full integrated curriculum.

CDIO SKILLS GAP ANALYSIS													
University Name: CAMARINES SUR POLYTECHNIC COLLEGES										Revision Date: November 5, 2018			
Program Name: MASTER OF ENGINEERING										Faculty Name: COLLEGE OF ENGINEERING			
Program Coordinator Name:													
Year / Semester	Course (Subject) Name	CDIO 3.1: Multidisciplinary Teamwork				CDIO 2.4: Attitudes, Thought and Learning				CDIO 3.2: Communications Communication			
		Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessed (Y/N)	Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessment (Y/N)	Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessment (Y/N)
Year 1 Sem 1	Engineering Research and Development									B	N	Y	Y
	Probability & Statistical Concepts												
	Advanced Engineering Mathematics 1												
Year 1 Sem 2	Computer Engineering												
	Advanced Engineering Mathematics 2												
	Numerical Methods												
Year 1 Sem 3	Computer-Aided Design Applications												
	Production Eng'g. & Management												
	Environment, Energy & Tch. Mngt.												
	Major Course 1												
Year 2 Sem 1	Major Course 2												
	Industry Immersion	B	N	Y	Y	A	N	Y	Y	L	N	Y	Y
	Thesis 1					A	N	Y	N	A	N	Y	Y
Year 2 Sem 2	Major Course 3												
	Major Course 4												
	Thesis 2					A	N	Y	N	A	N	Y	Y

Use the following symbols for "STATUS"

- B CDIO Skill reflected in Learning Outcomes and Learning Activities
- L CDIO Skill reflected in Learning Outcomes but NOT Learning Activities
- A CDIO Skill reflected in Learning Activities but NOT Learning Outcomes

Fig. 1. Current Gap Analysis

University Name: CAMARINES SUR POLYTECHNIC COLLEGES  
 Program Name: Master of Engineering

Year / Semester	CDIO SKILLS	Teamwork	Attitudes	Communications
	Course (Subject) Name			
Year 1 Sem 1	Engineering Research and Development		U	TUA
	Probability & Statistical Concepts	UA		
Year 1 Sem 2	Advanced Engineering Mathematics 1		U	
	Computer Engineering	U		
Year 2 Sem 1	Advanced Engineering Mathematics 2		U	
	Numerical Methods			UA
Year 2 Sem 2	Computer-Aided Design Applications	U		
	Production Eng'g. & Management	UA		UA
Year 2 Sem 3	Environment, Energy & Tch. Mngt.		U	
	Major Course 1		U	UA
Year 3 Sem 1	Major Course 2		U	UA
	Industry Immersion	UA	UA	UA
Year 3 Sem 2	Thesis 1		U	UA
	Major Course 3		U	UA
Year 3 Sem 2	Major Course 4		U	UA
	Thesis 2		U	UA

Legend: T - TEACH  
 U - USE  
 A - ASSESS

Fig. 2. Skill Map

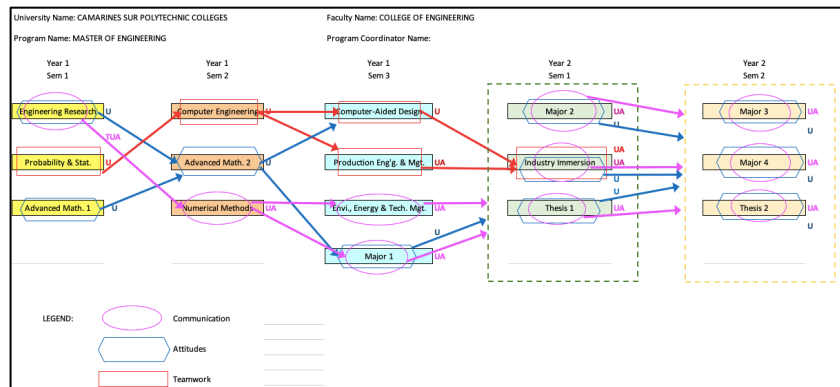


Fig. 3. Integrated Curriculum (Same for the Four Programs)

## 5 Conclusion and Recommendations

The developed integrated curricula for the master of engineering programs using CDIO framework conforms with the current educational standards in engineering education. The contents of the curricula were revised. Graduate attributes were developed, and the industry needs survey was conducted as bases in the integration of various skill-sets and attributes of graduate students. Multidisciplinary teamwork, attitudes, thought and learning, and communications were integrated into the curricula. Policies regarding admission, industry immersion, comprehensive examination, thesis/research, and other academic-related policies on the master's degree in engineering which are not part of this study can be developed based on the approaches of the CDIO framework. The developed curricula can now be in the process for approval with the academic council for implementation. Stakeholder's validation will be essential to determine the effectiveness of the developed curricula. Faculty professional and teaching enhancement will lead to a successful implementation of the developed curricula.

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