THE CDIO-BASED CURRICULAR FRAMEWORK AND GUIDELINES FOR AN OBE IMPLEMENTATION

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ABSTRACT

In response to outcome-based education (OBE) implementation needs, Vietnam National University-Ho Chi Minh City (VNU-HCM) proposed a solution that involved adapting CDIO approach to systematically reform the curricula of its strategic university departments to provide students with the skills, knowledge, and attitudes desired by relevant stakeholders, and to use the pilot implementation as a means to develop common frameworks for curriculum design and development that can be exported and replicated at universities within VNU-HCM and at other HEIs throughout Vietnam. In this paper we present a curricular framework and guidelines generalized from adaptations of the CDIO Syllabus and the CDIO Standards 1, 2, 3, 7 and 11, that can help HEIs establish and implement an OBE system for engineering as well as non-engineering programs. The curricular framework addresses different levels of detail for program educational objectives and learning outcomes at both program and course levels, therefore enables linking the program components and assessing progression of student skills. The widespread implementation of the curricular framework at universities within VNU-HCM and its effectiveness for outcomes-based curriculum design and development suggest that it has a potential to help accelerate the OBE implementation.

KEYWORDS

CDIO implementation, curricular framework, CDIO Standards: 1, 2, 3, 7 and 11.

INTRODUCTION AND BACKGROUND

The need for a curricular framework for OBE implementation

The OBE requires HEIs to demonstrate that their graduates have met the program learning outcomes (PLOs). This implies that all program curriculum, teaching, and assessment decisions have to be made based on the goals of accomplishing that PLOs. It was identified that the biggest challenge for the programs is to classify the learning outcomes at both program and course levels and to link the program components to formulate appropriate assessment models (Aravind, & Rajparthiban, 2011) (Trinh, & Nghia, 2013). There are many feasible approaches to address that systems problem. However, it is a well-known consensus that a key aspect to the systems solution is the development of a framework to systematically address interrelated issues (Binh, et al., 2010).

In Vietnam, OBE implementation has been initiated at the national level, through the mandates of Ministry of Education and Training that all HEIs develop and publicly declare their PLOs, and implement programs that meet the needs of society. However, the existing descriptors and guidelines for PLOs and curriculum development are very general (Trinh, et al., 2012). Therefore, while these mandates have served as a measure to facilitate the curriculum reform efforts, it remains a challenge for HEIs in Vietnam to develop a curricular framework to establish and ensure the sustainable implementation of an OBE system at the institutional level (Trinh, & Nghia, 2013).

Decision to implement CDIO approach

The CDIO Initiative provides an integrated framework consisting of the CDIO Syllabus--a comprehensive and well-structured list of educational goals, and the CDIO Standards to develop engineering programs. In response to OBE implementation needs, VNU-HCM proposed a solution that involved adapting CDIO approach to systematically reform the curricula of its strategic university departments to provide students with the skills, knowledge, and attitudes desired by relevant stakeholders, and to use the pilot implementation as a means to develop common frameworks for curriculum design and development that can be exported and replicated at universities within VNU-HCM and at other HEIs throughout Vietnam (Binh, et al., 2010).

In this paper we present a curricular framework and guidelines generalized from adaptations of the CDIO Syllabus and the CDIO Standards 1, 2, 3, 7 and 11, that can help HEIs establish and implement an OBE system for engineering as well as non-engineering programs. The proposed curricular framework addresses different levels of detail for program educational objectives and learning outcomes at both program and course levels, therefore enables linking the program components and assessing progression of student skills. The widespread implementation of the curricular framework at our universities and its effectiveness suggest that it has a potential to help accelerate the OBE implementation.

ADAPTATIONS OF CDIO FOR A WIDE VARIETY OF PROGRAMS

We will here discuss the CDIO adaptations in some typical cases, e.g. Linköping University (LiU) and Technical University of Denmark (DTU) (Gunnarsson, et al., 2007) (Gunnarsson, et al., 2009), The Royal Institute of Technology (KTH) (Edström, et al., 2009), Singapore Polytechnic (SP) (Sale, 2014), Shantou University (SU) (Wang, et al., 2012), and VNU-HCM (Trinh, et al., 2012).

Adaptations of the CDIO Syllabus

The principal value of the CDIO Syllabus is that it can be applied across a variety of programs and can serve as a model for all programs to derive program educational objectives and specific learning outcomes at both program and course levels. It has been found in all cases that local adaptations of the Syllabus have been made in order to cover programs in related areas as well as to meet regulations by authorities in higher education. For example, in order to cover various discipline areas in engineering offered at the university, customized CDIO Syllabus was developed (at SP, SU, and VNU-HCM); in order to adapt the CDIO Syllabus to non-engineering programs, e.g. natural sciences, the title of Section 4 of the Syllabus has been modified and the product development framework (C-D-I-O) is there replaced with a more research oriented one (at LiU, DTU, KTH, VNU-HCM); in order to meet the national requirements emphasizing on sustainable development (at LiU), a modified version of Section 4 has been developed.

It has been found in almost cases that the four-section structure of the CDIO Syllabus remained unchanged. The adaptations of the CDIO Syllabus to programs beyond engineering education have proven the high generality of the CDIO Syllabus. In order to clear the differences between the engineering programs and programs beyond engineering education, the extended versions of the CDIO Syllabus so-called the program learning outcomes syllabi (PLOs-Syllabi) have been developed and used at VNU-HCM.

PLOs-Syllabi for various discipline areas at VNU-HCM

We adopt CDIO Syllabus v.2 as PLOs-Syllabus for engineering programs and adapted it for various discipline areas. Based on the Section 2 and Section 3 of the CDIO Syllabus v.2, the national qualifications frameworks, and related accreditation criteria, the PLOs-Syllabi for various discipline areas have been proposed (Trinh, et al., 2012) so that they can serve as frameworks for programs to derive PEOs, and specific learning outcomes at both program and course levels:

- The Section 1 and 4 of the PLOs-Syllabus at x-level of detail, i.e. "Disciplinary knowledge and reasoning", and "Competences for professional practice" address the PEOs, e.g. as required by ABET Criterion 2-Educational Objectives (www.abet.org).
- The PLOs-Syllabus at x.x-level of detail consists of topics that are roughly at the level of detail of national standards or accreditation criteria, e.g. as required by ABET Criterion 3-Student Outcomes (www abet.org), the Washington Accord Graduate Attributes and Professional Competences (www.washingtonaccord.org).
- The PLOs-Syllabus at x.x.x and x.x.x.x-level of detail are necessary to transform high-level goals to teachable and assessable learning outcomes. Specifically, the PLOs-Syllabus at x.x.x-level consists of topics that are at the level of detail of learning outcomes at program level; and the PLOs-Syllabus at x.x.x.x-level consists of topics that are at the level of detail of learning outcomes at course level.

Adaptations of the CDIO Standards 1, 2, 3, 7 and 11

Based on CDIO Syllabus and the standards for curriculum design, several models and frameworks for course and curriculum development were developed and implemented for CDIO-based and non-CDIO-based curricula, e.g. the Integrated Program Descriptions (Malmqvist, et al., 2006) (Berglund, & Malmqvist, 2007), the CDIO course development model (Edström, et al., 2009). However, challenges include determining the appropriate level of detail for program goals, the adaptation of CDIO terminology in a particular subject area.

VNU-HCM has implemented CDIO since 2010. To consider the adaptation possibility of the CDIO principles, the pilot implementation has been executing for six different programs in mechanical engineering, computer science, and computer engineering which are also taught in large classes as common in almost HEIs in Vietnam, to evaluate and find the appropriate solutions (Nghia, et al., 2012). Based on the program evaluations, then the generalization of the results of pilot implementation, and the CDIO adaptations at other HEIs, the common frameworks and models that can be exported and replicated at universities within VNU-HCM and at other HEIs in Vietnam were developed and implemented. These include the PLOs-Syllabi, the model integrated curricula, the model CDIO-based courses, and the curricular framework and guidelines for OBE implementation that currently are being adopted as the guidelines for widespread implementation of CDIO and institutionalized to be the framework and guidelines for outcomes-based curriculum design in general (VNU-HCM, 2013).

THE CDIO-BASED CURRICULAR FRAMEWORK FOR OBE IMPLEMENTATION

The relationship between the program components in OBE

In OBE, the relationship between the intended learning outcomes, teaching and learning activities, and assessment of student learning outcomes were referred as Backward Design (Wiggins, & McTighe, 1998), or Constructive Alignment (Biggs, 1999). All these models of OBE design highlight the centrality of learning outcomes and the importance of the alignment of curriculum, teaching and learning, and assessment.

The CDIO-based curricular framework for OBE implementation

Based on the adaptations of the CDIO Syllabus and the CDIO Standards 1, 2, 3, 7 and 11 for a wide variety of engineering and non-engineering programs, a curricular framework for OBE implementation was developed. As showed in Figure 1, the curricular framework contains nine components: (1) the PLOs Syllabus, (2) PEOs, (3) PLOs, (4) program ideas, (5) program plan, (6) skill development routes, (7) curriculum design matrix, (8) course syllabi and plans, and (9) skill progression matrices, that are closely interrelated by PLOs.

In comparison with the Integrated Program Descriptions (Malmqvist, et al., 2006), the curricular framework contains three more components: the (1), (5), and (9), that enable classifying the learning outcomes at both program and course levels and assessing progression of student skills.

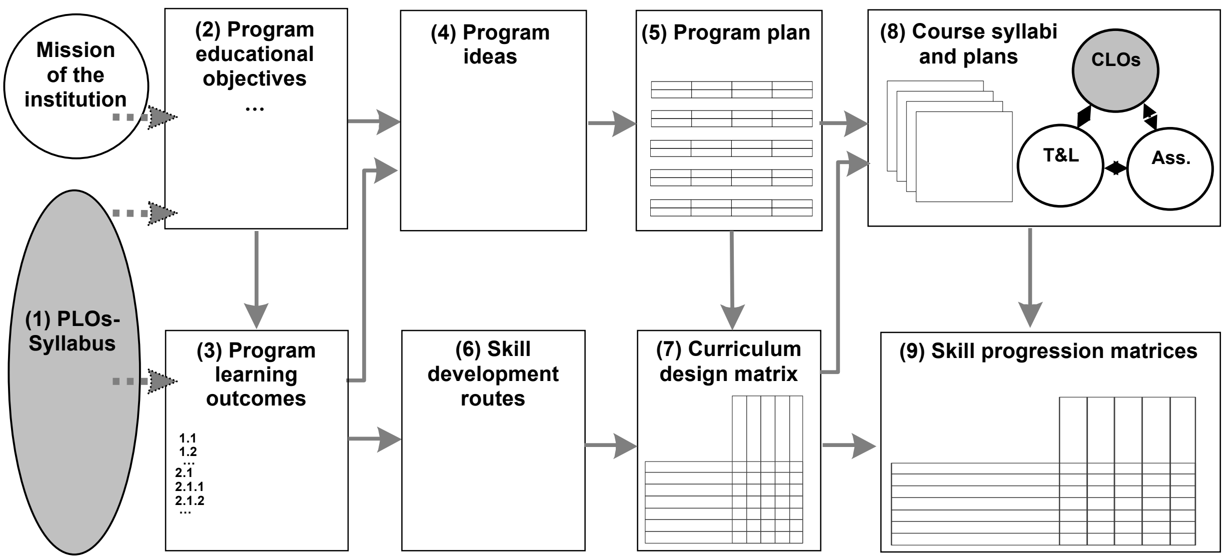

Figure 1. The CDIO-Based Curricular Framework for OBE Implementation

Outcome-based curriculum design and assessment

Figure 1 indicates that the mission of the institution and the PLOs-Syllabus are used as a starting point for defining the PEOs. PLOs are then defined in line with the PEOs and the PLOs-Syllabus. Next, program ideas are determined, program plan is defined in line with the program ideas. Skill development routes are determined. Curriculum design matrix is defined in line with the program plan, PLOs, and skill development routes. Course syllabi and plans are designed to align the learning outcomes at course level (CLOs), teaching and learning activities, and assessment. Finally, the skills are assessed at various point of the student's progress.

THE GUIDELINES FOR CURRICULAR FRAMEWORK IMPLEMENTATION

In order to assist the programs to plan and assess their curriculum systematically accordingly to the proposed curricular framework, a set of curriculum design templates was developed. The content of each template was defined based on the adaptations of the CDIO Syllabus and the related standards.

Formulation of program educational objectives

PEOs is a statement of reason for program, which defines the overall purpose of the program, including its context and the future professional tasks and roles of its graduates (Malmqvist, et al., 2006). PEOs can be structured according to the Section 1 and Section 4 of the PLOs-Syllabus at x-level of detail, as a sample presented in Table 1.

Table 1. A Sample of PEOs

AeroAstro's undergraduate degree programs graduate students who - have mastered a deep working knowledge of technical fundamentals (derived from **Section 1**: Disciplinary knowledge and reasoning) - can lead in the creation and operation of new products and systems, and understand the importance and strategic impact of research and technological development in society (derived from **Section 4**: Competences for professional practice) (aeroastro.mit.edu)

Formulation of program learning outcomes

PLOs define the knowledge, skills and attitudes that the graduates are expected to have developed upon graduation (Malmqvist, et al., 2006). PLOs have to be described as a concretization of the PEOs into a set of assessable learning outcomes structured according to the PLOs-Syllabus at x-level to x.x.x.x-level. As presented in Figure 2, the PEOs above presented map to four topics of x-level (Section 1-4) with a detailed subset of 16 topics of x.x-level. Further, the topics of x.x-level have to be detailed into the topics of x.x.x-level and x.x.x.x-level.

x.	x.x	PLOs Topics
1.		**Develop a working knowledge of technical fundamentals**
	1.1	Demonstrate a capacity to use the principles of the underlying sciences of math, physics, chemistry, and biology
	1.2	Apply the principles of core engineering fundamentals in fluid mechanics, solid mechanics and materials, dynamics, signals and systems, thermodynamics, control, computers and computation
	1.3	…

2.		**Develop a refined ability to discover knowledge, solve problems, think about systems, and master other personal and professional attributes**
	2.1	Analyze and solve engineering problems
	2.2	Conduct inquiry and experimentation in engineering problems
	…	
	2.5	Master professional skills that contribute to successful engineering practice: professional ethics, integrity, currency in the field, career planning
3.		**Develop an advanced ability to communicate and work in multidisciplinary teams**
	3.1	Lead and work in teams
	3.2	Communicate effectively in writing, in electronic form, in graphic media, and in oral presentations
4.		**Develop skills to conceive, design, implement, and operate systems in an enterprise and societal context**
	4.1	Recognize the importance of the societal context in engineering practice.
	4.2	Appreciate different enterprise cultures and work successfully in organizations.
	4.3	Conceive eng. systems including setting requirements, defining functions, modeling, and managing projects.
	4.4	Design complex systems.
	4.5	Implement hardware and software processes and manage implementation procedures.
	4.6	Operate complex systems and processes and manage operations.

Figure 2. A Sample of the engineering program learning outcomes at x.x-level of detail (aeroastro.mit.edu)

Formulation of program ideas

Program Idea describes how the program is designed in order to meet its goals. It states the main principles and considerations that underlie the program design (Malmqvist, et al., 2006). Figure 3 presents the ideas for a four-year engineering program with min. 32 credits per year that meets ABET-EAC Criterion 5-Curriculum (www.abet.org) and CDIO Standard 3-Integrated Curriculum:

- Program consists of (A) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences; (B) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study; (C) a general education component that complements the engineering content of the curriculum and is consistent with the PEOs, that are mutually supporting. The personal skills (section 2), the interpersonal skills (section 3), and other skills specific to the engineering profession (section 4) to be interwoven in the curriculum.
- Engineering sciences and engineering design consist of (B.1) core engineering fundamental courses and projects, (B.2) advanced engineering fundamental courses and projects, and (B.3) intern, capstones or final project.
- General education component consists of (C.1) social sciences and humannities, business administration, and (C.2) standalone courses for other generic skills.

Subject areas	**(A) Math. & Basic Sciences**				**(B) Eng. Sciences & Eng. Design**			**(C) General Education**	
Course, project group	Math	Bio	Chem	Phy	**(B.1)** Core eng. fund knowledge	**(B.2)** Advanced eng. fund knowledge, methods and tools	**(B.3)** Intern, capstones/ final project	**(C.1)** Social. sciences and human., business administration	**(C.2)** Standalone courses for other generic skills
100 %	25%				37.5%			37.5%	
Credits	32				48			48	

Figure 3. A Sample of the ideas for a four-year engineering program

Formulation of program plan

Program plan is the formal specification of what courses are included in the curriculum, their credits and placement in the curriculum (Malmqvist, et al., 2006). In the program plan, courses are listed according to the subject areas that are defined in program ideas. Figure 4 presents a program plan structured according to the above presented program ideas.

No.	Course Code	Course Title	Course Category (Compulsory/ Elective)	Credits	Semester
	(A) Math. & Basic Sciences				
	(B) Eng. Sciences & Eng. Design				
	(B.1) Core eng. fundamental knowledge				
	(B.2) Advanced eng. fundamental knowledge, methods and tools				
	(B.3) Intern, capstones/ final project				
	(C) General Education				
	(C.1) Social. sciences and human., business administration				
	(C.2) Standalone courses for other generic skills				

Figure 4. A Sample of plan for a four-year engineering program

Formulation of curriculum design matrix

As specified by CDIO Standard 3, the curriculum design matrix shows the integration of the topics of PLOs Section 2-4, i.e. the personal skills, the interpersonal skills, and other skills specific to the engineering profession, into courses so that it is clear in which course each learning outcome is addressed with its determined level of competence. The curriculum design matrix must list courses in the semester order so that it shows the skill development routes throughout the curriculum. Figure 5 presents a template for curriculum design matrix.

Sem.	Course Code	Course Title	PLOs Section 2-4 (x.x.x-level)									
			2.1		…	**3.1**			**3.2**			…
			2.1.1	…	…	3.1.1	3.1.2	…	...	3.2.3	…	…
1.		Course…					2			2		
		…										
2.		Course…					3			3		
…		…										

Figure 5. The Template for program design matrix

Formulation of course syllabi and plans

Course syllabi and plans define the goals, CLOs, content, and assessment of each of the courses in the curriculum. The syllabi and plan should also include the brief description that explains the role of the course in the program, the major purpose and content. As specified by CDIO Standard 7, the course goals should include goals for disciplinary knowledge as well as skills, and must be linked to the related PLOs topics at x.x.x-level. A course plan template to align the CLOs, teaching and learning activities, and assessment, has been designed as shown in Figure 6. The course grades are computed using the assessment evidences, criteria and standards used to judge the learning outcomes evidences.

Course title: **Course code:**

General Information

Course Description

Course books, reference books, and softwares

Course Goals

Goals	Descriptions	Competence levels	PLOs Topics at x.x.x-level
G.1			x.x.x
…			

Course Learning Outcomes

CLOs	Descriptions	Teaching Levels (I, T, U)
G1.1		
…		

Lesson Plan

Session	Contents	CLOs	T&L Activities	Ass. evidence
1		Gx.x…		Ax.x…
…				

Course Assessment

Ass. Components	Ass. evidence	CLOs	Ass. Criteria	Ass. Standards	Points/ %
A1. On-going assess.	A1.1	Gx.x…			
	…				
A2. Mid-term exam	A2.1				
	…				
A3. Final exam	A3.1				
	…				

Course requirements and expectations

Figure 6. The Template for course plans

Skill progression matrices

The skill progression matrices needed to assess an achievement of the PLOs at various point of the student's progress. As seen in Figure 7, it shows the overall quantitative achievement of PLOs through the CLOs specified in course plans.

Sem.	Course Code	CLOs		PLOs Section 1-4 (x.x.x-level)									
				1.1		…	2.1		…	3.1		…	…
				1.1.1	…	…	…	…	…	...	3.2.3	…	…
1.		Course…	Gx.x										
			…										
		…	…										
2.		Course…	Gx.x										
			…										
…		…	…										

Figure 7. The Skill progression matrices

CURRICULAR FRAMEWORK IMPLEMENTATION AND CONCLUSION

In comparison with the Integrated Program Descriptions (Malmqvist, et al., 2006), the curricular framework contains three more components: the PLOs-Syllabus, skill development routes, and skill progression matrices, that enable classifying the learning outcomes at both program and course levels, and assessing progression of student skills. Since 2013 to present, 38 more programs within VNU-HCM have implemented the curricular framework to transform their educational programs into outcomes-based ones with all program components arranged as illustrated in Figure 8. The widespread implementation of the curricular framework and its effectiveness for outcomes-based curriculum design and development suggest that it has a potential to help accelerate the OBE implementation.

Degree program: **Program code:**
Introduction
Program objectives and learning outcomes
  Program objectives
  Program learning outcomes
Curriculum
  Program ideas
  Program plan
  Curriculum design matrix
Program Assessment
  Plan for program learning outcomes assessment
  Skill progression matrices
Appendices
  Skill development routes
  Course plans …

Figure 8. The Template for program documentation

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