

CDIO BASED CURRICULUM DESIGN AND DEVELOPMENT OF UNDERGRADUATE PROGRAM

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ABSTRACT

The CDIO approach has been successfully applied to the design of integrated engineering technology curricula worldwide. CDIO based curriculum reform can result in an overwhelming process when universities lack experience in the consolidation of curricula that integrate disciplinary knowledge with engineering skills.

The Department of Communication Engineering Technology(DCET), School of Information and Communication Technology(SICT) has been working for last four years on curriculum reform and the implementation of the CDIO approach for two undergraduate programs named Telecommunications Engineering Technology(TET) and Wireless Communications Engineering Technology(WCET).

This paper addresses the process of curriculum development. We have started working with key stakeholders to identify the demand from the labor market and defined Program Educational Objectives (PEOs), and Program Learning Outcomes (PLOs). Then the process was continued with the selection of required courses, mapping of the PLOs to the PEOs of program and relation between courses in curriculum and PEOs, and PLOs.

Our experience for revision of curricula and implementation of CDIO approach reported in this paper will provide a set of guidelines that can be replicated and tailored by other departments of MUST and institutions of Mongolia.

KEYWORDS

PEOs, PLOs, CDIO, curriculum, Standards: 1, 2, 3

1. INTRODUCTION

Ministry of Education, Culture, and Science (MECS) of Mongolia established minimum requirements of the undergraduate study program in 2014. All public and private universities are reforming their undergraduate study programs in order to meet general requirements set by MECS.

The MUST which is the biggest public university has been working to reform whole educational system including innovation of curriculum, training of faculty and establishing new training facilities and environments since 2014.

The MUST have been started implementation of CDIO standards as a pilot project since 2013-2014 academic years for 3 undergraduate study programs and joined to the worldwide CDIO initiative in March 2015 as a member.

In the scope of higher education reform project funded by Asian Development Bank loan and cooperation with MECS of Mongolia and Singapore Temasek Foundation and Singapore Polytechnic, more than 100 teachers from 8 schools of MUST attended 5 component training courses about CDIO standards in the 2015-2016 academic year and 20 of them selected as national master trainers. Currently, 28 undergraduate programs are introducing CDIO standards since the 2016-2017 academic year.

Since 2014-2015 academic years, SICT has started to reform the curriculum of Telecommunication engineering technology program (TET) according to CDIO approach. It is one of three undergraduate programs which are implementing CDIO approach by the higher education's reforming project funded by the Asian Development Bank loan.

The curriculum is the key document which describes the general learning structure, learning content, the scope of curriculum, list of offering courses and their content extent, sequence, and practical training type, demonstrating how to provide the education service to the students and achieve the attainment of program learning outcomes.

This paper presents some results of curriculum development process of TET program based on CDIO approach. It is focused on defining PEOs and PLOs and other required processes.

2. IMPLEMENTATION OF OUTCOME-BASED EDUCATION USING CDIO APPROACH

CDIO is a new standard and approach that based on theory and methodology of outcome-based education and it was started for engineering technology programs but nowadays it is used for many different programs in a number of universities in the world such as engineering, economy, and management etc.

We evaluate learning outcomes or achievement level of student knowledge, skills, and attitudes as a result of teaching and learning process by the theory and methodology of Outcome-based education, course content is not the main focus area of this methodology.

Constructive alignment is a principle used for teaching and learning activities, and assessment tasks, that directly address the learning outcomes in a way not typically achieved in traditional lectures, tutorial classes and examinations (Biggs and Tang, 2011). Constructive alignment was devised by Professor John B. Biggs and represents an interrelation between a constructivist understanding of the nature of learning and an aligned design for outcomes-based education. There are two basic concepts behind constructive alignment:

- Learners construct meaning from what they do to learn. This concept derives from cognitive psychology and constructivist theory and recognizes the importance of linking new material to concepts and experiences in the learner's memory, and extrapolation to possible future scenarios via the abstraction of basic principles through reflection.
- The teacher makes a deliberate alignment between the planned learning activities and the learning outcomes. This is a conscious effort to provide the learner with a clearly specified goal, a well-designed learning activity or activities that are appropriate for the task, and well-designed assessment criteria for giving feedback to the learner.

Table 1 shows a relation between CDIO standards and Constructive alignment model of Outcome-based education.

Table 1. The relation between CDIO standards and Constructive alignment model of Outcome-based education

No	CDIO standards	Constructive alignment model
1	CDIO as Context	Learning outcomes
2	CDIO Syllabus Outcomes	
3	Integrated Curriculum	
4	Introduction to Engineering	Teaching and learning activities
5	Design-Build Experiences	
6	CDIO Workspaces	
7	Integrated Learning Experiences	
8	Active Learning	
9	Enhancement of Faculty CDIO Skills	
10	Enhancement of Faculty Teaching Skills	
11	CDIO Skills Assessment	Assessment
12	CDIO Program Evaluation	

For implementing CDIO approach, we have to define learning outcomes and then reform a curriculum according to the learning outcomes.

We proposed that program learning outcomes defined by following processes:

- University's strategic plan, vision and mission statements including development trends should be revised.
- Each school of the university should be revised their vision and mission statement in accordance with university's strategic planning.
- Each department of the schools should be revised their vision and mission statements as well.
- To be defined a Program Educational Objectives in accordance with the result of surveys taken from employers and graduates.
- Program Learning Outcomes should be defined based on PEOs of the program. Defined PLOs must be consistency with CDIO syllabus and national and international accreditation criterion and confirmed by surveys taken from employers and graduates.

3. REVISION OF PROGRAM OUTCOMES

In order to fulfill a stakeholder needs, Program Educational Objectives (PEOs) and Program Learning Outcomes (PLOs) must be defined optimally and properly. The process for the establishment, monitoring, and improvement of the PEOs and PLOs of the Telecommunication Engineering Technology (TET) program has been performed by the following principles within last 40 years.

- Prior to 1990, PEOs and PLOs of TET program were defined consistent with needs of the specialist who can deal with operation and maintenance of telecommunication systems used in Mongolia and included the courses to attain PLOs in the curriculum. In other words, PLOs was focused to prepare graduates with technical knowledge and maintenance skills by the request of the biggest government companies of information and communications technology.
- Since 1990, it is transition time to the market economy and Mongolia has gradually reformed the higher education system and introduced degree programs such as diploma, master, bachelor and doctoral level according to the International Standard Classification

of Education (ISCE). Since this time, PEOs and PLOs have started to be defined in accordance with international standards. However, PEOs was defined as a specialist model and job requirements and PLOs was defined generally as knowledge, skills, and attitude until 2000.

- Since 2001, American credit system successfully implemented in MUST first time in Mongolia and PEOs and PLOs have been defined same as foreign universities. In other words, course content and its credit hours are defined in accordance with PLOs which are consistent with PEOs of program and mission and vision statement of department, schools, and university.
- In 2009, the higher education standards of the undergraduate program are elaborated and approved by the Standardization Agency of Mongolia. The graduate's requirements described in section 4.2 "Common requirement of graduates" and section 4.3 "Common requirement of graduates for the program of Telecommunication engineer" of this standard.
- In conjunction with the development roadmap-2021 and renovation of vision and mission of MUST in 2012, SICT revised its vision and mission, and PEOs and PLOs of all study programs. In this time, PEOs and PLOs of TET program were revised based on survey results conducted by employers, alumni, faculty members and senior students. Moreover, we compared PLOs of TET program with the student outcomes defined by accreditation criteria 3 of Engineering Technology Accreditation Commission of Accreditation Board for Engineering and Technology (ABET) and made some necessary changes.
- The latest improvements which are made since 2014 and related to the facts that MUST joined worldwide CDIO initiative. Principal changes were made into the curriculum in order to maintain the new PEOs and PLOs as well as to implement CDIO standard. During the 2014-2015 academic year, according to the decision of the CDIO implementation in some programs of MUST, many activities to reform a curriculum, improve the learning activity, realistically assess and evaluate the learning outcomes and continuously improve the program is been planned and executed.

3.1. Revision of Program Educational Objectives

In the 2012 year, the School Curriculum Committee and Program Advisory Board have been made the analysis in the PEOs used in that time in terms of structure, contents, and formulation, and they have considered that the revision is necessary to be consistent with the MUST development policy, vision, and mission.

The revised PEOs was described as follows and confirmed in relevance based on the survey results from employer and alumni.

PEO1: The graduates of TET program will be able to completely solve the broadly defined engineering problems by applying their acquired knowledge, skills and techniques of mathematics, science and engineering technology.

PEO2: The graduates will be able to pursue successful careers in their chosen professional field and will have the personal and professional responsibility and ethics, a creative thinking and to address initiatives, productively and critically to any issues, and will have the commitment to lifelong learning and professional development.

PEO3: The graduates will have the skills both in the written and oral communications, as well as the knowledge of foreign language to communicate in the professional level, and to function as a member or leader of a team.

PEO4: The graduates will be able to design, implement and process the systems and products to meet the market demands and further trends of development.

Because of the percentage of "extremely important" and "highly Important" responses of the employer participated in the survey was higher than the minimum achievement level except for PEO1, so these PEOs has adhered in TET program until the 2016 year.

According to the assessment and evaluation cycle, the evaluation has been made in PEOs of TET program in the 2016 year and only revised in terms of formulation and wording due to following reasons.

- It is considered that no need to revise in term of PEOs' content because of employers and alumni scored the performance level of PEOs higher than the minimum achievement level.
- There were many comments that to improve the formulation and expression to be easily understandable, clear and as short as possible
- With regard to the policy of Ministry of Education, Cultural, Science and Sport that to intensively introduce the CDIO standard and methodology in the engineering and technology programs and improve the curriculum structure and content, learning activity, assessment and continuous improvement according to this methodology, the PEOs of TET program are monitored and revised consistent with CDIO standard.

The revised PEOs of TET program in terms of formulation and wording is as follows.

PEO1: Demonstrate a deep working knowledge and skills of engineering technology and modern tools.

PEO 2: Fully apply and master personal and professional skills and attitudes.

PEO 3: Effectively apply communication skills, and work as a member or leader of a team.

PEO 4: Create and apply any system, product and process to meet societal and organizational desired requirements and needs.

Current PEOs can be consistent with the CDIO standards and correlated to the educational 4 pillar principles of UNESCO that learn to know, learn to be, learn to live together and learn to do.

3.2. Revision of Program Learning Outcomes

During the spring semester of the 2015-2016 academic year, we are revised PLOs of TET program consistent with CDIO approach and regrouped them according to the 4 learning reference outcomes given as a CDIO syllabus and reordered PLOs within the group. It is shown in table 2.

Table 2. PLOs of TET program

No	Program Learning Outcomes
A.1	Ability to apply knowledge of mathematics, physics and basic science for engineering technology problem-solving.
A.2	Ability to apply core engineering fundamental knowledge of electric circuits, electronics, programming, communication technology and networking for engineering technology problem-solving.
A.3	Ability to apply advanced telecommunications engineering technology fundamental knowledge of switching technology, multiplexing, optical and telecommunication network and modern software and tools for broadly-defined engineering technology activities.
B.1	Ability to identify, analyze, and solve broadly-defined engineering technology problems.
B.2	Ability to conduct measurements; to conduct, analyze, and interpret experiments on telecommunications equipment and system; and to apply experimental results.
B.3	An ability to apply system thinking
B.4	An ability to apply and demonstrate personal skills and attitudes such as creative and critical thinking, life-long learning and time management.
B.5	An understanding of and demonstrate professional ethics, integrity, and responsibilities.
C.1	An ability to function as a member and leader of a team

C.2	An ability to apply written and oral communication in technical and non-technical environments; use appropriate technical literature
C.3	An ability to demonstrate communication skill of technical English.
D.1	An ability to explain and analyze the impact and importance of any engineering technology solutions in a societal, environmental, enterprise and business context.
D.2	An ability to execute conceiving and designing stages of any products, processes, and systems to meet customers' needs and requirements.
D.3	An ability to execute implementation and operation stages of products, processes, and systems by the phased planning process.

4. MAPPING OF PEOs AND PLOs TO THE CDIO SYLLABUS, ABET ACCREDITATION CRITERIA AND COURSES IN THE CURRICULUM

Table 3 and 4 describes how PLOs of TET program meets CDIO syllabus in the second level and ABET Engineering technology accreditation criteria 3. As shown in table 5, PEO1 has relations with PLOs which are defined as knowledge of mathematics, science and engineering technology and skills to apply this knowledge and problem-solving. The PEO2 is consistent with PLOs which are focused on personal and professional skills and developments. PEO3 is related to outcomes which focused on the communication skills. The PEO4 is consistent with outcomes which focused to develop skills to design and implement products and systems that meet any organizational and societal needs.

Table 3. Mapping of CDIO syllabus to PLOs of TET program

CDIO Syllabus	Program Learning Outcomes													
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	D.1	D.2	D.3
1.1	■													
1.2		■												
1.3			■											
2.1				■										
2.2					■									
2.3						■								
2.4							■							
2.5								■						
3.1									■					
3.2										■				
3.3											■			
4.1												■		
4.2												■		
4.3													■	
4.4														■
4.5														
4.6														■

Table 4. Mapping of PLOs of TET program to ABET ETAC student outcomes

ABET outcomes	PLOs of TET program													
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	D.1	D.2	D.3
a														
b														
c														
d														
e														
f														
g														
h														
i														
j														
k														

Table 5. Correlation between PEOs and PLOs of TET program

Program Educational Objectives	PLOs of TET program
<u>PEO 1:</u> Demonstrate a deep working knowledge and skills of engineering technology and modern tools.	(A.1) - (A.3)
<u>PEO 2:</u> Fully apply and master personal and professional skills and attitudes.	(B.1) - (B.5)
<u>PEO 3:</u> Effectively apply communication skills, and work as a member or leader of a team.	(C.1) - (C.3)
<u>PEO 4:</u> Create and apply any system, product and process to meet societal and organizational desired requirements and needs.	(D.1) - (D.3)

The relation between the PLOs and the offered courses in the curriculum is described by learning activities. Since the learning activities that TA-teach and assess; TUA-teach, use and assess; UA-use and assess; are directly connected to the PLOs and the relation between PLOs and the offered course is described according to these categories and shown in Table 6 as an example.

Table 6. The relation between courses in the curriculum and PLOs

Course Name	PLOs of TET program T-Teach, U-Use, A-Access													
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	D.1	D.2	D.3
Mathematics I	TA			TA										
Physics I	TA			TA										
Physics I (Lab)	TA				TA				UA					
Communication English												TA		
History of Mongolia							TA	TA						

Course Name	PLOs of TET program T-Teach, U-Use, A-Access													
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	D.1	D.2	D.3
Oral communication skills										TA				
Electrical Circuits I	UA	TA	UA	TA						UA				
Electrical Circuits I (Lab)					TA					UA				
Civil Defense							TA							
Mathematics II	TUA			UA										
Physics II	TUA			UA										
Physics II (Lab)	TUA				UA				UA					
Introduction to Electronics	UA	TA		TA						UA				
Introduction to Electronics (Lab)		TA			UA				UA					
Introduction to programming	UA	TA	TA		TA								UA	UA
Introduction to programming (Lab)	UA			TA	UA						UA			
Physical Training							TA		UA					
Introduction to engineering		UA	TUA	TUA		TA	TUA	TA	TA	TUA			TA	TA

5. INTEGRATION OF CDIO SKILLS INTO THE CURRICULUM OF TET PROGRAM

The curriculum of TET program comprises the project courses learned in every year. These project courses wrap up and make connections between the courses taken in that year, and are intended to develop a student's skills to Conceive, Design, Implement and Operate (CDIO). In later years, a project task involves the contents of all taken courses and becomes more complex. During the implementation of a project, the students not only strengthen their technical knowledge and attain skills but also, they obtain the skills to express themselves, communicating, working in a team and leading it. For example, through the course named "Introduction to Engineering (J.TC101)", in first phase, students obtain basic understanding of ICT and project management, and then become fond of their major in consequence of working in teams on a certain project, and have motivation to create a new product as well as to attain skills to assemble electronic circuits, to do experiment and measurement, and to operate them. The project courses included in the curriculum are shown in table 7.

Table 7. Project courses

No	Courses		Credits
	Code	Name	
1	TC101	Introduction to Engineering	2
2	TC201	Engineering Project I	2
3	TC305	Engineering Project II	3
4	TC390	Thesis Project	5

These project courses are indispensable for the students to acquire some specific PLOs and relation between the particular PLOs and these project courses is presented in Table 8.

Table 8. The relationship between PLOs and Project courses

No	PLOs	Introduction to Engineering	Engineering Project I	Engineering Project II	Thesis Project
1	(A.1)	U	U	U	U
2	(A.2)	UA	UA	UA	UA
3	(A.3)	TUA	UA	UA	UA
4	(B.1)	TUA	TUA	UA	UA
5	(B.2)	U	U	U	U
6	(B.3)	TA	TUA	UA	UA
7	(B.4)	TUA	TUA	UA	UA
8	(B.5)	TA	TUA	TUA	UA
9	(C.1)	TA	TUA	UA	-
10	(C.2)	TUA	TUA	UA	UA
11	(C.3)	-	U		UA
12	(D.1)	U	TUA		UA
13	(D.2)	TA	TUA	TUA	UA
14	(D.3)	TA	TUA	TUA	UA

The table 8 shows that which PLOs related to particular project course in terms of learning activities such as teach (T), use (U), assess (A). This table reflects that most of PLOs can be assessed by these project courses.

The different learning methods will be used to the project courses in every year depending on the current level of student's attainment of knowledge, skills, and attitudes. The project courses of the 1st, 2nd, and 3rd year, instructor teach (T) the particular knowledge, skills and attitudes and students execute the project according to the given task. While, in the thesis project, the student implement project himself according to advisor's proposed topic and students' performance to apply and develop the knowledge and skills possessed during program progress should be assessed and evaluated.

6. CONCLUSIONS

1. In order to implement Outcome-based education, we have designed curriculum of the undergraduate program consistent with CDIO twelve standards and constructive alignment model that is focused on learning outcomes, learning activities and assessment of learning outcomes.
2. It's necessary to organize phased training about how to define program outcomes, to design curriculum, to plan, teach and assess course learning outcomes, and to continuously improve student achievement level of PLOs by planned assessment cycle.
3. Our experience on the revision of undergraduate curricula and implementation of CDIO approach reported in this paper can be used as a set of guidelines in other departments of MUST and other institutions of Mongolia.

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BIOGRAPHICAL INFORMATION

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