EXPERIENCE OF DEVELOPING STUDENTS' CDIO SKILLS USING DESIGN BUILT PROJECTS

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ABSTRACT

CDIO is a worldwide movement to restore the balance between teaching 'practice' skills and the fundamentals of math and science to engineering students. Mongolian University of Science and Technology just joined to the Asian CDIO initiative in March, 2015 as a member. Since 2014-2015 academic years, SICT started to reform the curriculum for students of Telecommunication Engineering Technology (TET) and Wireless Communication Engineering Technology (WCET) according to CDIO approach. In the scope of curriculum reforming process consistence with CDIO approach, we increased project courses from 7 to 12 credits. Undergraduate students implement a project every year and they get an opportunity to utilize their previously attained knowledge and skills when working in teams to design and develop a certain product, system or process.

The tasks of projects courses described as followings: For course of Introduction to engineering, the Course Learning Outcomes more focused on developing student soft skills and implement mini project by the given tasks in the level of Design, Implement and Operate (DIO). In the second year, student implement engineering project-I which is dedicated for developing student soft and hard skills and students organized in teams and executes the project tasks by using microcontroller and embedded systems in the level of conceive, Design, Implement and Operate (CDIO). In the third year by the engineering project-II course, the teacher gives the more major oriented project tasks to Conceive, Design, Implement and Operate (CDIO) product, process and system. In the fourth year, student implement thesis project by the given tasks that to cover Conceive, Design, Implement and Operate (CDIO) stages of any product, process and system.

For all the project courses, students use workspaces equipped with computer, 3D printer, turnery machine, laser printer, microcontroller based embedded devices such as CNC machine, Arduino, IoT, telecommunication equipment and electrical measurement and tools etc.

In this paper, we addressed experiences about teaching and learning activities and assessment results of project courses taught in last 3 years.

KEYWORDS

Design built projects, CDIO skills, Standards: 1, 2, 3, 4, 5

THE PLANNING TO DEVELOP CDIO SKILL SETS

Since 2014, we have been implementing CDIO approaches at engineering technology programs of Mongolian University Science and Technology (MUST). In the table 1, the comparisons of the contents of Telecommunication Engineering Technology (TET) and Wireless Communication Engineering Technology (WCET) program's curriculum with CDIO syllabus 2.0 and program's curriculum before we introduced CDIO approach to program in School of Information and Communication Technology is shown.

Table 1. Contents of TET and WCET correlated with CDIO syllabus 2.0

Contents of CDIO syllabus 2.0	Old contents of TET program		
	Teach	Use	Access
1.1. Knowledge of underlying sciences	√	√	√
1.2. Core engineering fundamental knowledge	√	√	√
1.3. Advanced engineering fundamental knowledge	√	√	√
2.1. Engineering reasoning and problem solving	√	√	√
2.2. Experimentation and knowledge discovery	√	√	√
2.3. System thinking			
2.4. Personal skills and attitudes			
2.5. Professional skills and attitudes			
3.1. Teamwork		√	
3.2. Communication		√	
3.3. Communication in foreign languages		√	
4.1. External and societal context			
4.2. Enterprise and business context			
4.3. Conceiving and engineering systems		√	
4.4. Designing		√	√
4.5. Implementing		√	√
4.6. Operating			

Table 1 is illustrating that our teaching process has provided theoretical knowledge to students, letting students use gained knowledge by making them work exercises, problems and exams, and assessing their works exam. Therefore it is shown that when we make students work on assignments and laboratory works during lessons included in curriculum, we used team work approach, but there isn't any process to assess their team making process, whether if they worked as a team, their critical and creative thinking. According to such things, it can be seen that we have missed the whole process of developing personal and interpersonal skills.

Thus companies' and employers' demand have changed with society. They seek not only employees who have excellent academic knowledge, but professionals who have 'skills' to perform effectively. And we have faced the need of preparing professionals that meets the requirement of companies and employees.

In case of "Telecommunication Engineering Technology" program we have summed up purpose of education of program, advices and suggestions from employees and stakeholders, structure of CDIO syllabus and came up with 14 indications to identify learning outcomes of the program. We attempted to provide learning outcomes to students not only by theoretical knowledge but also by combining practical skills and theoretical knowledge through project and problem based learning approach. To reach this desired result, program syllabus have indicated that students who are in Telecommunication Engineering Technology" project of SICT must complete 4 projects in their whole length of learning period, as well as planned through the projects they will gain CDIO skills such as teamwork and communication skills, ethical skills and skills to create products and systems. In the table 2, it is shown that how project courses (Introduction to Engineering I and II, Engineering Project I and II, Thesis Project) and CDIO skills relates through learning activities. TUA can be read as Teach Use Assess. Teach means teaching said skills and related concepts to students. Use means let students use the knowledge and skills they achieved through assignments. Assess means always assessing every used skills.

Table 2. The relationship of Project courses and CDIO skills

Project courses	CDIO skill sets												
	2					3			4				
	Personal and Professional skills and attributes					Interpersonal skills: Teamwork and Communication			Conceiving, Designing, Implementing and Operating systems in the Enterprise, Societal and Environmental context				
	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
Introduction to Engineering I	TUA		TUA	TUA	UA	TUA	U				UA	UA	UA	UA
Introduction to Engineering II		U	UA	UA	UA	UA	UA		I	I	UA	UA	UA	UA
Engineering Project I		U	UA	UA	U	UA	UA	U	TUA		TUA	TUA	TUA	TUA
Engineering Project II		U	UA		TUA	UA	UA	U	TUA		TUA	TUA	TUA	TUA
Thesis project		U	UA	UA	U	U	UA	U	U	U		UA	UA	UA

Table 2 shows soft skills which are provided to students and used by them as well as assessed in Introduction to Engineering-I lesson, it is possible that they can also use the skills they gained in this lessons to their future projects and develop it even further. And in Introduction to Engineering I and II courses, students will gain skills conceive, design, implement and operate in an elementary level by using these skills in a range of given works, exercises, problems and assignments, but in lesson Engineering Project I and II they will use their knowledge and skills learned, make an experiment in similar environments and will be assessed. Therefore we are forecasting that when students are working on their Bachelor thesis project, they will be possessed the full skills to complete the project by accumulating knowledge and skills they have achieved in first three years of their studying. Project lessons

are explained in the next section. How project lessons are connected to Program Learning Outcomes is shown in table 3.

Table 3. Relationship of Program Learning Outcomes to Projects

Program Learning Outcomes	Introduction to Engineering I	Introduction to Engineering II	Engineering Project I	Engineering Project II	Thesis Project
(A.1) Ability to apply knowledge of mathematics, physics and basic science for engineering technology problem solving.					■
(A.2) Ability to apply basic engineering technology fundamental knowledge of electric circuits, electronics, programming, electro-magnetic wave and computer network for engineering technology problem solving.		■			■
(A.3) Ability to apply advanced telecommunication engineering and technology fundamental knowledge 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 execute measurements; to conduct, analyze, and interpret inquiry and experiments; 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 on a team		■	■	■	
(C.2) An ability to apply written and oral communication in technical and non-technical environments; identify and 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.	■	■	■	■	■

Table 3 shows the planned program learning outcomes which provided to the students of TET and WCET programs and able to gain and to be developed through the project lessons. Therefore, undergraduate student who is carrying out thesis project will have a full capacity of using Program Learning Outcomes (PLOs) and will be able to develop oneself further.

PROGRESSION OF DESIGN BUILT PROJECTS

Introduction to Engineering

As our discussed above, the curriculum of TET and WCET reformed in 2014-2015 academic year with Introduction to Engineering course (IEC) in first year. So, firstly, we introduced the introduction to engineering course to Wireless communication engineering and telecommunication engineering students in 2014. Through the IEC, students are divided into four to five members and assign CDIO skills by the way of performing project assignment. In the first year IEC, we gave different topics to each team for the project assignment. From first year of experience, we observed that student's ability of team work and designing are improved rapidly. Specifically, each team worked hard and closely with the teacher and each other to make a solution for engineering project. Finally, we faced the problem for evaluating and comparing students in the end of semester. For example, students for each team are worked differently for performing different topics. Some teams worked harder and some teams easily solved project assignments etc. Also, it is impossible to organize the competition for different products. So, since 2015, we started to give same topics to each team for performing engineering project. The project was an electric car with remote control. Under the project, students designed electric circuit and external case and produced them with some easy materials. Students learned to work on simple software modeling and simulation of electric circuits, and they draw their Printed Circuit Board-PCBs using Altium designer and Eagle modeling tool as well as soldered lumped and integrated elements on printed on a copper-laminated board. Each team prepared the project reports as a hard copy, presented presentation and participated in the car race competition. This year project has attracted student more than previous projects. Over the past two years, students have been working on a remote radio-controlled car project and add Ardiuno based part of automatic operation which is sensing white line. Hence, it is possible to organize individual hands on and automatic car competitions which encourage students and possess CDIO skills for them.

Engineering Project I

Second grade of student study Engineering project I and this course conducted 2 times in 2014-2015 and 2015-2016 academic years. The objectives of Engineering project I is more deeply developing acquired CDIO skills of students in Introduction to engineering course. For example, when producing the circuit board, before students was drawing in single sided, while now they should drawing in double sided for printing. Also, external case design is made by hand, now it should be to use 3D printers. The Introduction to engineering course assigns a project on the same subject and results shows in race car competitions among student's team, while the engineering project I carried out with a 4-5-members of students to perform a wider range and practical applications of themes. It is required to find project topics themselves such us observing and brainstorming. For instance, in first year of this course, students performed the design-built projects named greenhouse automation, smart power outlet, remote controlled heating system and money counting machine while in second year of this course, they performed project assignments which is processing data of the amount of money, heat, water and weights received real sources using sensor device, then transmit the digitalized information of these data to next device through wireless transmission and

receiver is creating a physical object by received information which is same amount of data with real sources.
This topic has covered project session for Wireless communication students and they engage to understand basic principle of communication system. Students are engaging to process information, assemble scheme, design prototype and implement-operate prototype. In addition, it is challenging them to optimize data rate and transmitting signal in long distance.

Engineering Project II

Third year students studied engineering project II and they have already studied introduction to engineering and engineering project I. In 2016, first time lesson of engineering project II studied by students. During the this season, all students divided to teams of 4-5 students and every teams worked on building projects of Cansat with its earth station and water rocket for national Cansat competition. In the end of lesson we organized 1st stage of Cansat competition at our university and then chosen best two teams to representing our university for national Cansat competition.

Thesis Project

Students choose too hot topics and create new ideas according to the practices and then they build new products or solution using their older CDIO skills in thesis project. Another advantage of this project course is related to student's main profession and students work can be any products, any technical solution and study and comparison of theories with simulation and estimation according to the communication engineering. Students team can be consists of two members maximally. However usually students work alone for thesis project. The most thesis topics focused on developing new solution for national communication networks and theoretical comparison with simulation according to new communication technology. Also in last years, students are working new topics. For example: wireless network development for automation systems and communication hardware development etc

ASSESSMENT RESULTS OF PROJECT COURSES

Performance evaluation of Program Educational Objectives (PEOs), Program Learning Outcomes (PLOs) and Course Learning Outcomes (CLOs) is performing by direct and indirect assessment methods and basically using following assessment methods:

- Direct assessment methods: which include Midterm exam/test, Final exam, Assignment, Course work, Project and Laboratory work
- Indirect assessment methods: which include Course survey, Exit survey, Alumni survey, Employer survey and Program Advisory Board survey, meeting and discussion

For program, required courses to be conducted assessment report of learning outcomes are shown in Figure 1 and both direct and indirect assessment must be used and evaluation results are applicable for improving performance of CLOs of certain course.
We regularly analyse and write the assessment report of learning outcome of required courses in curriculum plan. This method is mainly used to define performance level of CLOs of all courses which are taught in certain academic year and to plan how to improve performance level for next semester or academic year. The evaluation of learning outcomes described in this way is not appropriate for the evaluation of PLOs in terms of the courses taught by several teachers with different teaching methods and different criteria. Therefore, this evaluation method is used to assess PLOs when only one teacher is taught for that

course or learning outcomes of course related with only one PLO of program. The required courses of program to be conducted survey for assessment report of learning outcomes are shown in Figure 2 and both direct and indirect assessment must be used and evaluation results are applicable for improving performance of CLOs of certain course.

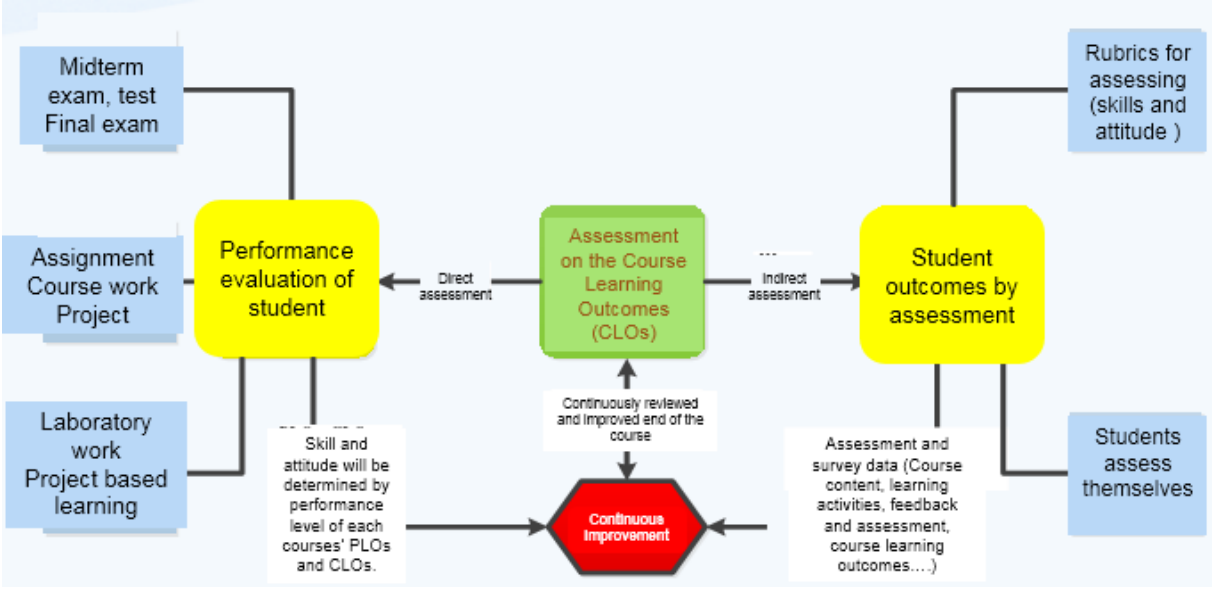

Figure 1. Evaluation process of CLOs

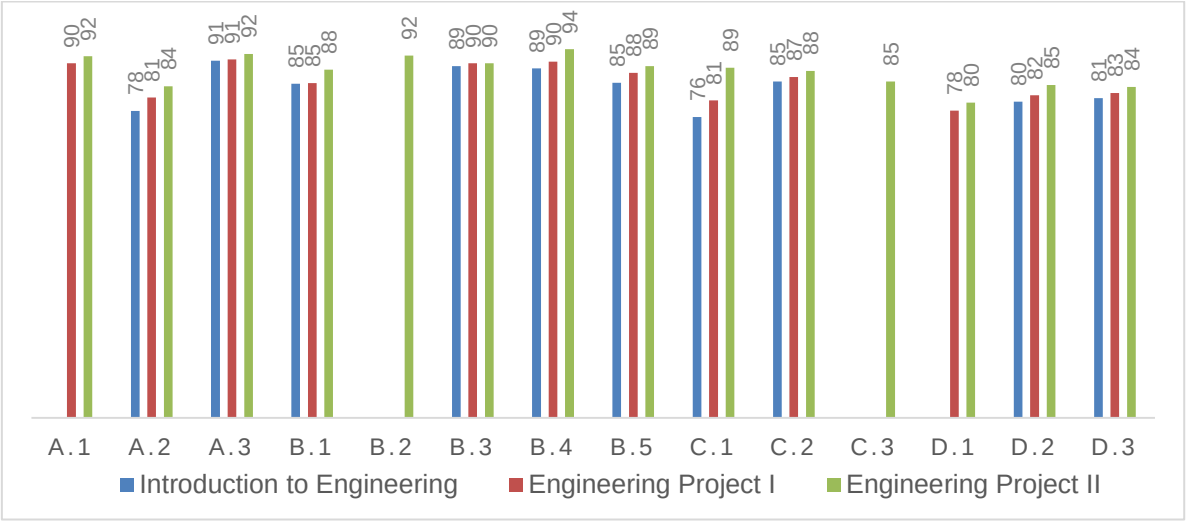

Figure 2. Performance evaluation of Course Learning Outcomes (CLOs) is performing by direct and indirect assessment methods

Direct assessment plan

In order to do, the learning outcomes of the course will be included in the Course Learning Outcomes (CLOs) section and classified by lecture, seminar and laboratory. Then deciding on how to evaluate the assessment methods and what points will be allocated. Evidence at

bottom of should be prepared for each assessment method and, which will be the key materials to validate assessment results.

Figure 3. Student's activity for introducing designed works to each other

Indirect assessment plan

At the end of the course, students assess themselves their achievement level of learning outcomes including knowledge, skills and attitudes through the conducting survey. This questionnaire must be conducted within 16th week of semester.
Student's attainment level of course learning outcome is assessed by (0-4) points and other questionaries' are assessed by (1-5) points. Student survey. This survey is obtained to evaluate the attainment of Course Learning Outcome (CLOs) of the courses conducted in the particular semester. In other words, it described how students acquired the CLOs in this course through this survey. The department secretary and assistant teacher collect this survey from the students by each courses conducted in every semester and transfer the filled answer sheets to the faculty who teach that course. Then, the faculty elaborates the results of survey and do the CLOs' report of the course.

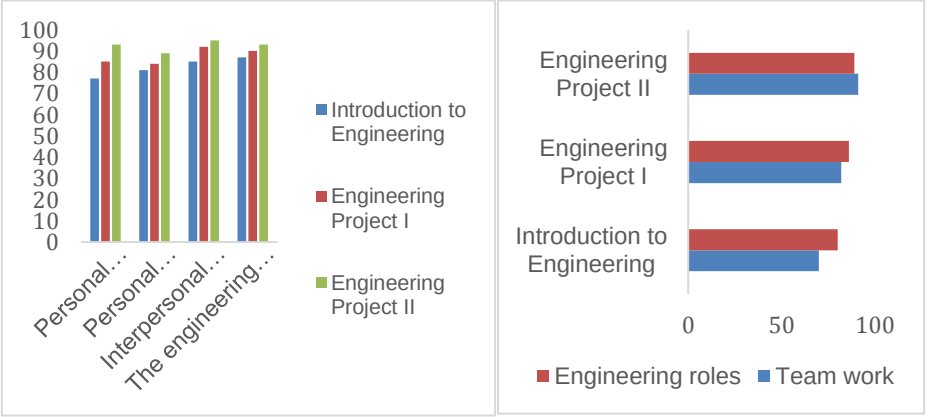

Figure 4. *Comparison* of soft skills' (Team work, Engineering roles) assessments by each project course

Having groups with students from different year is very valuable for the knowledge transfer among students. Students do not know about what they are going to work with in the future. One task they career to get insights into the real life, practice listening and develop their professional. Assessment report of course learning outcomes
In this way, each teacher performs a direct and indirect assessment of the all taught courses at the end of semester, prepare the "Assessment report of course learning outcomes" using template and submit to the Department Curriculum Committee (DCC). DCC analyses the assessment report of course learning outcomes of all courses which taught in certain semester and prepare the recommendation, send it to teachers before 14 days starting the next semester. Also DCC organize meeting and introduce the result of analysis for assessment reports and discuss about how to plan to organize activities about improving of performance level of courses which is required improvement. If performance level is below 70%, it is not satisfied. If performance level is above 70%, it is satisfied, however, it determines how to make improvements depending on performance percentage.

CONCLUSION

An attempt has been sincerely made to introduce design-built projects in the TET and WCET programs to impart personal and interpersonal skills listed in CDIO syllabus. The engineering project courses are a very important technical fundamental subject in training and improving the students' attributes. The developed curriculum is now in the process of program committee, curriculum committee, higher education commission and the ministry of education, science and culture. According to curriculum, we taught design-built projects in last three years. At the end of the project courses, students assess themselves their achievement level of learning outcomes including knowledge, skills and attitudes through the conducting survey. This questionnaire must be conducted within 16th week of semester. We carried out the direct and in-direct assessment to evaluate the student's achievement level. In last three year's indirect ant direct assessment shows student's soft and technical skills has improved. Although indirect assessment, which is the assessment that students assess themselves, has shown higher grades than their performance, the fact that there is an improvement means using project course is enhancing students' CDIO skills.

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BIOGRAPHICAL INFORMATION

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