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Integrated Curriculum Development in Industrial Engineering Program Using CDIO Framework

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This paper shares Thai industrial requirements for new graduates entering real-life workplace and the development of an integrated curriculum using CDIO framework. The result from a questionnaire survey showed high needs for personal and interpersonal skills with strong industrial engineering background. These skills were integrated into courses in 4-year program.

Key words: CDIO, engineering education, integrated curriculum, curriculum development, industrial engineering.

Introduction

CDIO framework has been influencing the reformation of Engineering Education for the last decade. Founders of the CDIO framework are professors from world class institutes; namely, Chalmers University of Technology, KTH Royal Institute of Technology, Linkoping University in Sweden and Massachusetts Institute of Technology (MIT) in the USA since 2000. The key stakeholders of engineering education mentioned that the engineering students should be exposed to professionalism in their school through conceiving, designing, implementing, and operating. Those are the most important contexts of engineering professions [1]. In 2004, 12 CDIO standards were defined to distinguish a CDIO program. They serve as guidelines for educational program reform and evaluation, create benchmarks and goals with worldwide application, and provide a framework for continuous improvement [2].

Industrial Engineering Program at RMUTT

Rajamangala University of Technology Thanyaburi (RMUTT) has long been developed and has gained high recognition for its educational quality for over 30 years under the name of Rajamangala Institute of Technology (RIT). RIT with its 35 nationwide campuses became 9 Rajamangala Universities of Technology on January 18, 2005. Among the nine universities, its original main campus is called RMUTT. The university still maintains the original focus on quality teaching and the learning of science and technology and aims for high recognition from industries and organizations for its qualified graduates who are well-equipped with professional knowledge and practical skills. The vision is to produce professional hands-on graduates in the field of science and technology. Presently, RMUTT has 10 Faculties and 1 college of Thai traditional medicine. The university offers four levels of educational programs in various disciplines: diploma programs in vocational education, a bachelor's degree, a master's degree and a doctoral degree programs [3].

The Faculty of Engineering puts its focus on the development of engineers well-equipped with professional knowledge, skills, and the ability to apply the knowledge and skills in the working situations [4].

The programs offered are as follows:

1. Four-year bachelor's degree program in Engineering for graduates with a vocational education or grade 12 certificate (Science and Math). Both full time and part time programs include the following disciplines: Civil Engineering, Electrical Engineering, Mechanical Engineering, Industrial Engineering, Electronic & Telecommunication Engineering, Textile Engineering, Computer Engineering, Chemical Engineering, and Material & Metallurgical Engineering.
2. A credit-transferred three-year bachelor's degree program in Engineering for graduates with a diploma in vocational education.
3. Master degree programs in Engineering for bachelor degree graduates of any fields. The programs include the following disciplines: Civil Engineering, Mechanical Engineering, Electrical Engineering, Industrial Engineering, Production Engineering, Textiles Engineering, Electronics & Telecommunication Engineering, Chemical Engineering, Materials Engineering and Agricultural Engineering
4. Doctoral degree programs in Electrical Engineering and Materials and Energy Engineering.

RMUTT has participated in Conceive, Design, Implement, and Operate (CDIO) Framework for Re-Thinking Engineering Education, Thailand supported by Temasek Foundation and Singapore Polytechnic. After one year of implementation, the CDIO framework has proved to be the most appropriate framework to produce hands-on graduates. RMUTT has been appointed as CDIO collaborator in the CDIO Worldwide Initiatives since March 2014. Out of 8 disciplines, Industrial Engineering and Textile Engineering programs are only two programs which fully implemented the CDIO framework.

Industrial Needs Survey

The on-line questionnaire survey was distributed to major employers of RMUTT graduates. The designated respondents were plant/factory managers, production managers, quality control, production planning & control as well as industrial engineers who have at least 3 years of work experience. The questionnaire had 3 parts: part 1 – industrial engineering responsibility in the workplace, part 2 – levels of expectation of proficiency, part 3 - general information of respondents. Of the 300 questionnaires, 212 were returned, resulting in a response rate of 71%. The Cronbach's Alpha equaled 0.979 which was higher than 0.7 yielding in accepting the survey reliability. The data received were statistically analyzed using the Statistical Package for the Social Sciences software application (SPSS). The statistical analysis is composed of percentage, arithmetic mean, and standard deviation.

Table 1 showed the result of the industrial engineering responsibilities in the workplace. From the score of 1 (least important) to 7 (most important), the Likert scale could be used to interpret the average score as shown.

The highlight of the survey was in part 2; when the respondents were asked about knowledge, skills and attitudes relating to CDIO knowledge, and skill sets. The 1 – 5 scores were used to indicate levels of expectation of proficiency for each component; 5 = to be able to lead or innovate, 4 = to be skilled in the practice or implementation of, 3 = to be able to understand and explain, 2 = to be able to participate in and contribute to, and 1 = to have experienced or been exposed to. Table 2 showed the result from the survey.

Fig. 1 showed proficiency expectation from the industrial group. Referring to the findings of Crawley [5] in 2002, the survey of faculty members, industries and alumni of MIT, there were similarities in the results. Personal skills (2.4), Teamwork (3.1) and Communication skills (3.2) were in those top 5 from both surveys where Enterprise & business context (4.1) and External & societal context (4.2) had the lowest expectation proficiency.

Integrated Curriculum Development

The 12 CDIO Standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10),

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Table 1. Industrial engineering responsibility in the workplace

No.	Responsibility	Mean	Std. Dev.	Meaning
1	Method/Time/Productivity Improvement	6.2217	0.98467	Most important
2	Quality Control/Assurance/ Improvement	5.9245	0.82838	Very important
3	Production Planning and Supply Chain Management	5.8066	1.07331	Very important
4	Product Design/Development	5.6840	1.18006	Very important
5	Manufacturing/Tooling/ Maintenance	5.3538	1.16925	Very important
6	Project Management	5.2642	1.27908	Important
7	Training/Technology Transfer	5.2311	1.30561	Important
8	Inventory Management	5.0566	1.22633	Important
9	Financial decision making, break-even analysis, investment	4.7358	1.33705	Important

and assessment and evaluation (Standards 11 and 12). Of these 12 standards, seven are considered essential because they distinguish CDIO programs from other educational reform initiatives. An asterisk [*] indicates these essential standards [3]. The curriculum development process involved with 5 the CDIO standards. The standards are listed below:

Standard 1. CDIO as Context*

Adoption of the principle that product and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education.

Standard 2. CDIO Syllabus Outcomes*

Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders.

Standard 3. Integrated Curriculum*

A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills.

Standard 4. Introduction to Engineering.

An introductory course that provides the framework for engineering practices in product and system building, and introduces essential personal and interpersonal skills.

Standard 5. Design-Build Experiences*

In order to meet standard 1, the statement indicating that the Industrial Engineering curriculum 2015 has adopted CDIO as a context for industrial engineering education. For implementation of standard 2: RMUTT has defined its graduate attributes as stated in the university vision as "to produce hands-on graduates" who are ready for real-life work. The graduates' attributes are conformed to CDIO knowledge and the skill sets from CDIO Syllabus as shown in Fig. 2.

Standard 3: from the survey, the top 5 expectations from the industrial group requested for Teamwork Skills, Personal

Table 2. Mean and Standard Deviation of Proficiency Expectation by Industries

No.	Knowledge, Skills, Attitude	Mean	Std. Dev.
3.1	Multi-disciplinary Teamwork	4.1698	0.80839
2.4	Personal skills & Attitudes	4.0425	0.82788
1.2	Core engineering & fundamental knowledge	4.0236	0.74427
4.5	Implementing	4.0189	0.74122
3.2	Communications	3.9575	0.82788
2.3	System thinking	3.9198	0.8135
2.1	Engineering reasoning & problem solving	3.9104	0.74559
4.4	Designing	3.8962	0.79607
4.6	Operating	3.8962	0.7145
4.3	Conceiving & engineering systems	3.7972	0.72947
3.3	Communications in Foreign Language	3.7453	0.89296
2.2	Experimentation & knowledge discovery	3.6604	0.99655
1.3	Advanced engineering fundamental knowledge	3.6085	0.92492
2.5	Professional skills & Attitudes	3.4811	0.97096
1.1	Knowledge of underlying science	3.3255	0.78052
4.2	Enterprise & business context	3.2170	0.82617
4.1	External & societal context	3.1604	0.85028

Fig. 1. Proficiency Expectation by Industrial Group

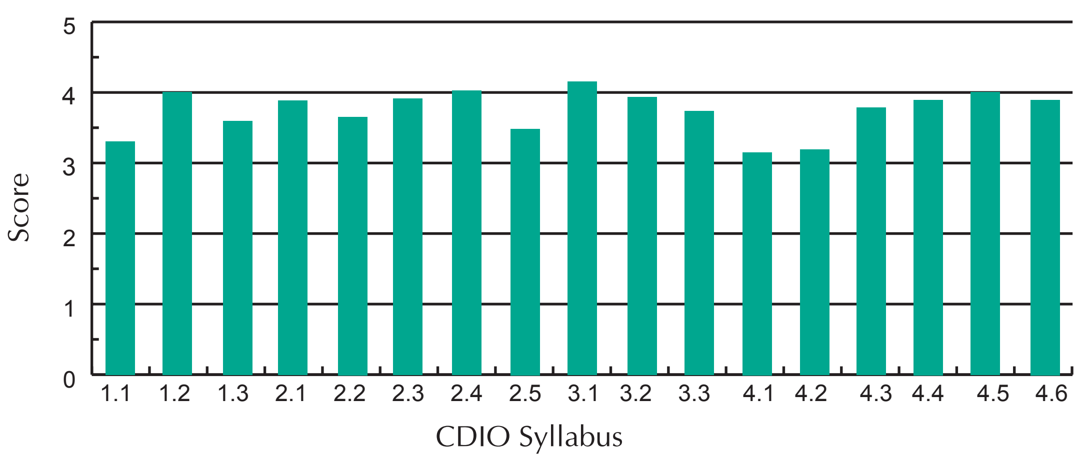
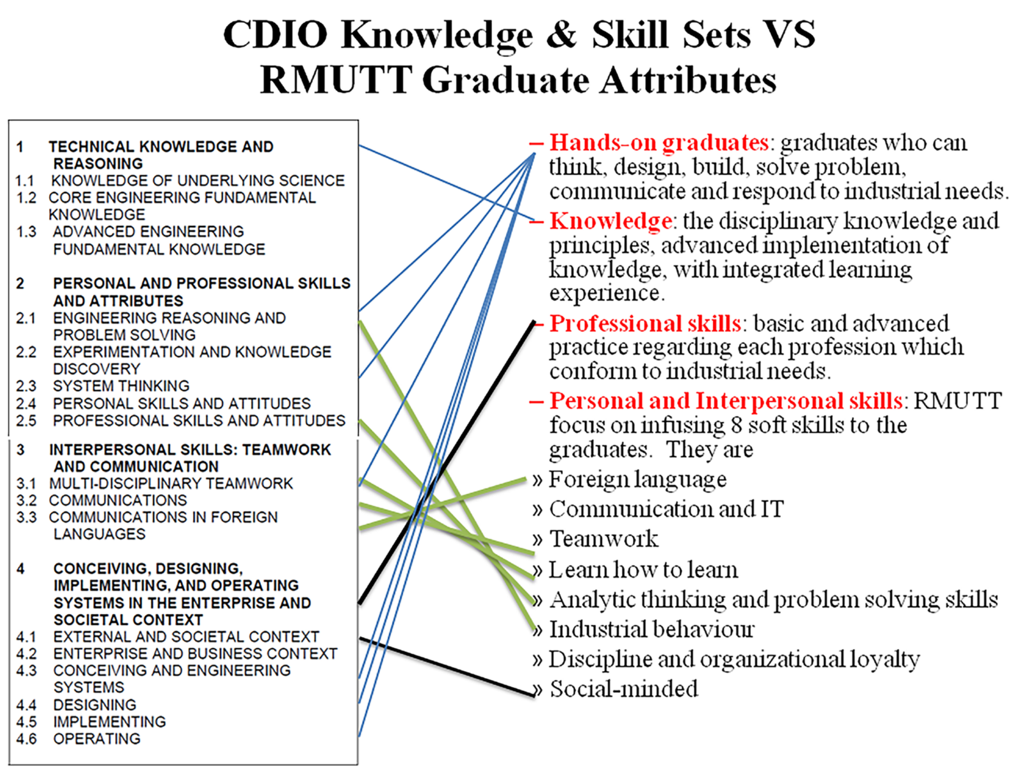


Fig. 2. CDIO Knowledge & Skill Sets VS RMUTT Graduate Attributes



skills & attitudes, Core engineering & fundamental knowledge, Implementing skills, and Communication skills. The gap analysis and skill mapping were analyzed by the program manager and department members. The full integrated curriculum is shown in fig. 3.

Teamwork skills (purple line with circle symbol), Personal skills & attitudes (blue line with hexagonal symbol) and communication skills (red line with rectangular symbol) were integrated into existing courses. The letter T=Teach means the skills will be taught to the students. The letter U = Use means the students will use the skills in that course. The letter A = Assessment means the teacher will assess the students on those particular skills. For teamwork skills, Basic Engineering Training and Computer Programming courses (semester 1, year 1) are offered to the student. The teacher will teach and will let the student use teamwork skills via class activities. Figure 4 shows the teamwork activity for the Computer Engineering course in which the students must build simple robot kits and program the robot depending on the task they receive. From year 2 to year 4, teamwork skills are integrated in IE Design & Build, Mini Project, IE Pre-Project, Co-operative Education, IE Project and Industrial Plant Design which allow the students to use teamwork skills and be assessed by the teacher. In addition, new courses: Productivity Management, Feasibility Study & Project Management, Design of Experiment and IE Laboratory aim to equip the student with teamwork skills and experiential learning. The students are expected to be able to form effective teams, manage and participate in them.

Fig. 3. Integrated Curriculum for Industrial Engineering Program

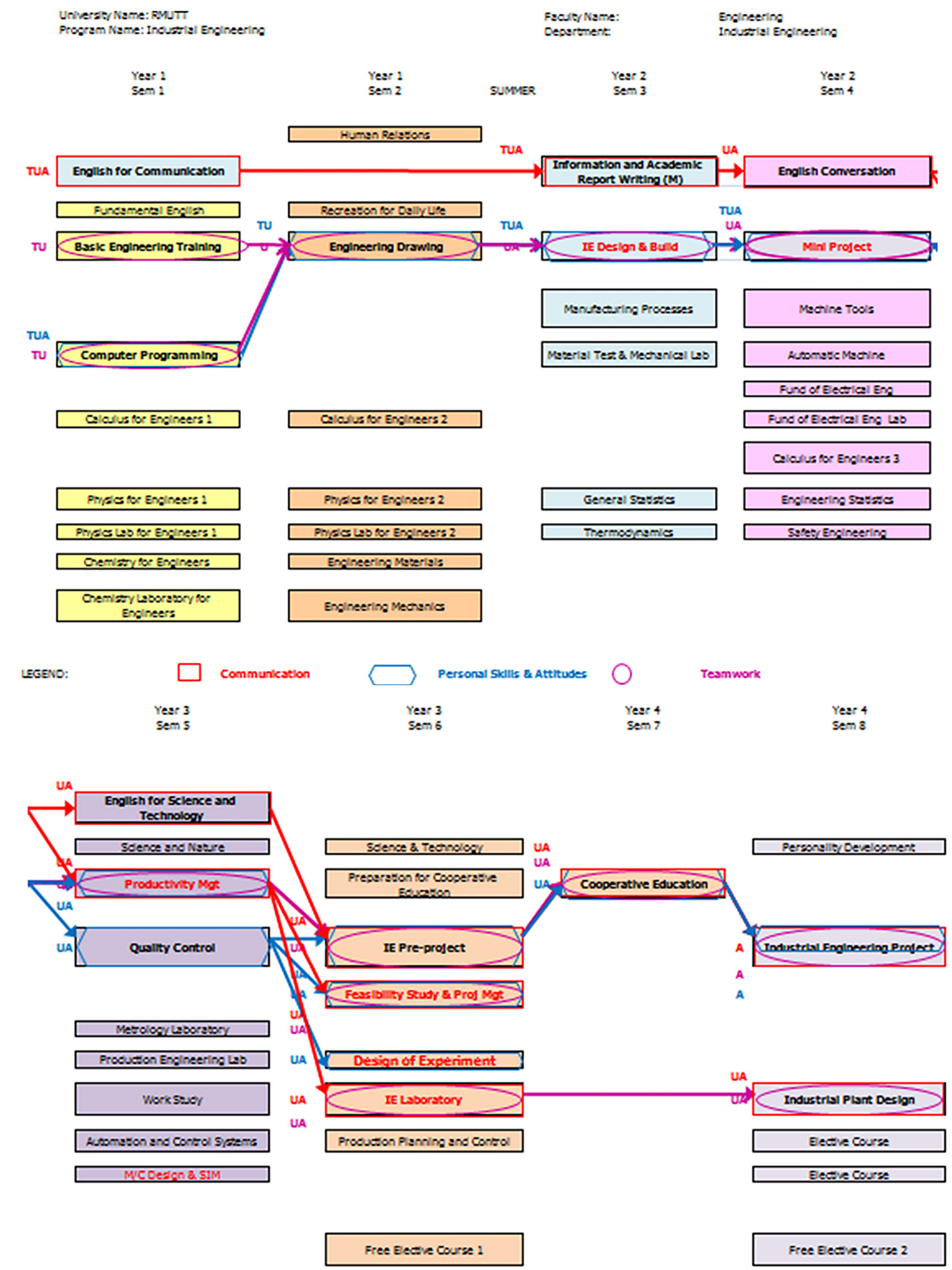
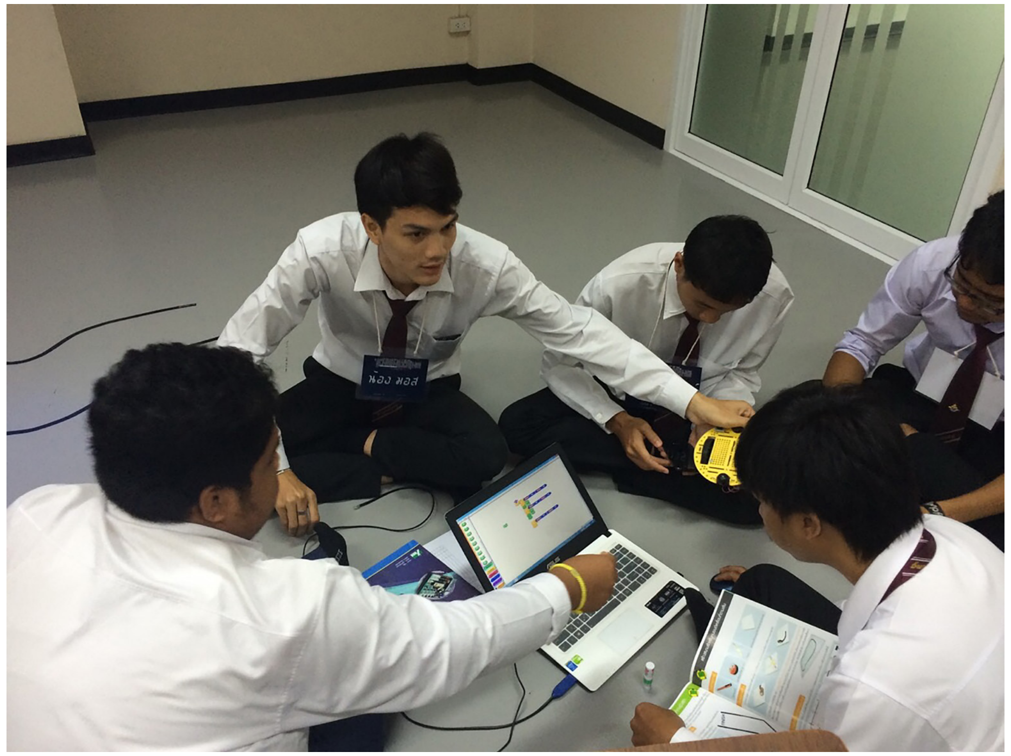


Fig. 4. Teamwork skills within the course «Computer Engineering»



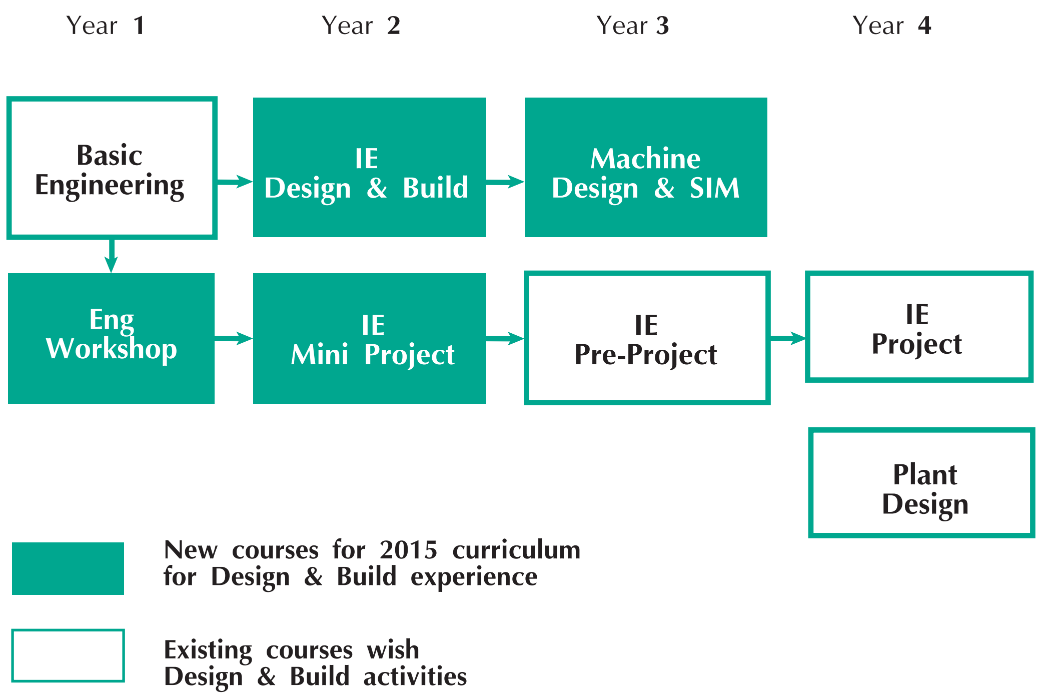
For communication skills, 3 courses of English and 1 course of report writing are offered as background. Furthermore in the study plan, the student will exercise and be assessed on their communication skills in the context of the industrial engineering profession in Productivity Management, Feasibility Study & Project Management, IE Laboratory, Pre-project, Project, Cooperative Education and Industrial Plant Design. Personal skills and are well integrated into both existing and new courses.

The existing course "Basic Engineering" plays a role as "Introduction to Engineering" which offers fundamental engineering practice as stated in Standard 4. Four new courses were added to enhance the implementing skills along with Design & Build experience (Standard 5) as shown in Fig. 5.

Conclusion

The developed curriculum is now in the process of stakeholder validation, academic council, higher education commission and the council of engineering approvals. The curriculum will be launched in August 2015. Other factors leading to the success in implementing the curriculum are faculty member enhancement in their professional skills as well as teaching skills. Reflections by the assessment at course level and program level will contribute to continuous improvement.

Fig. 5. New courses: Implementation Skills and Design & Build Experience



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