INTEGRATION OF DESIGN PROBLEMS AND PROJECTS INTO COURSES FOR MANUFACTURING ENGINEERING PROGRAM

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ABSTRACT

Since 2010, Faculty of Mechanical Engineering has piloted the CDIO model for the manufacturing engineering program. Up to now, various engineering skills have been integrated into the courses. Innovative design problems and projects are planned throughout core courses. Those engineering skills are consolidated by four project-based courses of the program, including: Introduction to engineering project, Machine Design project, Manufacturing engineering project, and Capstone project. In this paper, we present the objectives, contents, innovative design problems, implementation process, the measures and results achieved after three years of CDIO implementation. After completing some core courses, the project courses will help students improve the CDIO skills through the designing and building of a real model. E-Learning system has supported a lot for teaching and learning process so that these activities can take place anytime and anywhere. Student's scores are evaluated by not only lecturers but also classmates. The achievement of intended learning outcomes is verified from student's surveys, together with the results of assessment activities. The end of this paper is the analysis and assessment of results achieved through the active, experiential learning methods, the integrating skills into subjects as well as addresses lessons learned from the CDIO implementation.

KEYWORDS

Manufacturing engineering program, intended learning outcomes, experiential and integrated learning, design problems and projects.

INTRODUCTION

For most engineering courses, students are taught to work short problems which illustrate the principles of the course, but bear little resemblance to practical applications. The problems assigned are short, well defined, and have only one correct answer, whereas realistic problems are much longer, not as clearly defined, and may have many solutions. The focus in the courses is on individual effort and ability, rather than contributing to a team effort [1]. However, most students, after they graduate, will work as a member of a team, so developing the skills necessary to provide technical input to a team effort is an important part of their education. He emphasized the need for engineers to have good communication skills, a thorough understanding of modern design and simulation tools to help make the design succeed the first time, and a sense of the total business equation. Good communication skills and understanding how the company makes a profit are important for the engineer to be successful. Carlos Sanatamarina, who has written about and studied the teaching of creativity, states that [2] “There are skills that can be learned… every student can be creative. Better at problem solving and invention of they are aware of their own creativity and how to improve it.”

INTEGRATION OF DESIGN PROBLEMS INTO COURSES

In order to determine how to best integrate design into the courses, it is necessary to assess how the design taught fits into the curriculum as a whole. Problem-based learning and design-implement experiences are integrated across the undergraduate manufacturing engineering program in Table 1 and are done via 04 student projects of the program: Introduction to engineering project (elementary project), Machine Design project (intermediate project), Manufacturing engineering project (intermediate project), and Capstone project (advanced project), from low to high level of performance.

Table 1. Manufacturing engineering program

Semester								
1	2	3	4	5	6	7	8	9
Mathematics and Natural Science						Internship		
				Social science and Humanities…				
Engineering Fundamental and Manufacturing Knowledge								
Introduction to Engineering (C,D,I,O)		Machine design project (C,D,I,O)			Manufacturing Engineering project (D, O)		Capstone project (C,D,I.O)	

Design problems and the skills as creative thinking, teamwork… are integrated or embedded in the technical context via courses and projects (from 1 to 8) as shown in Figure 1.

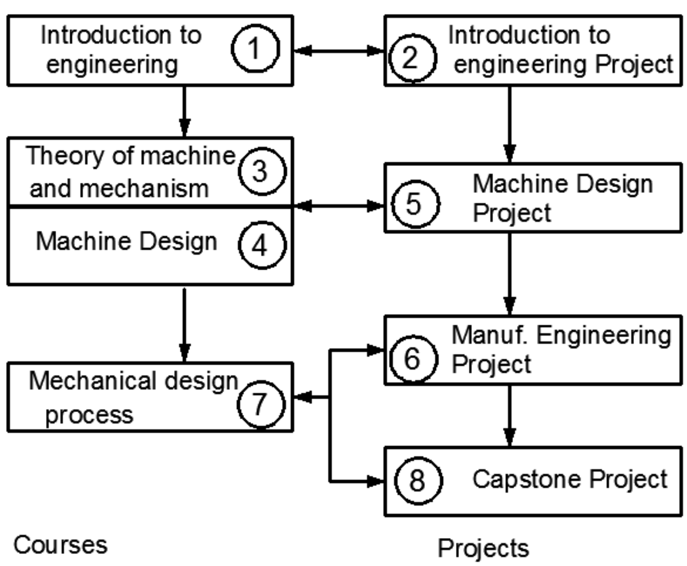

Figure 1. Systematic progression of creative thinking, teamwork

FOUR DESIGN-IMPLEMENT PROJECTS FOR PROGRAM

First-year Project **– 'INTRODUCTION TO ENGENEERING'**

A design project gives first-year students some of the hands-on experience and practical knowledge required to do engineering design work as illustrated in Figure 2. Throughout this project, students realized that an engineer needs a broad historical knowledge of how things have been designed, and the common hardware, fasteners, and components available in order to carry out a design.

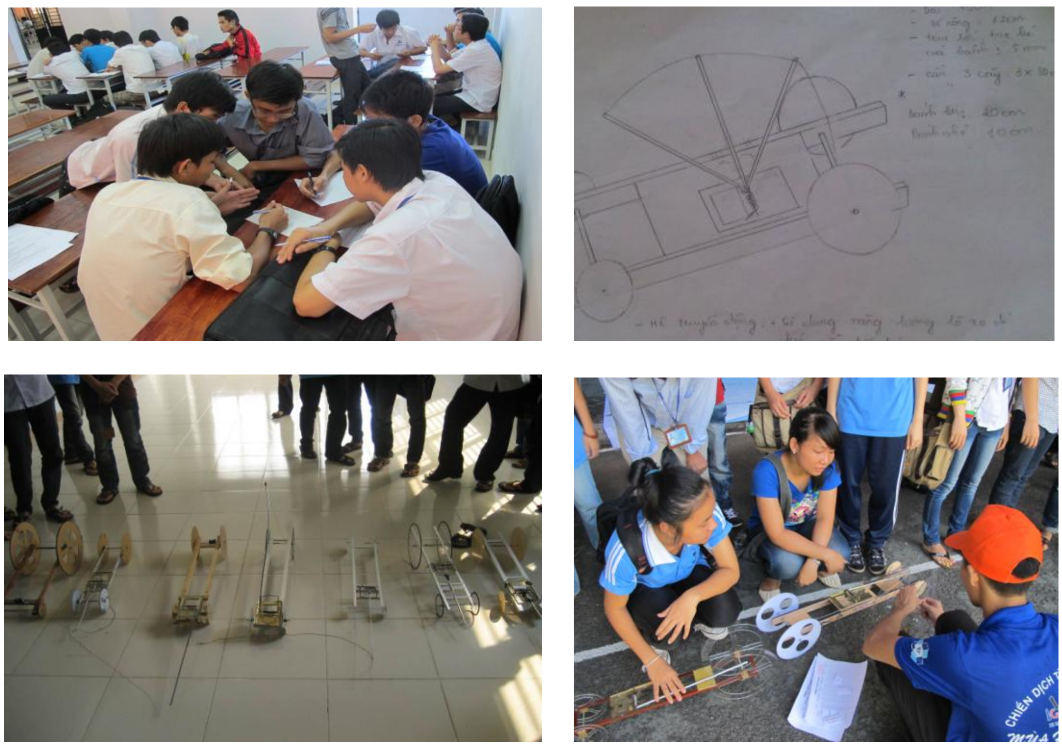

Figure 2. Hand-on experience for first-year students

The first attempt to integrate design into an 'Introduction to engineering' course seemed very straightforward: divide the students into groups of five or six students, and have them design a Mousetrap car as part of the course.

Second-year Project **– 'MACHINE DESIGN PROJECT'**

The machine design projects are important engineering knowledge for mechanical engineers. All the mathematics, natural science and fundamentals engineering knowledge and CDIO skills are expressed in this area. Considering the knowledge of machine design course and machine design project are the application of several subjects such as mathematics, kinematics, statics, dynamics, mechanics of materials, engineering materials, manufacturing engineering, engineering drawing and so on. It also involves the application of other subjects, for example, thermodynamics, CAD, CAE, fluid mechanics, engineering design, etc... Engineering drawing is the integral part of the machine design, since all the components or the machines that have been designed should be drawn to manufacture them as per the specifications.

Working in groups was a good experience for the students, so the idea of working in teams was retained for this project. The students investigated the designs using the analysis taught in the course; they were able to gain some understanding of why these devices were designed as they were and to discuss some alternatives to the design. They were also able to see the safety factors employed for a typical machine. An effort was made to develop projects which required a reasonable amount of work by the students and a reasonable grading workload for the teacher.

The machine design project include 4 stage of CDIO process as shown in Table 2, which lasts 15 weeks has approximately 44 students divided into 11 teams of four students. It consists of a step by step approach from given specifications about the fundamental requirements of a product. To complete the description of the final product drawings form, the logical sequence of steps usually are employed to all design projects as illustrated in Table 3. These steps are inter-related and inter-dependent on each other. Reflecting and affecting all other steps.

Table 2. The steps of process of machine design project - CDIO process

CDIO process	Process of machine design project	CDIO Syllabus
C - Conceive	Step 01: Identify the problem**,** Understand the need Step 02: Define working criteria and goals The step 1, 2 consists of preparing a complete list of the requirements of the product. Make the written statement of what exactly is the problem for which the machine design has to be done.	4.3 Conceiving and engineering systems 2.4 Personal skills and attributes 2.4.3 Creative thinking
D - Design	Step 03: Selection of mechanism In this step, the students prepare schematic diagram of different possible mechanical drives and elements of machine. Step 04: Layout configuration The next step in design procedure is to prepare a block diagram showing the general layout of the selected configuration. Rough sketches of shapes of individual components are prepared. Step 05: Design of individual components The design of individual components (or) machine elements is an important step in the design process. Step 06: Preparation of drawings, modelling and dynamic simulation with CAD/CAE software	4.4 Designing 3.2 Communications 3.2.1 Communications Strategy 3.2.3 Written Communication 3.2.5 Graphical Communication 3.2.6 Oral Presentation and Inter-Personal
I - Implement	Step 7: Build and Test the machine - Build the machine (manufacture and assembly) - Test the machine - Record the data - Analyze the data according to the “Design Requirements” … - Redesign and retest as necessary	4.5 Implementing
O - Operate	Step 8: Perform post implementation and review assessment: Operate the machine	4.6 Operating

Table 3. Gantt chart for machine design project

Weeks	2	3	4	5	6	7	8	9	10	11	12	13	14	Student
Forming teams	■													A, B
Problem identification and formulation modelling	■	■												Team
Technical requirements of machine		■												C, D
Conceive – Decision making of kinematic diagramm of machine		■	■											Team
Layout configuration			■	■										Team
Design, select and sketch machine parts and machine				■	■	■	■	■	■					Team
3D Modelling and 2D drawing of machine						■	■	■	■	■				Team
Dymamic and Analysis simulation								■	■	■	■			Team
Implement of machine								■	■	■	■	■		Team
Documentations and presentation											■	■	■	Team

The final product of the Machine design projects is the real model of the machine as seen in Figure 3. It helps the students turn all ideas and designs into real products through design - implement experiences.

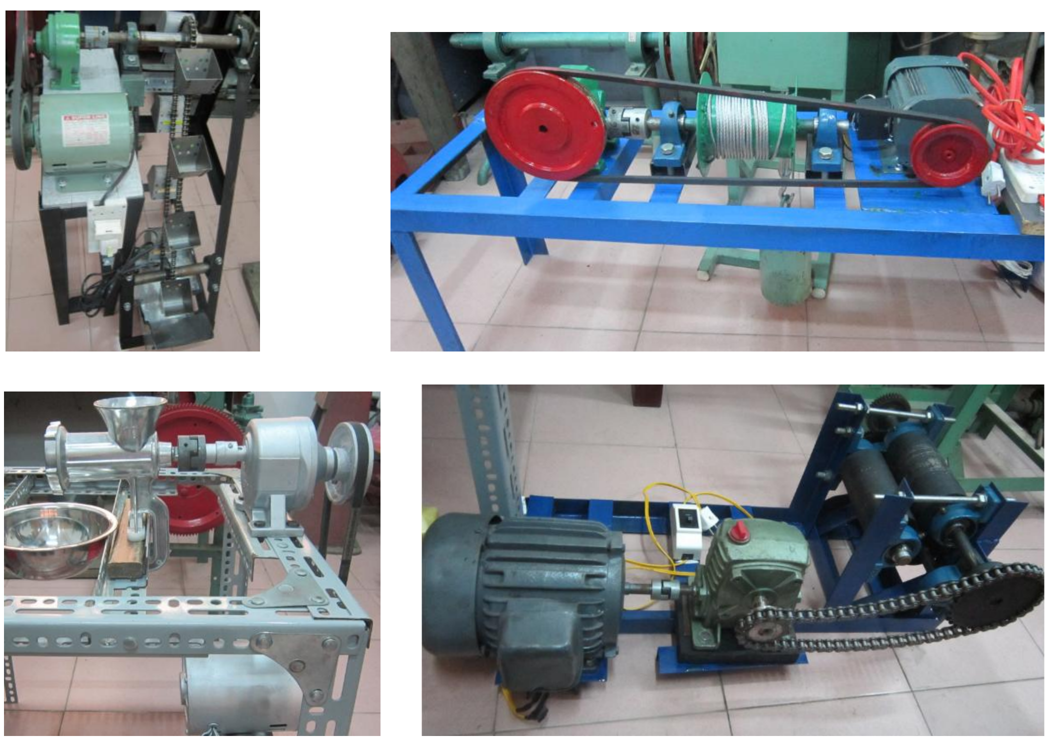

Figure 3. Hand-on experience for second-year students

Third-year Project – 'MANUFACTURING ENGINEERING PROJECT'

In this project, students are required to make physical part in a certain mechanism or machine elements. They have to do everything as demonstrated in Figure 4 from drawing, 3D modeling. selecting material, choosing suitable machine, manufacturing process, design fixtures and manufacturing it. Students learn 3-D solid modeling with CAD software, create prototypes from CAD models using CNC machining or machine tools.

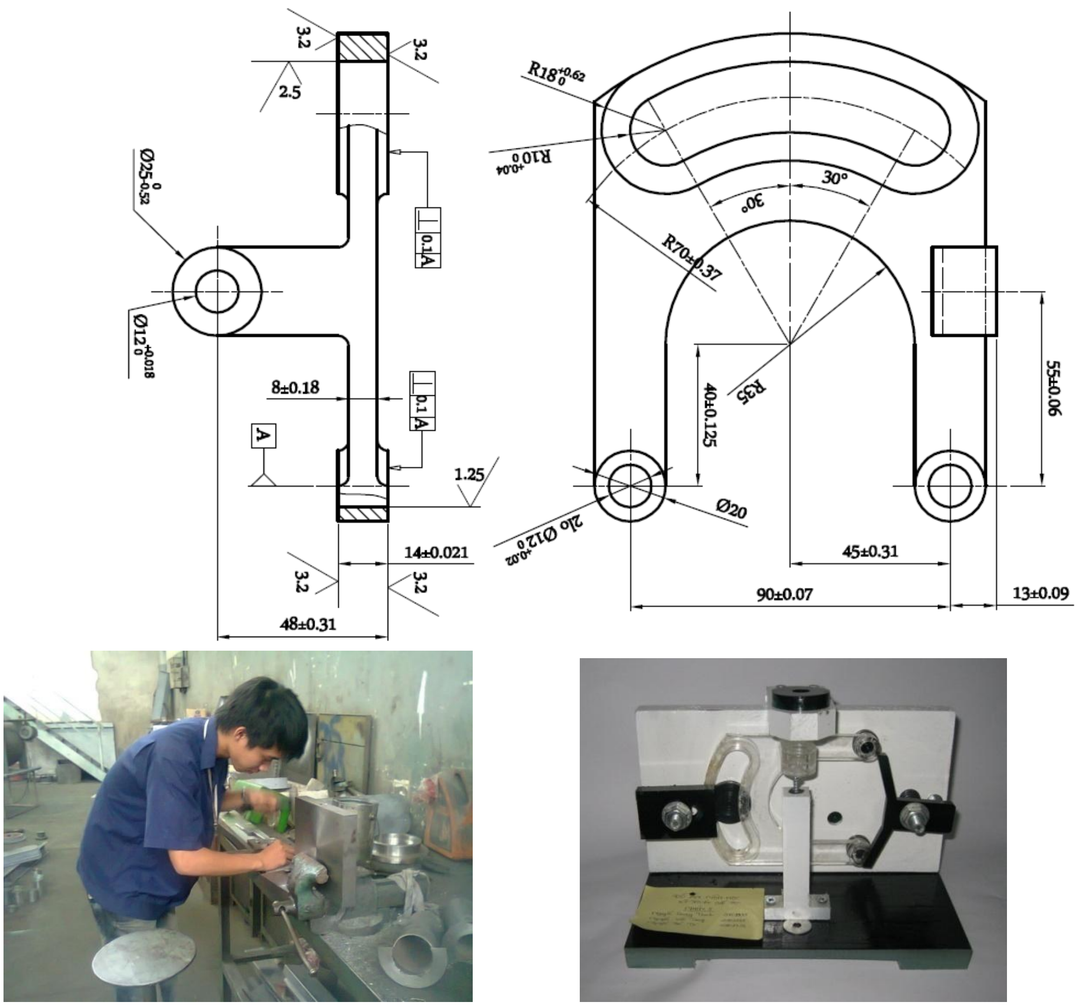

Figure 4. Hand-on experience for junior students

***Forth-year Project* – 'CAPSTONE PROJECT'**

The purpose of the final design experience is to allow students to use mathematics, natural science and fundamentals engineering knowledge they have learned to solve a particular engineering problem. It is not "seat-of-the-pants design" like the first years design projects, but intends to provide the students with a professional design experience. Students developed plans, cost estimates, specifications, and ultimately a full proposal for the project. The objective was to incorporate realistic group design projects into the program as illustrated in Figure 5.

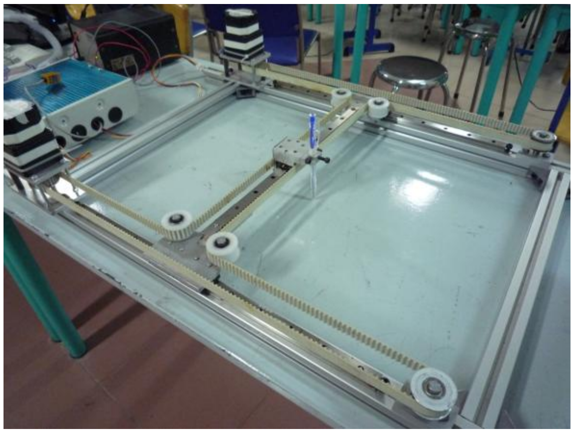

Figure 5. A prototype of 2-DOF CNC system developed by senior students

ACTIVE, EXPERIENTIAL AND INTEGRATING LEARNING METHODS

Besides doing project, students also experiences new teaching methods through activities of active learning, creativity, and teamwork as illustrated in Figure 6. This allows students to have an opportunity to experience in design analysis and have an opportunity to practice communication skills via using lectures, concept questions, case study, teamwork, brainstorming, seminar reports, multiple choice questions, etc.

Figure 6. Design problems in the Thermodynamics course

Base on E-learning system, website... communication with professor and others students on forums becomes very helpful for active learning. This interaction encourages students to study more actively, creatively and achieve better results. It also provides information about design simulation, video of manufacturing methods etc. It works as a virtual lab and library to help activities for individual and teamwork. E-Learning system has supported a lot for teaching and learning process so that these activities can take place anytime and anywhere. Innovative forms are always encouraged. This provides students opportunities to solve the technical problems by trying new and better ideas as shown in Figure 7.

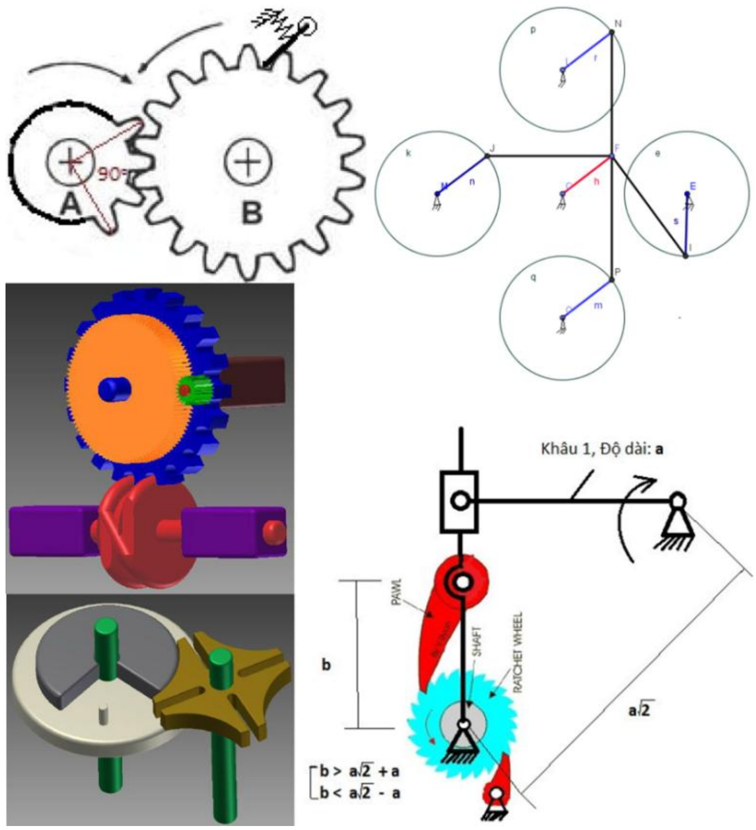

Figure 7. Four student's ideas in the "Kinematics and Dynamics of Machine" course

The analysis and assessment of learning outcomes (LO) (before, during and after phases) achieved through the active learning methods, experiential learning methods, integrated learning across design-implement experiences as demonstrated in Figure 8 for the machine design project.

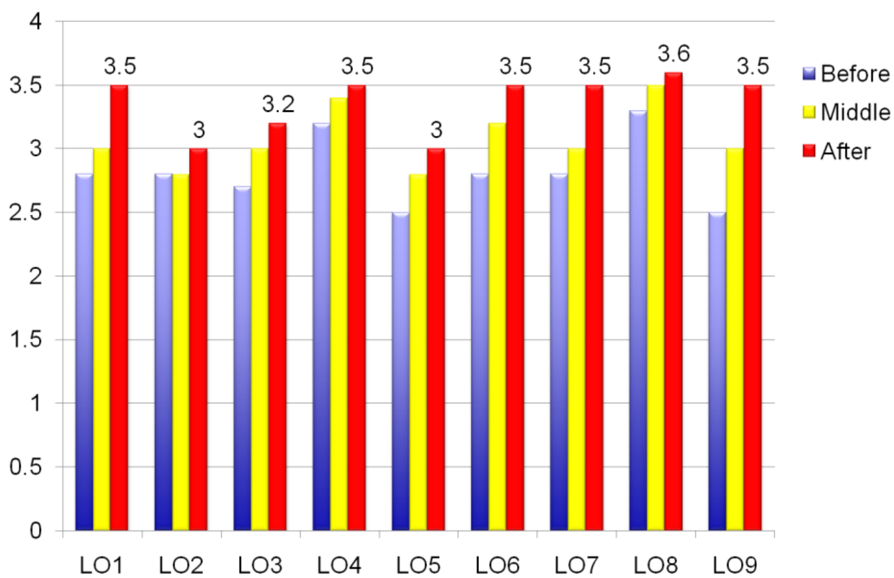

Figure 8. Results of assessment in the before, during and after phases

Using the rubrics to evaluate levels of performance to each of the 12 CDIO Standards. Result of self-assessment before and after three years implementation of the 12 CDIO Standards (St) is shown in Figure 9.

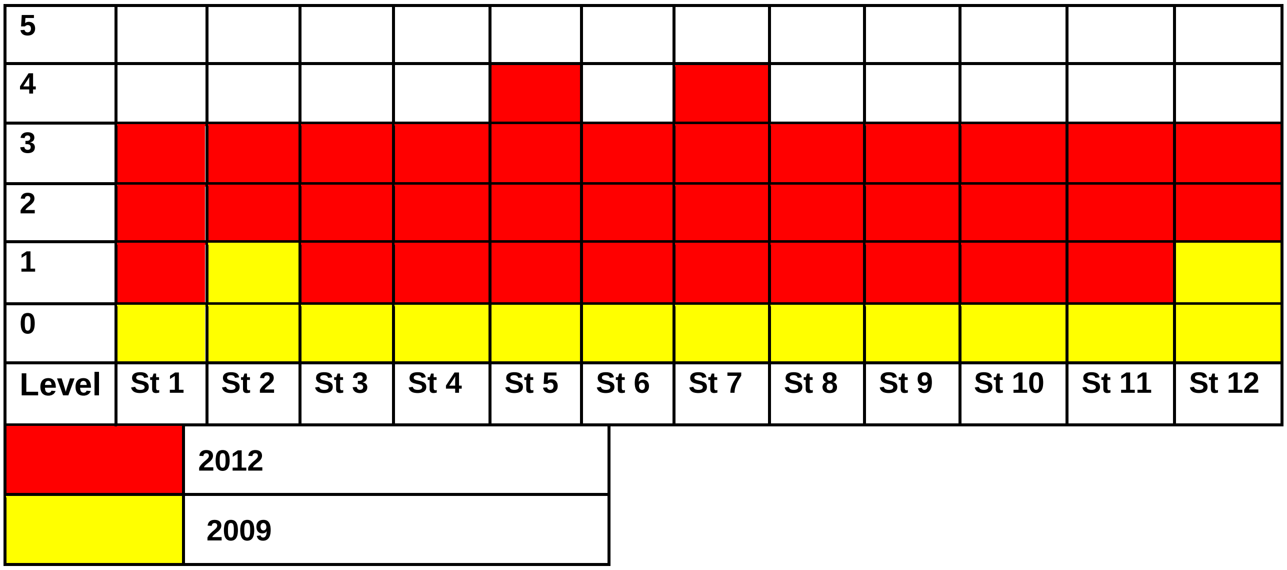

Figure 9. Result of self – assessments of the 12 CDIO standards

CONCLUSION

The creative thinking, teamwork and communication skills, innovation process have been integrated into the courses and projects in the teaching process. The CDIO Syllabus with design-Implement experiences are done via 04 student projects of the program: Introduction to Engineering project, Machine design project, manufacturing engineering project and Capstone project. After three years of CDIO implementation for mechanical engineering program, students find that learning is more interesting and engaging and that they develop a greater understanding of engineering fundamentals knowledge's and improving their personal and professional skills, teamwork and communications, CDIO skills and the innovation process. Through assessment activities, students are able to monitor their own learning, assess their progress, and evaluate their own to the success of the projects. Moreover, students see the connections between the subject and industry. The courses and projects have been redesigned for the contents and teaching methods to provide students the essential engineering knowledge and skills that employers required. The projects also help students improve the CDIO skills with high levels of innovation through the building of a true model from their design drawings.

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BIOGRAPHICAL INFORMATION

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