INTEGRATED LEARNING EXPERIENCES IN THE MACHINE DESIGN COURSE TO ASSESS THE ACHIEVEMENT OF INTENDED LEARNING OUTCOMES

Nguyen Huu Loc

University of Technology, VNU-HCM, Vietnam

Pham Quang Trung

University of Technology, VNU-HCM, Vietnam

ABSTRACT

Manufacturing Engineering Program with CDIO approach has been adopted at Faculty of Mechanical Engineering, Vietnam National University – Ho Chi Minh City University of Technology since 2010. Up to now, the CDIO skills have been integrated into the courses 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. This paper introduced the teaching of Machine design course and Machine design project to achieve the intended learning outcomes.

The learning outcomes of the course are achieved corresponding to teaching and learning activities, assessment methods. Assignments and seminar reports are integrated to help students achieve most of the outcomes of the course.

E-learning system has supported a lot for teaching and learning process so that these activities can take place anytime and anywhere. Grade subject is evaluated not only through lecturer but also via using of rubrics for each student and student groups assess each other. To assess the achievement of intended learning outcomes based on the rubrics student survey, the results of teaching and learning activities and assessment methods respectively.

After completing this subject, the machine design project will help students improve the CDIO skills through the building of a true model from their design drawings. The end of this paper is the analysis and assessment of results achieved through the active learning methods**,** experiential learning methods, integrated learning across design-implement experiences.

KEYWORDS

Manufacturing Engineering Program, Machine design, Machine design project, learning outcomes, integrated learning experiences

INTRODUCTION

Machine design and 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. Problem-based learning and design-build experiences are integrated across the undergraduate manufacturing engineering program. The new manufacturing engineering program has 04 projects, which are showed as table 1.

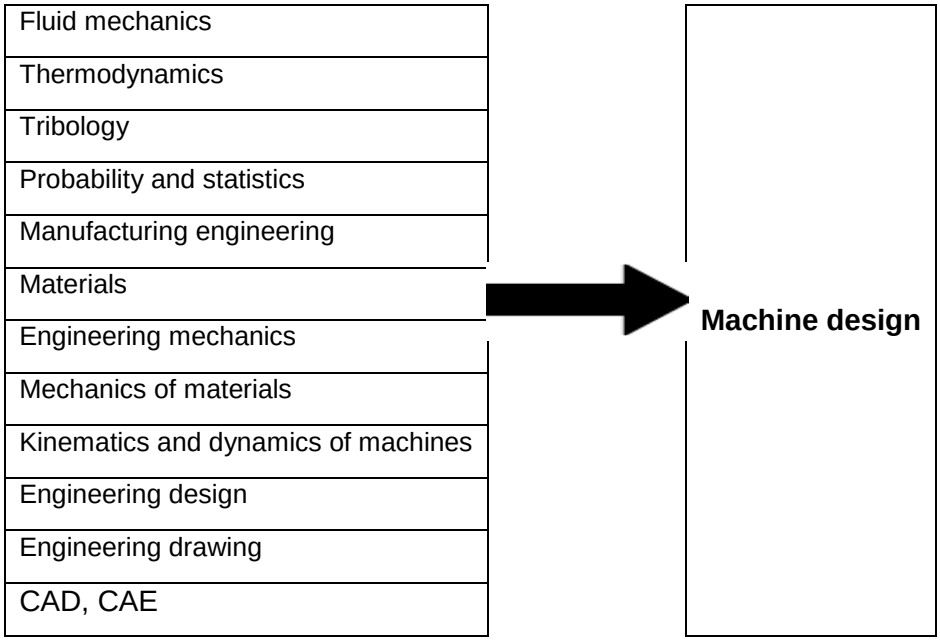
Table 1
Design-Implement Courses

<table>
<tr><td colspan="9">Semester</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td colspan="6">Mathematics and Natural Science</td><td colspan="2">Internship</td><td rowspan="3"></td></tr>
<tr><td colspan="5"></td><td colspan="3">Social science and Humanities, economics, political knowledge</td></tr>
<tr><td colspan="8">Engineering Fundamental and Manufacturing Knowledge</td></tr>
<tr><td colspan="2">Introduction to Engineering (C,D,I,O)</td><td colspan="3">Machine design project (C,D,I,O)</td><td>Manufacturing Engineering project (D, O)</td><td colspan="3">Capstone project (C,D,I.O)</td></tr>
</table>

This table demonstrates that the Machine design project is carried out all C - D - I - O skills at a higher level than Introduction to Engineering.

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. (see Table 2). 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.

Table 2
Subjects related to the machine design



Here are some important knowledge, skills and attributes that student should possess after learning of machine design course and machine design project.

Table 3

Knowledge, skills and attributes (KSA) blocks in learning outcomes

KSA	CDIO Syllabus	Description
Mathematics and Natural science	1.1 Knowledge of underlying science 1.4 Other supportive knowledge	A good student is the one who has thorough knowledge of and in depth training in the natural science knowledge in which they are doing designing. All types of designs involve lots of mathematical calculations and iterations. A good student should have the knowledge of all the basics and advanced mathematical concepts so that they can be applied fruitfully and effectively wherever required.
Engineering knowledge and analysis	1.2 Core Engineering Fundamentals	Engineering analysis is the ability of the student to analyze the given component, system or the process using engineering and scientific principles. Student has an ability to use techniques, skills and modern engineering tools, such as CAD/CAE software, necessary for modern engineering practice.
Identify the problem	2.1 Engineering reasoning *Problem Identification and formulation* *Modelling*	Preparing a complete list of the requirements of the product: outer, capacity of machine, service life, cost and reliability. Make the written statement of what exactly is the problem for which the machine design has to be done.
Creative thinking, Decision making and Time Management	2.4 Personal skills *Creative thinking* *Critical thinking* *Curiosity and lifelong learning* *Time and resource management*	Without creative thinking skill the student cannot start the process of machine design. Any new design starts with the need or some objectives. A good student should have creative thinking skill, which is the ability to think of or discover valuable and useful ideas or concepts for the things or processes to achieve the given objectives.
		In some certain cases that a number of uncertain situations arrive during designing, the student should be able to take the decision with balanced mind considering all the relevant factors involved. If the person doesn't maintain the balance of mind and doesn't consider all the relevant factors there are greater chances of taking the wrong decision
Teamwork	3.1 Teamwork *Forming effective teams* *Team operation* *Team growth and evolution*	Two key themes of the engineering design process are teamwork and design. Since students are working in small groups, encourage them to think about the steps of the engineering design process. How will they work well together, listening to and respecting all ideas in the brainstorming session, reserving any judgment until a decision is made? Even then, make the decision-making process as democratic as possible, with all opinions being heard. Once a teamwork base is established, build upon that with a creative design. If a team of students is excited about their idea, they can come up with some fun methods for improving or extending the original idea. Reinforce with them that the end goal is a final design solution that is a seamless blend of creativity and utility.
Communication skills	3.2 Communications *Written communication* *Electronic/multimedia communication* *Graphical communication* *Oral presentation and inter-personal communications*	Skill is the ability of a design student to express oneself clearly and persuasively orally, graphically as well as in writing. Apart from this there are many other skills desired from a good students, these are: skill in design, good judgment, simulation skill, measurement skill, thought skill, team work, ability to make conclusion etc. Apply thinking skills and communicating through drawing and sketching
Design process	4.4 Designing	Students should understand and be able to apply the

and multidisciplinary ability	*The design process* *The design process phasing and approaches* *Utilization of knowledge in design* *Disciplinary design* *Multidisciplinary design multi-objective design (dfx)*	engineering design process, the design process phasing and approaches: a series of steps that the students use to guide them as they solve problems. A good student is the one who has the ability to solve the problems not only those related to his/her specialty, but also have the ability to competently and confidently deal the basic problems or ideas from other disciplines which are in some or the other manner linked to the machine they are designing.
Manufacturing processes	4.5 Implementing *Designing the Implementation process* *Manufacturing process* *The manufacturing of parts* *The assembly of parts into larger constructs*	The student should have the knowledge of the manufacturing process like cutting, drilling, milling, welding… and the knowledge of all the machines. They should also have the knowledge of potential and limitations of all the machines and manufacturing processes which may be old or new.

LEARNING OUTCOMES AND ASSESSMENT METHOD

According to the above knowledge and skills of the Machine design course, the learning outcomes and assessment method can be achieved as following table.

Table 4
Learning outcomes and assessment method

LO	Learning Outcomes	Oral test	Written tests (In class)	Homework	Case Study	Presentation (Seminar)	Written tests (Final exam)	CDIO Syllabus
LO1	Have ability to apply mathematics, natural science and fundamental engineering knowledge to perform load analyses on machine element parts and assemblies, stress and strain analyses on machine elements and determine element deflections and stability.	✓	✓	✓	✓		✓	1.1, 1.2, 1.3, 2.1
LO2	Utilize standard failure theories and fatigue analysis to develop safety factors, failures and reliability for machine elements.	✓			✓		✓	1.2, 1.3, 2.1
LO3	Select materials for particular machine elements and machine element assemblies.			✓	✓			1.2, 2.1
LO4	Design and analysis of machine elements, machine element assemblies and power transmission system. Select standard machine elements.	✓	✓	✓	✓		✓	1.2, 2.1, 2.3, 3.2, 4.3, 4.4
LO5	An ability to use techniques, skills and modern engineering tools, as computer software, necessary for modern engineering practice				✓	✓		1.4 2.1, 4.1, 4.4

LO6	Students will demonstrate the ability to seek and learn new material outside the class... Using handbooks, standards such as TCVN*, ISO…		✓	✓	✓	✓	✓	2.2, 2.4, 2.5
LO7	Knowledge of contemporary issues: updating knowledge via the latest versions of software and standards				✓	✓		1.4 2.4, 2.5
LO8	Work effectively as part of a design team.	✓			✓	✓		3.1, 3.2
LO9	Have the good communication skills: orally, graphically as well as in writing.				✓	✓		

TCVN – Vietnam National Standard - **Tiêu **C**huẩn **V**iệt **N**am*

Moreover, each CDIO skills can be reached by studying each machine element, i.e. the following table represents the skills for a gear element.

Table 5
The CDIO skills for a gear

Machine element – Gear	
Writing skill (Communication)	The verbal or textual representation of the gear "Spur gears consist of a cylinder or disk with the teeth projecting radically"
Graphical skill (Communication)	The drawings of the object: 3D solid models, orthogonal drawings, sketches, or artistic renderings 
Design (Analytical)	The equations, rules, procedures representing the form or function of the object, finite element analysis, dynamic simulation… i.e. $\sigma_H = Z_M\sqrt{\frac{q_n}{2\rho}}$ 
Implement (Physical model)	A physical model of the object 

Selection and application of the student assessment methods are based on the following principles [8]: 1) Assessment requires attention to outcomes and to the experiences that lead to those outcomes; 2) Different types of learning objectives require different methods of assessment; 3) Teaching and assessment are intertwined; 4) Any assessment is only a sample; 5) Assessment works best when it is regular and ongoing, and not just a final measure; 6) There are trade-offs between authenticity and efficiency, i.e., the closer the tasks are to real-world experiences. To get the right assessment methods, the relationship between tools and level of intended learning outcomes should be referenced [8]. From this principles and tools, to evaluate the development of the students in their studying, the percentage progress assessment table was being applied as Table 6.

Table 6
Percentage assessment

Mini test in class	Homework	Case study		Seminar 1	Seminar 2	Final test
		Progress	Final			
5%x3=15%	10%	10%	15%	5%	5%	40%

TEACHING AND LEARNING ACTIVITIES

Applying new teaching methods allows students to get active learning, creativity, teamwork, 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.

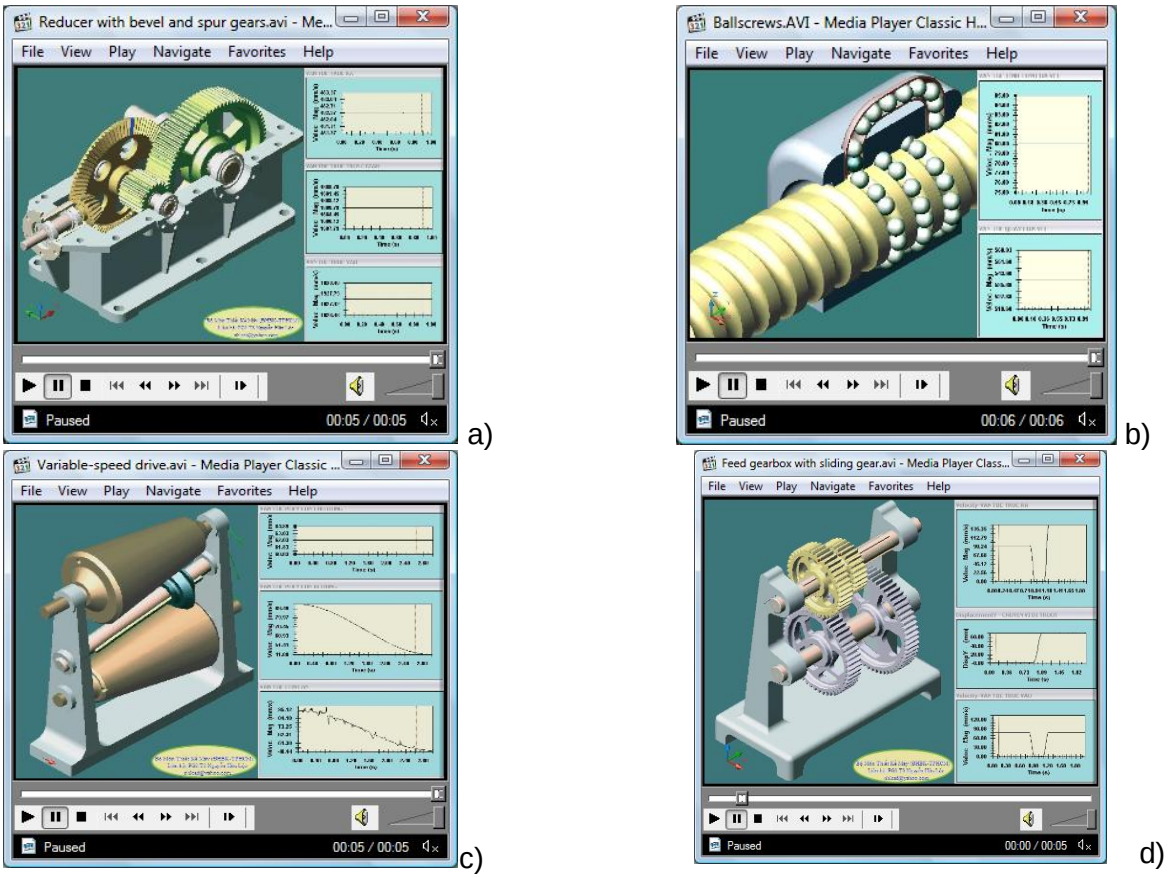


Figure 1. 3D modelling and dynamic simulation of mechanical drives

Teaching and learning methods: Applying a variety of teaching methods in the subject. However, use of blended learning: Incorporate visual simulations of real-life scenarios into classroom, students participate more and have a more satisfying learning experience. Likewise, 3D animation and walkthrough computer models demonstrate construction processes, and complementary text describes the various steps for dual coding of information. Shown below is the 3D modelling and dynamic simulation of the transmission systems and machine parts for the teaching of subjects, these images as a virtual laboratory for students (Figure 1).

Base on E-learning system, communication with professor and others students on forum becomes very helpful for active learning. Those methods encourage student to study more actively, more interested and achieved better results than the previous year. It provides information about design simulation, video of manufacturing methods and etc. It works as a virtual labs and library to help student can study by himself and teamwork.

RESULTS OF STUDENT ASSESSMENT

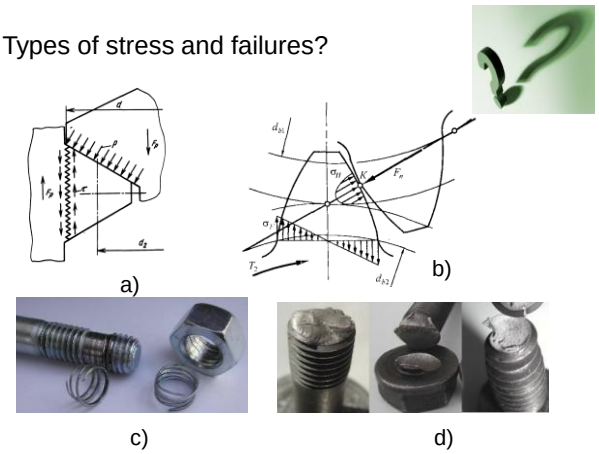
The following table 7 gives some results of student assessment with different teaching and assessment methods.

Table 7
Student assessment can be evaluated from oral text in class

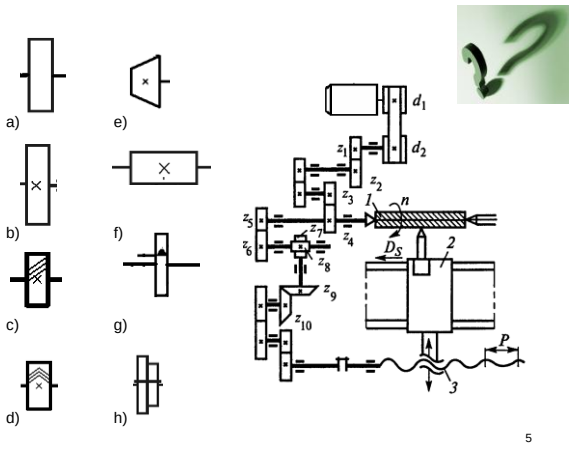
LO	Learning outcomes	Oral text in class
LO1	Have ability to apply mathematics, natural science and fundamentals engineering knowledge to perform load analyses on machine element parts and assemblies, stress and strain analyses on machine elements and determine element deflections and stability.	✓
LO2	Utilize standard failure theories and fatigue analysis to develop safety factors, failures and reliability for machine elements.	✓
LO4	Design and analysis of machine elements, machine element assemblies and power transmission system. Select standard machine elements.	✓
LO8	Work effectively as part of a design team.	✓

The following examples of oral test (questions and answers) in class after teaching chapters.

Chapter 2. (LO2- Utilize standard failure theories and fatigue analysis to develop safety factors, failures and reliability for machine elements)



Chapter 3 (LO4 - Select transmission system and standard machine elements for machine): *Explain a graphic symbols of gear and kinematic diagram of bolt-threading machine?*



In the final exam, the questions should be specified the levels of proficiency. For example, Table 8 presents the questions in the exam related learning outcomes of subjects.

The specific results of a test in class, final test and final grade are pointed as following figures. Figure 1 displays that the result of midterm and final test are similar. Figure 2 proves that the assignment component of case study is higher the others.

Table 8
Results of student assessment can be evaluated from final text in class

LO	Learning outcomes of course	Final test	Questions	Levels of proficiency
L01	Have ability to apply mathematics, natural science and fundamentals engineering knowledge to perform load analyses on machine element parts and assemblies, stress and strain analyses on machine elements and determine element deflections and stability.	✓	1a 2a 2c 3a	3 3 3 3
L02	Utilize standard failure theories and fatigue analysis to develop safety factors, failures and reliability for machine elements.	✓	1b 3c, d	3 4
L04	Design and analysis of machine elements, machine element assemblies and power transmission system. Select standard machine elements.	✓	2a 3b	3 3
L06	Students will demonstrate the ability to seek and learn new material outside the class... Using handbooks, standards such as TCVN, ISO …	✓	3b	3

To assess levels of proficiency in the learning outcomes we surveyed students by rubrics and statistical results after teaching like table 9.

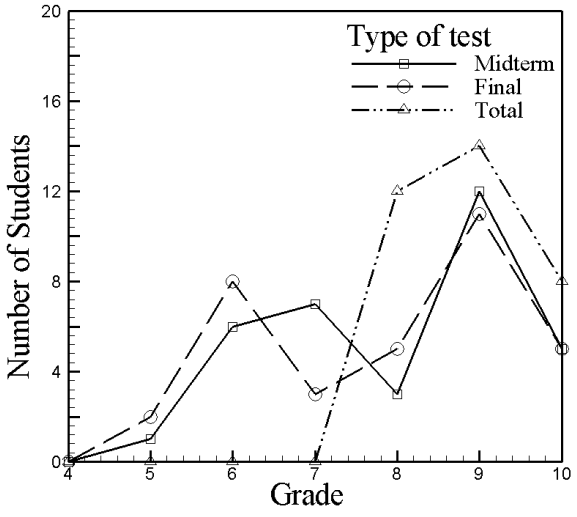


Figure 2. The distribution of grade of student in different type of test

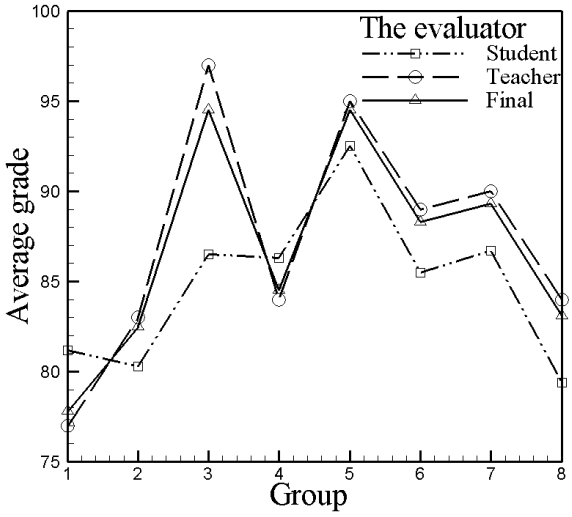


Figure 3. Comparison the average grade of students in seminar report with different evaluator

Table 9
Levels of proficiency in the learning outcomes

LO	Learning outcomes	Levels of proficiency			
		1. No Satisfy (0%- <25%)	2. Need improve (25%- 50%)	3. Satisfy (50%- <74%)	4. Good (75%-100%)

LO1	Have ability to apply mathematics, natural science and fundamentals engineering knowledge to perform load analyses on machine element parts and assemblies, stress and strain analyses on machine elements and determine element deflections and stability.		7 22%	23 72%	2 6%
LO2	Utilize standard failure theories and fatigue analysis to develop safety factors, failures and reliability for machine elements.		8 25%	20 62,5%	4 12,5%
LO3	Select materials for particular machine elements and machine element assemblies.		14 44%	11 34%	7 22%
LO4	Design and analysis of machine elements, machine element assemblies and power transmission system. Select standard elements, select standard machine elements.		4 12,5%	20 62,5%	8 25%
LO5	An ability to use techniques, skills and modern engineering tools, as computer software, necessary for modern engineering practice	4 12,5%	11 34%	14 44%	3 9,5%
L06	Students will demonstrate the ability to seek and learn new material outside the class... Using handbooks, standards such as TCVN, ISO…		9 28%	19 59,5%	4 12,5%
LO7	Knowledge of contemporary issues: updating knowledge via the latest versions of software and standards	1 3%	9 28%	18 56,5%	4 12,5%
LO8	Work effectively as part of a design team.		2 6%	19 59,5%	11 34%
LO9	Have the good communication skills: orally, graphically as well as in writing				

The survey results and student learning presented in Figures 3 and 4.

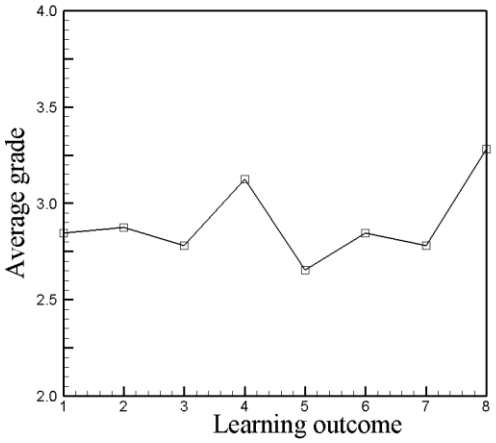


Figure 4. The average levels of proficiency of 8 learning outcomes

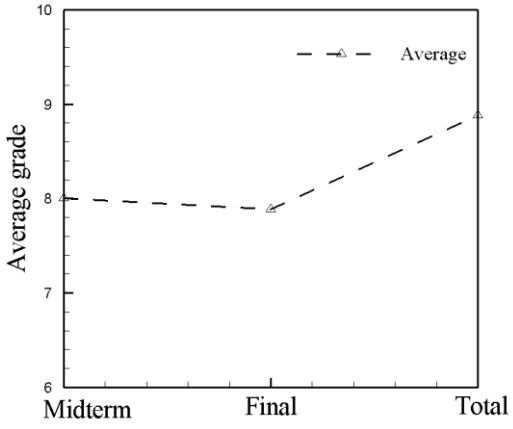


Figure 5. The average grade of students in different tests

Based on the results, after teaching of machine design course, the average levels of proficiency of students by taxonomic level are 3.

MACHINE DESIGN PROJECT DESCRIPTION

The machine design project include 4 stage of CDIO process, which lasts 14 weeks has approximately 34 students divided into 9 teams of four or five 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 10. These steps are inter-related and inter-dependent on each other. Reflecting and affecting all other steps.

Table 10
Gantt chart for machine design project

Weeks	2	3	4	5	6	7	8	9	10	11	12	13	14	Stud.
Forming teams														Duy Khanh Duc
Problem identification and formulation modelling														Team
Technical requirements of machine														Vy Khanh - Duy
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

Table 11
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 (Picture 5). 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.	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
	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 (Picture 6)	
I- Implement	Step 7: Build and Test the machine - Build the machine (manufacture and assembly) - Test the machine - Record the data	4.5 Implementing

	- Analyze the data according to the “Design Requirements” … - Redesign and retest as necessary	
O-operate	Step 8: Perform post implementation and review assessment: Operate the machine	4.6 Operating

The final product of the Machine design projects is the real model of the machine (Figure 7). It helps the students turn all ideas and designs into real products through design - implement experiences.

Figure 6. Design experiences - 3D modelling of transmission systems

The progress evaluation included the process notes, product, process performance, records, logs and design drawing and final report is done by evaluation board included manufacturer’s representative.

Figure 7. Implement experiences: Build the machine

CONCLUSION

After machine design and machine design project, students find that learning is more interesting and engaging and that they develop a greater understanding of mathematics, natural science and engineering fundamentals because they find the information for themselves and actively use the information to complete their projects. 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 machine design course and machine design project have been redesigned for the contents and teaching methods to provide students the essential engineering knowledge and skills that employers required. The applications of new teaching methods, active learning and a variety of evaluations have brought the excitement for learning in machine design course

and machine design project. These methods can be widely applied for other courses in order to ensure the intended learning outcomes. Via considering the result of outcome assessment, the contents and learning outcomes should be adjusted as following:
1) Correct the learning outcome LO1: Have ability to apply mathematics, natural science and fundamentals engineering knowledge to perform load analyses on machine element parts and assemblies, stress and strain analyses on machine elements and determine element deflections and stability.
2) Add a skill into learning outcome LO9: Have ability to write and present the report.
3) Need to add the knowledge to accomplish the learning outcome LO3 and LO9.

This process is reviewed annually to complete syllabus.

REFERENCES

[1] Svensson T. and Gunnarsson S., Using a project model for assessment of CDIO skills, 1st Annual CDIO Conference, Queen's University, Kingston, Ontario, Canada.

[2] Daryl G. Boden, Peter J. Gray, "Using Rubrics to Assess the Development of CDIO Syllabus Personal and Professional Skills and Attributes at the 2.x.x Level", Global J. of Engineering. Educ., Vol.11, No.2, 2007.

[3] Geoffrey Cunningham, Melissa Balson, Johan Bankel, Charles D. McCartan, Craig Putnam, Christian Vandenplas, "Comparison of first-year design-implement experiences, their assessment and resources", Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, USA, June 11-14, 2007.

[4] Greg Huet, Bernard Sanschagrin, Martine Gagnon, Daniel Spooner, Aurélian Vadean, and Ricardo Camarero, "The assessment of student teamwork to promote cdio learning objectives", Proceedings of the 4th International CDIO Conference, Hoogeschool Gent, Gent, Belgium, June 16-19, 2008.

[5] Stefan Hallström, Jakob Kuttenkeuler and Kristina Edström, "The route towards a sustainable design-implement course" Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, USA, June 11-14, 2007.

[6] Raucent B., "What kind of project in the basic year of an engineering curriculum", J. Eng. Design, vol. 15, No. 1, February 2004, 107–121.

[7] Marwan M. Shamel and Mushtak Al-Atabi, "Multidisciplinary Projects for Second Year Chemical and Mechanical Engineering Students", 20th Australasian Association for Engineering Education Conference University of Adelaide, 6-9 December 2009.

[8] Andrew McLaren, Anastassis Kozanitis, "Assessing Student Learning", 2010

Biographical Information

Assoc. Prof. Dr. Nguyen Huu Loc is Vice Dean of Faculty of Mechanical Engineering, University of Technology, Vietnam National University - Ho Chi Minh City. Assoc. Prof. Dr. Nguyen Huu Loc leads for the implementation of the CDIO approach in the Faculty of Mechanical Engineering at University of Technology. His fields of research and teaching are machine design, geometric modeling, reliability based design…

Mr. Pham Quang Trung is a young lecturer in the Faculty of Mechanical Engineering, University of Technology, Vietnam National University - Ho Chi Minh City. Mr. Trung is a member of the implementation of the CDIO approach in Hochiminh City University of Technology His current research focuses on Plastic Working, Metal Forming, and Material Engineering.

Corresponding author

Assoc. Prof. Dr. Nguyen Huu Loc
Faculty of Mechanical Engineering, University of Technology, Vietnam National University - Ho Chi Minh City.
Block B11, 268 Ly Thuong Kiet Street, Dicstrict 10, Ho Chi Minh city, Vietnam
nhloc@hcmut.edu.vn, nhlcad@yahoo.com