A Problem-Based Learning Strategy in an Introductory Mechanical System Design Course

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Abstract

This paper described a model for the mechanical system design instruction that was adapted from the IDC Robocon events. Students attended short lectures and then divided into groups for the design, built and test of a drill-powered bicycle retrofit in a 3-weeks project. The process involved problem specification, conceptual designs and cardboard/wood real-scale prototypes before building the working products for testing. All process were peer discussed in class and a facebook page. The model was very successful for both the outcome and student's satisfaction. All groups were exposed to the first full-design circle and could achieve the objectives with increased creative thinking.

Keywords: Problem-based learning, mechanical design, IDC Robocon

1. Introduction

In a Thai University, a main problem during a mechanical engineering curriculum revision was to ensure the design-related and associate soft-skills outcomes. Being restricted by the demands of the professional authority in Thailand, the Council of Engineers, on course contents and Ministry of Education regulations on all curricula (Pimpin & Maneeratana, 2010), most of the possibly related and spared credits were channeled into the so-called design and experiment streams of connecting courses. Even with the new design stream, it was apparent that the changes were not enough; new instructional and learning approaches were sorely needed to cope with students who lacked the real-life, hand-on experiences and needed repeated exposure to design process from conception, design, manufacturing, operation, redesign and, if possible, creativity as well as entrepreneurship.

The descriptions of two related courses, 2103313 Mechanical System Design I and 2103314 Mechanical System Design II were ‘Theories of Failure; fatigue design; design of machine elements: gear, shaft, screw, fastener, rolling element bearing, journal bearing, clutch and brake, belt, and chain.’ and ‘Introduction to design process: the specification development/planning phase; the conceptual design phase; concept generation, concept evaluation; product design phases, product generation, evaluation of function and performance, evaluation of cost, ease of assembly; finalizing the product design; design projects, covering assumption, calculation and design evaluation and presentation and with a complete report’. These courses were quite cumbersome and uninspiring even though they satisfied the requirement from the Council of Engineers.

During the transition from the old 2002 curriculum to the new one in 2011, it was decided that some old courses would be used as the pilot courses before the full implementation in the revised curriculum. Specifically, a design-centered course in the sixth semester of the program, 2103314 Mechanical System Design II, was selected. With 2-year leading time, the new instructional model could be deployed, accessed and refined twice. The key was not to change the overall contents but the instructions and learning had to be changed so that both contents and outcomes were satisfied.

The new instruction model was inspired by the International Design Contest, popularly known as the IDC Robocon. The first event was organized in 1990 by the Massachusetts Institute of Technology (MIT) and Tokyo Institute of Technology in Japan (Yamakita, 2009). The concept of the event was to bring engineering students from different countries together. Competing teams for specific objectives with limiting resources were formed by mixing students from various backgrounds so that the teamwork was emphasized (Getschko, 2009). Thailand joined the event in 2007 by hosting the event in Bangkok (Pipatpongsa *et al*., 2008). To select students for this international event, the national event Robot Design Contests (RDC) had been jointly hosted by the National Metal and Materials Technology Center (MTEC) and the Faculty of Engineering, Chulalongkorn University (Rungfapaisarn, 2012). The first rounds of activity were organized at regional locations – Chiang Mai University in the northern, Prince of Songkla University in the southern, Suranaree University of Technology in the north-eastern. The national rounds were held at Chulalongkorn University with the final competition at a popular department store. The 4-week activities started with some theoretical and practical training before commencing with the specified tasks of robot design, building and testing.

The activities were so successful with very positive feedbacks from students and lecturers alike. At the Department of Mechanical Engineering, Chulalongkorn University, there were huge demands from students for the limit number of seats in the event. Hence, it was logical that the gained expertise would be incorporated into a design course for all students. For the implementation during the transition from the old to the new curriculum, the adapted instructional model was first piloted in the Academic Year 2010 with supporting expertise from a lecturer and a Ph.D. student of the Faculty of Education (Seechaliao *et al*.,

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2011, 2012a & 2012b). The model was further refined for the course in 2011 before the formal implementation in a second year course in the academic year 2012.

It was the model and experience in 2011 that was described in this paper. As the previous articles focused on the development and validation of the generalized instruction model and assessing instruments, the course management was left out. In addition, the emphasis was on the working prototypes in 2010; in 2011, the instructional model was also further refined to add the construction and operation of the final prototypes. Hence, the objective of this paper was to describe in details the revised instructional model as well as how the course was actually conducted as a realistic example. In the following sections, the instructional model, course descriptions and selected case study as well as the actual conduction were described.

2. Instructional Model

This design course was a part of the educational research and development of the instructional design and development for engineering creative thinking (IDECT) model (Seechaliao *et al*., 2012a) which was implemented and evaluated across three engineering disciplines. This IDECT model of instructional strategy was a systematic step-by-step activity that could improve the instructional design skills of instructors in a more efficient manner (Seechaliao *et al*., 2012b). Six experts agreed that the instructional model was appropriate in good and excellent levels as the instructional models specifically included several features that promote creative thinking and product designs, including mind-mapping, brain-based learning process and constructivist via electronic portfolio, etc. In the evaluation of students' skills in the Academic Year 2010, post-test score for creative thinking was significantly higher than the pre-test score at the 0.05 significant levels. The post-test score for creative product was at fairly good level (Seechaliao *et al*., 2011).

The design instructional approach required repeated sets of 'think' and 'do' as shown. When compared to the previous year (Seechaliao *et al*., 2011), the cycle contained the third 'think' and 'do' sets for the final prototypes (Figure 1) in addition to the first sets for the conceptual design and second sets for the quick prototypes. By adapting the instruction model based on engineering creative principles for developing creative thinking skills (Seechaliao *et al*., 2011) by adding the last set, the revised instructional process was shown in Figure 2.

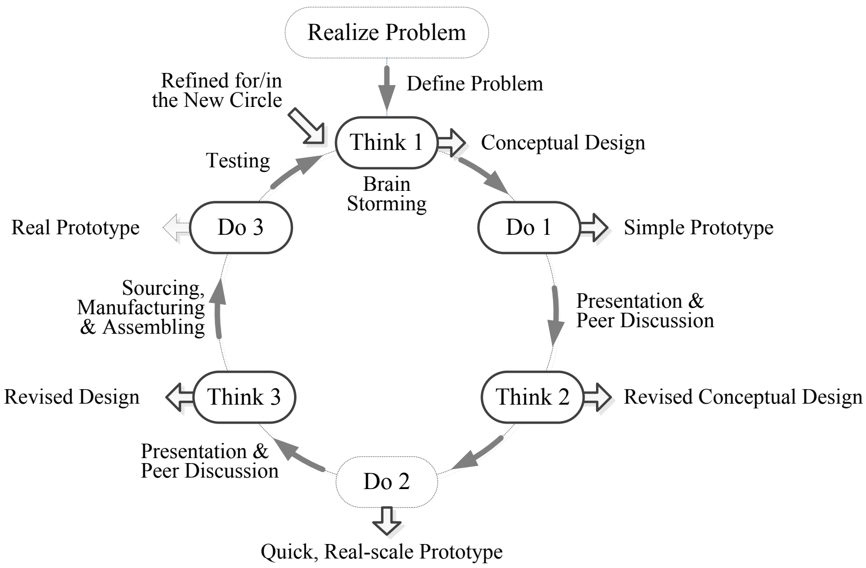

Figure 1. Design approach model

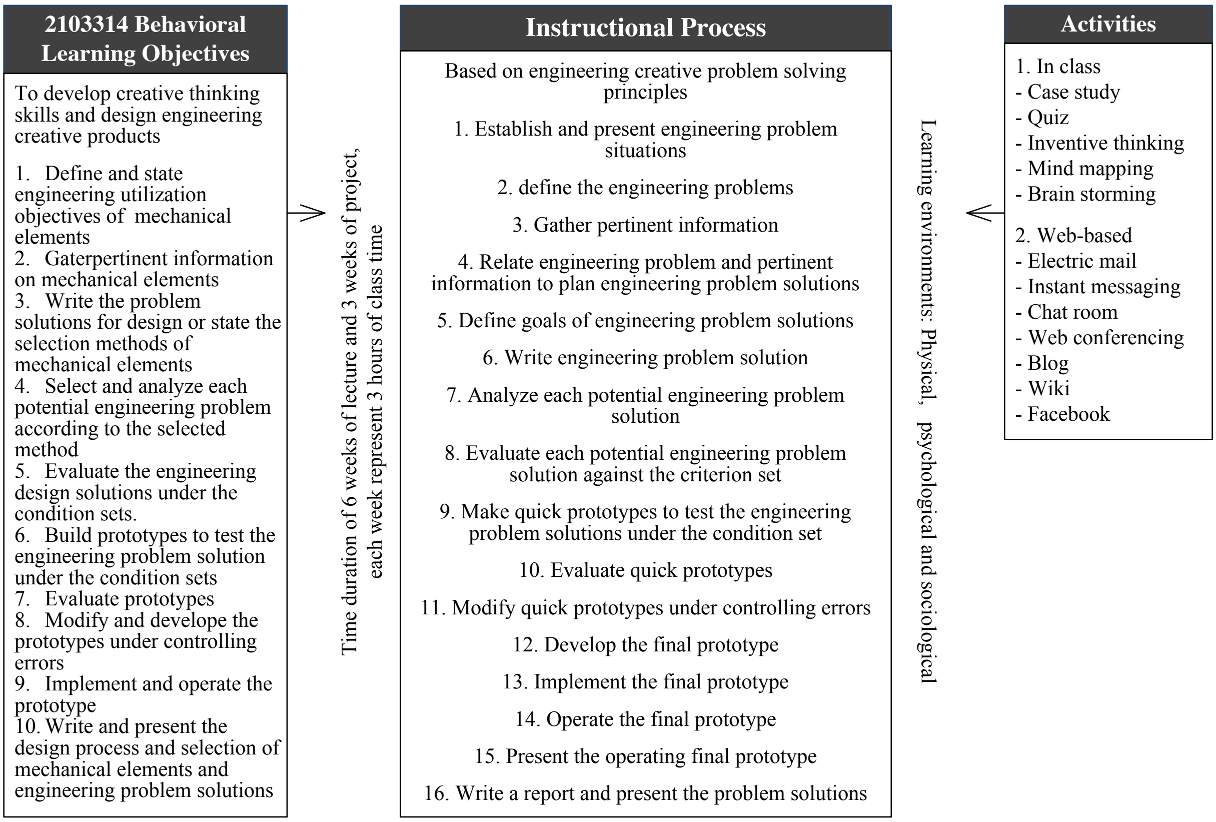

Figure 2. Part of the instructional model based on engineering creative problem solving principles, modified from Seechaliao *et al*. (2011)

3. Course and Case Study

During the transition to the new curriculum, the course conduction was split into two parts (Table 1). The first part involved traditional lectures and quizzes. Then, the class of 75 students was split into 3 groups which would attempt 3 three-week projects in parallel. One of these projects was chosen for the new instructional model.

Table 1. Course Structure

Week	Activity		
	Group I	Group II	Group III
1-6	Theory (Lectures and Quiz)		
7-9	Project a	Project c	Project b
10-12	Project b	Project a	Project c
13-15	Project c	Project b	Project a

The design cycle was imparted to students in a step-by-step approach (Table 2) in only 3 weeks. The students were cycled through the cooperative learning process for problem defining, product requirement, product specification, conceptual design, simple prototypes, revised conceptual design, quick cardboard and wood prototype, final design, final prototypes and testing such that each groups had to present their works and progress to others for discussion and approval.

Table 2. Step-by-Step Activity and Outputs

Process	Activity	Output
Problem statement	Group work/brainstorming	Defining problem
Design requirement	Group work/brainstorming	Design Requirements
Review of information	Information research	Existing products, patents, related standards, user interfaces, ergonomics, and other information needed in the design calculation for products and users
Conceptual design	Group work/brainstorming	Poster and presentation to other groups for discussion, vote and approval
Revised conceptual design	Group work	Specification for quick prototype
Quick prototype	Cardboard/wood building	Real-scale model with the bicycles/sketchboards and presentation to other groups for discussion, vote and approval
Final design	Group work/engineering sizing, component selections	Detailed design with analyzed load and detailed specification and calculation for components and parts
Working prototype	Manufacturing, purchasing, assembling & tinkering	Final products for testing
Presentation	Testing rounds	A4 brochure and reports (with CD for reports, references and activity VDO)

Different new case studies that increased the students' awareness on the societal and environmental impact and responsibility were selected each semester. For the first run in 2010, the soda can crushers were designed (Seechaliao *et al*., 2011). For the second time in the academic year 2011, the drill-powered bicycle/handle skateboards retrofits were used as the case study. The origin of this project topic came from the BOSCH Thailand Cordless Racing 2011, the national qualifying round for the Power Tools Asia Cordless Race 2011, in which the company invited vocational and engineering students to participate in the competition to celebrate the 125th Anniversary (Bosch Thailand, 2011). The company presented teams that passed the first round with 4 cordless BOSCH GSB-18-1-li drills. A team of second-year students from the Department of Mechanical Engineering participated in the competition and came back wondering that they ought to be able to perform better. They, thus, consulted lecturers and suggested the project topic which led to the drill-powered bicycle retrofit by converting a regular bicycle or skateboard to electric bicycle. However, the problem was of a smaller scale with only one drill as the power source with strong emphasis on the learning experiences.

4. Couse Conduction

As described in Figure 1 and Table 2, students started working in assigned groups with brainstorming on the problem statement and design requirement, followed by information search and gathering on the existing products and related information for needs, requirements and inspiration. They, then, produced conceptual designs (Figure 3) to fit their selection platforms, bicycles or handle skateboards which were presented to other groups for peer discussions and voting for the best options in class under the lecturer's observation and supervision. The works and the amount of efforts required to complete the projects required the approval from other groups in the mutual agreements. Then, the conceptual designs were revised and presented to the class for discussion again. Some quick 'dirty' real-scale prototypes, made from cardboards, wood, ropes and similarly simple components, were used to demonstrate the working of the system.

Figure 3. Examples of product statements and preliminary designs

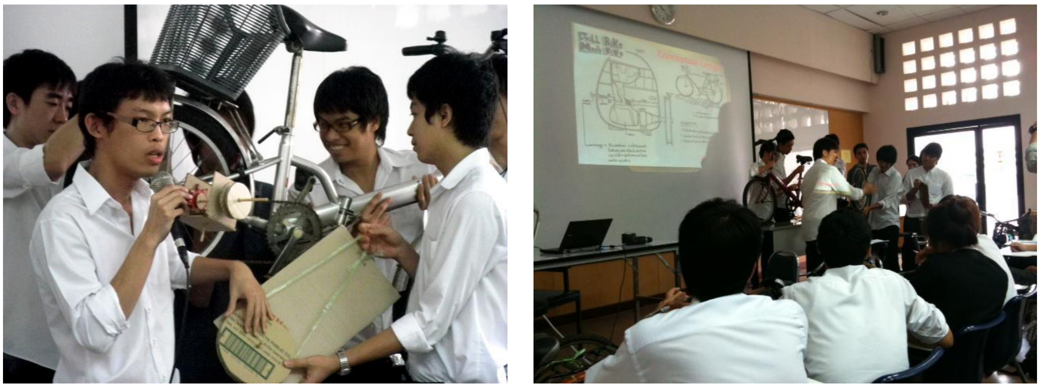

Figure 4. Presentation of quick, real-scale prototypes

For the final designs, students had to provide the full analyses, components and other details before embarking on building of the working prototypes. The additional resources and cost were minimal. Old bicycles and handle skateboards that belonged to students were used. Standard components, be new or second-hand, were searched for and procured from local shops by students themselves. The average spending per group was only 1,000 Bahts (roughly 33 USD) with the maximum of 1,500 Bahts (about 50 USD). For non-standard parts, students manufactured them themselves in the Departmental machine shops of which the upkeep and safety training was a standing cost in the Department. These activities were crucial to students with few or non-existent hand-on experiences in engineering tools.

All the time, students reported the progress and discussed the experiences and results with lecturers and peers in class, face-to-face and, more frequently, facebook. Figure 5 was an example of the second update on a working prototype. Students aligned the driven wheel to the bicycle rear wheel and secure the driven wheel frame to the bicycle frame. The lecturer posted comments on the compressive force and related friction as well as recommending some testing for which students posted the testing VDO clips with descriptions of encountered problems, correcting actions, good points and proposed further improvements. This communication was not only a part of the recorded portfolio, it also provided cooperative learning atmosphere and peer pressure on the other groups.

Figure 5. Online discussions on a prototype

Even though the schedule was very tight, students usually finished the working prototypes quite ahead of the deadlines and had much fun riding the final products and posting the VDO clips in facebook. Some groups had enough time to improvise additional improvements. The formal testing rounds, prototype presentation and actual runs, were held during lunch breaks at the main Faculty-wide students' activity space adjacent the canteen and in full view of all faculty and students who were invited to observe and comment on the prototypes (Figure 6). Obviously, students were very proud of their works and showed increased confidence in the ability to be creative and succeed. Some students even expressed further interested in similar works or competitions.

The whole process, discussions and results were also recorded and shared to other students in the same class as they studied the other parallel projects. Thus the first loop in the 3-week design cycles (Figure 1) was completed. The first set of students went on to other projects but still kept in touch with the progress via personal contact and facebook. The second set of students (Table 1), who just completed another project, started the design cycle again. However, they had the choice of either doing the whole new design or taking over the first retrofits and refining the old design. Due to the short period involved, they inevitably chose the refining path. It was noted that the required works for refining involved no less effort than the first design as students had to modify and add extra mechanism that boosted the performances, users' safety, comfort and maintenance, etc., under a higher level of constraints.

Figure 6. Some of the testing rounds

5. Conclusions

This instructional model was based on repeated ‘think’ and ‘do’ process for the conceptual design, quick real-scale prototype, and final working prototypes in the cooperative learning setting. Throughout, the ideas and works in each group were shared, discussed and approved by peers while the lecturer provided technical advices and expertise. Even the percentage of the awarded scores for the project were quite low as it was just a small part of the course, students were very enthusiastic and eagerly embarked on the challenge.

This problem-based learning strategy for a mechanical system design course was found to be very successful and cost effective, both in terms of learning efficiency and resources as well as much increased motivation, enthusiasm and satisfaction of students who expressed much appreciation, confidence and pride in their works. In the 2011 revised curriculum, this model was pushed forward to the third semester of the study. This was the earliest possible time that the Department took full responsibility of the students after they selected the discipline at the end of the first year.

In many ways, this course addressed many issues that in many engineering schools implements for new students during the first year (Ambrose & Amon, 1997). This push forwards was expected to relieve the major problems of few full-circled design and manufacturing experiences. This situation exerted some limitation on the scope for the senior projects due to the need to ensure that students were repeatedly exposed to complete design cycles (Sripakagorn & Maneeratana). Preliminary results for the first semester of the academic year 2012 were even better, judging from the products and reflective journals. The medium term strategy included the refinement of the model as the first spearhead into the adoption of the CDIO concept (Crawley *et al*., 2007). The cooperation and integration with other courses, particularly the related one in the same semester for parallel and integral experiences would reduce the total workloads of students and demonstrate the importance and real-life application of the basic engineering theory (Maneeratana *et al*., 2012).

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