Systematic Infusion of Creativity in Engineering Design Courses

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Abstract

Earlier studies have shown that the level of creativity of the fourth year students of the Mechanical Engineering and Manufacturing Engineering Programmes at the Universiti Kebangsaan Malaysia are low to average, as reflected in the evaluation of their group based design projects. Based on the finding for the next cohort of students, several creativity techniques are introduced in the course such as mind mapping and combined with the conventional techniques in design engineering which includes Morphology analysis and Pugh Evaluation matrix. Students are required to apply the techniques and report the implementation in their log books. It was observed that the students are more creative and able to propose ideas that are ‘out of box thinking’. These achievements showed that the creativity level can be enhanced through teaching and learning. In order to ensure an effective infusion of creativity among students in the Mechanical Engineering and Manufacturing Engineering Programmes, it is proposed that the students are exposed to effective creativity techniques combined with the standard engineering design methods for generating ideas. Students should be introduced to the creative techniques through design-based courses from their first year at the university.

Keywords: creativity; engineering design courses; mind mapping; design techniques;

1. Background of Study

Preliminary studies by Jaafar Sahari et al. (2009) and Syazrin Aklili et al. (2009) on students’ creativity in the Mechanical Engineering and Manufacturing Engineering Programme has found that the creativity level of students is relatively low as reflected in their inability to generate ideas that are ‘out of the box thinking’. However, the study also leads to new findings that individuals’ creativity can be enhanced by learning and applying creativity techniques in their work. Previously, Syazrin Aklili et al. (2009) have studied two cohorts of students taking the Product Design course (KP4273) and it was found that there is an increasing capability in generating ideas for those who have been exposed to the creativity enhancing techniques like brainstorming, mind mapping and the conventional techniques. From the study, a proposal has been made to review the design-based curriculum for both programmes and propose suitable methods to foster the creativity in a systematic and structured manner starting from their first year. According to Stenberg (1999), the engineering curriculum provides exposure to the problems...
that can develop students’ creative thinking skills. Creativity in the context of engineering design is related to problem solving and cognitive activities. This study will explore the engineering design curriculum issues and how to foster creativity systematically in the learning curriculum.

2. Methods of Study

Kemmis & McTaggart (1982) defined that the research are conducted based on the framework of the design action research. The main features of action research are to improve practice. Practice in this research context is the teaching and learning practice that can enhance creativity through the design courses of the Mechanical Engineering Programme and Manufacturing Engineering Programme in the Faculty of Engineering and Built Environment (FKAB), Universiti Kebangsaan Malaysia. The phases of action research are as follows (Jaafar et al. 2010):

i. Planning.
ii. Action.
iii. Observation.
iv. Reflection.

These four phases form a complete loop and the loop can be repeated until the researcher is satisfied with the results of observation and reflection of the actions planned and implemented for each loop. In the planning phase, reflection can be used to identify problems that arise in the current practice. In this study, the identified problem is the inability of students to generate creative ideas as reflected in the medium to low scoring on creativity. Thus the lecturers plan to introduce an approach to brainstorming and mind maps. Action phase is where the lecturers implemented the approach and evaluate the effectiveness of the actions. In the reflection phase, the lecturers analyzed data obtained through observations and assessments. Results of the reflection is used in the planning of the next loop should there be any gaps between the findings and the targets. This paper focuses on the findings for the first loop only.

3. Design-Based Curriculum

For both The Mechanical Engineering programme and Manufacturing Engineering Programme, design-based courses are not taught in every semester. Table 1 shows the lists of design-based courses by semester for both programme (FKAB Undergraduate Handbook, Academic Session 2009-2010).

| Semester | Mechanical Engineering Programme | Manufacturing Engineering Programme |
|----------|---------------------------------|------------------------------------|
| 1        | -                               | -                                  |
| 2        | KF1174 Engineering Graphic      | KF1174 Engineering Graphic         |
| 3        | -                               | -                                  |
| 4        | -                               | -                                  |
| 5        | KJ3934 Design of Machine Components | KP3214 CAD/CAM                   |
| 6        | KJ3944 System Design            |                                    |
| 7        | KJ4955 Design Project           | KP4274 Product Design             |
| 8        | -                               | -                                  |

From Table 1, it is clear that students began to be exposed to design-based courses starting from the fifth semester. Upon completion of the Engineering Graphics courses in year 1, students are no longer exposed to the design-based courses until they are in the fifth semester. For example, in the Mechanical Engineering Programme, design concepts are introduced in the Engineering Graphics course. The learning outcomes of the Engineering Graphics course include understanding the formation of the basic geometry design. Students are also expected to be capable of developing multi-view and section view drawings. In the fifth semester, students will have to enrol for the Component Machine Design course in which the learning outcome is an understanding of the concepts of Mechanical Engineering Design and safety factors. In the following semester, students taking the Systems Design course are required to design a set of mechanical components together with the complete system. Finally in Design Project course, the students are required to use all the basic sciences and engineering fundamentals to perform
design analysis using Computer Aided Design (CAD) and Computer Aided Engineering (CAE) technology. Apart from the lack of continuity in design synthesis and analysis in the academic curriculum, it is also observed that there are no specific courses that focus on the innovative techniques and applications.

According to Pahl (1996), brainstorming is one of the creative techniques most commonly used in design teaching. For the purpose of comparison, the design curriculum of the Department of Mechanical Engineering, University of Auckland has been referred to in this study. Seidel (2004) reported that in the University of Auckland, brainstorming is introduced through a project during the first semester of Year One. This method is widely applied for the design project concept curriculum. Other techniques that combine the development of creative ideas with systematic approaches, such as functional analysis, the objective tree and morphological analysis are introduced through courses for various design concept projects within the overall curriculum.

According to Seidel (2004), at the Department of Mechanical Engineering, University of Auckland, design classes are taught in each semester. Details of the design courses in each semester are outlined as follows:

1. **Year 1 Design**
   In the first year, students were introduced to engineering drawings, graphics and written communications design. In both design courses, 3-dimensional CAD package is used. At this point, students may have very limited knowledge in the fundamentals of engineering science as well as low communication skills. Therefore, the design course focuses more on solving open-ended problems.

2. **Year 2 Design**
   In the first semester, basic knowledge in engineering drawing including tolerance are strengthen prior to the introduction of CAD. The second semester design course is structured as a mixture of design project with lectures in specific design topics. This lecture covers topics related to the design process, machine element design, used of catalogue for selection of standard components and off-the-shelf design task.

3. **Year 3 Design**
   Design works for both semesters are project-based, with lessons limited to the lectures’ introduction of each courses and projects. Usually lectures are only taught regarding to specific raised issues in projects only. Students are required to complete two projects per semester. Each project is group based with different project title, design tasks and the techniques.

4. **Year 4 Design**
   For the fourth year design projects, each group must complete four design projects including the final year project. Students are expected to apply the principles learned in Year 2, 3 and 4 effectively, and must be capable of dominating a variety of advanced engineering application methods. The learning objectives in the design course are:
   - To understand the concept of ‘Design for X’ (assembly, manufacturing, fatigue, quality, etc.).
   - To understand the issues associated with design in a wider context, such as product life cycle from idea generation (including market analysis) until the disposal of the product.
   - To prove competency in the synthesis and detailed design of a product.
   - To continue with teamwork practice.

4. **Systematic Application of Creativity in Curriculum Design**

   For the design courses in the Manufacturing Engineering Programme, students are introduced to the basic methods in product design stages starting from identifying the problem and the objectives of the design, followed by generating design concepts until the detailed design in which the design are ready to be turned into products. Methods or approaches to produce a quality product based on the perspective of an integrated product development process are introduced at each stage of the product design. In this course, students were exposed to some common methods such as brainstorming, a technique to enhance creativity and finding solutions to problems in product design together with other conventional engineering design techniques such as morphological analysis.

   Evaluators for the product design projects in session 2008/2009 generally felt that the students are less creative in generating ideas to design a product. Thus, another technique known as the Mind Mapping is introduced to students of the 2009-2010 sessions. The Mind mapping technique is introduced by Tony Buzan (Buzan & Buzan 1996) and proved to be effective in promoting ideas and solving problems. Many examples of problem solving using mind mapping techniques are discussed during lectures. Methods that can be used to enhance creativity and stimulate
imagination include synectics, lateral thinking, morphological analysis, analogy, TRIZ, mind mapping, 6-3-5 chart and etc. For this study, the design curriculum of the Manufacturing Engineering program is used as a case example. Goel & Nanua Singh (1998) has highlighted a few creativity enhancing techniques as shown in Table 2.

Table 2. Details on Creativity Enhancing Techniques

| Techniques                | Descriptions                                                                 |
|---------------------------|------------------------------------------------------------------------------|
| Brainstorming             | The basic of brainstorming is the generation of ideas in a team; proven to be very productive for an individual and also team members. |
| Mind Mapping              | Every ideas has its own link to other ideas and concept; an effective method for taking notes and very useful in generating ideas. |
| Synectics                 | A method to assemble or disassemble findings in order to get a new insight to a variety of problems, Trigger Questions is one of the synectics technique commonly used. |
| Fermi Approach            | A method capable of ensuring feasibility of the generated concepts.            |
| Engineering Design        | Functional analysis, Morphology analysis.                                    |
| Conventional Techniques   |                                                                                |
| TRIZ                      | Theory of Inventive Problem Solving; generating creativity through patents.    |

The main purpose of this study was to find the best way to enhance creativity and evaluate its effectiveness on students so that they can solve problems and make decisions effectively. Thus, systematic methods such as brainstorming, mind mapping and conventional techniques of mechanical engineering design such as morphological analysis must be emphasized. Each of these methods has its own strength and if combined will enhance idea generation. Table 3 shows potential techniques to be applied in the Manufacturing Engineering Programme design courses. The Conventional engineering design techniques are not listed in the table since students are already familiar with the techniques.

Table 3. Potential Techniques to be applied in Design Courses

| Semester | Manufacturing Engineering Programme | Brainstorming | Mind Mapping | Synectics | Fermi Approach | TRIZ |
|----------|-------------------------------------|---------------|--------------|-----------|----------------|------|
| 1        | -                                   |               |             |           |                |      |
| 2        | KF1174 Engineering Graphics         | ✓             | ✓            | ✓         | ✓              |      |
| 3        | -                                   |               |             |           |                |      |
| 4        | -                                   |               |             |           |                |      |
| 5        | KP3214 CADCAM                       | ✓             | ✓            | ✓         |                |      |
| 6        | -                                   |               |             |           |                |      |
| 7        | KP4274 Product Design               | ✓             | ✓            | ✓         | ✓              | ✓    |
| 8        | -                                   |               |             |           |                | ✓    |

Referring to Table 3, TRIZ will be an appropriate technique for a capstone design project such as KP4273 as it allows students to be exposed to patents and higher level inventive methods. TRIZ according to Goel & Nanua Singh (1998) is a combination of algorithms and principles. While for Michael (2006), TRIZ is a qualitative theory not a mathematical or quantitative one and noted that the theory’s formal ideas and concepts are like categories patterns and metaphors. Algorithms are defined as the procedural method that consists of several steps to solve tasks. Michael (2006) has explained in detail the objects of TRIZ such as inventions, technical systems and components. Below as listed is the essential of the learning experiments:
i. Presentation of the key problem is solved using a concrete invention.
ii. Solving the problem using the definition of the main procedure together with this invention.

The following methodological procedures will then be used later:

i. Generalization and classification of the models of the key problems and of the main procedures used solve problems with inventing.

ii. Presentation of laws for the creation of problems, prognosis and the controlled and systematic solution problems.

5. Conclusion and Suggestion

This paper has discussed two issues from the findings of previous studies on the creativity levels of students design-based courses. First, a recheck on the design curriculum for Mechanical and Manufacturing Engineering Programme and second is to propose suitable methods to foster creativity systematically in design courses starting from year one. This proposal is made after discovery that students lack creativity based on observation and evaluation on their capabilities to generate concepts and thinking ‘out of the box’. Actions have been taken to introduce students to various other creativity enhancing techniques, such as mind mapping and brainstorming apart from the conventional techniques of mechanical engineering design, such as the morphological analysis approach to problem solving. From the lecturers’ observations, it was found that students, who were exposed to more creative techniques, are capable of generating better design ideas and solutions. The study has also found that creativity levels can be enhanced through systematic application of these techniques. In order to enhance students’ creativity, it is proposed that students are exposed systematically to the creativity techniques through their design-based courses as early as in their first year. The implementation of these techniques should be systematically reported and monitored by the lecturers involved.

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