OPEN-ENDED DESIGN PROBLEMS FRAMEWORK: A WAY TO ADDRESS PROGRAM OUTCOMES

F. Tarlochan[a,b] and L.M. Sidek[a,b]
[a]College of Engineering, Universiti Tenaga Nasional, 43009 Kajang, Selangor, Malaysia
[b]Engineering Education Technical Division, Institution of Engineers Malaysia
Email: faristarlochan@gmail.com

ABSTRACT

The days of conventional engineering education has taken a shift with the formulation of engineering accreditation criteria being introduced into program outcomes. For example the now familiar ABET Criterion 3a – 3k [1] and in Malaysia; the Engineering Accreditation Council (EAC) Criterion 4 [2]. As such, engineering faculty members who teach undergraduate engineering courses are under immense pressure to address wide variety educational goals that extend well beyond the traditional student learning of engineering science and design. The engineering faculty as whole has to ensure that our graduates have abilities in the areas of teaming and communication and understandings in the areas of ethics, global and societal impact, and contemporary issues. Besides this, the students are expected to demonstrate some level of creativity and innovation. The expectation is that all of these topics will be integrated throughout an engineering curriculum with some fraction being addressed in every core course without compromising fundamental engineering science and design. What becomes clear is that engineering faculty needs a framework for developing, implementing, and assessing open-ended problems that fulfill a variety of educational outcomes. In this paper, we present a description of a framework that is found to address many of the program outcomes outlined in the accreditation manuals.

Keynotes: *open-ended design problems, program outcomes.*

INTRODUCTION

Faculty members who teach engineering courses are under great stress to address wide variety of educational goals that extend well beyond the traditional way of teaching students engineering sciences. Besides this, through the enhancement of knowledge and technology, the new paradigms of engineering practices are also influencing programme outcomes. This creates a need to ensure that the program is not overly burdened with engineering sciences and little on the latest technologies out there. A strike of balance between both is needed. For lecturers teaching 1st and 2nd year courses there is an added responsibility of providing a conducive teaching and learning environment that enables a smooth transition from high school to university or college.

In general the generic educational goals can encompass soft skills, leadership, team work, ethics, awareness on issues both local and international, study skills development and development of problem solving skills, to name a few. How are we to achieve all of these? The solution is through a well constructed open – ended engineering design problem course. What becomes clearly apparent is that lecturers need a structure for creating, implementing, and assessing open ended design problems that fulfill a variety of programme outcomes. In this paper, we present four guiding principles that guide to the development of an open ended design problems, and discuss the opportunities and challenges to creating, implementing, and assessing such design problems.

Looking on a holistic view, most open-ended, real-world, engineering design problem that lecturers have assigned to their students emphasizes on the final solution or product. For an open ended design problem the principles suggested here focuses on the development of understandings (process) that lead to solutions or viable products. Even in the industry, often a company wants to develop a product without understanding the market demand for it. Even though the idea is creative and innovative, it is useless unless they can be matched to a market need. Hence in the design of a solution or product, the process is crucial to better understand market demand.

Why is it that the process is important? It is evidently clear at the end of the day, the product that is actually evaluated and rewarded. Hence the importance of the process becomes secondary and it is a rat race to push the product or solution out into the market. Most companies adopt the principle of "*over the wall design method*" [3]. The short come of this method is that products designed may not necessary fit what the customer had in

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mind. While driving for a strong product or solution is important to the success of an engineering organization, the need for a robust process is equally important in developing students' higher-order cognitive skills in order to design or find solutions that fulfill the customers' needs of requirements.

Herein lays the difference between the proposed framework and the traditional open-ended problems that lecturers typically assign; which are product oriented. Meaning that emphasize is given to the final product or solution and generally the assessment of students' learning is based majority on the final solution, which talks little on the process the student used to create the product or solution. The proposed framework requires that students show how they interpret a physical problem through a purposeful documentation effort that promotes their ways of thinking. The four principals in formulating an open ended design problems are: project definition, specification definition, conceptual solutions and realization of solution(s).

THE GUIDING PRINCIPLES

Project Definition

The students are required to explore the market demand for a certain product. Once a market demand is acquired, they are to plan for the design process in order to allocate the resources for their activities. But we have to understand that this market demand needs to be scrutinized further. We need to make sure we have enough information to generate an understandable, explicit problem definition that focuses on the real need. The problem definition must address the real need yet not bias to preclude certain solutions. An extensive definition of the problem allows you to look at a wide range of alternative solutions before you focus on a specific solution. Since planning requires a commitment of people, design teams are formed. Within these principles, students will cover several learning outcomes such as; to digest and understand contemporary issues, working and communicating in teams and the sense of leadership for spearheading a design team. The design team which comprise of students have to work independently with minimum interaction with the lecturers. The challenge of the lecturer is to design appropriate assessments to measure these learning outcomes from this first very principle.

Specification definition

In this principle, the design teams are required to understand the problem definition or market need and lay the foundation for the remainder of the process. The teams need to identify customers for the product, generate customers' requirements, correct evaluation of the existing competition (benchmarking) and to generate engineering or design requirements to be achieved. It is here students are required to use quality function deployment. This method assists the students to organize major pieces of information such as the specifications of the product, the competitors, customers' preferences and targets to be achieved. This helps to better understand the problem at hand and what needs to be focused to produce a product or solution that has a market need. This principle also promotes continuous communication between a number of individuals (e.g. within teams, between teams, and with the potential customers). Here the students are exposed to be able to digest information accurately whilst working in a teaming environment. Since this principle involves extensive work, and accurate reporting, team dynamics and ethics come into play.

Conceptual solutions

The earlier principle went into great lengths to understand the design problem and to develop its specifications and requirements. Now the students with a better understanding of the problem at hand can start to generate concepts that will lead to good design solutions. This can be easily done by decomposing the problem in terms of flow of energy, material and information. The teams will have to find the overall function that needs to be accomplished, followed by creating sub-function descriptions, ordering these sub-functions and developing concepts for each sub-functions. In this principle, students are exposed to learning outcomes that promote innovation and creativity that is more focused because the teams understand fully the problem and specifications at hand.

Realization of Solution

The first three principles have involved the students in many aspects such as team working, communication, innovative, creativity and translating requirements to specifications. These cover many of the learning outcomes in most engineering program. In this fourth principal, students are needed to use the fundamental core engineering subjects to convert selected concept(s) to actual products via proper and sound engineering analysis.

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The aim is for students to create a product or solution that is easy to do yet at the same time there are applications of engineering fundamentals. This is wrapped up with an oral presentation and final team report.

ASSESSMENT METHODOLOGY

For the development of the assessments frame work for open ended design problems, the fundamental assessment should comprise of two major areas, which are student development and solution development. Under the student development, the emphasis is on two performance areas: student capacity and team capacity. For the solution development the performance areas should be solution acquirement; on whether the specifications reflected in-depth understandings of the customer needs, economic matters, technology readiness, and societal isssues about the solution, and provide clear targets for development of a valuable solution. The other performance is the overall solution itself which looks at the final product or the outcome of the project. The challenge of the lecturer is to design appropriate assessments to measure these learning outcomes.

REASONING FOR PROPOSED FRAMEWORK

This framework was realized in one of the courses within the third-year engineering program. Its objective was to provide a learning atmosphere customized to a more diverse and open in nature than common course experiences as they allow students with different backgrounds and values to emerge as a team, promoting communication, team work, leadership skills, creativity and innovation. This course creates an atmosphere in which practical engineering is emphasized rather than just science, mathematics and engineering content. The focus is sidetracked from the use of prescribed fundamental theories and equations but to the usage of a broader spectrum of skills required for effective engineering problem solving. In a nutshell, the intention of this framework was fourfold. First, current engineering students have a very narrow vision or understanding on engineering; they should have broader perspective on engineering and its role in society. Second, our students need more realistic engineering experiences rather than idealized textbook based problems. Third, our students have to develop engineering problem solving skills. Finally fourth, students have to develop soft skills such as team working, communication, long life learning, leadership not forgetting creativity and innovation.

CONCLUSION

The use of the given principles is to create open ended engineering problems opportunities to address a variety of educational goals or learning outcomes. It is to be noted here that the level to which this framework can address each EAC outcome varies according to the content and implementation of the problem. Table 1 summarizes the level of this framework in addressing some of the outcomes under the EAC criterion 4.

Table 1: Mapping of course outcomes

EAC Programme Outcomes	Level	Achievements
i. Ability to acquire and apply knowledge of science and engineering fundamentals;	High	Design teams must use their knowledge of engineering science, and mathematics in designing the product or solution.
ii. Acquired in-depth technical competence in a specific engineering discipline.		
iii. Ability to undertake problem identification, formulation and solution;	High	Students need to interpret the customer's needs to better define and solve the problem. The engineering problem solving method can be highlighted through this problem.
iv. Ability to utilize systems approach to design and evaluate operational performance;		
v. Understanding of the principles of design for sustainable	Low	Design teams will be exposure through the guiding principles to the use of

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development;		technology in a more responsible manner, i.e. waste management, sustainable issues.
vi. Understanding of professional and ethical responsibilities and commitment to them;	Low	Students focused on the impact of creating a faulty or unreliable product or solution
vii. Ability to communicate effectively, not only with engineers but also with the community at large;	High	Students practice their written communication skills through the writing of the reports and their oral skills through oral presentations and surveying potential customers
viii. Ability to function effectively as an individual and in a group with the capacity to be a leader or manager ;	High	Student design teams create their planning and work through the principles as a team. In the process some take on the role of leaders in the groups to facilitate discussions.
ix. Understanding of the social, cultural, global and environmental responsibilities of a professional engineer;	Medium	Design teams will be exposure through the guiding principles to the use of technology in a more responsible manner, i.e. waste management, sustainable issues.
x. Recognizing the need to undertake life-long learning and possessing/acquiring the capacity to do so.		

Having said that, there are still some challenges for successfully implementing this proposed framework into an existing curriculum. A typical course of this nature takes about an hour of lecture time and three hours of lab time. Continuous assessment of students work is a challenge mainly due to the number of students registered in this course. The issue is that the more subjective a problem is, the harder the grading becomes. Even assessing the quality of students' solutions or products can be an uphill task. Evaluations criterion have been developed to overcome some of these issues. At the end of the day the goal is to make sure the students learning experiences has been enriched and the participation of other faculty members are much appreciated to further strengthen the framework.

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[2] Malaysian Engineering Programme Accreditation Manual 2007.

[3] Accreditation Board for Engineering and Technology, Criteria for Accrediting Programs in Engineering, Baltimore, MA: ABET, Inc., 2003.