Teaching Design to First-Year Engineering Students

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Abstract: Design is the core activity of engineers. Learning how to design implies learning how engineers work. There is a challenge for academicians on how to effectively teach design to engineering undergraduates. Another issue, which requires examination, is when, within a normally 4-year engineering course, should design be taught. The two issues are interrelated in the sense that how it is taught depends on when it is taught. This paper proposed a methodology on how to teach design to first-year engineering students. This proposal is based on observations and analysis after five semesters of teaching the subject at a newly established university in Malaysia.

The methodology has been developed based on the common axiom: "The best way to learn design is by doing design". The method has to consider the background of the students, the optimum use of academic workforce in handling a normally large class, the optimum use of the facilities available, and the limitation on the time allocated for the course by the students and many other factors. The types of projects selected and sizing of project groups are some of the issues, which will be discussed, along with suggestions on how design theories can be integrated into practical sessions. The author will also discuss how the class is conducted and how the team dynamics allow students to experience working in teams. The various different roles of the 'design guru' will also be examined. Several types of deliverables will be outlined. The assessment of the projects and the subject will be described and discussed. The effectiveness of the methodology is remained to be proven as this can only be determined based on the performance of the students who have taken the subject in conducting design in the later stages of the engineering course and after they graduated.

Keywords: Design, Teaching, Methodology

1. Introduction

Design is considered a speciality of engineers. Being so, it is suggested that the design element be included in every engineering subject and started early in the studies. Learning how to design implies how engineers work and this encompasses wide spectrum from the capability of synthesis problem solving, teamwork skills, leadership skills, written communication and oral communication.

The challenge is how to teach design to first year engineering students at the same time to inculcate self-learning capability, teamwork and leadership skills, creativity , innovation and communication . The fact it usually involves large group further complicates the facilitation, monitoring and assessing the progress. In our university, this is done via combination of lectures, group sessions, design project and individual effort in line with the university vision to produce well-rounded students through multi-mode delivery techniques.

2. Teaching Design

In the University Teknologi PETRONAS (UTP), the design is introduced in the first year through the subject “Engineering Profession and Communication”. This is to expose the engineering students right from the start to the real life engineering work through the project-based design project. This will motivate them to see some real application and have real feel of engineering practice . At the same time, students will find relevances of basic physical sciences which they take concurrently such as Physics , Chemistry, Maths and even English which they can now appreciate and connect to the engineering application. Furthermore, this early introduction will help the students in design projects later in their studies.

In addition to assimilate engineering work, there are other objectives that we want to cultivate from the subject such as self-learning capability, innovation , creativity, teamwork skills, leadership skills and communication skills.

First-year engineering students in UTP are fresh school-leavers who are used to receive education simply through spoon feeding /rote learning from the teachers to the students .This transition from rote learning - memorisation and replication- to understanding, analysing and creative problem solving will require quite a paradigm shift. Thus the inclusion of the element of self-learning is critical for the rest of their studies in UTP.

The design project given to the students will provide the avenues for students to develop their creativity and synthesis skills. Furthermore as engineers rarely work alone but rather as a member of a team, teamwork and leadership skills must be developed. The element of engineering communication is also emphasized.

Thus, in order to develop the said skills and values, the methodology has been formulated consists of formal face-to-face lecturing, group sessions, invited external speaker, independent tasks and design project.

3. Modes of course delivery

The course title is Engineering Profession & Communication. It is a 2-credit course that implies a 2-hour lecture weekly for 14 weeks or equivalent. The course has been offered for five consecutive semesters, with the number of students of 85, 305, 68, 231 and 353 respectively. The major contents of the course are as the following:

- Part 1: Engineering Profession (Definition of engineering and science, functions and disciplines in engineering, engineering professionalism and code of ethics.).
- Part 2: Engineering Design (Design process: Identifying customer need, defining problems, specifying design constraints and criteria, generating ideas, selecting concepts, specifying design details and communicating the design).
- Part 3: Engineering Communication (Brief guide on writing technical report, conducting meetings and technical presentation).

3.1 Lecture and group sessions

The Part 1 is mostly delivered through lectures while the Parts 2 and 3 are delivered through a combination of lecture and group sessions. In the lecture sessions, each step in the design process is described with examples. The lecture is done in the lecture theatre to accommodate all the students whereas the group sessions are conducted in a hall where chairs can be rearranged in a circle to allow the team to conduct a meeting. A lecturer can conveniently attend to about six (6) team meetings in the hall, where each team might comprise eight or nine students. The lecturer will go from one team to another to monitor progress and answer queries from the teams.

Some topics related to design or project management can also be presented during the group sessions as a one-point lecture. Examples of topics that can be presented are rules of brainstorming and creating a Gantt chart. The one-point lecture might take between 5 to 10 minutes and can be immediately practised in the following group session. One-point lecture registers more readily on the students' mind compared to if the same content is part of a 60-minute lecture.

3.2 Invited speaker from the industry

Through the UTP's "Adjunct Lecturer Programme", external speaker from industry is invited to supplement and enhance the course content especially in the practical domain of the curriculum such as in project management,

engineering design, operations and maintenance. The objective is to integrate industry experiences and practices to relate the relevance of the course content in the subject.

3.3 Design projects

The crux of the subject is to introduce the engineering design methodology to the students with the aim to develop the self-learning capability, innovation , creativity, teamwork skills, leadership skills and communication skills. Some of the implementation issues are discussed below.

4. Implementation Issues

4.1 Choice of projects

What kind of projects should be assigned to students with little or no engineering knowledge? The aim of the course is to teach the students on how to design and not to teach them engineering. The students, in the same semester, are taking Chemistry, Physics, Mathematics, Computing and English. We have come up with several factors to consider when specifying a project for this course. They are:

- Cost

As the number of students is large, there is a need to control the cost to implement the project. The expenditure to. purchase the raw material is borne by the students and normally limited to RM100 (= US$30).

- Complexity

There are some projects, which require the students to have basic engineering knowledge, and students would need time to learn all this. There is a danger that if the project demands engineering knowledge at a higher level, the students will be distracted from learning about the design process.

- Potential for creativity

A design project can help students more in learning design if there is potential for many different solutions.

We have experienced two different design projects of open-ended type and guided/prescribed type. Examples of open-ended design projects are: Is there a need to improve public garbage handling? Is there a need to recycle household wastewater? Example of a prescribed design project is such as designing motorboat with certain constraint and criteria set.

The salient difference lies in the fact that for an open-ended design project, students need to establish the client and define the problem, develop design constraint and criteria. They are encouraged to meet and interview the external client such as from city council. From our experience, students feel more involved in the open-ended design project that drives them to prepare survey and interview the client and the users. Nonetheless, the students need to be assisted in this. From this students are introduced to do self-learning and research on the related issue.

4.2 Team sizing

Most engineering design projects are performed by teams. To replicate this working environment, the students are assigned projects, which they have to work in team. The marks given for each team member are similar. The students learn that their outputs will depend on the team output and not the individual. This will influence the effort made by each individual and some of the efforts will be redirected towards getting the team to work

effectively together. The students start to appreciate the importance of teamwork and leadership skills as they progress through the project.

How big is the project team? The author has experienced with 5, 8 and 13 students per team. As the team grows bigger, as in 13-person team, there are tendencies of idle students contributing very little or not at all. They are popularly termed as 'passengers' or 'sleeping partners'. Although this effect is negative, it provide a lesson to students of what is actually happening in real working environment when the team is too large for the tasks given. This phenomenon is also observed in smaller groups, but at a smaller scale. Positive attitude of the team members and the high-handedness of the project team leader can reduce the chance of this from happening. It was also observed that a team of 13 members would split their team into 2 or 3 sub-groups to conduct meeting effectively.

5. Deliverables and assessment

What is the best way to evaluate a student's level of competency in performing design? The student's knowledge is gauged through a written examination (40%) and the project coursework output (60%). In the examination, half the marks are on design while the rests are on the engineering profession and ethics. Table 1 shows the deliverables of the project coursework output and their proportions.

Table 1. Design project deliverables and assessment

1	Progress Report Log Book Technical Report	60%
2	Design Exhibition /Prototype	25%
3	Technical Presentation	15%

All the deliverables require a team effort. All team members receive similar marks and this would be peculiar to most students because this might be the first time for them. Some students might want to take advantage due to the situation while aggressive students might become less aggressive. There are no easy and fair ways the instructor can penalise inactive students. Penalty points are applied to students who were absent from the group sessions in which attendance can be quickly checked.

There is a biased emphasis on the technical report. The students have learnt the techniques in another course also in the first year. The technical report reflects the effort of the team in performing the design. The team is encouraged to record everything and document them in the report. The flow of the report almost duplicates the design process. A typical report content is shown on Table 2.

Table 2. Technical Report Content

Problem Definition / Objectives
Problem Analysis/ Design Criteria & Constraints
Alternative Solutions Analysis & Selection
Detail Design

5. Roles of a design lecturer

The design lecturer can play many different roles in teaching the students how to design. The author assumes the roles of a client, a facilitator, a lecturer, a counsellor, an instructor, an expert, a disciplinarian and a reconciliator. Different situations require the lecturer to play a different role. However, the dominant role is the facilitator.

There is a danger when the lecturer becomes an 'expert' who offers an opinion, which may or may not be supported by facts. At this level of study, students were observed to accept uncritically and they will not be learning. It is more suitable at this stage for the lecturer to act as a facilitator. The facilitator facilitates the team to conduct the design project on their own. They might have to refer to an expert who might be one of the academic staff of the same university. The facilitator might give a hint to the team who might be the expert. The different responses of the facilitator as compared to that of an expert can be illustrated as depicted in Table 3 below.

Table 3. Comparison of responses between a facilitator and an expert

Question from project team	**Expert Advice**	**Facilitator response 1**	**Facilitator response 2**
We have designed the steel frame. Any comment?	The material is not suitable. You should use aluminium. It is lighter and will not rust.	Why do you have to us steel? Any reason?	Are you sure about the material? Why don't you Check with your Material Science lecturer. Get her advice.
The team shows a design with a very large base	The base is too big. You can make it smaller and it will still work.	Why do you make the base that big? Can you justify that?	Do you think if you make the base smaller will improve the design?

The facilitator helps the team justify its decision and also might deter the team from making a poor decision. Justifying design decisions is the heart of engineering design. The technical report will be more valuable by having lots of these.

In the early stage of design, the instructor will act as a client. The team needs to understand the problem and probably redefine the problem with the client. In this manner, the students learn the importance of interacting with the client in doing design. They also learned that the client might not describe the problem in full and the client might not know what to expect in the solution.

6. Conclusion

To teach design is to expose students to real engineering design practices. With the clear requirements to assimilate real engineering practices, the salient elements of creativity, innovation, teamwork skills, leadership skills and communication skills could be consciously incorporated. Self-learning capability, which requires paradigm shift among the first year university students, must be addressed and emphasised. These elements could be introduced through proper selection of design projects, lecture and group sessions. The opportunities to practise the communication skills are provided through the design exhibition and oral presentation. Co-ordination, monitoring and assessing may be a stumbling block due to large numbers of students which necessitates for optimisation of resources and facilities. General responses from students projects a sense of satisfaction to be able to assimilate engineering function right in their first year despite the need to allocate time and resources to grasp the content and implement the actions.

7. References

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