Project-Based Learning in Engineering Education: an approach used by Monash University Malaysia

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Abstract — *This paper describes the conduct and delivery of the teaching, and the assessment of Engineering Context using project-based approach. Engineering Context, a common and compulsory subject in the 1st year engineering curriculum, is introduced to all engineering students at Monash University Malaysia. This subject has been developed to overcome two key perceived problems of new engineering students: a lack of understanding of what engineers actually do, and of the environment in which they work and interact with the community. It uses project-based learning to allow an introduction to engineering. Key engineering issues such as product life cycle design, economics, sustainable development, ecology and professional ethics are taught. The project-based approach assists students understanding the client-tenderer relationship, and the interactions between different engineering disciplines in a project team environment. Management concepts and communication skills are developed through team activity. The approach also cultivates an active learning process among students through group work and library skills. The subject is conducted in a four credits hours of lecture and tutorial per week over one semester period. Students are continuously assessed through oral presentations, written progress reports and a final written examination. It also highlights various problems faced by students due to their former learning methodologies, culture and language diversities, individual goal and interest, and group conflicts. However, the resolution of these problems is a major part of engineering student development and is a necessary and valuable skills that will be useful throughout their professional working life. The paper further enhances the use of group work and project-based learning approach as an important teaching model for the education in engineering.*

Index Terms — *continuous assessment, engineering education, group work, project-based learning, Malaysia*

INTRODUCTION

Most modern engineering activities are conducted in team settings with a great amount of interaction among team members. It is paramount for engineers to acquire early in the pursuit of their career as competent engineers both technical knowledge and non-technical skills. Furthermore, the constant changing nature of society and the borderless world of work demand a similar changes in engineering works, and thus engineering education [1]-[2]. Hence, in addition to the teaching of basic and specialist knowledge, skills such as communication, problem solving, social and team working, together with the role of practice are highly important in engineering education [3]-[4].

MONASH UNIVERSITY MALAYSIA

Monash University Malaysia [5], the first overseas campus of Monash University Australia [6], offers a four years full-time study of engineering programmes. The first year of the Bachelor of Engineering degree is common to all engineering disciplines. This enables students to compare engineering disciplines before making their selection. The first year of the course introduces and develops engineering knowledge in a range of disciplines areas, but also focuses on the role of the engineer in today's and tomorrow's world. Although most of the engineering students are local, 10%-12% are from overseas, in particular Asia and Middle East. Around 10% of the yearly intake is female and the trend is upwards. Academic entrance qualifications including English proficiency tests are of the same level to that in Australian campuses.

ENGINEERING CONTEXT

One of the compulsory units in the first year engineering programme is Engineering Context. This unit has been developed to overcome two key perceived problems of new engineering students: a lack of understanding of what engineers actually do, and of the environment in which they work and interact with the community.

In addition to lectures, the unit uses project-based learning as an introduction to engineering. These include issues such as and ecology, economics, product life cycle design, sustainable development, quality management, and professional ethics. Communications skills and management concepts are developed through team activity, and written and oral presentation of project progress reports. Library skills are developed through lectures, 'hands-on' tutorials, and exercises. The ability to search for, and find information is essential to the project based learning approach, and will be invaluable throughout the engineering course.

The emphasis in the unit is on 'self learning' through group work. This may cause problems for some students. However, the resolution of these problems is a major part of students' development and is a necessary and valuable skill that will be useful throughout their working life.

This unit is conducted in a four credit hours of lecture and tutorial per week over a 13-week semester period. A 'real life' project, supported by an industrial partner, is integrated into the unit. The lecture component is assessed by examination and the project by continuous assessment. The project mark represents 70% of the unit mark reflecting its importance and the time committed to it.

PROJECT STRUCTURE

Students are grouped into project groups of 4-5 with mixed gender and nationality. A 'real-life' project outline which specifies the nature of the project together with the design requirements, is given to all groups. The nature of the past projects varied from the extension of a private medical centre, a modern petrol station for a busy town, the renovation of the national birdpark, to the electrified double rail track. Each of these projects was supported by the owner company or the tenderers of the project.

A guest lecture on the business operation, problems and requirements, conducted by the owner or tenderer, is given to the students. The students will then have to play different roles in four project phases, mimicking both the client's and tenderer's interests in a typical engineering project tendering process. In order to provide realistic elements and an industrial exposure to students, a project site visit is arranged.

PROJECT PHASES

The project is organized into four phases; Project Brief, Two Alternative Designs, Preferred Solution and Final Solution. Each phase of the project ends with the submission of a group report. As the students work through the project, they will take on various roles in each of the phases.

Project Brief

Students act as the client who is commissioning the project. This will require the group to produce a Project Brief report setting out the project specification and a letter of invitation to project tender. Lectures on system approach and group management are delivered in this phase. The former lecture sets to assist students in adopting a holistic manner in undertaking an engineering project and defining problems, while the latter in appreciating group dynamics, overcoming group conflicts and project management. The scenerio here is that the client produces a set of project document to be sent to a number of different consulting company or potential tenderer to submit their ideas and solutions. Group oral presentation in the scene of project briefing is conducted after report submission.

The emphases in this phase are on:

- Students' understanding of the specific problems and identify real needs of the project given
- Students' appreciation of the significance of the principles of system approach and that there is more than one solution to a given problem.
- Identification of project boundary, constraints, systems and components of project, and components interaction
- The importance of group work, project management and people management in engineering practices.

Two Alternative Designs

Students act as a tenderer or a consulting company. This will require the group to develop two alternative conceptual designs for the project based on the client's specifications in the Project Brief report. Lectures on oral and written communication, sketching, library and information searching skills are delivered. The alternative designs report consists of sketches and scaled drawings for the proposed areas of interests. A description of each design solution and how it meets the Project Brief

is presented. Students are encouraged to develop innovative solutions. The conceptual designs should reflect the group's ideas or based on specific theme with justification.

The emphases in this phase are on:

- Students' ability to meet project specifications, in problem solving, and to develop creative and innovative solutions
- Students' ability to translate ideas and solutions into drawings and sketches, and also to express them in a written report
- Students' ability in searching information from various sources via the use of library and the internet

Preferred Solution

Students again act as a tenderer or consulting company. The group is required to evaluate the two alternative designs and finally select a preferred solution to be submitted to the Client. The preferred solution could be either one of the alternative solutions or an amalgamation of designs from both alternative solutions with justifications. However, the key point here is on the development of an assessment scheme for the selection process, with indication of criteria used, and more importantly the reasons for using the chosen criteria. These may include economics, sustainability, life cycle aspects, aesthetics, health, social and environmental impact, etc. Many of these aspects and principles are conveyed to students through lectures and tutorials.

The emphases in this phase are on:

- Students' ability to evaluate designs based on key criteria which reflects the real world needs
- Students' approaches and their abilities in developing a transparent and objective evaluation process
- The importance of professional ethics whilst working for a client

Final Solution

Finally, students acts as a shortlisted tenderer. A final group report summarizng the development of a final solution for the project is produced. It encompasses discussion on key issues specified in the two alternative designs report and preferred solution report, and other issues such as safety analysis, quality assurance, cost estimation and project payback analysis. The group is then required to conduct a final group oral presentation and questioning, mimicking a final interview with the client.

The emphases in this phase are on:

- Students' ability in technical writing
- Group oral presentation skills and interviewing skills
- Students' appreciaiton on how knowledge may be implemented in practice

PROJECT ASSESSMENT

Project assessment is based on all the above described project reports, individual and group oral presentations and questioning. In the Final Solution phase, a panel of assessors comprising of senior academic staffs and industrial partner assess the group oral presentation. The assessment also evaluates project process or management and effectiveness of group work. This assessment is based on group discussion and minutes. Group members are also asked to do a peer assessment in each of the project phases.

A combination of these assessment criteria allows academic staff to gauge the true stage of progress and contribution of each member, since inconsistencies and uneven workload will be easily highlighted. In terms of weighting of the assessment criteria for group reports, the group element and group meeting minutes account for 50% of the marks and individual element for the remaining 50%. Group marks can only be given to members who have attended and contributed to meetings and workload, as documented in the minutes and in peer assessment.

DISCUSSION

Project-based learning is introduced to all first year engineering students in Monash University Malaysia. It aims to instil active student learning by providing a simulated scenarios of the working life and experience of an engineer through the use of a real life project. This is important as fresh engineering undergraduates generally lack understanding of the work of an engineer, the environment and the community he serves and faces.

With the support given by industrial partners participating in these projects, students learn specific industry business, the needs of clients, the community and its environment, and professional ethics. It helps the students to develop a holistic approach in solving problems, taking into consideration both technical and non-technical issues. Students will also gain an understanding of the client-tenderer relationship, and the interaction between different engineering disciplines within a project.

One of the strength of project-based learning is that it promotes teamwork. This is achieved through group work, group development and group assessment. Although students initial group assessments of their peer's strengths and weaknesses were generally poor, and the group coordination and cooperation were not strong, which was expected, these were soon overcome in later phases of the project. These were reflected in their group discussion during tutorial classes and the minutes of group meetings that mature as weeks passed. Both task-related and maintenance related roles in group behaviours were observed. Obviously, groups that have strong cohesiveness, good time management and work plan performed better than others. Again, these were revealed in the quality of their reports, minutes and group oral presentations. The performance elements were highlighted to the students to enhance their understanding of the relevance of teamwork and activity.

There are various problems faced by the first year students in the undertaking of project-based learning. First, it poses a big challenge to them in taking up a real life large scale project as these students are novice and naturally feel rather timid and confused at the beginning. Second, the ways their former educations were conducted were very much the 'didactic' type and examination oriented with few having any experience in this approach of learning. It is a new learning method for them and time is needed for them to get acquainted to it and be good at it. However, the learning curves of these first year students are steep, and with guidance, project-based learning has helped most of them to learn fast and well.

The other problems faced by some of the students are culture and language diversities, individual interest and group conflicts. The culture diversities among the students are small because most of them are local who have been living in a multicultural society and this exposure allows them to work well in a multicultural group. Some international students are the one who may need support in adapting to a multicultural environment but yet there is not much evidence to suggest that these students are facing major cultural problems. Nevertheless, the setting of the project group allows the students to appreciate the importance of communication and to solve any group conflicts that exist. Therefore, project-based learning will hopefully enhance their communication skills, which is imperative for their future undertaking as a professional. Language does not seem to have pose much problems to most students except a minority as English is a pre-requisite to academic entrance and is the teaching medium. Most students here would have learned English as a second language in their secondary education.

Some students were dominant in group work and have individual interests. However, as the individual's assessment is based on peer assessment and group meeting, it discourages them to be individualistic and place importance on teamwork.

Feedback from the students indicated that they have gained a better understanding and appreciation of engineering through the project-based learning, and confidence is developed in undertaking future engineering projects, both individual or group works. Remarks from industry partners about using this approach towards the development of engineering graduate have been very positive and encouraging. Therefore, whilst promoting active learning, project-based learning enables a student to acquire valuable skills such as communication skills, teamwork, methodical skills and problem solving that will enrich their development as a good engineer in future.

CONCLUSION

The approach taken by Monash University Malaysia in using project-based learning in the first year engineering education has been very successful and encouraging. Benefits include students gaining better vision and understanding of the scope of engineering and its interactions and linkages with other disciplines. It helps in the development of student attitudes leading to increase motivation to study engineering and work towards an engineering career. Through group work and real life project, students learn to appreciate the teamwork and the multidisciplinary nature of engineering, the role of the engineer in society, including environmental and engineering ethics.

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