An Outcome-Based Learning Project: Producing Sustainable Construction Materials from Soft Soil

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Abstract

Engineering subject teaching has almost always been considered as dry and complicated, with much emphasis placed on the definition of principles and derivation of formulae. It is indeed essential for engineering students to understand and learn the fundamental principles and theories of the subject, but that does not suggest any less importance in the application of the knowledge. This is especially important to prepare the undergraduates for the industry, where they are expected to apply their knowledge and skills in practice. Therefore an outcome-based learning project was introduced in the teaching of Geotechnics in the Faculty of Civil and Environmental Engineering, UTHM. The project involved designing and producing construction materials from clay retrieved from the university's grounds itself. The project was tailored to encourage creative thinking in solving technical problems, while allowing students to apply basic Geotechnics knowledge as well as practical laboratory skills they have learned throughout their degree programme. It was found that incorporating project-based learning in the subject not only achieved the intended goals, but also promoted team work and sharpened problem-solving skills among the students.

Keywords: problem-based learning; engineering subject; creative thinking; problem-solving skills

1. Introduction

In teaching engineering subjects, it is very easy to fall into the trap of delivering excellent lectures which, unfortunately, fall on deaf ears. Traditionally, engineering subjects mainly revolves around giving lectures and tutorials, with active discussions involving students which usually arise from question and answer sessions. Detailed explanation on engineering fundamental principles and founding theories, as well as the derivation of formulae and equations, are perhaps the central part of teaching an engineering subject.

Such approach are effective to a certain extent, provided the students come for lectures prepared with some background reading. However it does not provide room for the students to exercise their creativity or put into practice the knowledge gained from the lectures. Considering that engineering is the application of scientific knowledge and technology, it is of utmost importance that students are exposed to real-life situations in which to apply their lessons learned.

Geotechnics is a subject on the application of engineering mechanics to problems with soils as a foundation and a construction material, and it is used to understand and interpret the properties, behaviour and performance of soils. It is therefore obviously a subject that requires the students to grasp the theories and principles first, and then use them to deal with soil problems. The scope of study encompasses laboratory and field work techniques as well, most of which students are unable to perform and relate to the lectures, despite the fact that Geotechnics Laboratory Practice is a subject by itself. Students more often than not see the laboratory work as a separate entity from the body of lecture notes and examples.

The project-based learning concept introduced in the subject teaching was aimed to bridge the gap between theories and principles with application, with laboratory and field work acting as the channels. As described in the next section, the project was conceived to gather the lectures, laboratory tests and field work into one, where students were required to apply relevant knowledge and skills that they have gained from the subject.

2. Project background

The project was based on a case scenario, where students were taken as consultants to solve the particular problems presented. Description of the project and the group tasks were given in a handout. Outline of the project is given below:

The Research Centre for Soft Soils (RECESS) Malaysia (based in UTHM) would like to help the local council to develop a low-cost residential area using sustainable materials, specifically the soft soil available in Parit Raja.

As sustainable geotechnics is a new field in the country, RECESS has enlisted the help of five (5) consultants to achieve the main aim of this development project, which is to produce renewable, reusable and relatively cheap products for the construction.

The five consultants have different specialisations and expertise as listed below:

1. building blocks- structural and non structural 2. slabs and flooring
2. road pavement
3. pedestrian / sidewalk pavement
4. decorative and ornamental components

Being young and upcoming consultants eager to prove your engineering skills, you are expected to fulfill the following requirements:

1. design and produce prototypes of the construction materials;
2. use only sustainable raw materials - e.g. soft soil (from RECESS test site), oil palm waste, rubber chips, rice husks, etc.;
3. determine the relevant engineering properties of the composite materials- compressive and tensile strength, durability, resistance to weathering, abrasion, etc.;
4. deliver a final product that has enhanced qualities compared to the conventional construction materials- e.g. lightweight, inter locking system, economical, environmental friendly, low production cost, etc.

The handout also includes a reminder on the key issues to be addressed: to reduce costs in all ways possible, yet not compromising the safety and quality of the products. The products must be strictly 'sustainable' too.

The sustainability theme was highlighted in the project to create awareness among students on the threat engineering and technology could be causing nature, a rather heated issue at the moment, particularly concerning the construction industry. As the Sustainability Development Unit of the British Department of Environment, Food and Rural Affairs (DEFRA) rightly addressed the current state of "sustainable development", noting that far from catering for the future generation, we indeed struggle to meet the needs of present [DEFRA 2006]. Our excessive dependence on Mother Earth are clearly shown in the significant climate change, depletion of natural resources, damage of the environment as well as loss of biodiversity [DEFRA 2005].

Having been briefed on the project, students then had eight (8) weeks to organize and execute the project. Regular meetings were arranged to help the students along, such as suggestions on the materials and test methods, samples preparation procedure and curing processes.

3. Project execution

Five groups of 5 - 6 students each were formed for the project. A rotational system saw that the leadership of each group was held by a different student every two weeks. This was to optimize the effectiveness of team work, where the members were prepared to lead as well as to be led, for the good of the team.

Students first retrieved bulk soil samples from the RECESS test site, followed by identifying the engineering properties via appropriate laboratory test methods. This required students to revise on the test procedures based on established standards (e.g. British Standards). Next designs on the product mixtures were obtained via brainstorming sessions, where creativity and innovation of the students were put to test. Once the design mixes were determined, they had to outline an execution plan to prepare the trial samples. This involved critical thinking in identifying the relevant topical background knowledge (e.g. engineering properties of construction materials) and laboratory techniques (e.g. compaction). They were also required to manage their limited resources in terms of time, money and labour, exercising their project management skills.

When the recipe and flow of work were decided, full swing laboratory work was carried out. More creativity was observed at this practical stage. For instance, improvising existing compaction tools to fit into the smaller and irregular shape moulds. Details of the methodology and experimental work can be found in Chan (2007).

With the product finally ready, a compilation of the work done was reported in writing and an oral presentation slot. Here, students were trained to prepare concise and precise technical reports based on their findings. In addition, the oral presentation gave students the opportunity to express their scientific discovery and invention verbally, with the aid of suitable media like computer simulation, posters and flyers.

4. Project evaluation

Evaluation of the project was based on the report as well as the oral presentation. The oral presentation was judged by a panel which consisted of lecturers from various disciplines of Civil Engineering, namely Construction Management, Geotechnical Engineering, Highway Engineering, Environmental Engineering and Building Services. The multi-discipline panel was to ensure an all-round assessment towards the products, in terms of feasibility, practicality and relevance in the construction industry. The question and answer session after each presentation was a lively exchange of views and suggestions. Students were trained to be receptive of comments and criticisms for continuous improvement, and at the mean time prepared to

defend one's work in a rational manner, in these at times grueling sessions.

The panel was impressed with the students' achievements, made even more so by the demonstration of their products and highly creative brochures for 'selling'' the products (Fig. 1). One group even came up with a complete design and conceptual model for a roadway section based on the laboratory tests conducted with the various mixes (Fig. 2). This was an excellent example of the resourcefulness of the students, turning unexpected results of their research into useful products or designs, instead of simply discarding unexpected or 'unfavourable' experimental data.

(a)

(b)

Fig. 1. Examples of the products: (a) Pebble decorated paver (b) tile with coloured leaf imprints.

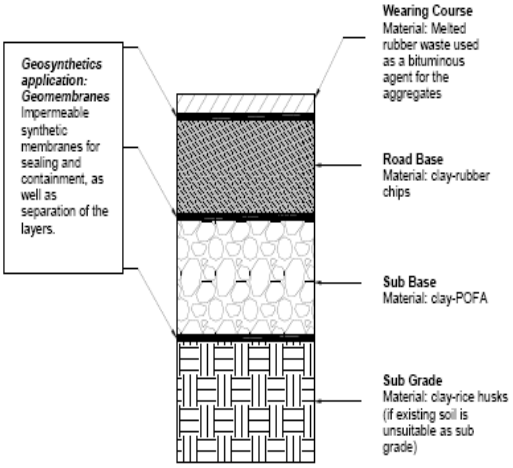

Fig. 2. Conceptual model of a roadway section using clay-based materials

5. Discussions

5.1. Programme Educational Objectives (PEOs)

The Programme Educational Outcomes (PEOs) of Bachelor in Civil Engineering, as offered by the Faculty, was undoubtedly supported with implementation of the project in the subject teaching. Given below are the four (4) PEOs:

1. Knowledgeable in various civil engineering disciplines in-line with the industrial requirements.
2. Technically competent in solving problems through critical and analytical approaches with sound facts and ideas.
3. Effective in communication with strong leadership quality.
4. Capable of addressing engineering issues and able to conduct their professional responsibilities ethically.

For PEO 1, with the project, students were trained to fulfill the construction industry's need for new, sustainable and environmental-friendly products, using their knowledge and skills learned from Geotechnics and other related subjects. The systematic and scientific approach adopted in the project clearly built on the students' competency as a practicing engineer (PEO 2). As for PEO 3, team work to make the project a success was a good exercise by itself to nurture leadership and communication skills, further enhanced by the written and oral presentation training at the end of the project. Besides, students were taught to be alert of current issues and problems in their field, and to address them in an ethical and professional manner (PEO 4).

In a nutshell, it is clearly shown that the project-based learning concept incorporated in the subject was effectively supporting the PEOs in producing

graduates of high credibility and quality to serve the industry.

5.2. Programme Learning Outcomes (PLOs)

Following are the five (5) out of ten (10) Programme Learning Outcomes (PLOs) of the Faculty that are expected to be achieved by students through the project:

1. Apply knowledge of science, mathematics and engineering.
2. Identify problems and formulate systematic solutions in Civil Engineering practices innovatively.
3. Apply scientific methods in research and development for engineering practices.
4. Recognize the roles and ethics of professional engineer in fulfilling social, cultural and environmental obligations.
5. Display leadership, entrepreneurship and team working skills effectively.

At the end of the project, a survey was conducted among the students as their self-reflection on how the project assisted them in achieving the PLOs. The survey revealed that majority of the students perceived that through the project they achieved all the PLOs significantly (Fig. 3). It was obvious from the study that the first three PLOs which are revolves around the fundamental technical skill as an engineering graduates can be acquired significantly through this kind of project.

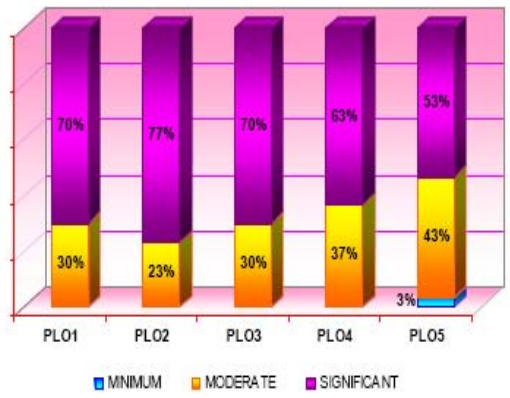

Fig. 3. Students' Self Evaluation on PLOs Achievement through the project.

4. Conclusions

Project-based learning was successfully incorporated in the teaching of Geotechnics, one of the core Civil Engineering subjects. The end-of project survey clearly indicated an effective knowledge transfer and training process, which may not have been achieved with traditional spoon feeding classroom method. Students were also found to be positively responsive to the project implementation as part of the coursework, which created more room for creativity, innovation and imagination. Finally, similar projects could be implemented in other engineering subjects, but the scope and time requirement must be carefully planned to avoid overloading the students.

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References

1. Chan, C-M. 2007. "Soil-based Construction Materials for Sustainable Development". Proceedings of the International Conference on Engineering and ICT (ICEI 2007). Pending publication in November 2007
2. Department of Environment, Food and Rural Affairs (DEFRA). 2005. "The UK Government Sustainable Development Strategy"; p 12.
3. Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia. 2007. "Programme Educational Objectives".
4. Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia. 2007. "Programme Learning Outcomes".
5. Sustainable Development Unit (SDU), Department of Environment, Food and Rural Affairs (DEFRA). 2006.
6. Website: htto://www.sustainable-development.gov.uk/index.asp Accessed: *05 November2006*