Effective Teaching of Geo-engineering Subjects via Project-based Approach

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ABSTRACT: The delivery of geo-engineering subjects, as with most other engineering subjects, are often considered as dry and rigid, and worse still, intimidating, by the students. The traditional teaching method of one-way lecture does not particularly stimulate students to think and analyze the subjects in a creative manner, but usually results in students learning the facts and equations by heart for examinations. This could lead to students who fail to relate theories and principles to actual, real-life situations, who eventually find themselves inadequate to face the challenges of a geotechnical engineer upon graduation. In order to cultivate genuine interest and curiosity about the subjects, relevant projects were assigned to groups of students taking the subjects of Geotechnics and Advanced Geotechnics at Universiti Tun Hussein Onn Malaysia. The projects involved developing sustainable 'green' construction materials from soils, formulating suitable mix designs for earth bricks, as well as experimenting with various compacted soil mixtures for the optimum mixes. These projects did not only encourage students to relate lectures with laboratory work and practical problems, but also instilled team-working spirit in them. In addition, the projects promoted a sense of responsibility and accountability towards the environments as modern engineers, who do not just construct and develop, but protect the environment for the future generation too. In a nutshell, end-of-project surveys conducted among the students revealed that the incorporation of project-based learning in geo-engineering subjects can effectively deliver the knowledge and technology, while at the same time help mould the students to become responsible engineers when they leave the university.

1 INTRODUCTION

The teaching of geo-engineering subjects could be a daunting task, considering that the technicality and facts must be conveyed, yet at the same time the students' interest and learning capacity have to be kept optimal. As aptly described by Ramsden (1992), engineering lecturers often lament on the following issues: firstly, students simply fail to learn much of the materials presented to them; secondly, they pass examinations even with misintepretations of fundamental concepts. While students are not always to be blamed for ineffective teaching and learning of engineering subjects, truth is, the motivation to scrape through examinations, obtain a degree, and hence a job, may have overwhelmed the interest and drive to engage in genuine learning (Mickleborough and Wareham 1993).

It is therefore important for lecturers to adapt and change in the way they deliver engineering subjects, so as to produce students who are not only well versed with the subject, but also capable of effective problem-solving, communication skills as well as team-working. Of course, employing innovatory teaching methods can be perceived as 'additions' which are translated into extra time and effort requirements, not to mention the uncertain outcomes that can be seen as a threat to a the lecturer's authority (Staniskis and Stasiskiene 2007). Nevertheless this cannot be taken as an excuse to persist with traditional prescriptive teaching methods and opposed to changes for more creative and innovative delivery of engineering subjects.

This is even more crucial for the teaching of engineering subjects as the rapid evolution in technology demands more flexibility, less specialisation, as well as higher capability for innovation in graduates (Sparkes 1993). To produce engineering graduates with an edge and competitiveness in today's job market, it is high time to get back to the drawing board for some serious contemplation of improvement in the way we deliver the knowledge and mould our young would-be engineers.

This paper describes an attempt to make the teaching of geo-engineering subjects more effective through the incorporation of project-based learning in the Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia. Project-based learning is known to enable students to develop strategies, skills and confidence to create and maintain their own knowledge bases instead of being on the receiving end playing the role of a mere passive learner (McKay and Raffo 2007). The lecturer, on the other hand, experiences a change of role to that of a coach while the students become active problem-solvers (Tan 2004). Unlike problem-based learning, which usually involves an interdisciplinary problem (Ditcher 2001), project-based learning is more focused on a particular subject matter, as in this case, geo-engineering related topics.

In addition to learning the topics dutifully in the conventional manner (i.e. with tutorials, quizes, tests and final examination), students were engaged in group projects which involved developing sustainable 'green' construction materials from soils, formulating suitable mix designs for earth bricks, and experimenting with various compacted soil mixtures to improve soft ground conditions. Three batches of students underwent this newly formulated project-based learning approach for three different semesters, for the subjects of Geotechnics (third year subject) and Advanced Geotechnics (fourth / final year subject).

2 PROJECT BACKGROUND

2.1 *Context of projects*

The projects were soil-based so as to keep the relevance to the geo-engineering subjects. However the context of each project was closely tied with the environment, society and economy, which are defined as the three pillars of sustainable development (Strong and Hemphill 2003). Essentially students were encouraged to develop a keen sense of responsibility and accountability towards the well-being of all parties and the environment in the area of geo-engineering.

Widening the narrow interpretation of geo-engineering subjects, students are stimulated to look at problematic soft soils, for instance, in a different light, by converting them into useful, cheap and practical solutions in the construction inductry. It is no longer just a matter of learning about the fundamental characteristics and engineering behaviour of soils per se, but exploring the potential and possibilities of integrating soils as part of sustainable development. This is even more significant considering that the University and its surrounding area sit on such soft and weak soil (i.e. soft marine clay) which requires special attention in construction (Figure 1).

The project briefs for all three projects are given below:

Project 1

Sustainable geotechnics: soil-based construction materials.

Project Description

RECESS Malaysia 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 5 consultants to achieve the main aim of this development project, which is to produce *renewable*, *reusable* and *relatively cheap* products for the construction.

Project Task

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

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

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

- design and produce prototypes of the construction materials
- use only sustainable raw materials- e.g. soft soil (from RECESS test site), oil palm waste, rubber chips, rice husks, etc.
- determine the relevant engineering properties of the composite materials- compressive and tensile strength, durability, resistance to weathering, abrasion, etc.
- 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.

REMEMBER, it is a low-cost residential project! The key thing here is to CUT COST in all ways possible, yet NOT compromising the safety and quality of the structures. Also, your client, RECESS, strictly requested for 'sustainability' in the new products.

Project 2

Alternative clay bricks admixed with natural waste materials.

Project Description

The new clay brick could be used as an alternative to conventional bricks, but having the advantages of being relatively cheap (clay and natural wastes are free, the costs incurred will only involve those of labour and manufacturing) and environmentally-friendly. In today's world where natural resources are being exhaustively utilised, developing alterna-

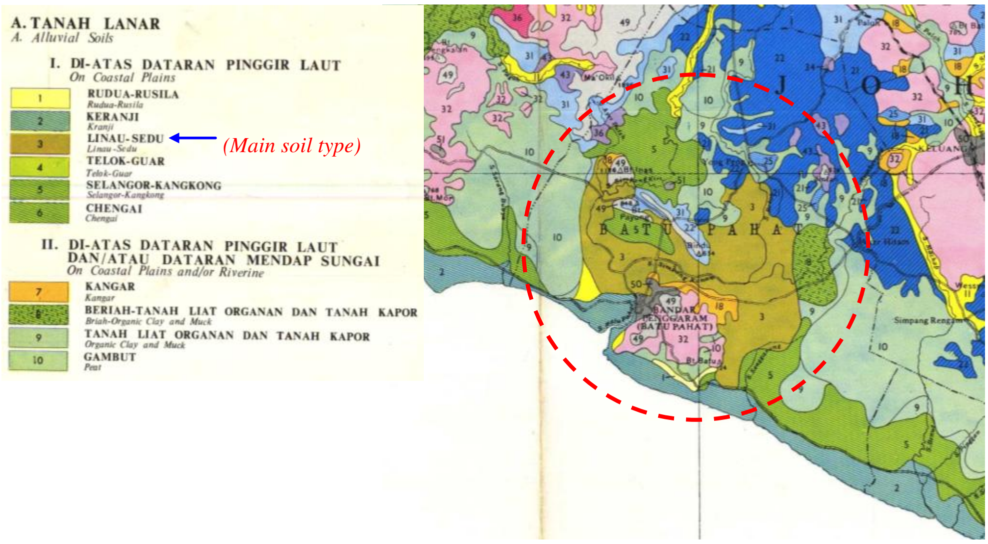


Figure 1. Soil map of Batu Pahat, Johor (adapted from the Reconnaissance Soil Map of Peninsular Malaysia, 1968).

tive construction materials (e.g. bricks) using waste products is apparently a positive move towards conservation and promoting sustainability. Socially, the low budget bricks can be of substantial help in providing homes for the poor and needy. Besides, the new composite materials can open up new opportunities for creativity and innovation in the construction industry, especially in the design of structural components.

Project Task

- A laboratory-based testing of the clay composite specimens using geotechnical and material engineering test equipment will be carried out.
- Focus will be placed on establishing the mechanical properties, as well as to determine the suitable admixed material(s) and optimum mixing proportions.
- Comparisons with conventional bricks will be required to ascertain the added values of the newly developed products.

Project 3
ComSoil: compacted soil mixtures.

Project Description
The clay found in abundance in the Parit Raja area is generally categorized as 'problematic' and 'useless'. However there is a possibility that the mixture of this clay with other soils, properly compacted, can produce sufficiently strong platforms for further construction works. This project aims at identifying the optimum mixes which bring forth the best compaction and strength characteristics.

Project Task

- To produce mixtures of clay and/or laterite soil and/or sand at different proportions (C:L:S)- clay must be of the highest proportion in the mix, and to identify physical properties of the individual mix.
- To determine the compaction characteristics (i.e. w_{OPT} and ρ_{dMAX}) of the soil composites.
- To determine the undrained shear strength of the soil composites.

2.2 *Assessment of projects*

Assessment must be designed with utmost care so as not to counteract the aims of the course or subject (Ditcher 2001). In addition, based on his studies in problem-based learning, Drinan (1997) rightly stressed that assessment should require students to demonstrate understanding and integration of knowledge, otherwise they may 'guess their way from problem to solution without seriously engaging either sources of information or mental faculties'.

Based on the above mentioned criteria, the project assessment was focused on two main components: the written and oral presentations. Although the projects did result in the production of prototypes and samples for display, the ultimate aim of the projects were really to ensure that students took responsibility for the group's learning and progress, which were demonstrated via the presentations.

The written reports adhered to the standard format of technical writing, with emphasis on comprehensiveness and technical accuracy, as well as proper referencing. As for the oral presentations, each group was allocated 15 minutes to 'sell' their products and findings to a panel of lecturers from various civil engineering fields, such as geotechnics, environmental engineering, building and construction management. Members of the panel were intentionally diversified to provide the students with exposure to expertise from different areas, as would be encountered in the actual construction industry.

3 PROJECT EXECUTION

3.1 *Sampling of clay*

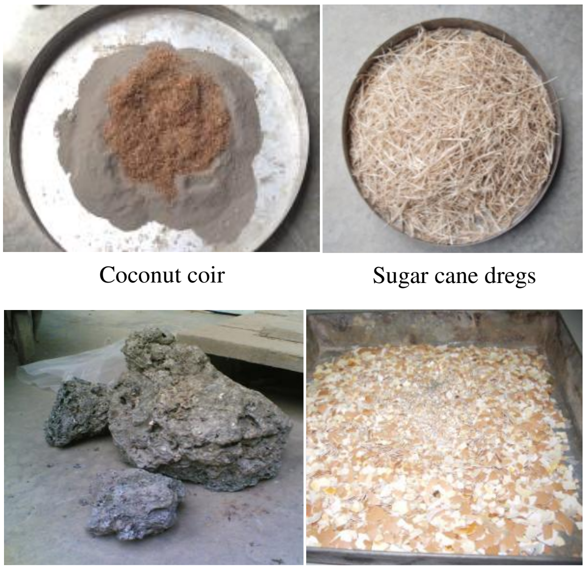
The clay used is the projects was retrieved from the RECESS test site in the University, which is located on a flat terrain of deep soft marine clay deposit (Figure 1). A compact track auger was used to collect the soil sample from approximately 1.5 – 2.0 m, then transported to the laboratory for storage.

Figure 1. Retrieval of clay sample.

3.2 *Preparation of specimens*

The clay and other raw materials, such as coconut coir, sugarcane dregs, palm oil clinker and others were first oven-dried at 105°C to remove any moisture contained in them (Figure 2). The waste materials were either used as they were or pre-processed by shredding or grinding into suitable forms for mixing with the clay.

Students next experimented with different proportion of mixes and quantities of water added to identify optimum contents of each material. The specimens were either air-dried, oven-dried or furnace-baked, depending on individual product design and requirement.



Coconut coir | Sugar cane dregs

Palm oil clinker (POC) | Crushed egg shell

Figure 2. Waste materials for mixing.

4 PROJECT DELIVERY

Creativity and innovation were clearly demonstrated in the products created, as shown in Figure 3. The prototypes included bricks, paver blocks, floor tiles, interlocking pavers and other construction materials. Although most of the products required further work to be ultimately applicable commercially, the students should be applauded for the effort put in the projects for a tight 14 weeks, on top of studying for the subjects.

Clay-laterite paver blocks with decorative pebbles

Clay-POC bricks | Clay-laterite floor tile with leaf imprint

Figure 3. 'Green' construction materials.

5 PROJECT OUTCOMES

The Programme Educational Objectives (PEOs) of Bachelor in Civil Engineering, as offered by the Faculty, were referred to as the long term yardstick for the projects. 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.

The project-based learning approach adopted in the subjects must be ensured to meet the PEOs in producing graduates of high credibility and quality to meet the industrial demands. Graduates should be evaluated between 4-5 years upon graduation, where their performance and achievements while in service within the period would reflect the PEOs.

Besides, more immediate results of the project-based approach were evaluated based on achievemnt of the Programme Learning Outcomes (PLOs). Note that only five out of the original ten most relevantPLOs were selected to better represent the specific outcomes expected of the projects. The five selected PLOs are given below:

1. Apply lessons learnt during lectures in practical applications.
2. Identify problems and formulate systematic solutions in the project.
3. Apply scientific methods for a project of R&D (research and development) nature.
4. Recognize the roles and ethics of a professional engineering in fulfilling social, cultural and enviromental obligations.
5. Display leadership, entrepreneurship and team working skills effectively.

Figure 4 depicts pie charts summarising the responses of students in the end-of-project surveys. Generally speaking the five PLOs were all satisfactorily achieved with moderate or significant impact.

All the students agreed that the projects allowed them to apply theories to applications in a moderate or significant way (PLO 1). This was in-line with the purpose of the projects, that was to bridge the gap between lectures and pratical work for the subject.

As for PLO2, half the students responded that they learned to horn their problem-solving skills, either significantly or moderately. Curiously, 2 % thought that the projects did not help them at all in that area, seeing that the projects were formulated with a problem or issue as the starting point.

The positive response on PLO3 suggest that the students considered the projects to be small-scale research exercises which trained them in R&D work. This was encouraging as research is part and parcel of an engineering subject and cultivating interest in that direction, especially in geo-engineering areas, should be welcomed.

As all projects highlighted the environmental, sustainability, social and economic issues, it was of little surprise that PLO4 received an almost 100 % positive response. The response also indicated that

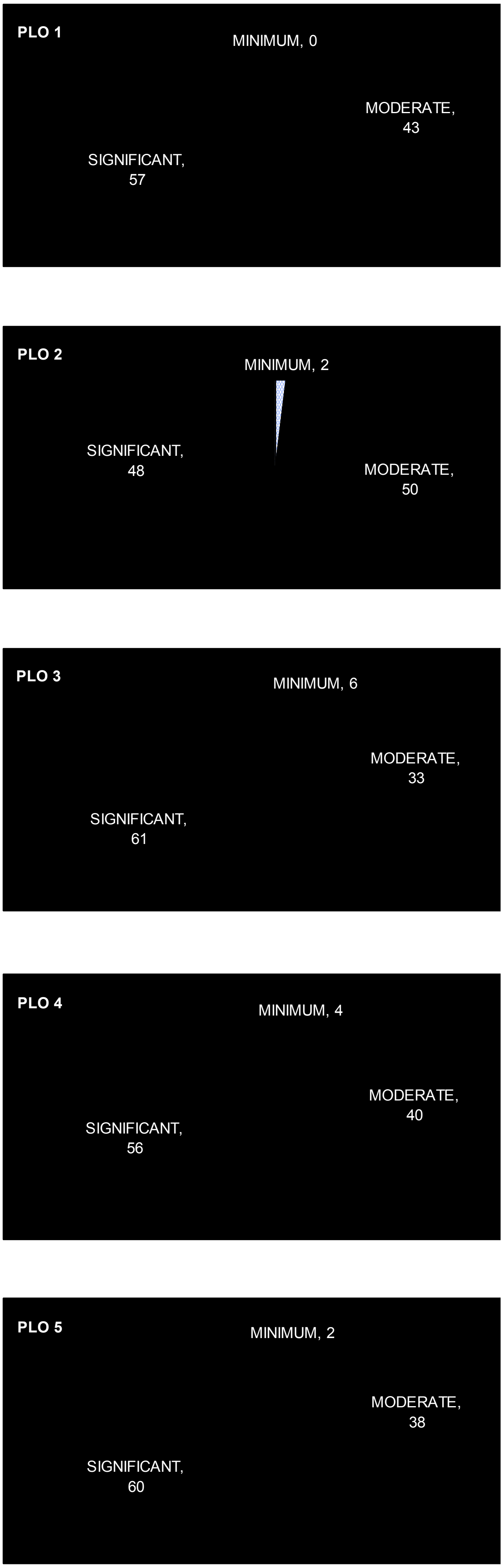


Figure 4. Students' perspectives on the PLOs achievement.

students were aware and conscious of their responsibilities to conduct their routine job as an engineer with professionalism and ethics.

Finally, students agreed that the projects have trained them in leadership, entrepreneurship as well as team working (PLO5). Considering that the projects required them to go through a process of self-learning, planning and execution, the ability to function as a leader and a team player must be essential to accomplish the projects. Entrepreneurship, on the other hand, was a silent component in the projects, where recycling and reutilising soils and wastes indirectly steered them towards enterprising.

From the response described above, it is apparent that the project-based approach helped the students in more ways than one to learn more effectively in the subjects, apart from stimulating their interest in the geo-engineering area.

6 CONCLUDING REMARKS

Incorporation of well-designed projects in a geo-engineering subject can be immensely helpful for students to understand the subject. It is also found to be instrumental in polishing the soft skills which are attributes expected of a young professional engineer. Also, the project-based learning approach encourages understanding rather than memorising and 'regurgitating' the facts. These are all crucial to enhance the effectiveness of geo-engineering education in specific, and engineering education in general.

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