Application of Research-Inspired Assessment to Enhance Students Learning in Civil Engineering

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INTRODUCTION

A wide range of teaching strategies aiming to motivate and develop deep learning approaches in engineering students and to turn students into active, reflective and long-life learners have been previously explored by researchers and educators [1,2]. Moreover, it is well-established in the literature that different types of students are more motivated by one teaching/learning strategy than another and the ability of lecturer for combining various activities that engage different types of students at different moments of the class is the key to successful implementation of any strategy [2]. However, effectiveness of research-inspired teaching/learning strategies for engaging a wide range of students with different motivation, attitudes and learning styles has not been adequately investigated [3]. Furthermore, application of research-inspired teaching strategies for developing graduate attributes such as teamwork, problem-solving skills and long-life learning attitude remains largely unexplored.

The relationship between teaching and research has become a highly challenging issue due to evidence of synergy between them and complexity of integrating them. As reported by Locke [4], the separation of research and teaching could be the result of policy and operational decisions to distinguish the way these activities are funded, managed, assessed and rewarded. However, this would not necessarily excuse higher education institutions from a commitment to optimise the beneficial relations between teaching and research. For example, research conducted by Posch and Steiner [5] at the Swiss Federal Institute of Technology (ETH) in Zurich on innovation for

sustainability, concludes that appropriate integration of research and teaching activities leads to mutual benefits for both higher education institutions and students.

Civil Engineering course in majority of universities in Australia attracts the highest number of engineering students each year, and there is a high demand in the industry to employ competent civil engineers. Due to high demand of construction in challenging areas such as congested urban areas and coastal areas with poor ground quality and fast growing technologies in the construction materials and methods, engineers need to update their knowledge on regular basis through continuous learning. Therefore, it is essential to train students at university level to be lifelong learners after graduation, to stay competitive and to deliver innovative and practical projects. A very limited number of Civil Engineering subjects in most of Australian Universities try to encourage students to conduct research and teachers bring their own research into teaching to inspire students in undergraduate level. Many Civil Engineering subjects and projects require students to follow the existing national and international standard step by step for design and construction purposes. Thus, these subjects do not give students the opportunity to build their research skills by being active in research and not being only the recipients of research-based standards. Students should be encouraged to be actively involved in inquiry from first year. Afterwards ample opportunities should be provided for students to improve their research and critical thinking skills through research–inspired assessments, which have proven to be an effective method of learning. In this study, effects of alternative research-based assessment tasks on students' learning experience and academic attainment in two major subjects of Civil Engineering (i.e. Geotechnical and Structural Engineering disciplines) are evaluated by replacing parts of traditional assignments with research-based assessments. It should be noted that the plagiarism rate, in assignments which are based on step by step calculation and following design standards, is very high and it is hypothesised that the research-based assessment strategies can lower the rate of plagiarism and enhance the learning experience for a wider spectrum of students by promoting individualised assessment set up with respect to students' ability and interests.

According to Jenkins and Healey [6], the key to developing undergraduate research and inquiry is to integrate it into the curriculum for all students. Moreover, Jenkins and Healey considered four main approaches of engaging undergraduates with research and inquiry, including:

- research-led: learning about current research in the discipline,
- research-oriented: developing research skills and techniques,
- research-based: undertaking research and inquiry and
- research-tutored: engaging in research discussions.

However, the above mentioned approaches are not independent. For instance, undertaking research and inquiry and engaging in research discussions are effective ways to learn about current research in the discipline and develop research and inquiry skills and techniques. Jenkins and Healey [6] believe that all these approaches of engaging students with research and inquiry are valid and valuable, and university curricula should contain elements of all of them. In general, regarding the influence of research-inspired learning strategies on students' satisfaction and learning experience, the results of survey reported in the literature shows that most of the students (60-70%) are often inspired by lecturers whom they perceive to be experts in their field, and who convey their enthusiasm for the subject by discussing the state-of-art and practice in

their lectures [7]. This clearly demonstrates the efficiency of research-inspired strategies for engaging students with different attitude and learning styles.

Following this introduction, the research methodology adopted in this study is explained. In particular, incentives as well as types of research projects in two different subjects are described. Students' feedback and statistical analysis results evaluating effects of Research-Inspired Assessment task on students learning experience and performance are also discussed.

1 RESEARCH METHODOLOGY

The aim of the designed activity has been enhancing research capabilities of civil engineering undergraduate students, including: (i) ability to conduct independent and innovative research, (ii) ability to report the outcomes professionally, (iii) increased confidence in ability to seek out opportunity and apply knowledge in new and emerging fields in civil engineering, (iv) awareness of intellectual honesty and ethical issues in research and (v) competence to work collaboratively with individuals and groups across diverse levels, backgrounds and experiences.

According to Bloom's taxonomy, the development of thinking commences with remembering as the lowest order of thinking followed by understanding, applying, analysing, evaluating and creating as the highest level. Research integration learning is an effective approach for graduates to achieve a higher level of thinking. The proposed activity has been designed to address the following two fundamental questions regarding benefits of students' engagement in the proposed research-inspired assessment:

- What students identify as the benefits of this activity in their study experience and in the longer term, particularly for their future career;
- Which graduate attributes will be developed.

Soil Behaviour and Steel and Timber Design subjects were selected by the research team. Students take these subjects in mid to late stages of their study after internship so they will have the basic professional knowledge to conduct the research. Then, based on the number of students in the class and the contents of the subjects, several different micro-research projects were prepared including the title, the scope of research and the possible expected outcomes. The defined research projects were directly related to one or some of the lectures allowing the investigators to monitor the students' improvement in that specific part as well as the whole subject. The research project ran in two different modes. In autumn 2011 the research project was considered as an optional part of the subjects, which allowed some students earn some bonus marks, whereas in spring 2011 the research project was incorporated into the subject outline as one of the compulsory assessment tasks attracting 5% and the best top three projects could be given up to 5% bonus marks depending on the quality of their work. In the first mode, where the micro-research projects were considered as an optional part of the assessment, similar incentives as the second mode (compulsory assessment tasks) were used for encouraging the students to participate. Furthermore, incentives such as book vouchers and movie tickets were used for encouraging the students to deliver higher quality projects. Adopting both optional and compulsory tasks made it possible to build a comparison and determine whether learning through such research projects would be more efficient if these micro-research projects were treated as optional or compulsory part of the subjects. This research-inspired learning project targeted Civil

Engineering students at mid- late stages of their undergraduate studies. It is believed that Civil engineering students in their third year and above have acquired the fundamental knowledge (e.g. mechanics of solids and fluids) and skills which are the basic requirements for doing further research in different Civil engineering disciplines. Each micro-project was assessed based on two reports delivered before mid-semester exam and final exam. The reports were assessed based on criteria such as their thoroughness and novelty.

Examples of micro-research project topics adopted in Soil Behaviour and Steel and Timber Design subject are given below:

- Discuss on geotechnical causes contributing to the collapse of the roof of Lane Cove ventilation tunnel in 2005
- Design and execution of ground improvement works for Port Botany Expansion and Ballina Bypass projects
- Reliability of timber frames designed according to Australian Standards AS1720.1-2010
- Limitations of Australian Standard AS4100-2009 for lateral-torsional buckling design of slender beams

2 RESULTS AND DISCUSSION

In Soil Behaviour and Steel and Timber Design subjects, slightly different approaches were adopted for preparing and delivering the micro-research project. In Soil Behaviour subject, different research projects were allocated to students after meeting with them face-to-face. Students could directly connect the defined research projects to one or some of the lectures hence, they could gain deep understanding of the topics involved in the subject through research based learning. The Investigators gave detailed constructive feedback on the project progress early on; therefore students could address the comments in their final submissions. In Soil Behaviour subject, students got involved in original research conducted as an individual project providing students a wonderful active-learning experience that they typically embraced with increased motivation and interest. By introducing mini-research projects related to the subject, students learned first-hand the challenges of reviewing the relevant research literature, when formulating research hypotheses. A list of topics was distributed in the tutorial classes and uploaded on UTS-Online and the main purpose of the research project was engaging students with research and encouraging them to be research oriented and life-long learners. In the tutorial classes, the lecturers/tutors explained the efficient approaches to conduct critical review of articles and how a review report should be structured and written. The main aim of the research project was to develop design skills for solving geotechnical problems. It is believed that students gain extensive experience presenting research, while getting immediate and specific feedback about their research work. A few highlights from anonymous online Students' Feedback Surveys regarding these points are as follows:

- *"This semester we had the opportunity to do research projects and I did a power-point presentation on Indian earthquakes. I believe geotechnical engineering/soil behaviour is an important aspect as in some developing countries such as India and other parts of South East Asia the infrastructure/guidelines are not as enforced as compared to the western countries such as Australia, UK, USA, Japan where the infrastructure has to meet the specific standards. As after the initial research I found*

most of the infrastructure in these countries does not meet Earthquake resilience standards, thus the infrastructure is prone to harm during earthquakes and as a result a lot of lives are lost and infrastructure is damaged. Thus I believe Civil Engineers (Geotechnical) have a role to play in ensuring these standards are enforced through research and development and that buildings are earthquake prone so less causalities result. (Survey 58814, 2011.1 - 48330-AUT-U-S-LEC1-01)

- *"The research project that was implemented by the lecturer was very enjoyable and I learnt a lot about the importance soil mechanics and the liquefaction process. Also this assessment task provided variety because most of the other assessment tasks are all calculations based or lab reports where as this one we did our own research and I think it was a very good task overall." (Survey 65501, 2011.2 - 48330-SPR-U-S-LEC1-01).*

Regarding Steel and Timber Design in autumn 2011 (when the mini-research project was an optional part of the assessment with some bonus marks considered) only four students opted to do the project. In spring 2011, however, all students enrolled in the subject handed in the projects at the end of semester which clearly showed that solely adding the research projects into the subject outline as a task with bonus marks would not encourage the students to eagerly participate in this research-based self learning process.

In Steel and Timber Design, ten general topics were chosen within the scope of the subject and the students were given the option to pick up one of these topics and narrow it down based on their interests. The rationale behind such an approach to introduce the micro-research projects into Steel and Timber Design subject was to encourage the students to do the research projects based on their interests as well as practical needs. Because most of the Civil Engineering students at year three and above typically work in industry and involve in real-life engineering problems and accordingly it was believed that there exist a tendency among such students to focus on the research projects and literature review which they can benefit from during their career. During the semester, the students were given a chance to discuss their projects and their progress with the subject coordinator and get some feedback. At the end of semester, each student handed in an individual report that reflects the performance of the student based on three major criteria, including thoroughness of literature review, presentation, format and the report set out as well as the novelty of material in relation to what is typically delivered in the subject. Furthermore, the students were asked to elaborate on their findings at the end of the report and explain whether the research-based learning process has been helpful and how it might have helped them to develop new skills. All students unanimously believed that they had learned new things about analysis, design and construction of steel and timber structures that could not have been delivered within the limited lecture times during the semester.

By introducing these mini-research projects in the target subjects, students had the opportunity to develop practical approaches to broaden and deepen their research and inquiry involvement. Overall the investigators have been successful to encourage the students to adopt research-inspired learning. In addition, students had the chance to familiarise themselves with the current research challenges in both Geotechnical and Structural Engineering disciplines. Therefore, as expected, the project goals have handsomely been achieved.

The results of this study indicate that by incorporating research components in Steel and Timber Design and Soil Behaviour subjects, research-based learning culture among Civil Engineering students have been developed. This clearly gave more satisfaction to the students about their learning experiences. Furthermore, students participated in the tutorial classes more actively and they showed more interest to practical and real life engineering cases, discussed in the lectures. Results showed that optional research projects were mainly welcomed by the high calibre students, however, the compulsory micro-research projects promoted involvement of all students. The statistical results indicate that there is a reasonable correlation between the overall performance of the student in the subject and quality of the conducted research. Students, who took the research project more seriously and spent quality time on that, performed better in other assessment tasks too. Furthermore, the results of this study show that the research-based learning process would be more appealing to undergraduate students, particularly senior students at year three and above, if the research topics are prepared with regard to real life engineering problems. In addition, the results of this research indicate that by introducing the micro-research projects in the above mentioned subjects plagiarism rate in assignments were significantly reduced as the research-based assessment tasks encouraged students to complete the task by themselves.

A few more highlights from Students' Feedback Surveys regarding these points are as follows:

- *"I liked the research assignment. It got me to use books for information rather than just searching everything on the internet. Even though I am not sure whether I did it correctly, the project will hold me in good stead going into the future as I will be required to undertake further readings" (Survey 65501, 2011.2 - 48330-SPR-U-S-LEC1-01).*
- *"In Soil Behaviour subject, I got some knowledge about soil and its characteristics. As an engineer some parts covered in lecture e.g. the use of proper words in my opinion is really important. Besides, some research also help students to find more about what's happening surrounding us. Sometimes we see things like we know how it works. However sometimes our prediction/assumption about the things is probably wrong, thus research give more detail information and proof about what things do. For example my research in extra mark project, before I started to do it, I assume I know some parts of the content I am going to write. However, I got some idea, clearer explain, and engineering terms that I had never heard about. This makes my view on things not only for writing what I know but also other information that related to the topic. In fact this project is a mutualism process as marker and students got some information. I took this project as an important picture to do better presentation for future." (Survey 58814, 2011.1 - 48330-AUT-U-S-LEC1-01)*

The project success was evaluated in two different ways. In the first step, all students enrolled in the target subjects and more specifically the students who were involved in this project were asked to participate in the online survey and give feedback on the implemented research-inspired learning model. In addition, some students were informally interviewed, while conducting the project and after completion. The combined results of surveys and interviews show that a research-based learning culture has been developed among Civil Engineering students in the above mentioned subjects rather

than being merely a user of standards. Interestingly, some students with higher quality were motivated to consider research postgraduate studies as an option for the future.

In the next step, a statistical analysis was undertaken based on the performance of the students the subjects as summarsied in Figures 1 and 2. The figures show that students with better performance in mini-projects have performed better in the final exam, which is totally an independent assessment task. Clearly, the averaged final exam mark of students with good quality projects was higher than one of that for other students.

Another challenge was defining individual projects for students in large classes. In Soil Behaviour subject all the tutors of the subject were involved in preparing the topics. In addition, we asked our PhD students to help with this. Each semester, we prepared 150 topics so each student could have a different topic.. Considering the growing number of Civil Engineering students, in the future, it will be necessary to define group projects rather than assigning an individual project to each student.

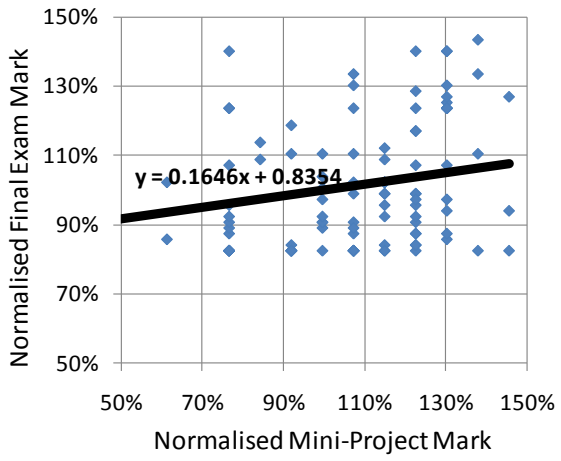

Figure 1. Statistical Analysis Results (Soil Behaviour Subject)

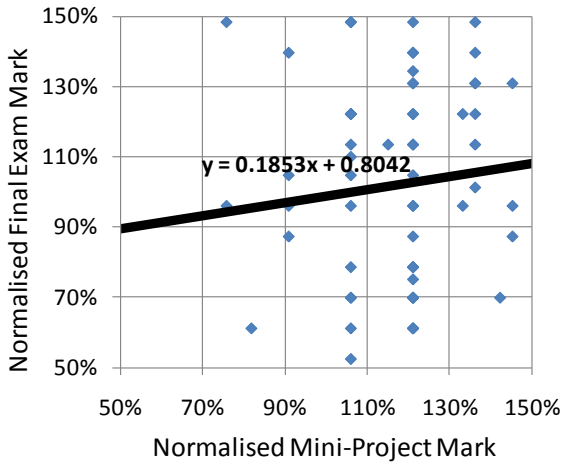

Figure 2. Statistical Analysis Results (Steel and Timber Design Subject)

The results of this study indicate that the research-inspired learning project can run with available resources and facilities and not much external fund or resources in future will be required to keep the project running. The investigators have already discussed the results with some other colleagues and the school's course coordinator to get other subjects across Civil Engineering discipline or the faculty to be involved in this project. This project now is a compulsory component of Soil Behaviour and an optional part of Steel and Timber Design assessment tasks. Subject outlines of both subjects clearly explain about the mini-research projects and set of field of practice skills and knowledge achievable by conducting high quality research in predefined projects. Particularly, by including research inspired projects in curriculum, following aims have been achieved:

- Providing opportunities for students to integrate core and fields of practice specialist knowledge in project based work; and to examine how the knowledge applies in a workplace context,
- Promoting dialogue between students and teachers that in turn, would ignite students' learning experience and promote culture of lifelong learning among students as well as lecturers

- Providing an opportunity for students to develop reading habits and critical thinking skills, and learn from authentic experiences while drilling in practical work for complete mastery

3 CONCLUSIONS

In order to further develop undergraduate research integrated learning in the School of Civil Engineering at the University of Technology Sydney (UTS), two subjects namely Soil Behaviour, and Steel and Timber Design were selected by the research team. Many appropriate micro-research projects were carefully prepared by the lecturers including the title, the scope of the research and the expected outcomes. The projects and proposed methodologies were well received by the involved students. The implementation of these mini-research projects in the target subjects, students gained heightened confidence in broadening and deepening their research and inquiry involvement. Introducing the research project as a compulsory part of the assessments was found to be more effective than having the research project as an optional component for encouraging students to engage in a research-based learning programme. Moreover, a meaningful correlation between the students' performance (i.e. final mark) in the subject and the delivered research project was observed, however, drawing a firm conclusion about the long-term impact of the research-inspired learning due to small size of the specimens considered in this study and absence of a longitudinal study is not possible.

Overall, it was a successful practice to encourage students to adopt research-inspired learning. Results of this study indicate that incorporating research components in target subjects, promoted research-based learning culture among civil engineering students.

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