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Teaching Sustainable Stormwater Management Using Project Based Learning

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ABSTRACT

Project Based Learning (PBL) is increasingly becoming popular as a teaching aid in many universities across Australia. The theory associated with the Stormwater Management course is taught to students by solving practical problems associated with real life situations. Persistent drought has resulted in treating stormwater as a valuable resource when securing sustainable water futures for capital cities across Australia; including Melbourne. Based on feedback from potential employers of Civil and Environmental Engineering graduates the Stormwater Management course at RMIT University was reorganized to be structured around a major stormwater project to facilitate learning. The project involves arrangements to manage stormwater quantity and quality, when an undeveloped (Greenfield Area) was transformed from barren land to a fully developed urban area consisting of domestic and industry infrastructure and open space. The introduction of PBL to the course has improved the students' satisfaction rate with the course and the overall score obtained for the 'Good Teaching Scale'. The paper covers the description of the project, changes made to course content and delivery arrangements from the previous year, adopted teaching approach, students' feedback and challenges faced in delivering the course. A 66% student satisfaction rate confirmed the benefit of introducing PBL for facilitating sustainable stormwater management learning at RMIT University in Australia.

INTRODUCTION

Project Based Learning (PBL) is increasing in popularity as a teaching method in many Universities across Australia. The theory associated with the course is taught to students solving practical problems selected from real life applications. As articulated in its Teaching and Learning Strategy (2007), pedagogy at RMIT University is based on respect for student diversity to provide learning opportunities for all. It recognizes that:

- Students enter the university with a wealth of experience
- Learning and teaching is an experience between teacher and students, students and students, and students and teacher where all parties learn
- Cultural, social, gender and age differences is a positive attribute to learning
- Intellectual freedom requires nurturing

Further details of RMIT's Teaching and Learning Strategy could be obtained by visiting www.rmit.edu.au.

In PBL students generally work in teams and are more responsible for their own learning. This is a more effective way of delivering the range of graduate capabilities such as teamwork and communication, problem solving as well as technical skills required by Engineers Australia. The author reviewed a number of published research papers on Project Based Learning (PBL) related to engineering education in Australia as well as overseas. Aziz (2004) introduced PBL to counter rapid developments in very large scale integration (VLSI) technology and to expose students to life long and self motivated learning to ensure they stay up to date with technology. End program qualitative

assessment reported a high level of student satisfaction with PBL. Hadkaew et. al (2006) used a PBL model to teach students the mechanics behind blood flow in the human blood circulation system. The authors observed student interest increasing exponentially as the course progressed although some initial difficulties were faced when teaching the mathematical principles behind blood flow. Jayasuriya et. al (2007) reported the introduction of PBL to engineering education at the Victorian University and the reflective journey of two students in the first year. The authors concluded that the students embraced PBL and they performed better in the PBL subjects when compared with subjects delivered in the traditional mode. It was observed that most of the studies sighted, reported on conclusions based on observations of the researchers or qualitative data collected. Conclusions drawn from the study reported herein relied not only on observations but hard quantitative survey data collected throughout the study.

The new Civil and Infrastructure Engineering program was commenced at RMIT University in Melbourne, Australia in 2004. The program focuses on educating students on the whole lifecycle performance of infrastructure (as opposed to design and construction) and on the responsibility of the engineer with regard to sustainability of the built environment (Molyneaux and Brumley; 2007). According to above authors the following characteristics were identified by Hadgraft (2003 and 2004) as main goals when developing the new Engineering program:

- Develop the conceptual understanding required by a graduating civil and infrastructure engineer
- Develop the graduate attributes sought by Engineers Australia
- Adopt problem (and project) based learning methods to accelerate learning; and
- Engage students in the profession with the theme of sustainability when dealing with all aspects of engineering

Persistent drought has resulted in treating stormwater as a valuable resource when securing sustainable water futures for capital cities across Australia. This includes Melbourne. The Stormwater Management course at RMIT University has been offered to Civil and Environmental Engineering students since 2004. Based on feedback from potential employers of graduates, the Stormwater Management course in the new Civil and Infrastructure Engineering program was reorganized and structured around a major stormwater related project to facilitate learning in 2007. The paper covers description of the project, changes made to course content and delivery style from the previous year, adopted teaching approach, students' feedback and challenges faced in delivering the course.

REAL LIFE URBAN DRAINAGE PROBLEM

Due to urbanization and the corresponding increase in impervious area, the stormwater that previously infiltrated into the soil now flows over the hard surface increasing the surface runoff quantity. Urbanization will also increase the pollutants washed off to urban channels, creeks and the receiving waters. The Victorian Government's White Paper on water, '*Our Water Our Future'* (DSE, 2004) promotes the use of alternative sources such as stormwater for substituting potable water supply to save precious water resources. The poor quality of stormwater is the key factor limiting the use of stormwater for fit-for-purpose productive use. Receiving waters such as creeks, rivers and the Port Phillip Bay and Westernport in Melbourne, Australia are also impacted by poor stormwater quality.

Water Sensitive Urban Design (WSUD) is the integration of water cycle management into urban planning and design. Key principles of WSUD listed in Urban Stormwater-Best Practice Environmental Management Guidelines (Victorian Stormwater Committee; 1999) include: protecting natural systems; integrating stormwater treatment into the landscape; protecting water quality; reducing runoff and peak flow and adding value while minimizing development costs. As recommended in the WSUD Guidelines (WSUD; 2006), the best practice stormwater quality management objectives are to remove 80% of the suspended solid annual load; 45% of total

phosphorus annual load and 45% of total nitrogen annual load before stormwater reaches receiving waters.

The course contents were significantly revised in 2007 to reflect the current industry needs and Government Policy detailed in *Our Water Our Future*. The continuous assessment component for this course was changed in 2007 from two individual assignments to one single project directly related to the urbanization problem. The project was based on converting a parcel of Greenfield land to an urban subdivision with all modern amenities and services. The land was to be developed for medium density housing and 35% of the area was assumed to be impervious for the residential area. In developing the parcel of land, students were instructed to assume that the water from the developed land drained into an environmentally sensitive wetland/detention basin at the downstream end of the development. The class was divided into a number of teams. Each group was given a different catchment location in Australia to encourage students to think innovatively and laterally and custom build design solutions to reflect individuality.

The objectives of the project were to:

- Design an efficient and effective drainage system to carry the excess runoff caused by a storm with a given Average Recurrence Interval of 10 years
- Design a water retention basin with an appropriate outlet structure to reduce the flood peak to the pre-urbanized flood level
- Develop a stormwater quality treatment strategy to meet best practice pollutant reduction targets as detailed in WSUD guidelines

INTRODUCTION TO THE LEARNING PROGRAM

Face to face teaching consists of 2 hours per week of formal lectures and 2 hours per week of tutorial classes for students to work on the project for 12 consecutive weeks. The lecture series covered:

- Introduction to stormwater management systems
- Urban drainage design
- Stormwater routing
- Detention basin design criteria
- Stormwater quality issues
- WSUD principles and applications
- Real-life issues focused when applying WSUD principles to Green-fields and developed areas
- Pollutant reduction techniques
- Hydrologic and hydraulic modelling of stormwater systems.

In addition to the above topics, the students were taken on a field visit to show practical applications of WSUD features that had been implemented by the water industry to manage stormwater in a sustainable manner. The students were also given opportunities to interact with industry partners to discuss the challenges faced by the industry in real life when integrating the above features into Greenfield or existing developed areas. The students also had hands on working experience operating a water quality improvement software package popular with industry practitioners. Furthermore, the theory section dealing with water quality improvements was taught by an industry consultant who was able to teach designs using practical examples.

GATHERING STUDENT FEEDBACK

At end of each semester a Course Experience Survey (CES) is carried out by the RMIT University survey centre for all courses offered at the University. The survey questionnaires incorporate items from the Good Teaching Scale (GTS) of the Course Experience Questionnaire (a national graduate

survey managed by Graduate Careers Australia. As detailed on the RMIT web (www.rmit.edu.au), the CEQ questions have been designed to measure the teaching and learning effectiveness of the following themes:

- Feedback
- Quality of the Teaching and Learning environment
- Learning Objectives
- Clear Goals
- Assessment – workload
- Commitment of staff – pastoral care
- Learning Resources
- The balance of theory/instruction and practice
- Course interest
- Online – computer based materials and
- Overall Student Satisfaction.

The questionnaire consists of 21 questions (Table 1) in total. Students were required to record a score between 1 to 5 for a given statement; with a score of 1 representing 'strongly disagree', 5 representing 'strongly agree' and 3 representing a 'neutral' response towards the statement. In addition, two open ended questions investigated the students' perception on what the best aspects of the course were and what improvements did the course require.

Good Teaching Scale (GTS) measures students' perceptions of teaching standards. It focuses on teachers' feedback, motivation, attention, understanding of problems and skill in explaining concepts. High scores on this scale are associated with the perception that there are good practices in place. Conversely, lower scores reflect a perception that these practices occur less frequently. The primary purpose of the data is to contribute to a systematic improvement cycle across RMIT at the course and program level. Items making up the GTS for the Higher Education version of the CES are:

- The teaching staff in this course motivates me to do my best work. (Item 9)
- The staff put a lot of time into commenting on my work. (Item 20)
- The staff made a real effort to understand difficulties I might be having with my work. (Item 19)
- The teaching staff normally gives me helpful feedback on how I am going in this course. (Item 5)
- My lecturers were extremely good at explaining things. (Item 4)
- The teaching staff works hard to make this course interesting. (Item 17).

RESULTS AND DISCUSSION

The GTS for the Stormwater Management course in 2006, 2007 and 2008 are 30.1, 43.3 and 46.7 respectively. The final GTS score in 2007 has improved by more than 13% compared to the GTS score in 2006. It is clear from the percentage agreed values given in Table 1, the percentage values for the Item numbers that are directly related to the GTS Score have gone up by about 12%, except Item numbers 19 and 20. Figure 1 depicts the distribution of percentage of students' satisfaction for each question on the CES. The figures clearly show the results moving towards positive skewness from 2006 to 2008.

Table 1: The Course Experience Survey questions and the scores obtained in 2006, 2007 and 2008

Item No	Question	2006 (%)	2007 (%)	2008 (%)
1	The learning objectives in this course are clear to me	38	53	76
2	I am learning what I expected to in this course	48	70	85
3	This course is well organized	29	52	61

4	The teaching staff are extremely good at explaining things	38	37	50
5	The teaching staff normally give me helpful feedback on how I am going in this course	29	45	41
6	This course contribute to my confidence in tackling unfamiliar problems	19	50	62
7	Assessment tasks in this course require me to demonstrate what I am learning	60	64	88
8	The amount of work required in this course is about right	43	66	67
9	The teaching staff in this course motivate me to do my best work	17	37	48
10	I enjoy doing the work for this course	14	33	62
11	I find the learning resources for this course useful (eg. Notes, handouts, books, readings and audio-visual materials)	43	46	56
12	The web based (online) materials in this course are effective in assisting my learning	33	50	47
13	There is effective use of other computer-based teaching materials in this course	33	54	63
14	The facilities (such as classrooms, lecture theatres, studios, labs, workshops) are adequate for this course	76	73	64
15	I feel I can actively participate in my classes	52	63	73
16	There is a good balance between theory and practice	40	67	69
17	The teaching staff work hard to make this course interesting	29	59	64
18	I can see how I'll be able to use what I am learning in this course in my career	38	70	76
19	The staff make a real effort to understand difficulties I might be having with my work	38	47	45
20	The staff put a lot of time into commenting on my work	29	37	31
21	Overall, I am satisfied with the quality of this course	33	50	66

Based on a study *'The drivers behind the good teaching component of the CES'* carried out by the RMIT School of Mathematics and Geospatial Science, it was revealed that the time staff put into commenting on student work (Item 20) and feedback on student progress (Item 5) were equally the most highly related items to the good teaching factor for 2007. This indicated that they are the most influential CES items on the GTS for Civil Engineering students. Although the percentage agree on Item 5 have improved considerably from 2006, the students had not been satisfied with the comments received by staff on the work that they have been carrying out (Item 20 in Table 1). With the aid of a real life project, it was easy for students to understand the objectives of the course and to develop interest in the course. They could clearly see the applications of the theory learnt in class in solving practical problems. This is clear from the 'percentage agreed' values given in Table 1 and Figure 1. The percentage values for Item numbers 1, 9 and 17 have mostly moved from the 'neutral' position to the 'agreed position'. The questions in Item numbers 19 and 20 directly relate to the individual attention that an academic could give to students. This in turn directly relate to student numbers in the class. In spite of the Stormwater Management course being an elective course, there were approximately 50 and 80 students enrolled in the course in 2007 and 2008 respectively. This explains the reason for the slight drop in the agreed percentages from 2007 to 2008 for Item numbers 19 and 20.

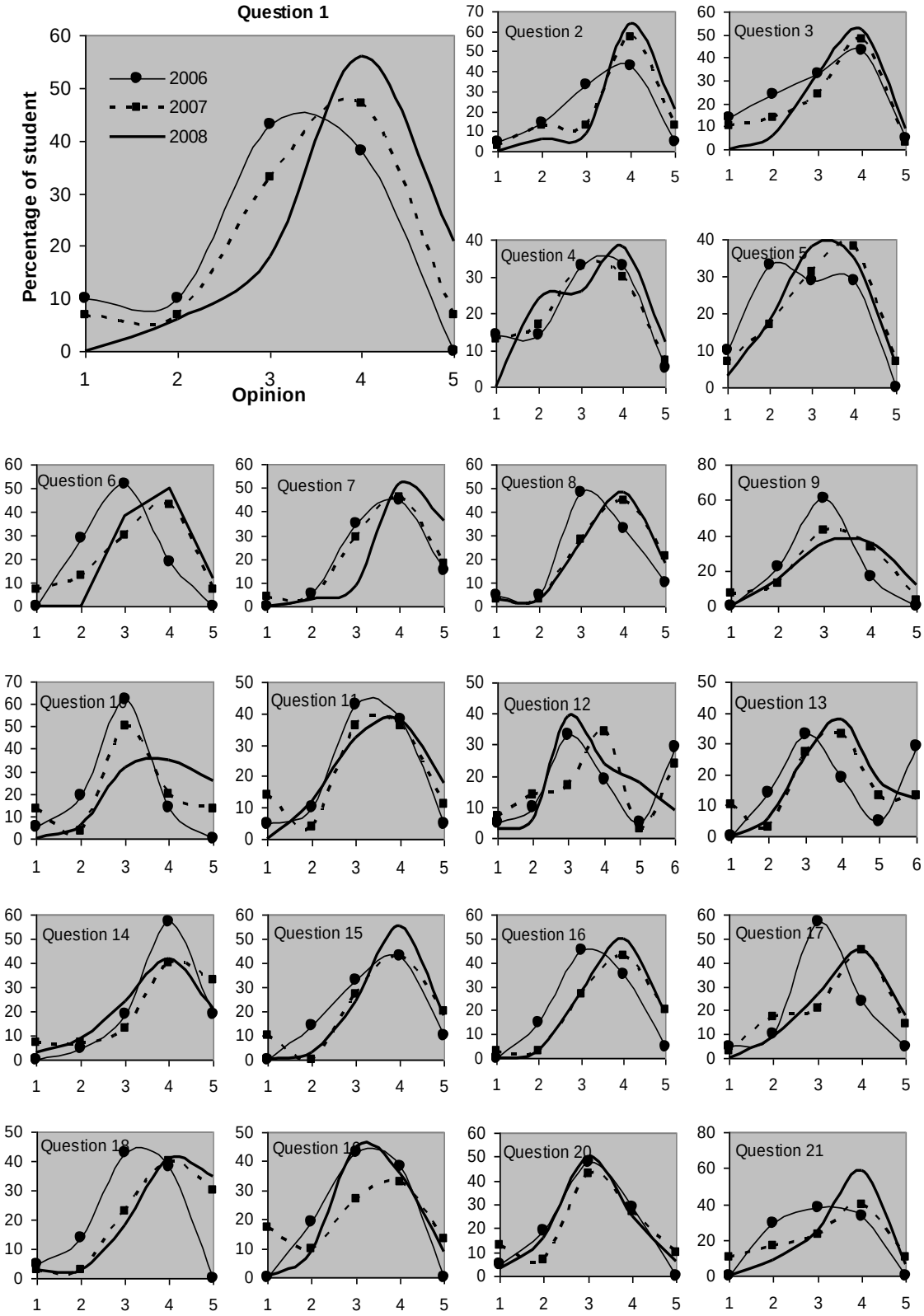

Figure 1 Course Experience Survey responses for years 2006, 2007 and 2008 (The questions are depicted in Table 1)
1= strongly disagree, 2 = disagree, 3=neutral, 4=agree, 5 strongly agree; 6 = not applicable

With the introduction of PBL, the percentage agreed scores for organization and application factors (Item Numbers 1, 2, 7 and 18) moved to being well above 75%. This was also highlighted in Section 2 of the questionnaire where they had to report on the best aspects of the course. Some of the comments given by students are reported below as being good features of the course (these are unedited quotes):

- Relating theory back to example the in real life
- Highlighting difficulties faced in industry, and what to look for
- Guest lecturers were good as their responses are based on actual industry experience
- Excursion to see structural examples performing their functions was appreciated
- Good application of theory to workplace
- The practicality of what was taught was good. I can now really see how it can be used in real life
- Assignments enabled me to put theory learnt into practice, and the result is something that I see will be useful and used in the real world
- Interesting advancements of technology in the industry and for the need for incorporating them into the course.

With the application of theory learnt in the class to the project, the students were clear on the objectives of the course. They could see how they could apply what they have learnt in theory at a later stage when they begin work as practicing as engineers. The course enjoyment (Item 10) has improved from 14% to 62% from 2006 to 2008. However, the students' responses on Environmental factors (Item 14 - facilities) have decreased from 76% to 64% from 2006 to 2008 which is again a direct reflection of the student numbers and congested lecture halls. The overall student satisfaction rate also has improved from 33% in 2006 to 60% in 2008 (Item 21). As mentioned before, the students were exposed to a popular software package used by industry named Model for Urban Stormwater Improvement Conceptualization (MUSIC; 2007) to investigate water quality improvements affected by introducing WSUD features. The results clearly show how students appreciated this as the responses for 2007 and 2008 are more skewed to the right side (agreed) when compared to the 2006 responses.

As reported in Chartier & Gibson, (2007), the above results clearly reinforced the fact that project based learning gives students' exposure to education in a manner which is both fun and motivating, whilst enforcing the knowledge gained in a variety of coursework through connection to real world applications. In addition, skills related to teamwork and constructive behaviour can be developed through project based learning. These skills are not always developed by students learning in a traditional classroom environment. Thus, project based learning offers students an effective means of developing a skill set, complementary to that learnt in the traditional coursework-style of learning.

CONCLUSIONS

Project Based Learning (PBL) was introduced in 2007 to deliver the Stormwater Management course in the School of Civil, Environmental and Chemical Engineering Programs at RMIT University. The real life problem faced by the development industry when converting urban greenfields to residential/industry development was used to teach a large class of students the theory and the application of the knowledge to solving practical problems. Significant improvements have been observed in a number of standard key performance indicators that measure the teaching and learning effectiveness of the course. Based on the above experience, Problem Based Learning has been introduced to a number of other courses such as Water Engineering and Water and Wastewater Management courses taught in the School.

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