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Engineering needs environmental and global thinkers: a contextual analysis of student learning preferences.

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Abstract: The need for engineering graduates who are environmentally and globally aware is now a recognized priority in professional practice. This paper presents an analysis of learning preferences of entry level students in a course which builds an early awareness of global environmental practice. The course on *Engineering and the Environment* started in 1991 as part of the undergraduate Environmental Engineering program at RMIT University. Subsequently the course was extended to Geological and then to Civil Engineering programs. The curriculum has paralleled the development of environmental practice in the professions of engineering and mining and provides a fundamental environmental context for students' subsequent learning in their programs and on- going professional practice. Curriculum development and some specific learning activities are briefly outlined. A challenge has been how to engage a diverse and increasingly large cohort of almost several hundred students in "non traditional" engineering lectures. A detailed analysis of student responses to a set of multiple choice exam questions has been conducted to test the hypothesis that various factors such as student choice of program may influence receptivity to different modes of learning and curriculum content. The study shows no significant difference between the various groups in regards to preference for evaluative type environmental learning, versus more traditional factual based engineering learning.

Keywords: Environmental curriculum, educational research, professional practice.

Introduction

The need for environmental and sustainability literacy in undergraduate engineering education became apparent in the early 1990s and Australian universities quickly responded by developing specific undergraduate Environmental Engineering degrees. Dandy & Daniel (1992) reviewed these early programs and Brumley & Horan (1995) provided an overview of the 1991 RMIT response which was the first undergraduate Environmental Engineering program to be developed in Victoria. The program has continued to evolve successfully by reflecting the development of environmental practice in the engineering and mining industries and has created a talented cohort of practitioners in the now well recognized discipline of Environmental Engineering.

It is interesting to note how readily the engineering and mining professions responded to the imperative for environmental and sustainability expertise to be included as defined areas of professional practice and education. By the mid 1990s the Australasian Institute of Mining and Metallurgy had included Environmental Engineering and Science as one of its four core disciplines and Engineers Australia had introduced an Environmental Engineering Chapter with its own technical journal. Both professional organizations also reviewed their educational objectives in major task force studies (Changing the Culture: Engineering Education into the Future, 1996; and Back from the Brink: Reshaping Minerals Tertiary Education, 1998).

It is timely that the broader education tertiary sector is now responding to the challenge under the encompassing concept of sustainability. Based on the United Nations 2005-2014 Decade of Education for Sustainability, the Australian Vice-Chancellors' Committee has developed a progressive policy on education for sustainable development which includes '*embedding elements of sustainability at appropriate levels in academic programs'*.

One of the key introductory courses in the RMIT Environmental Engineering program was *Engineering and the Environment.* It was taught to the inaugural group of fourteen students in 1991. It is now taught as part of *Environmental Practice for Sustainable Design* to almost 200 students who are mainly from three programs; Environmental Engineering, Civil Infrastructure Engineering, and a double degree in Civil Infrastructure Engineering and Business Management. A few other students are taking the course as an elective or in double degree engineering and international studies programs.

The ethical codes and sustainability policies of the Australian mining and engineering professions provide the rationale for a curriculum comprising:

- Exploration of the environmental issues which motivated the Western World to respond legislatively to abate environmental degradation that had become unacceptable to modern democratic societies.
- The concept of sustainability and what it means in professional practice. This includes an assignment in which students analyse current environmental articles from a sustainability perspective with a focus on the role of the engineering professional. The task builds on the skills learnt in Victorian year 12 English in analysing the use of language in the presentation of an issue in the media.
- The spectrum of techniques available for environmental assessment and management. These include environmental impact assessment, environmental management systems, cleaner production, triple bottom line, life cycle analysis, ecological foot print etc.
- The role of good science and systems analysis. For instance via an exploration of the issues concerning greenhouse gasses and energy.
- Field based studies concerning the integration of engineering infrastructure with natural systems i.e. *design with nature.*
- Forum discussions on topical sustainability issues such as nuclear energy and Australia's position in the nuclear debate.
- Case studies concerning water resources, environmental best practice in mining and sustainable buildings.

The course has had to adjust to the challenges related to teaching large classes. The progressive transformation over fifteen years from an intimate learning experience with fourteen passionate environmental students into successful engagement with a large diverse group involves many issues. It is just not enough to keep the content up to date, it is also necessary to address the size and diversity aspects that a large class introduces. The teaching-learning nexus of large classes is becoming a reality of modern tertiary education and is discussed in an accompanying paper of this conference (Buckeridge and Brumley, 2006). The development of an on-line learning package in 2001 provided considerable help, but it also introduced a level of disengagement which is not ideal in this type of course even though the package is treated as a supplementary resource rather than as a replacement for face-to-face learning.

The results of a small research project which was undertaken to throw some light on these issues are now presented.

Research Project Overview

The hypothesis was, *that if learning preferences could be distinguished between defined groupings within the student cohort, then an objective strategy could be implemented to enhance the overall learning experience.* For instance, students selecting a traditional Civil Engineering program may be more likely to be interested in factually based curriculum, whereas students choosing a Civil Engineering/Business Management or the Environmental Engineering program may be more comfortable in discussing more worldly abstract concepts.

To test the hypothesis, a multiple choice examination question was set requiring students to answer 5 out of 10 options. All the questions except one were based on factual learning, while the different question involved evaluation of societal values. Each of the multiple choice questions were worth 10% of the total examination marks. While engineering education is traditionally based on problem solving abilities, an emphasis in this course has also been placed on developing an awareness of values, and mixed success was being experienced in gaining dynamic engagement in opinion based discussions with the large class. It was considered that statistical analysis of the selection and quality of responses to the special question would be enlightening, especially in regards to obtaining an insight into how receptive the various groupings were to tackling problems arising from the technology-human behavior nexus. Using the assertion that sustainability science should incorporate inverse approaches that work backwards from undesirable consequences to identify better ways to progress (Lowe, 2005), the following question was set: *'discuss societal values that drive* ***unsustainable*** *practices, and provide suggestions for values that would support a more sustainable future'.*

While the study is restricted to structurally determined groups based on gender, program selection and onshore or international students, it is recognized that individual students think and learn in many different ways. This adds an extra layer of complexity which is only partially included in the study via the assumption that students with particular learning preferences will be differentiated to some degree by which course they choose. In this regard a more detailed study could be carried out using a selection of Howard Gardiner's (1999) 'multiple intelligences' as parameters. Gardiner has described ten intelligences (linguistic, logical- mathematical, musical, interpersonal, intrapersonal, bodily-kinesthetic, spatial, existential, moral and spiritual) which characterize individual learning strengths. Nafalski et al., (2001) also discuss the need to cater for increasing diversity of students' learning needs in tertiary education by recognizing that preferred learning styles are influenced by social and cultural backgrounds.

Statistical Analysis

Generally students performed quite well on the specific question of interest, the multiple choice question (section) and the total examination performance. Figure 1 shows that the performance distribution is similar for each of the examination levels under consideration. However, not all candidates who performed well on the question of interest had similar results for other levels of the exam. Figure 2 shows that there is much stronger correlation between the section and examination performance compared with the question of interest and either the section or examination. This is borne out through calculation of the Pearson's Product Moment Correlation Coefficient (PPMCC) as shown in Table1, although there was a high degree of correlation for all three results, with p-values of 0.000 for each.

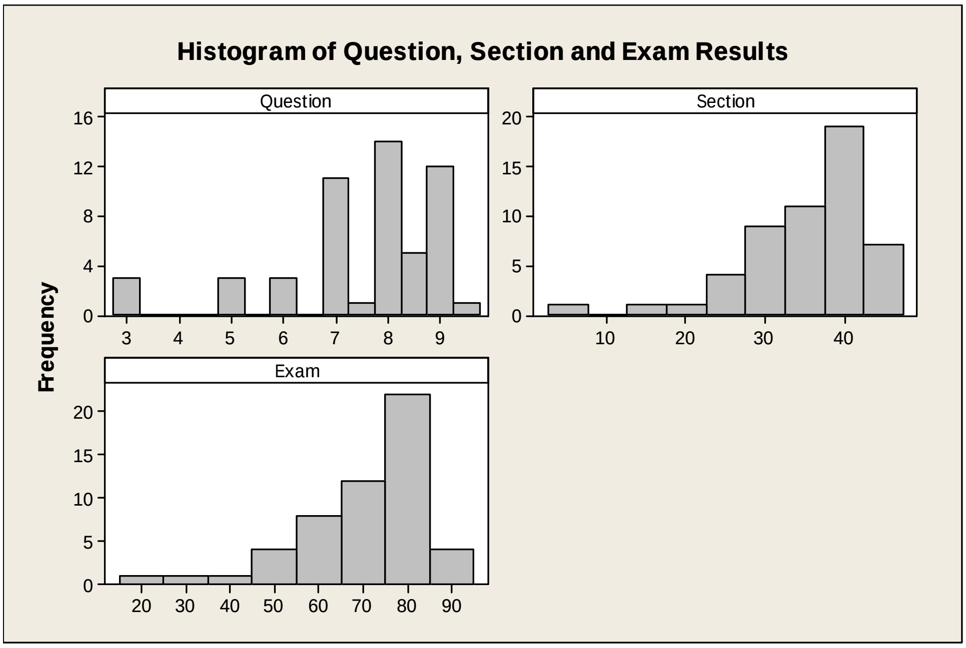


Figure 1. Histogram of Results for Question of Interest, Section and Examination

Table 1: Pearson's Product moment Correlation Coefficient for Question, Section and Examination Performance (all correlations show a p-value of 0.000)

	Question	Section
Section	0.770	
Exam	0.835	0.876

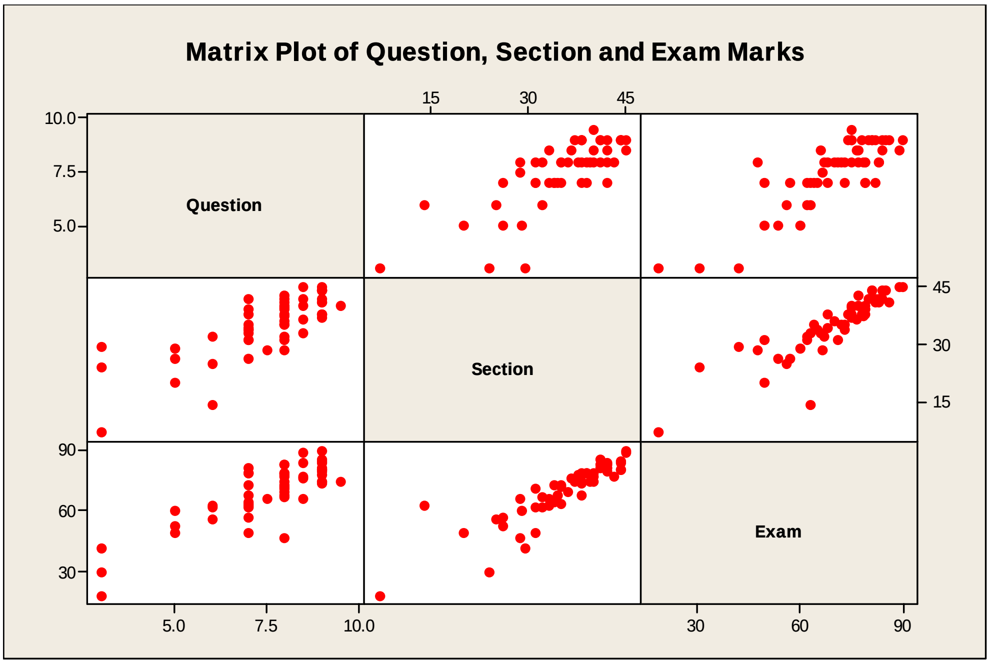


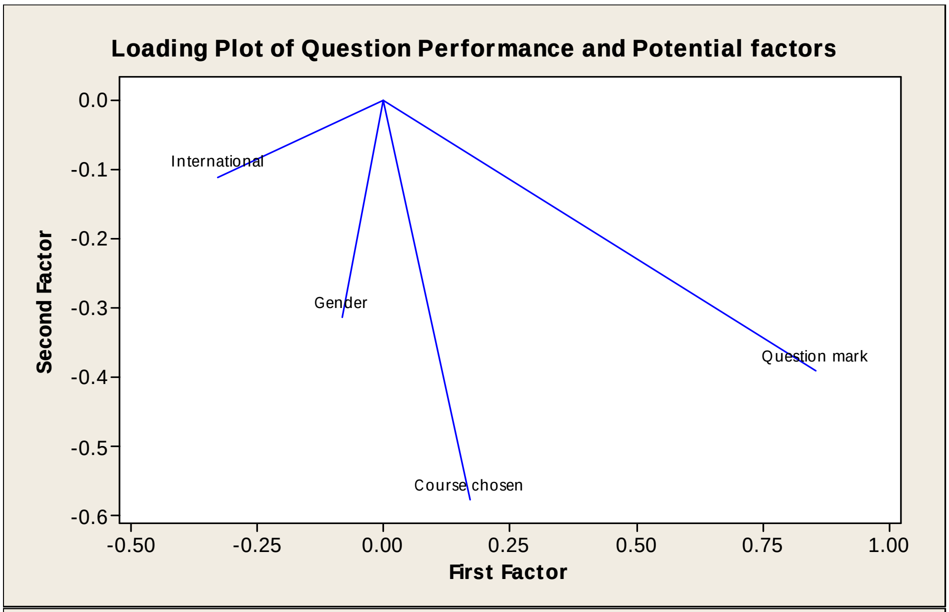
Figure 2. Matrix Plot showing Correlation between Question, Section and Examination Performance

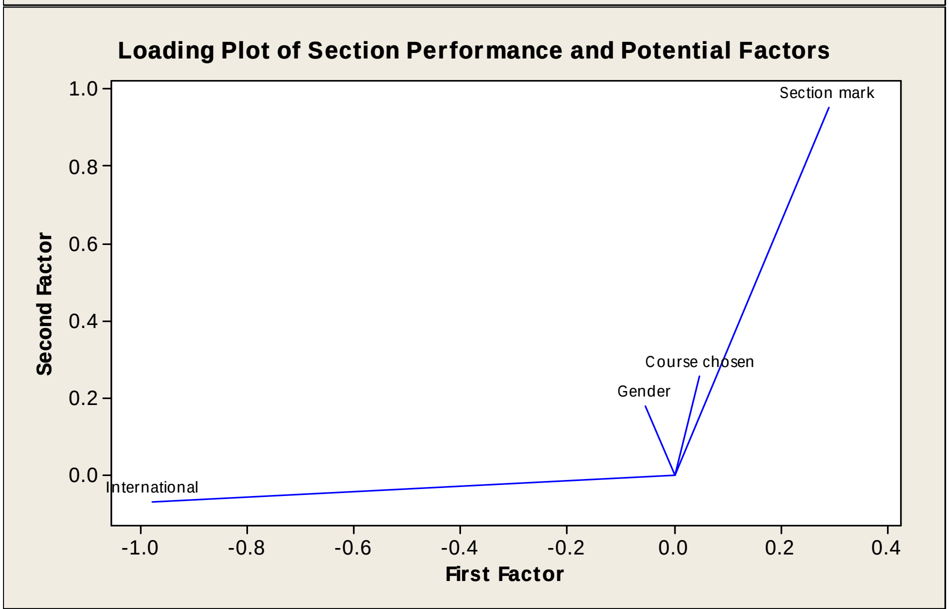
However, as shown in Table 2, if one probes further into the detail it can be seen that there were some students who performed well on the question of interest, but did not perform well on the examination overall. The converse did not apply; that is, all students who performed well on the examination overall, also tended to perform well on the question of interest.

Table 2: Detail Analysis of Examination and Question Results

Exam Results	Grade on Relevant Question Average	Minimum	Maximum
<50%	4.83	3.00	8.00
50 - 59%	6.00	5.00	7.00
60 - 69%	7.00	5.00	8.50
70 - 79%	8.18	7.00	9.50
>79%	8.62	7.00	9.00

Although the primary hypothesis relates to the performance on the question by course, it is important to exclude gender and residency as well. In order to determine the factors that are contributing to the variability in the data, factor analysis was undertaken. Factor analysis is a means of detecting underlying trends that may be linked. In the following plots (Figure 3), closely positioned lines imply close correlation and the length of the line is a measure of the degree of influence that the factor is likely to have. It can be seen that the strongest relationship between any of the factors is between the question performance and the chosen course. Detailed analysis of the data showed that the only students who failed the question of interest are the civil engineering students.


Loading Plot of Question Performance and Potential factors
Second Factor
First Factor
International
Gender
Question mark
Course chosen
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00


Loading Plot of Section Performance and Potential Factors
Second Factor
First Factor
Section mark
Course chosen
Gender
International
1.0
0.8
0.6
0.4
0.2
0.0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4

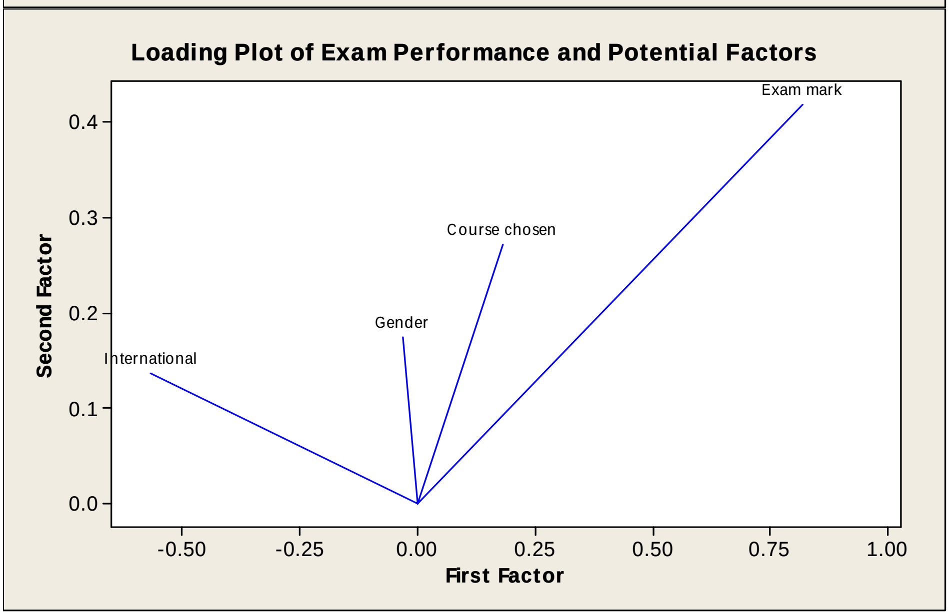

Loading Plot of Exam Performance and Potential Factors
Second Factor
First Factor
Exam mark
Course chosen
Gender
International
0.4
0.3
0.2
0.1
0.0
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00

Figure 3. Loading Plots of Question, Section and Examination Performance and Potential Factors

The data was not normally distributed and therefore a transformation was undertaken, so that ANOVA could be applied (Table 3). Normal distributions are continuous; a criterion that is not met through the marking system applied. Therefore the results should be treated with some caution, however as they are unambiguous they have been included. It should be noted that the following box plots (Figures 4, 5, 6 and 7) are of the untransformed data.

The analysis shows there is no significant difference in performance on the basis of gender, or residency (international students). However, in support of the hypothesis, there is a statistically significant difference in performance as a function of course. It is notable that the civil students performed the most poorly, followed by civil/business double degree students, then environmental engineering students and finally other students undertaking the subject as an elective.

Table 3: Summary Results of ANOVA for Gender, Course and Residency Classifications on Question Performance

	F-value	P-value
Course	2.9	0.043
Gender	0.32	0.575
Residency	2.07	0.157

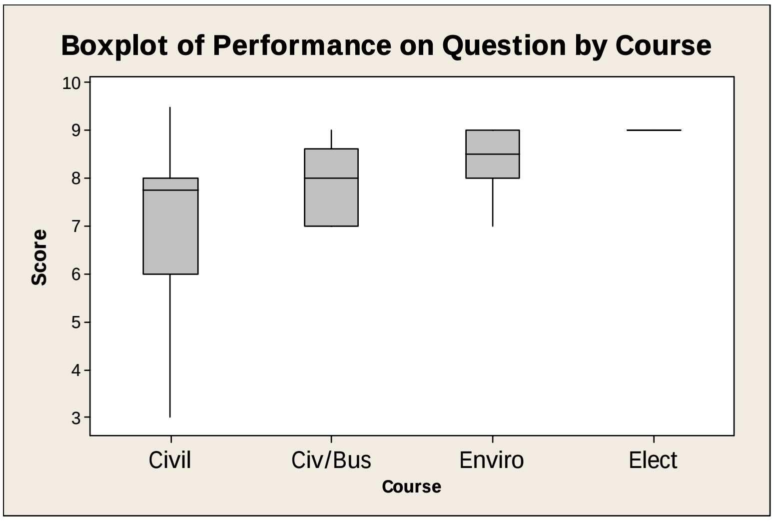


Figure 4. Distribution of Marks on the Specific Question as a Function of Course

It is acknowledged by the authors that the results may be biased by the likelihood of selecting the question as a function of gender, residency and course. In order to evaluate this, a chi-squared test was applied. It was found that there was no statistical significance in attempting the question as a function of gender, residency or course. It is of particular interest that the p-value for the selection of the question by course is 0.786; the result is unambiguous. There is some evidence of a preference for women and Australian residents to attempt the question; however this was not significant with p-values of 0.25 and 0.16 respectively.

Similarly the likelihood of selecting the Civil Engineering program as a factor of gender and residency was investigated. This was investigated using a chi-squared test, and p-values of 0.273 and 0.175 show that although there was some evidence of bias it was not statistically significant.

Finally, the performance on the overall examination on the basis of these three factors was compared. There was no significant difference in the examination performance as a function of gender (p-value = 0.375); however the international students and civil students performed less well on the overall examination result (p-value = 0.00). This supports the findings shown in the loading plots (Figure 3).

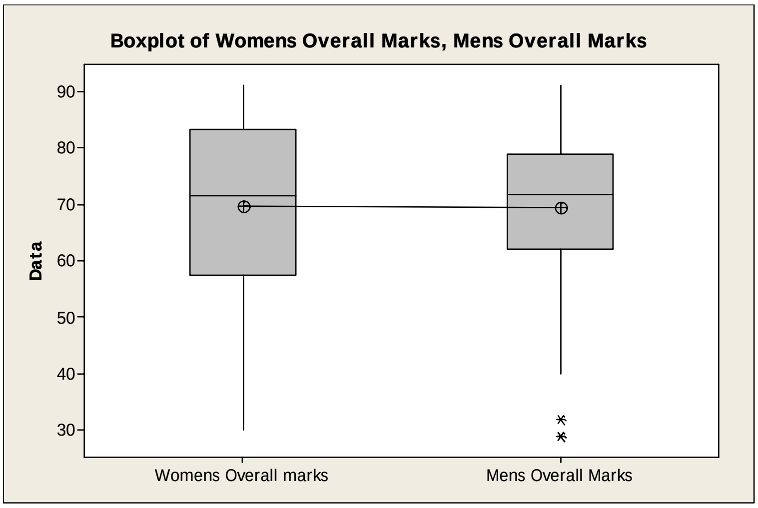


Figure 5. Distribution of Overall Marks as a Function of Gender

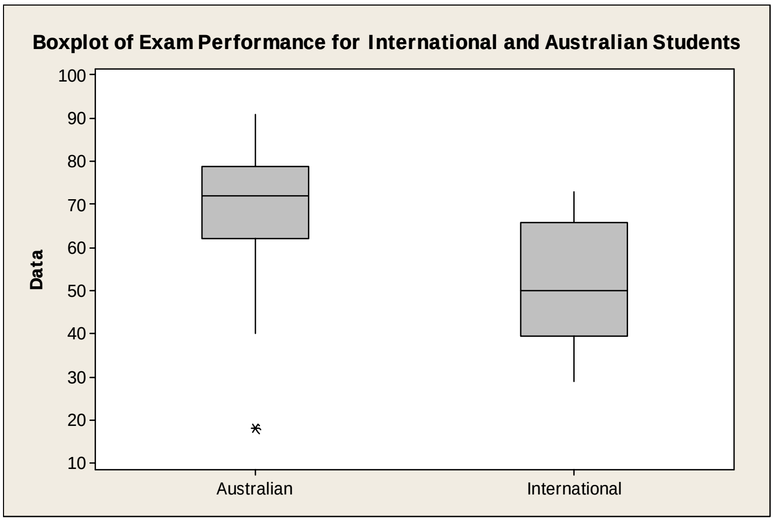


Figure 6. Distribution of Overall Marks as a Function of Residency

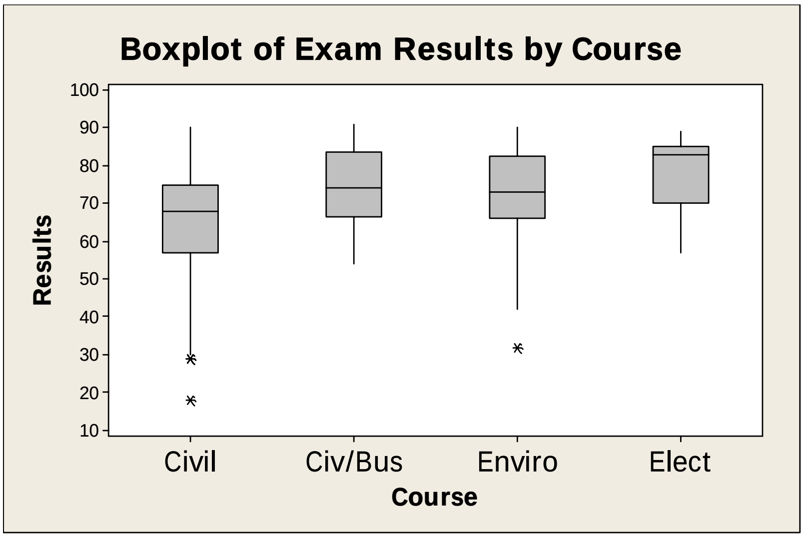


Figure 7. Distribution of Overall Marks as a Function of Course Enrolment

Conclusions

There was no statistically significant difference in the likelihood of attempting the question as a function of course, gender or residency. Nor was there a significant difference in the likelihood of choosing the civil engineering course as a function of gender or residency.

The key conclusion to this analysis is that students who performed well on the examination overall also performed well on the question of interest, and the relevant section, if they chose to undertake it. Civil engineering students tended to under-perform on the examination and on the question at a statistically significant level, as did international students. All the students who failed the question were civil engineering students. Whilst not statistically significant, it is also notable that of those students who failed the overall examination there were a few who performed very well on the question of interest.

In relation to gaining a better understanding of the influence of program diversity on learning preferences, the study has shown that ***one can not assume that any one group of students has less interest than another in factual versus evaluative type learning and discussion, even though clear differences in performance levels occur.*** This may well reflect an improved awareness of environmental and societal issues in both the broader community and secondary education. It also suggests that entry level engineering students are well primed for learning experiences that will strengthen their skills in environmental and societal issues within a context of sound engineering and science.

References

Back from the Brink, *Reshaping Minerals Tertiary Education.* Discussion Paper, Minerals Council of Australia. National Education Task Force, 1998.

Brumley, J. and Horan, E., 1995. Undergraduate Environmental Engineering Education: The RMIT Response. *Proceedings of the National Environmental Engineering Conference, Institution of Engineers Australia.* pp. 181-188.

Buckeridge, J. and Brumley, J., 2006 (in press). Ethics, engineering and the environment: Is Hawking correct. Is it all too late? 17th Annual Conference, Australian Association for Engineering Education, Auckland, New Zealand.

Changing the Culture: *Engineering Education into the Future*, Institution of Engineers Australia, Australian council of Engineering Deans and Academy of Technological Sciences and Engineering, Canberra, 1996.

Gardiner, H., 1999. *Intelligence Reframed. Multiple intelligences for the 21st century,* New York: Basic Books. 292pp

Lowe, I., 2005. A Big Fix: Radical Solutions for Australia's Environmental Crisis. Melbourne, Black Inc.

Nafalski, A., McDermott, K. and Gol, O., 2001. Innovation in Engineering Education at the University of South Australia. Global J. of Engng. Educ. Vol.5, No 1.