

Strategies for Progressing through Engineering

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Abstract

Entering university courses is often based on a single score or percentile ranking obtained at the end of high school. For entrance into university engineering courses the situation is complicated because many of these faculties have to accept students with lower entrance scores than recommended to fill quotas. Historically, students with borderline entrance scores have shown great difficulty during their first year in the engineering degree program. The challenge which faces many universities is that of balancing students' performance in first year, where subjects are familiar from their high school experience, with minimising the shock which will await them when commencing second year, where their subjects are engineering based often with industrial applications. At Swinburne University of Technology, a system of learning strategies has been tried to improve student success in their studies during their second year. Students were directed to analyse, ponder, and evaluate class problems in a real-world manner. Project work was utilised to encapsulate as much of the subject material into a single meaningful engineering task.

Keywords: progression, learning strategies, student performance

1 INTRODUCTION

Entrance into tertiary engineering study is achieved from a number of different routes. In Victoria this includes end-of-high school ranking processes; the ENTER is used either solely or in conjunction with other criteria as a selection tool for course entry.[1]; pathways from a technical institute, e.g. TAFE [2](Technical and Further Education) for those students holding a diploma or associate diploma; and a special entry scheme for mature age (over 25) students who are returning back to study without formal academic entrance requirements[3]. Prediction of success, i.e. progressing through all levels of tertiary study in different disciplines, has been shown to be highly dependent on measures or scores achieved by students in end of the last year of high school[2, 4-7]. This prediction has also been successfully implemented in determining academic success by pharmacy, computer science, medical and postgraduate students[8-11].

Over the past few years many Australian engineering faculties have seen a decreasing number of students entering into their courses. The selection criteria is based on an ENTER score or ranking. To overcome this problem a number of universities have resorted to lower their ENTER score requirements, or give "bonus scores" to students who have completed subjects allied to engineering, e.g. high levels of mathematics, physics and chemistry, so as to maintain student numbers(also predicated upon by government funding strategies). This strategy has brought its own problems, e.g. the students' ability to progress through the course in the minimum amount of time[4, 7] Although most universities may have maintained commencing student enrolment numbers at a constant level due to varying their entrance requirements, being able maintain student progression rates in subsequent years have proven to be extremely difficult[5, 12].

At Swinburne University of Technology (SUT), the ENTER requirement have ranged from 80 in 2004 slowly decreasing to 75 in 2008 over the intervening years. The work reported in this study investigated the relationship of ENTER scores with the success rate of passing three first year subjects, Engineering Mathematics 1, Energy and Motion(Physics) in first semester, and Mechanics of Structures(Stress Analysis) in second semester. This paper further presents the result of a teaching, learning and assessment methodology which has been trialled in the second

year subject Thermodynamics 1 with the student group who commenced their mechanical engineering course in 2004. This subject is widely seen as one of the most challenging subjects to these in the early part of their course.

1.1 Commencing ENTER scores

All engineering students are required to enrol in four subjects in first semester, and a further four subjects in second semester. The distribution of ENTER scores for students attempting Engineering Mathematics 1, Energy and Motion and Mechanics of Structures were compared for the 2004 and 2005 commencing student cohort. The ENTER scores results and trends for all three subjects were very similar so only the details for Engineering Mathematics 1 is presented here. Shown in Figure 1 is a distribution of commencing students with their ENTER score for 2004 and 2005. A lesser number of students with higher ENTER scores attempted engineering for 2005 (the latest set of complete data which is available) more students now fall into the 70 to 80 ENTER bracket. It is important to note that Swinburne has always had a significant intake of students from TAFE students and graduates which explains the student group with a lower than 80 ENTER for 2004 and those below 75 in 2005. Also noteworthy is the fact that Swinburne attracted a larger percentage post-95 ENTER students in 2005. Comprehensive data post 2005 is currently unavailable.

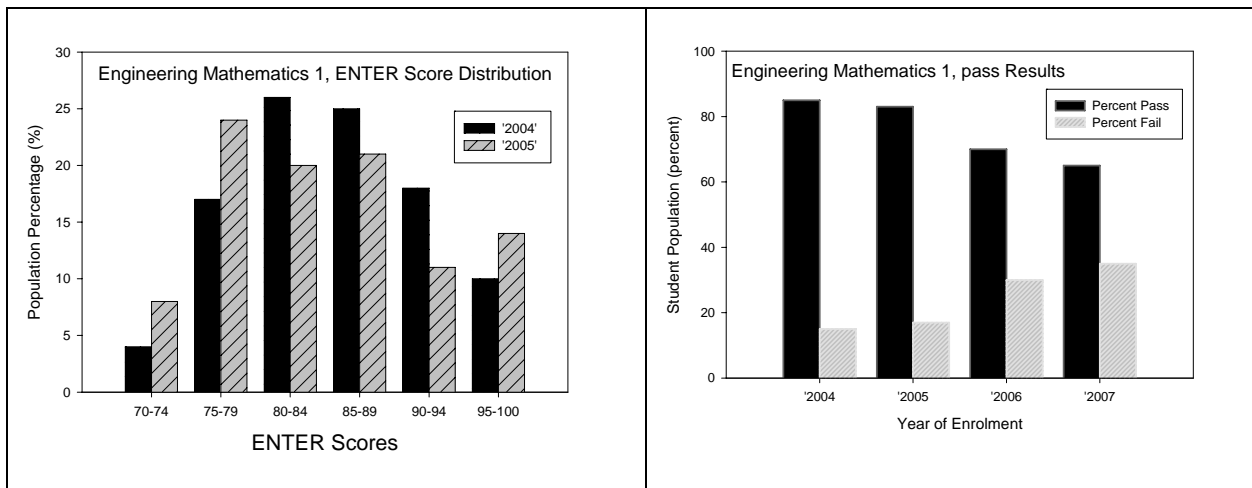


Figure 1. ENTER scores distributions

Figure 2. Student Pass Results

1.2 Engineering Mathematics Pass Rates

When considering the pass and failure rates for Engineering Mathematics 1, shown in Figure 2, the failure rate (N) has increased notably from 2004 to 2005. At the same time the pass rate (P – 50% and above) has decreased and likewise students who achieved credits (C – 65% and above) have reduced. The percentage of distinctions (D – 75% and above) have almost remained the same. The slight increase in high distinctions (HD – 85% and above) is explained by the increase in post-95 ENTER students in the 2005 intake.

2 EFFECT OF ENTER SCORES.

A reliable correlation between ENTER scores and subject results is difficult to achieve because of a large number of variables; e.g. gender, age, part-time work, ethnicity, socio-economic background, and the effect on studies of students being from non-English speaking backgrounds and cultures. Analysis of trends between ENTER scores and examination results for all three first year subjects examined from 2004-2005, were similar (Blicblau, 2005).

Regression analysis results indicated similar correlation coefficients for all three subjects and for both years of investigation. In all cases a larger percentage student population fall in the lower ENTER region. In attempt to increase the engineering intake into first year, larger cohorts of students were accepted into the 2006 and 2007 academic years with concomitant lower enter scores (a median of 76 and 75 respectively). The net effect of the larger group of lower ENTER students (Figures 3 and 4) can clearly be seen in the results in Engineering Mathematics 1 from 2004 and 2005. From the data for Engineering Mathematics 1, several important conclusions can be drawn)

- the scatter of the examination results become much greater at lower ENTER scores. It appears that that the results scatter becomes very large for enter scores below 80.
- it is also clear that there is a significant portion of students in the 70 to 80 ENTER band who have performed very well. This allows us to “pick up” the low ENTER students who could make it through the thermodynamics and fluid mechanics with the appropriate type of teaching and learning approaches.
- Assist high ENTER students to perform better.
- It is unusual for an 85 or 90 ENTER student to fail.

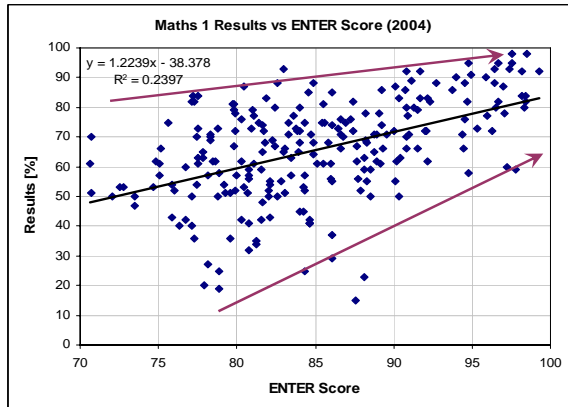


Figure 3. Trends between ENTER scores and mathematics examination results

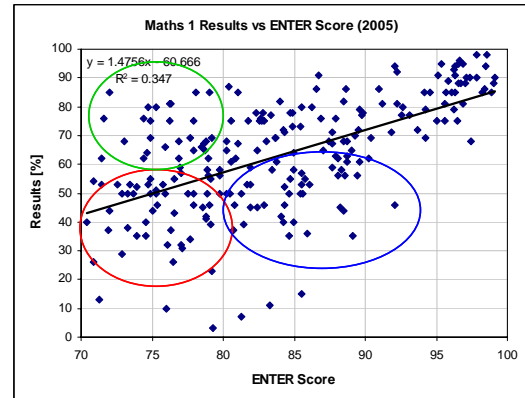


Figure 4. Results cluster between ENTER scores and mathematics examination results

It is clear from these results that the reduced ENTER requirements have negatively impacted on the overall performance of students. It is not always possible to predict outcomes based on ENTER scores, or GPA/SAT scores [13, 14]. A challenge therefore faces institutions with ENTER requirements below 80 or even 85 to prevent failure rates from increasing substantially, and so endeavour to reduce student failure rates in first year and subsequent years of their study.

3 HELPING STUDENTS TO LEARN

Both thermodynamics and fluid mechanics is widely seen by students as one of the most challenging subjects in the early part of the Mechanical Engineering course; mathematics is a necessary core requirement for undertaking the subject. Concepts such as entropy (mathematically based) are difficult to grasp and students find it challenging to bring theory and practice together. Hence, a comprehensive series of teaching and learning approaches were introduced to assist in the improvement of students’ abilities in these areas. These approaches were implemented utilising a variety of problem based and active learning approaches which were both traditional and inventive in the lecture, tutorial and laboratory sessions[15, 16]. In all these strategies, the students were kept constantly occupied and encouraged to explore further aspects of the subject to improve their knowledge and capabilities. The main purpose of these subjects such as Thermodynamics and Fluid Mechanics is to enable the students to think, to research, to analyse and design systems utilising problem based/project based learning approaches[16].

3.1 Scheduling of Classes.

The subject was delivered through the traditional structure of lectures, tutorial classes and laboratory activities. The students were given clearly a defined subject curriculum. The subject lecture delivery employed the use of electronic projection with Powerpoint™, where the students had copies of all the notes; but annotations and examples were presented for the first time in the lecture period. Active learning aspects were introduced to the students who were engaged in discussions of both difficult and easy topics as well as highlighting solutions of pre determined and open ended problems[17, 18].

3.2 Tutorial Classes.

For this project, the tutorial classes were scheduled such that they lagged one week behind the lectures in terms of the curriculum. This allowed students the opportunity to work on homework problems for a week to discover problems and formulate sensible questions for the tutorial classes. The laboratory classes were scheduled about two-thirds through the semester. This allowed the delivery of enough theoretical material to enable students to understand the concepts at hand, yet it allowed students to experience a practical application of the theory taught in the curriculum close to the point of delivery[19].

3.3 Assignments.

Assignment problems in many subjects, including Thermodynamics, were often meaningless and boring to students. Often, textbook questions were formulated in such a way that students were expected to calculate a single result – for example what the power output of a certain gas turbine cycle would be. These types of problems do not foster a habit of analysis and understanding with students[20]. The answer is merely a number. As such, they will often complete problems using textbook examples as templates and often arrive at correct answers without any physical understanding of the problem! Consequently, students often complete the problems without having any understanding of the validity of the results obtained.

3.4 Regular assessment and feedback.

It is common knowledge that many failures in the first and second years of study occur mainly because students fall behind the study schedule. In many cases they are not able to catch up at a later stage. One solution to this problem was the implementation of regular, short in-class tests. A system of short tests (10 minutes maximum) at the start of the weekly tutorial classes on the previous week's subject material was introduced. Peer group assessment was introduced such that at the conclusion of the tests they were collected and redistributed to be marked by fellow students – the marker adding his/her name to the marked test sheet. This afforded students the opportunity to get immediate feedback on mistakes made and the identification of subject material not understood. The opportunity therefore existed to deal with any problems in understanding and application during the tutorial classes. The weekly tests ensured that most students did indeed do some homework between the lectures of the previous week and the tutorials of the following week

3.5 Design tasks, parametric- and uncertainty analyses

One of the largest single contributing factors to the increase in success was the introduction of computer-based assignments. Students were introduced to an excellent computer package Engineering Equation Solver [20, 21] which is extremely simple to learn and use and is ideally suited for the modelling of simple engineering systems. In particular, EES is extremely well suited to do parametric studies (what-ifs) as well uncertainty analyses. It is also able to perform most of the mathematical functions that are encountered in engineering problem solving such as integration and differentiation.

4 HELPING STUDENTS TO THINK

Students were asked to solve real world problems in both their class examples and assignments. The employment of an engineering simulation and analysis software package such as EES has proven to be instrumental in assisting to solve these problems. A standard textbook (with supplementary material) was employed as the main resource[20]. Students were given homework problems each week. On average about two weeks were spent per chapter. At the conclusion of each chapter therefore, a problem from the textbook that is a good representation of the subject material was chosen as a computer-based assignment. Instead of simply asking students to solve the problem on computer, they were taught to create a computer model of which the inputs could easily be modified. The students then performed parametric analyses to investigate the influence of some independent variables on the system performance. These influences were then plotted which allowed them to visualize the interdependencies of variables. Two examples of analysis and implementation are given.

Example 1. The students were given an assignment where they had to investigate the influence of the boiler pressure in a Rankine cycle on both the efficiency and the power output. Varying the boiler pressure in a parametric study, they soon discovered that whilst an increase in pressure will theoretically result in increasing cycle efficiency, increasing the pressure beyond 42 MPa results in a decrease in power because of the decrease of the enthalpy of evaporation at those high pressures. Hence, they discovered the concept of an optimum pressure that is to be determined by maximising both power and efficiency. They learned that in the real world of engineering, trade-offs between competing parameters are a rule rather than an exception.

The students were also required to investigate the influence which uncertainties would have on cycle efficiency and power output. It often escapes the mind of many students that any given input data for a problem (or engineering model) carries with it a certain degree of uncertainty. They therefore had to analyse the system performance sensitivity to the combined influences of the given uncertainties. Students are often amazed at the findings when some parameter has an unexpected influence on performance (whether large or small). Ultimately, their understanding of the wider world of engineering was improved.

Example 2. A more interesting problem would be something that was more real-life: e.g. a hydro-electric plant performance similar to the one used in the Snowy Hydro Scheme in Australia[22], providing power for the state of Victoria; the students' home. Since this is a realistic problem, it offers great learning potential. The students were asked to investigate the financial viability of a proposed hydroelectric scheme where water is pumped to a high level reservoir during night time by buying electricity at discounted rates. The flow direction is reversed during peak hours, selling electricity at a higher rate. Not only did they need to perform the expected energy conservation calculations, they also had to find the most profitable operation level of the top reservoir via a parametric study. The problem was further complicated by specifying pump and turbine efficiencies that varied with reservoir height, as would be the case in reality. Moreover, uncertainties in pipe length, reservoir height, pump and turbine efficiency, pipe roughness, the purchase and selling price of the electricity and the flow rate was given. This problem involved the following requirements[20, 21]:

- Modelling of a system
- Parametric study (sensitivity analysis)
- Optimisation, and
- Uncertainty analysis.

This assignment was by no means trivial; several technical complications were added to the problem. They had to find the most profitable operation level of the top reservoir via a parametric study. In addition, the pump and turbine efficiencies were provided as functions of reservoir height, as would be the case in reality. Additionally, uncertainties in pipe length, reservoir height, pump and turbine efficiency, pipe roughness, the purchase and selling price of the electricity and the flow rate were also specified. Having completed this assignment, students not only had a solid understanding of the relevant equations, but they also understood the influence that each of the parameters (in the form of uncertainties) have on the system as a whole. They could therefore identify critical parameters that required more careful consideration during the design phase.

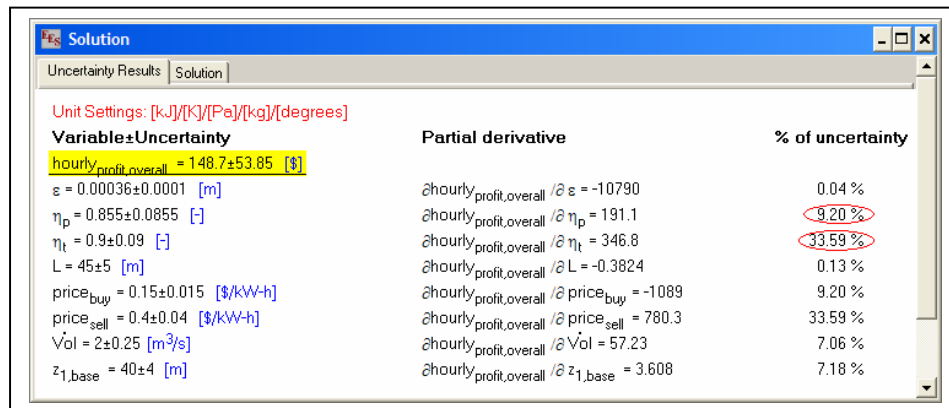


Figure 5. Results of a sensitivity analysis (utilising EES) ([21, 23])

The results of a sensitivity analysis indicated that the turbine efficiency is much more important than the pump efficiency. This result of the analysis is extremely important since the same turbo machine serves as a pump during the day, and as a turbine during the night. Hence, the machine could potentially be a more efficient turbine than pump or vice versa. The student will now understand that given these choices, it is obvious that the best machine choice will favour turbine efficiency and not pump efficiency. The student would also have discovered that the pipe roughness and length are not significant and can be compromised. Lastly, they had to contemplate the financial feasibility of such a system in practice and calculate the return-on-investment and provide an in-depth discussion on

their findings. From the results they learned that the selling price of the electricity or more critical than the purchase price and hence negotiations should focus on the selling price.

This type of assignment ensures a much more realistic, interesting and instructional way of doing homework problems than the traditional method of solving a problem with pen and paper, often arriving at meaningless answers. In addition, the students participated in an industrial visit to a coal-fired power station, which formed the highlight of the course (according to some student comments). The experience gained by physically seeing boilers, turbines, mills, the control rooms, cooling towers, smoke stacks and a large dredge operating in an open cast mine cannot be reproduced in a classroom or even a laboratory. They found it an awe-inspiring experience and a great source of inspiration allowing them to gain a deep appreciation of the theory and its relation to practice. It was overheard by a group of students, *“if I had seen this when I was a first year student, I would have been so motivated from the beginning that I would never have failed a single subject!”*

5 EMPLOYING AN ONLINE LEARNING SYSTEM (BLACKBOARD™).

Another major contributor to the teaching success of Thermodynamics 1 has been the use of the online learning system – Blackboard™(2007). Since assessments were done on a weekly basis and assignments on a fortnightly basis, student feedback was updated up to twice per week. The class test result was added to the online learning system (Blackboard) the same day, so that students could monitor their progress throughout the semester. Since students were able to monitor their progress regularly, they had regular and ample warning if they were not meeting the required standards. Furthermore, the Blackboard system was employed for submission of student assignments and hosted an inter-and intra faculty-student discussion forum. The discussion forum allowed students to get help online from lecturers, tutors, and fellow students, even after hours. The high degree of communication amongst students and faculty was evident in the “discussion forum” section of Blackboard and was considered to be an inter personal active approach to learning.

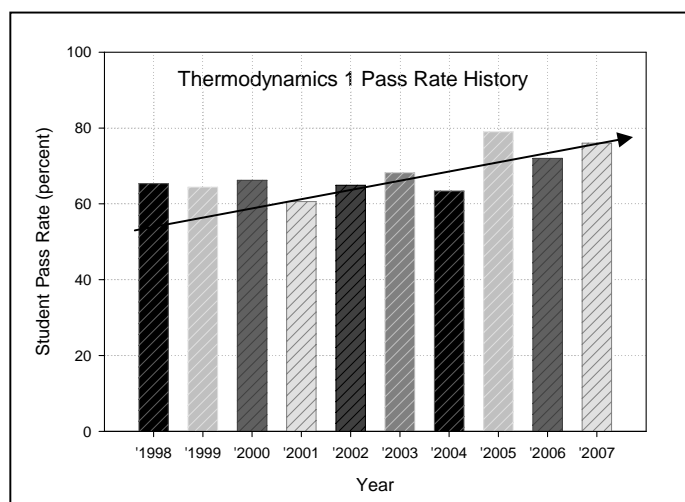


Figure 6. Improvements in Thermodynamics results.

6 OUTCOMES OF THE LEARNING STRATEGIES

The results for the subject, as far as pass-rate is concerned only varied marginally during this period. However, the results for 2005 show a 15% improvement on the average pass-rate of the previous years. Furthermore, on average, students have achieved substantially higher marks than in previous years. The success of the new Experiential Learning approach in terms of overall student pass rate is shown in Figure 6. It is evident that the pass rate remained constant from 1998 until 2004. However, in 2005 a 15% increase in the pass-rate was achieved (Figure 6). Whilst in subsequent years a slow increase in percent pass rate is becoming apparent. Further monitoring and analysis of the pass rate is required to determine if this approach is successful. Drilling into the individual data for the single years, there was a 25% increase in the number of distinctions and high distinctions (>75%) was achieved over the previous

year. The corresponding decrease in the students achieving passes and credits (>50%) indicate that a substantial portion of students from the 2004 and 2005 group have now performed successfully.

7 CONCLUDING COMMENTS

Student performance can be improved despite having low commencing student university entrance scores. It is possible to improve students' academic performance utilising both experiential and problem based learning strategies. The real-world environment is a challenging and engaging approach to student learning. They learn to analyse and solve real world problems. They become better at engineering design and synthesis. They become skilled in the use of engineering software tools.

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