The Importance of Mathematics and Statistics in Engineering

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Abstract

Mathematics is traditionally considered necessary for engineering courses. Over the last three decades the mathematics requirements for entry into engineering programmes has steadily weakened in Australia. Further, the mathematics component of engineering programmes has progressively decreased. This research aims to investigate the following two questions. Firstly, is mathematics a barrier for students to complete an engineering programme? And secondly, is performance in mathematics associated with performance in engineering?

We identified the significant factors associated with weighted average mark (WAM) and the completion status of engineering studies at both an undergraduate level and a Masters level. Of particular interest was the students mathematical background. Furthermore, a survey of students enrolled in engineering at the University of Western Australia was conducted to obtain more in depth views of student attitudes and perceptions towards how mathematics and statistics has affected their engineering studies. Binary logistic models were fitted to the survey data. Additionally, focus group interviews was conducted to gain insight on student perspectives of mathematics taught in their courses. The results are discussed in relation to the importance of mathematics and statistics for the engineering curriculum.

Keywords: Importance of Mathematics, Engineering completion rates, High School mathematics enrolment, Student performance.

Introduction

- Mathematics and statistics is a fundamental and key skill for engineers.
- Recently however, mathematics prerequisites in several university courses, including engineering, has been weakened [5].
- Many universities have softened their requirements for entry and this has necessitated an increase in the number of 'bridging courses'.
- Australian Mathematical Sciences Institute (AMSI) examined 268 undergraduate engineering courses from 34 Australian universities and found 38% of them did not have any mathematics requirements and 53% required only a intermediate mathematics prerequisite [5].
- This is a key reason for the decline in enrolments in intermediate and advanced mathematics in high school [6].
- Figure 1 shows an overall decline in the intermediate and advanced mathematics enrolments since 2008. Between 2008 and 2011 the percent enrolment in Intermediate and Higher mathematics dropped by 2%. Enrolments remained fairly steady from then on, with a slight increase between 2016 and 2018. The large decrease in 2020 was due to Queensland changing its Year 12 assessment from wholly school-based to a 50% external examination.
- Bell et al. [2] estimate that 50,000 engineers will be needed over the next few years. They also deduces that the problem is compounded by fewer students choosing to study intermediate and higher level mathematics at school, and a decline in the number of students opting to study engineering.
- In addition to a decline in the number of students choosing to study engineering, the retention rate in engineering course is low. Only 25% of students complete their study in minimum time, and only 50 to 60 percent of commencing students complete an engineering degree [1].

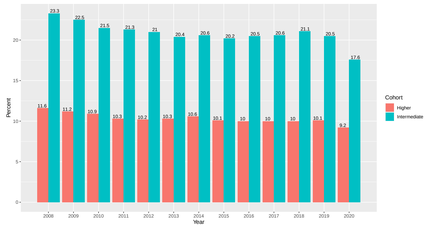

Figure 1: Enrolments in high school mathematics: percentage of year 12 students taking intermediate and higher mathematics.

Main Objectives

This study serves to compliment current literature by exploring variables related to the high school and university mathematics. We explore the importance of mathematics and whether it affects performance and retention of engineering students. This information is expected to inform universities and educators to implement strategies to help students and improve retention rates. Furthermore, it gives an Australian perspective to the current literature.

The primary aims of this project are as follows.

1. To investigate if performance in mathematics and statistics is associated with
   (a) overall performance of engineering students.
   (b) completion rate in the engineering programme.
2. To investigate student attitudes towards mathematics and their insight on how effective mathematics is taught in engineering.

Methodology

- The data for this research is university student-records for students who enrolled in an engineering programme at UWA in 2013.
- Surveys of students provided the second source of data.
- Interviews of individual students were conducted to obtain more detailed information on certain aspects of student attitudes towards engineering and mathematics.

The following statistical models will be fitted to the data.

1. A linear statistical model for WAM (Weighted Average Mark) [4].
2. A log-linear model for completion of undergraduate Engineering Science degree [3].
3. A log-linear model for completion of the Masters in Professional Engineering (MPE) degree.
4. A Principal Components Analysis based on the continuous variables in the data.
5. A k-means clustering based on the continuous variables in the data.

Results

Statistical Models

The following are the main findings based on the linear and log-linear statistical models.

1. A higher mark in first year university mathematics gives a higher WAM.
2. A 1% increase in WAM increases the odds of completing the undergraduate degree in engineering by 22%.
3. Taking a second year mathematics unit increases the odds of completing completing the undergraduate degree in engineering degree by a factor of 2.5
4.

The principal components analysis showed that:

1. students who perform well in mathematics in high school and university have higher WAM; and
2. students who complete the MPE do well in mathematics in high school and university.

The cluster analysis showed that three clusters best represented the data. Figure 2 shows a plot of the WAM against average mark in university mathematics mark, with the clusters superimposed.

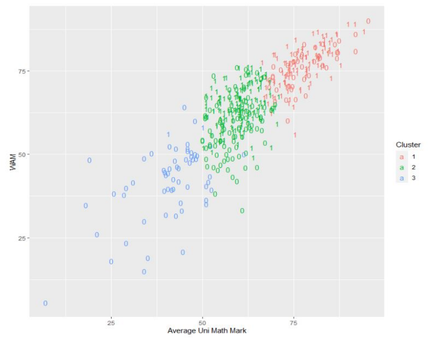

Figure 2: Plot of WAM against average university mathematics mark. Plotting character indicates MPE completion (1 = completed, 0 = not completed), colour coded by cluster number.

The following are key findings from the cluster analysis.

1. The first cluster contains students who have a high WAM, most above a 70. Almost all of the first cluster has completed their undergraduate (92%) in engineering and a good majority (72%) completing their MPE. This cluster mostly contains students who took the advanced mathematics (MAS3CD) whilst also performing well in it with a majority averaging above 70.
2. The second cluster contains students with mid range WAM, between 60 and 80. This cluster has a lower proportion of students completing their undergraduate (72%) and MPEs (60%) compared to the first cluster. Students in this cluster took the advanced MAS3CD (45%) or the intermediate MAT3CD (44%) and have an average mark of between 60 to 80 in their high school mathematics.
3. The third cluster has students with lower WAM, with most below 60 WAM. The cluster also has low rates of completion, with 15% completing undergraduate and only 3% completing MPE.

It is interesting to note that only the first cluster contained students with a WAM of above 80.

Survey Results

The main findings from the responses to attitude questions are:

1. 71% found mathematics enjoyable.
2. 55.7% found mathematics difficult.
3. 90% agreed that mathematics is important for engineering.
4. 80.3% said mathematics enhanced understanding of engineering.
5. For a student enjoys mathematics the odds of completing the undergraduate degree in engineering is higher by a factor of 20 , and by a factor of 3.5 for the MPE.

Conclusion

1. Performance in Mathematics at both high school and university is positively correlated with performance in engineering.
2. Completion rates for engineering are much higher for students who perform better at mathematics and for those who enjoy mathematics.
3. Mathematics enhances understanding of engineering.
4. Students who do not take the higher mathematics in High School have much lower rates of completion of the engineering degree.
5. Mathematics is a barrier to completion of the engineering programme.

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