Factors Influencing Student Success in Engineering Mathematics

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Introduction

Higher education in Australia has expanded rapidly over the last few decades, with a significant growth in university participation from 31,753 tertiary students in 1949 to 695,485 in 2000 (Department of Education and Training, 2001), and over one and half million (1,513,383) in 2017 (Department of Education and Training, 2018b). Universities are increasingly inclusive, with numerous entry pathways available to applicants of all ages and backgrounds who do not have recent secondary educational achievement. The majority who apply to university are admitted, with over 80% of applicants admitted each year since 2010, and 84% in 2018 (Department of Education and Training, 2018a). Only one in four domestic undergraduate students (26%) were granted admission to their course based on their Australian Tertiary Admission Rank (ATAR) in 2016 (Pilcher and Torii, 2018), and of those, the number admitted with low ATARs is increasing (Norton, et al. 2018). .

There are several issues which have arisen with the growth in the university participation and the relaxation or removal of entry requirements, with more students struggling academically (Lacy, et al, 2017). Low-ATAR students, for example, have less satisfactory outcomes than other higher education students, as they are more likely to obtain low marks, fail units, and if they complete their qualification, less likely to find professional employment or earn high salaries (Norton, et al, 2019). For the 2010 commencing student cohort, only 66% cent of the students had completed a course after six years, which is the lowest completion rate since the measure was initiated (Department of Education and Training, n.d.).

The secondary school mathematics curriculum varies within Australia. Some states do not require students to study mathematics in Year 11 and 12, while the majority of states only require one unit of mathematics to be undertaken in those senior years. Secondary mathematics in Australia can be broadly classified into three tiers (Dekkers, et al, 2000): high (such as extension mathematics units in NSW), intermediate (such as advanced mathematics in NSW), and low level (including general mathematics in NSW). There has been a decline in the participation in most Year 12 mathematics subjects in Australia, and higher level mathematics subjects are often replaced with lower level ones, with a change in participation from 1994–2013 of -7% for advanced mathematics, -11% for intermediate mathematics, -7% for physics, and a subsequent increase in entry level mathematics of 11% (Kennedy, et al, 2014).

As a result of the changing profile in mathematics participation at the secondary level, there are less students that have completed and are competent at higher level secondary mathematics and physics. Australia's mathematical literacy is decreasing, with the international ranking and Programme for International Student Assessment (PISA) score declining in mathematics (Thomson, et al, 2017a). Australia's performance declined significantly (by 30 points) between 2003 and 2015 (Thomson, et al, 2017a) There is also a generally negative attitude towards mathematics demonstrated by Australian students, as evidenced by the Trends in International Mathematics and Science Study (TIMSS), which found 50% of Year 8 students do not like learning mathematics (Thomson, et al, 2017b). Australian research has shown that both prior achievement and attitude towards mathematics are a significant predictors of mathematical achievement in secondary school (Hemmings, et al, 2011).

Students also enrol in university at different stages of life, with 32% of commencing students aged 25 or above in 2017 (Department of Education and Training, 2018c). Mathematics is a skill, which like many other skills, such as languages, requires frequent regular use to maintain fluency. Students who have not undertaken formal education for a number of years are likely to find their skills have declined due to lack of use in the intervening time, which presents challenges in refreshing their skills while they learn new content which is dependent on previous competencies.

Due to the factors discussed above, such as the declining rates of secondary mathematics participation, a resulting decrease in competency, multiple university entry pathways and a reduction in the entry requirements, students entering engineering degrees at Australian universities do not necessarily have the current background mathematics skills or fluency required for success at the more technical areas within an engineering degree.

This research investigates the factors related to the educational background of students which may predict success rates for the mathematics units in an undergraduate engineering degree at Southern Cross University. The insights into the predictors of success will be extremely beneficial in developing strategies to support students, enabling resources to be targeted to the student cohorts who are most at risk of not successfully completing the mathematics units, which are a compulsory component of the engineering degrees.

Methodology

Data for student admissions into the engineering degrees at Southern Cross University for 2013-2019 were analysed. The data includes student background, such as university admission basis, age at enrolment, years between enrolment in the engineering degree and completion of secondary school, and the secondary school mathematics level undertaken. The results from the engineering degree are considered, such as the current Grade Point Average (GPA), number of units failed and course completion status. In addition, the specific results for the mathematics units are analysed, including the number of mathematics units attempted and the results achieved in those mathematics units, such as grade, the number of those units passed and the GPA for those units. The mathematics units within the engineering degrees are the units that only teach mathematical content, including areas such as algebra, statistics, calculus, and linear algebra. The data considered included students admitted from 2013-2019, as at April 2019, with the criteria of at least one finalised attempt (i.e. not currently enrolled) for one of the mathematics units.

Secondary school mathematics subjects have been classified into three levels for the analysis: high (which are the extension mathematics units in NSW), intermediate (currently advanced mathematics in NSW), and low level (general mathematics or standard mathematics in NSW).

The data has been analysed to establish whether the educational background factors are predictors of success in the mathematics units in the engineering degree. The metric used to represent success in the engineering mathematics units was the proportion of failed attempts (i.e. not a passing grade) of the total finalised attempts (i.e. excluding current unit enrolments). The analysis was conducted with linear regression and correlations in IBM SPSS Statistics 25.

Results

To examine the relationship between different variables and success rate in engineering mathematics and the engineering degree generally, linear regressions were conducted. All assumptions were satisfied for each regression, and the potential predictor variable(s) were entered as the independent variable(s) with the proportion of failed mathematics units as the dependent variable. In addition, measures of success in the engineering degree generally, such as GPA or total units failed, were also considered as the dependent variable, with the results discussed below.

The analysis found that age at commencement, years between high school and enrolment, and whether high level mathematics was undertaken at high school predicted the successful completion of the mathematics units in the engineering degree (F (3, 159) = 4.82, $p < .003$, $R^2 = .085$).

In addition, the ATAR was a strong indicator of success, with the ATAR by itself, and in conjunction with other parameters, predicting a number of student success measures, including the successful completion of the mathematics units.

Figure 1 shows the average proportion of mathematics units passed in the engineering degree by ATAR. As can be seen in the graph, the success rate in the mathematics units is substantially lower for students with no ATAR or an ATAR under 60. The ATAR is a number between 0 and 100, although ranks below 30 are not generally reported.

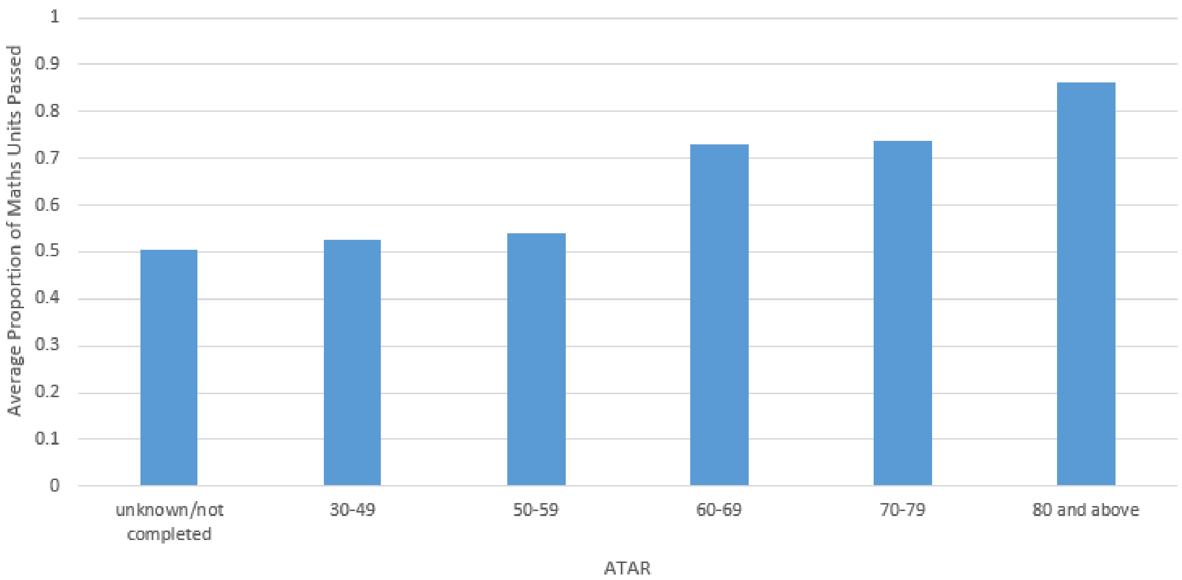

Figure 1: Average Proportion of Mathematics Units Passed by ATAR

Due to the different entry pathways, only 57% of students had an ATAR in the student system, however for the students that had an ATAR, this was a very strong predictor of success in the mathematics units at university. ATAR itself predicted total units failed (F (1, 112) = 13.807, $p < .000$, $R^2 = .111$), success in the mathematics units (F (1, 112) = 18.0, $p < .000$, $R^2 = .14$), and Course GPA (F (1, 112) = 12.912, $p < .001$, $R^2 = .113$). Together, ATAR and whether the high level mathematics was undertaken at secondary school predicted both course GPA (F (1, 112) = 6.709, $p < .01$, $R^2 = .118$), and success in the mathematics units (F (1, 112) = 9.947, $p < .000$, $R^2 = .153$). In the most noteworthy model, ATAR, age at commencement, and years between high school and enrolment strongly predicted the successful completion of the mathematics units in the engineering degree (F (1, 112) = 10.183, $p < .001$), and the predictors together accounted for 22.5% of the variance in maths units completed in the engineering degree.

Figure 2 shows the average of proportion of mathematics units passed in the engineering degree on the basis of entry into the course. The statistical analysis found that entry basis, however, was not a significant predictor of success in the tertiary mathematics units (F (5, 199) = .793, $p < .556$). This may be due to variability within the entry basis options, for example, entry based on secondary education can be due to an ATAR, completing a head start unit at university or an early admission scheme, such as STAR, with a principal's recommendation.

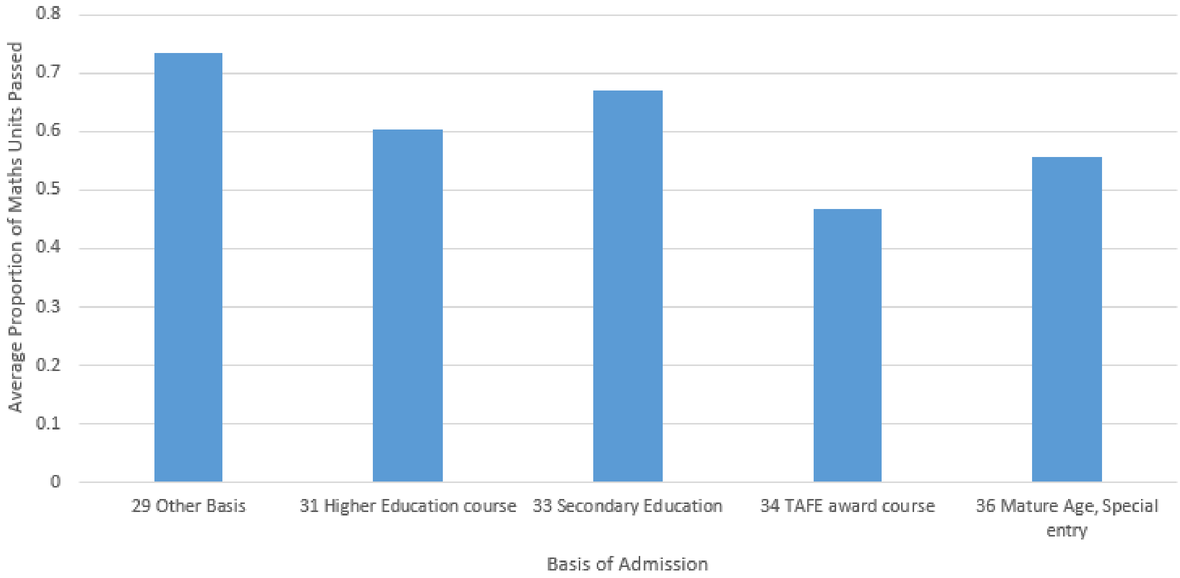

Figure 2: **Average Proportion of Mathematics Units Passed by Entry Basis**

The age of the student and the years between completing secondary school and enrolment in the engineering degree were both found to be significant predictors of success in the mathematics units at university, as discussed above. Figure 3 and Figure 4 show the average proportion of tertiary mathematics units passed considering age at enrolment year, and years between completing secondary school and enrolment in the engineering degree, respectively. The years between school and enrolment is not able to be calculated for students who did not complete secondary school, and these are within the unknown/not completed grouping.

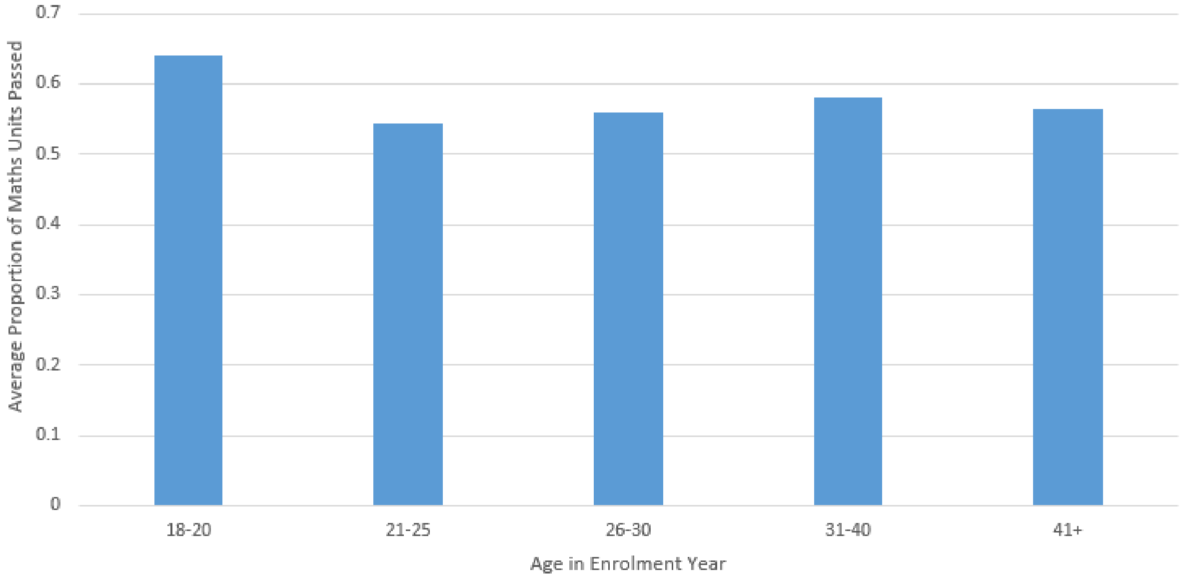

Figure 3: **Average Proportion of Mathematics Units Passed by Age in Enrolment Year**

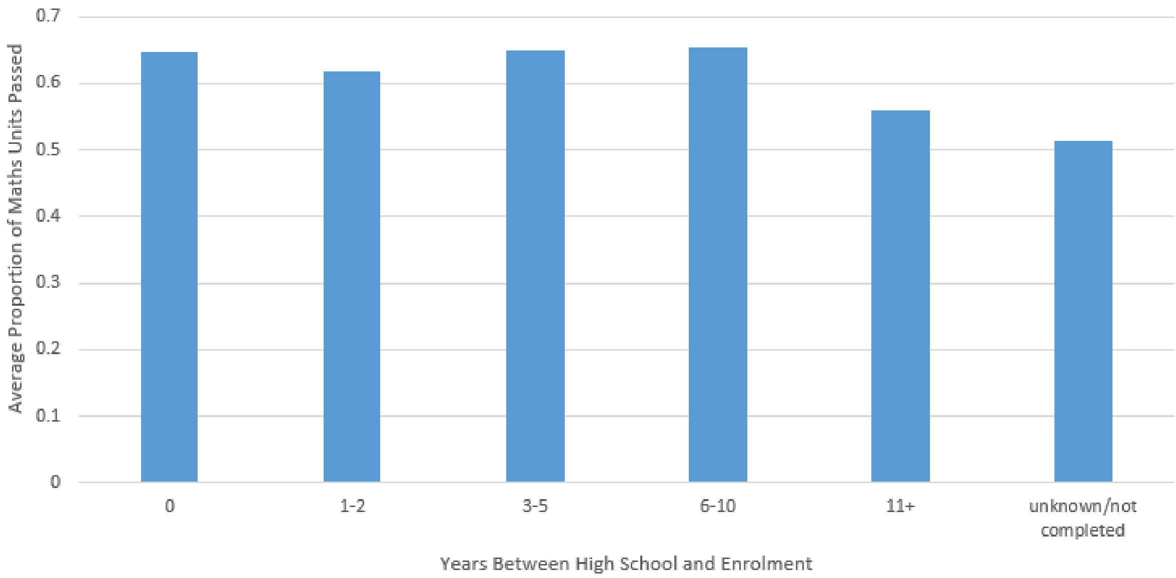

Figure 4: Average Proportion of Mathematics Units Passed by Years Between Completing High School and Enrolment

That the age of the student and the years between completing secondary school and engineering enrolment were both found to be predictors of success in the mathematics units is likely to relate to the students' fluency in mathematics. Even if a student did mathematics in high school, if a student has not performed mathematical calculations for a number of years, they are likely to be 'out of practice', which will impede their ability to build on the prior knowledge, and may influence their success rate. The statistical analysis also found that the age at commencement is a predictor of overall course GPA (F (1, 167) = .8.222, $p < .01$, $R^2 = .047$). This indicates that mature age students may benefit from additional support during their studies to achieve positive outcomes.

The average proportion of tertiary mathematics units passed considering the level of secondary school mathematics is shown in Figure 5, indicating a substantially higher success rate for students who did a high level of mathematics at secondary school.

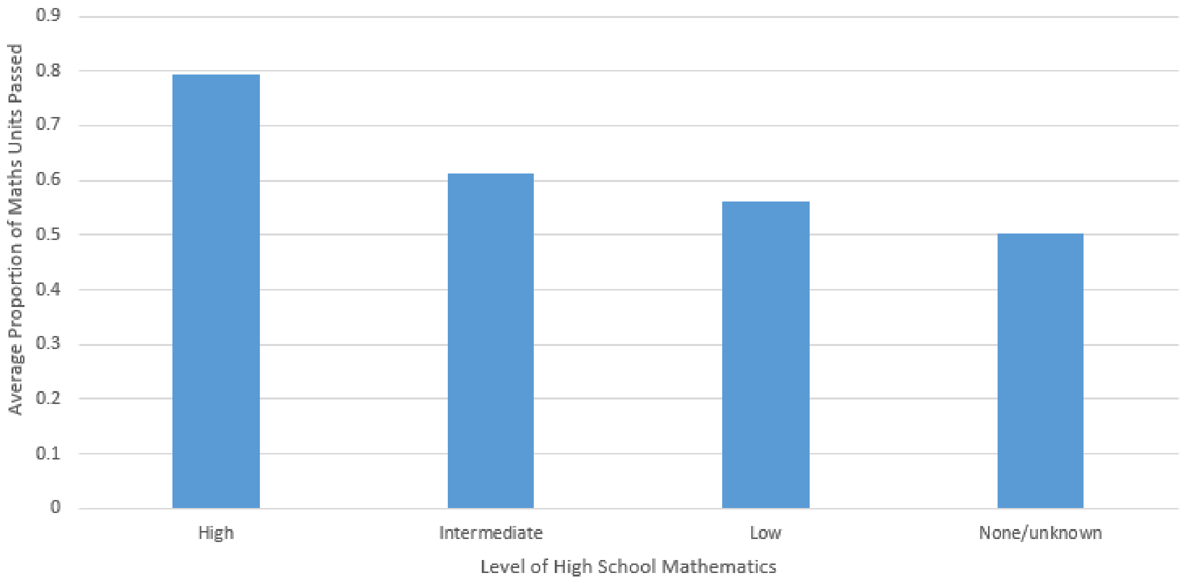

Figure 5: **Average Proportion of Mathematics Units Passed by Level of High School Mathematics**

The results considering the secondary school mathematics level are interesting, with the statistical analysis finding the completion of a high secondary mathematics level was a significant predictor of success in the mathematics units at university. The predictor was not the level itself (i.e. no mathematics, low level, intermediate level or high level), however, but whether the high level was done or not (i.e. high level versus all other levels) as the analysis found the high level mathematics was the only predictor that accounted for significant unique variance. Undertaking the high level mathematics at secondary school by itself is a predictor of overall course GPA (F (1, 167) = .5.598, $p < .05$, $R^2 = .033$), and success in the engineering mathematic units (F (1, 199) = 10.495, $p < .001$, $R^2 = .05$).

This suggests that choosing an intermediate level versus a low level secondary school mathematics subject will not substantially increase the likelihood of success in engineering mathematics at university, however, choosing the high level versus any of the other levels will. This is irrespective of the actual achievement at the higher level secondary mathematics, which suggests it is the exposure to the mathematical concepts that is important, enabling these to be built upon during the tertiary units. This supports the view that it is the high level secondary mathematics courses that provide the specialised knowledge-base required for tertiary studies in courses such as engineering. The result may also be related to mathematical confidence, in that students who do attempt a high level of mathematics at high school are less intimidated or anxious about mathematics, however further research is required to explore this possibility.

This result appears to be contradictory to the advice that is often given to students at high school, which is to undertake lower level mathematics unit, so they obtain a higher overall result and a better ATAR. With the numerous entry pathways to university study, and the majority of applicants being admitted, it appears that it would be more beneficial for students considering engineering to undertake a higher level of secondary school mathematics, regardless of how well they do at this subject, in order to increase their likelihood of success at the mathematics components at university.

Conclusions and Recommendations

The analysis of student background factors and unit outcomes identified that for engineering students, the age at commencement, the years between high school and enrolment, and whether high level mathematics was done at secondary school are predictors of successful completion of the mathematics units in the engineering degree.

For the students with an ATAR, it was a very strong predictor of success at university. ATAR and whether high level mathematics was completed at high school, predicts both course GPA and success in the mathematics units. In the most significant result, ATAR, age at commencement, and years between high school and enrolment strongly predicts the successful completion of the mathematics units in the engineering degree. The success rate in the mathematics units is substantially lower for students with no ATAR or an ATAR below 60.

This information is extremely beneficial in developing strategies to support the students, and attempting to improve the success rates in the mathematics units and the engineering degrees. Those particular student cohorts most at risk of not successfully completing the mathematics units can have targeted invention strategies with additional support.

This research also assists in understanding what entry requirements may be implemented to support good student outcomes. For example, the analysis indicated that providing additional support or implementing entry requirements on the basis of entry alone is not the most efficient use of the resources and may not have a substantial impact on student success. Providing additional mathematics support or bridging courses to mature age students, students with a low or no ATAR, or students without the high level of secondary mathematics is more likely to have an impact on the success rates in mathematics.

Importantly, what the research found was that secondary education is a vital part of a student's mathematical development and high school students should be encouraged to extend themselves to focus on concept exposure and learning, particularly considering the myriad of university entry pathways available.

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