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Mathematics in a Practice-Based Course: Entry Requirements and Diversity

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STRUCTURED ABSTRACT

CONTEXT

In the Bachelor of Engineering Practice (Hons) degree, all learning occurs in industry-led projects with no lectures or exams. This requires a novel way to support the teaching and learning of fundamental content such as mathematics and physics, with a scaffolded, just-in-time teaching approach delivering content as needed for projects, for which a system of credentials has been developed.

PURPOSE

The credential system spans the entire curriculum, covering both technical and professional skills, but has interesting features for engineering mathematics education in particular. The distribution of mathematical content throughout the course provides more time for students to master mathematical knowledge and develop mathematical competencies, allowing mathematics entry requirements to the course to be reduced. There is a decline in students taking higher level maths courses in secondary education and a known gendered and socio-economic status component to mathematics course selection, thus the removal of higher level mathematics prerequisites aims to increase diversity in the student cohort.

APPROACH

A longitudinal mixed-methods study is being conducted investigating the choices of and influences on selection of year 12 maths courses, the maths achievement and anxiety of students and their progress through the Bachelor of Engineering Practice course. This paper presents the preliminary results from the first cohort of students.

RESULTS

Of the first cohort of students entering the course, 35% had not undertaken the higher-level maths courses traditionally stated as an entry requirement to engineering. Credentials are marked as either achieved or not yet achieved rather than graded and multiple evidence submissions are allowed, reducing the effects of maths anxiety and allowing students to progress through the course at a pace that suits them. To date there has not been a significant correlation between the level of maths studied at high school and the progression through the credentials, with most students resubmitting evidence multiple times before achieving the credentials regardless of their prior levels of study.

CONCLUSIONS

The distribution of mathematical content throughout the course, coupled with the flexible pathways, timing and ability to resubmit, removes the barrier of higher level mathematics entry requirements to the course and opens up engineering as an option to a more diverse cohort.

KEYWORDS

Diversity, micro-credentials, just-in-time teaching, mathematics education

Introduction

The mathematics entry requirements to engineering degrees is a long contested topic, with calls for both lower and more stringent requirements from a variety of voices. The lack of mathematical preparedness is considered a barrier into studying engineering in higher education (Eleri et al., 2007) with many engineering courses starting with mathematics-based units and ending with more project-based studies. There is both an Australasian and broader international issue, sometimes dubbed the “maths crisis”, with numbers of secondary students electing to study higher level mathematics is declining, leading to a smaller pool of students meeting the entry requirements traditionally attached to engineering degrees. Forgasz & Leder (2017) found that younger groups (defined in their work as aged under 40) were more likely to hold traditional gendered stereotypes about maths than older groups, thus the gender gap in higher-level secondary maths uptake is a problem likely worsen without intervention.

Mathematics is known to be a subject with intense gendered stereotypes, social stigmas and pressures (Forgasz, Leder, & Kloosterman, 2004; Nosek et al., 2009). This paper describes the connection between diversity and year 12 maths course selection in the context of a practice-based degree in which maths content is delivered in a novel, credential based way.

Mathematics course selection and diversity

There are many intersecting factors that affect student course selection at higher levels of secondary education and many of these are closely linked to issues of diversity, equity and inclusion. In this paper year 11-12 maths courses are described using the classifications elementary, intermediate and advanced as defined by Barrington and Brown (2005). In Australia there are clear patterns in the female:male ratio of students selecting mathematics courses at each level, from approximately 1:1 or even a slightly higher proportion of females at the elementary level, to 3:4 at intermediate level and 1:2 at the advanced level (Forgasz, 2006).

In Australia, the proportion of students enrolled in year 12 who choose not to study maths has remained roughly constant over the past decade, with approximately 20% of female and 10% of male students studying no maths subjects in their final year of high school. Students enrolled in intermediate and advanced level maths courses has declined over the same time period (Barrington & Evans, 2016). While the decline is slightly less for female students compared to male students resulting in the proportion of female students increasing, the proportion of the whole year 12 population opting to study higher level maths is steadily dropping, with just 18.3% of female and 20.6% of male year 12 students studying the intermediate maths course usually required for engineering tertiary studies in 2016 (Li & Koch, 2017).

The diversity issues with maths are also not limited to gender. In fact, even more, significant differences in mathematics achievement regarding performance in standard testing arises from socio-economic factors than does from gender (Peard, 2002). School socioeconomic status (SES) has consistently been associated with achievement in mathematics regardless of an individual’s SES. (McConney & Perry, 2010). SES inevitably intersects with other factors such as rural location (Webster & Fisher, 2000) and cultural background. Indigenous students are amongst the most disadvantaged in mathematics education (Atweh et al., 2004), finding little relevance in the Eurocentric teaching of mathematics with teachers who often do not believe in their student’s abilities (Matthews et al., 2005) and receiving lower marks on standardised testing (Meaney, McMurchy-Pilkington, & Trinick, 2012).

There are also individual student factors which affect maths selection and performance such as maths anxiety, defined as the tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations (Richardson & Suinn, 1972), with students with high maths anxiety often avoiding higher level subjects.

It is clear that mathematics achievement and the selection of intermediate and advanced courses at secondary level are highly affected by the background of the students. Higher level maths as an entry requirement can therefore be perceived as a barrier to entering engineering as a higher education field of study. This suggests that lowering the prerequisite mathematics entry requirements to tertiary engineering courses could potentially improve the diversity of student cohorts and eventually of the profession.

Context

The need for intermediate or advanced maths subjects being prerequisites for tertiary engineering courses arises from the frontloading of maths topics into the first year or couple of years of engineering degrees. The Bachelor of Engineering Practice at Swinburne University has a very different course structure, removing this barrier. In this degree, students work on projects from day one throughout their course of study. This requires a novel way to support the teaching and learning of fundamental content such as mathematics and physics, with a scaffolded, just-in-time teaching approach delivering content as needed for projects, for which a system of credentials has been developed. Credentials are small, online modules and the credential system spans the entire curriculum, covering both technical and professional skills.

The maths content, along with the rest of the curriculum, is delivered through the credentials. Maths credentials are mapped to projects and maths content is thus distributed across the entire four years of the degree. This extends the period over which students study and absorb the maths content, therefore higher level prerequisites are not required for entry to the course. Credentials provide just-in-time content delivery but are different from merely being small modules in many ways (Cook, 2018). Credentials are assessed through applied tasks which are marked against a list of criteria related to the learning outcomes of the credential using a rubric. For a student to achieve the credential, they must provide evidence of being proficient in all the stated criteria. Credentials are not graded but are either achieved or not yet achieved and multiple submissions are allowed so students can progress at their own pace. The lack of examinations and flexible progression aim to reduce maths anxiety as alternative methods of evaluation have been suggested as a means of ameliorating maths anxiety (Miller & Mitchell, 1994).

The method of evidencing credentials against criteria also allows a variety of mathematical competencies to be included, beyond the typical knowledge, recall and basic applications that can be tested in exams. There are eight separate mathematical competencies as defined by Niss (2003), (thinking mathematically, posing and solving mathematical problems, modelling, reasoning mathematically, representing mathematical entities, handling symbols and formalisms, communicating in, with and about mathematics and making use of tools and aids) all of which are explicitly included in credential criteria.

Study

This paper presents the preliminary results from the first cohort of students in the Bachelor of Engineering Practice course. A longitudinal mixed-methods study is being conducted investigating the choices of and influences on selection of year 12 maths courses, the maths achievement and anxiety of students and their progress through the course. To understand their choices and influences semi-structured interviews were conducted during the course induction to explore complexities of the student experience. The data from this part of the study will be presented in future papers.

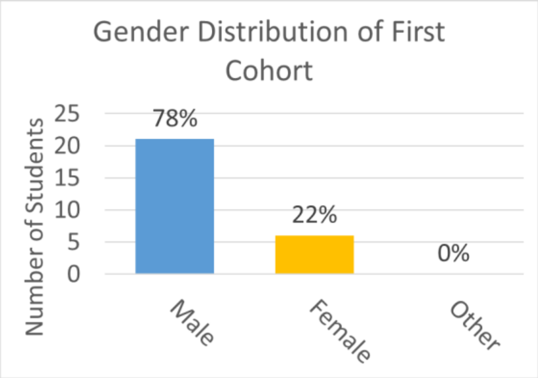
The tool used to measure maths anxiety was the abbreviated maths anxiety scale (AMAS) (Hopko, Mahadevan, Bare, & Hunt, 2003). The AMAS tool was selected as it has been shown to be as reliable as the original Maths Anxiety Rating Scale (MARS) designed by Richardson and Suinn (1972), but with only 9 questions compared to 92 it presents a significantly lower participant burden. The AMAS can also be divided into learning anxiety and evaluation anxiety components. This is relevant for this context as this course has no exams, thus future research will investigate if more students enter the course with higher overall anxiety or, in particular, higher evaluation anxiety.

A diagnostic test using paired questions was used as a measure of maths achievement on entry to the course (adapted from Carr et al. (2013a) and Carr et al. (2013b)). The maths anxiety survey was conducted immediately prior to the diagnostic test. Demographic data was also collected from students regarding their gender and the school they attended which was used to compare whether students came from single-sex or co-educational environments and for the ICSEA (Index of Community Socio-educational Advantage) value of the school (ACARA, 2015), which was used as an indication of SES. Although the ICSEA is a measure of the whole school community and not the individual student, the findings of McConney and Perry (2010) indicate that school SES correlated with mathematics achievement regardless of the individual’s SES so ICSEA can be considered an appropriate measure.

Results

Student Cohort

The first cohort on entry had 27 students of which 6 identified as female. Of the 6 female students, 5 had attended single-sex school, the other a co-educational school (see figure 1).



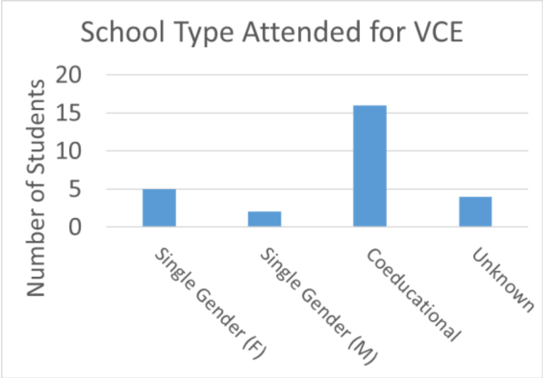


Figure 1: Demographic data from first student cohort

The ICSEA scores of the schools attended by students in year 12 were all above the national mean (figure 2) with 4 students (15%) coming from schools below the local median.

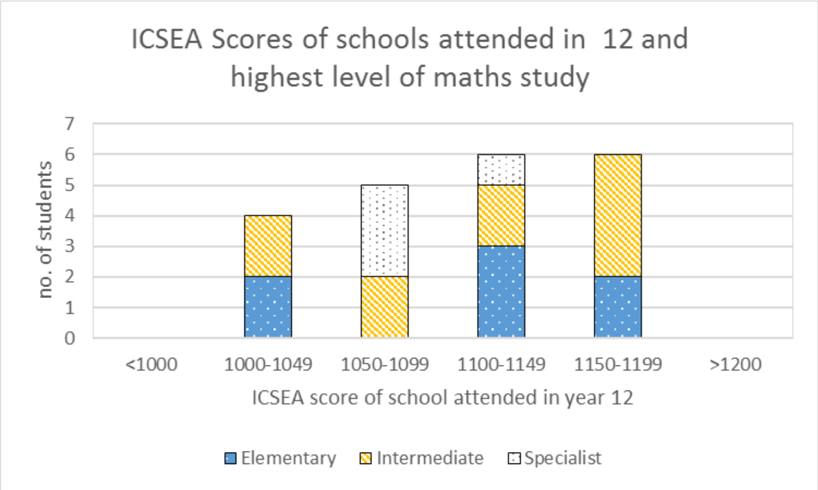


Figure 2: ICSEA scores of school attended in year 12 by highest level of maths studied in year 12. (National Median =1000. Melbourne Median =1040). Higher scores represent higher socio-economic advantage.

In this first cohort there is no relation between the ICSEA score of the student's school and level of maths studied. This will be examined in future cohorts to see if lowering the entry requirements to elementary maths removes a barrier for low SES students.

Diagnostic Test and Maths Anxiety Results

Test scores were calculated separately both including and omitting the 4 pairs of questions related to calculus, as those students whose highest level of study were elementary courses would never have seen this topic (figure 3 and table 2).

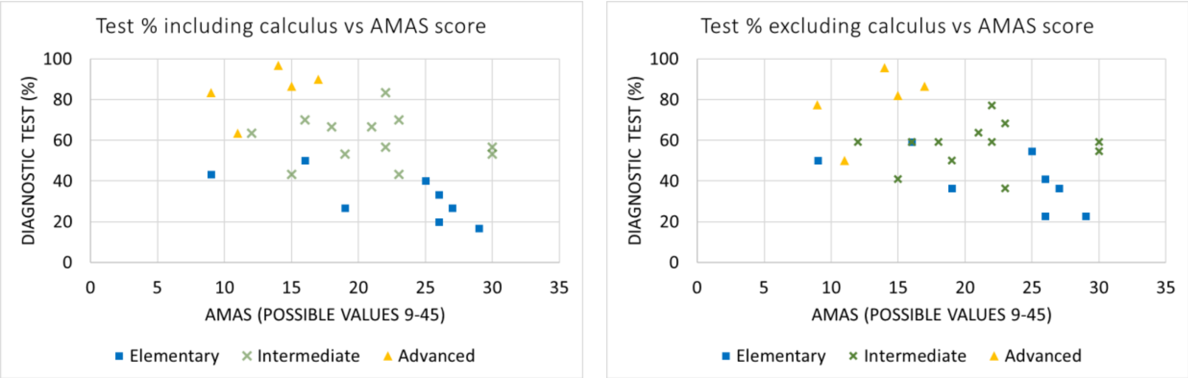


Figure 3: Diagnostic test results plotted against AMAS (maths anxiety) score.

There is a slight negative correlation between diagnostic test result and maths anxiety. For this study there correlation was -0.47 including calculus, -0.41 omitting calculus. This is a slightly stronger correlation than found in other studies (Ma, 1999) but with this small sample it is not possible to draw conclusions from this. As with the cohort data, this data will be used as a baseline from which to study future cohorts.

Table 2: Diagnostic test and maths anxiety results by highest level of maths studied in year 12.

	Elementary	Intermediate	Advanced
Highest level maths studied in year 12 – number of students (of which female)	9 (3)	12 (2)	5 (1)
Mean diagnostic test % (including calculus)	31	61	84
Mean diagnostic test % (excluding calculus)	40	57	78
Mean maths anxiety score (AMAS)	22	21	13

With only six female students it is also not possible to draw conclusions about trends in test performance or maths anxiety relating to gender, though the female students have comparable maths anxiety scores to the male students (see table 3).

Table 3: Maths anxiety results by gender

	Mean AMAS	Standard Deviation
Female	19.3	6.1
Male	19.8	6.0

Discussion

35% of the cohort had studied only elementary mathematics courses at year 12, thus would not meet common entry requirements to tertiary engineering courses. This group did not differ from the group who had studied intermediate courses in terms of maths anxiety, though their mean diagnostic test score was lower. The advanced maths group had significantly lower maths anxiety compared to the other two groups. As expected, those who had studied higher level maths performed better on average in the diagnostic test, though there was some overlap between all three groups when the calculus questions were omitted. With only six female students it is not possible to draw conclusions about trends in test performance or maths anxiety, though it is worth noting that if the entry requirements were set at intermediate maths the cohort would have been only 17% female compared to its current proportion of 23%.

Progress through credentials has been difficult to ascertain in terms of maths progress for a number of reasons. Most credentials are not achieved by students on their first attempt, a phenomenon seen across the curriculum and not just in maths. The number of re-submissions needed to achieve the credential also appears to have many influences with issues including students in their first year getting used to the idea that they need to meet all criteria, general time-management and navigating the Learning Management System. The need to meet all criteria has in particular taken time to adjust to, as they are used to grades. For example, not being proficient in one criterion out of ten would not would be 90% thus appears to be a high mark, though in this system it means the credential has not yet been achieved.

Further study is needed to develop metrics to measure progress in this course. In terms of raw numbers of credentials achieved, no particular patterns of progress have emerged. It is also worth noting that, due to the particular projects in this first year, none of the maths modules mapped to these projects contained calculus and instead there was a focus on algebra and statistics. This will not be the case every year, so the particular credentials needed will also influence progress in different cohorts and there may or may not be more visible effects in this cohorts next year of study.

Conclusions and Future Work

There is a strong link between maths achievement, subject choice and diversity. Maths entry requirements to the Bachelor of Engineering Practice degree have been lowered to include elementary maths subjects to redress this inequity. This has been possible due to the structure of the course which distributes maths throughout the degree by mapping small, modular credentials to projects. Preliminary data from the first cohort entering this course indicate there is no difference in levels of maths anxiety between those who had studied elementary and intermediate maths subjects, though anxiety was significantly lower in those who had studied advanced maths. The advanced maths students performed better in the diagnostic test on average, but there was overlap between the three groups in terms of diagnostic test results. Further work is needed to develop metrics to assess progress in terms of mathematical development during the course. Future research will also describe the reasoning and influences that led these students to select each particular level of maths course and will follow future cohorts to examine how maths entry requirements affect the diversity of the cohort.

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