The association between secondary mathematics and first year university performance in health sciences

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In recent years, there has been a significant decline in the rate of participation in secondary school mathematics courses within Australia, particularly in advanced or higher level mathematics. The aim of this study was to investigate how grade point average (GPA) differed between five health science degrees at an Australian university. The association between Australian Tertiary Admission Ranking (ATAR), the level of mathematics completed at secondary school and GPA was also investigated. Results showed that students studying Biomedical Sciences and Physiotherapy had significantly higher GPA and ATAR than students studying Exercise and Sports Science, Physical Education, and Nursing. A higher percentage of Biomedical Science, and Physiotherapy students undertook advanced mathematics (3C3D MAT) at secondary school than students in the other three degrees, who recorded lower secondary school mathematics result scores from an intermediate or elementary mathematics course studied (3A3B and 2C2D MAT, respectively). The results of this study accord with published literature from other university courses that the decline in numbers of students opting to undertake a higher level of mathematics at secondary school will impact negatively upon their first year university performance.

Introduction

There has been a significant decline in the rate of participation in secondary school mathematics within Australia. Participation in both intermediate and advanced mathematics has fallen by 11% and 7% respectively, in the period from 1994 to 2012. This decline has been met with an increase in entry level mathematics participation over the same period, indicating students are electing to study a more basic level of mathematics instead of more advanced mathematics topics such as calculus (Kennedy, Lyons & Quinn, 2014). This study examined first year student performance data from the Schools of Health Sciences, Physiotherapy, and Nursing and Midwifery at The University of Notre Dame Australia. At this university, the School of Health Sciences offers undergraduate degrees in Biomedical Science, Exercise and Sports Science, Physical Education, and other broad health-related degrees. The Schools of Physiotherapy and Nursing and Midwifery offer undergraduate degrees in physiotherapy and nursing, respectively. A traditional entry pathway into one of these degrees involves the successful completion of Year 12 and obtaining a requisite Australian Tertiary Admission Ranking (ATAR) score, which has been calculated with four or more Stage 2 or Stage 3 courses of study. While students can enter these degrees with any combination of secondary school courses of study, competency in English is a prerequisite. However, completion of secondary mathematics is not a pre-requisite for entrance into tertiary education, resulting in wide-ranging proficiency levels in mathematics amongst university applicants.

The aim of this study was to investigate how grade point average (GPA) differed between the five degrees offered in Health Sciences at The University of Notre Dame Australia (Fremantle campus), and if GPA was related to the completed mathematics level at secondary school. In the United States, the use of a GPA to calculate and report academic performance is common practice, and according to Bacon and Bean (2006), GPA has been used as a controlled covariate to gain insights into other relationships across a wealth of studies. In addition to GPA, between-degree differences in the level of mathematics studied at secondary school were also examined.

Literature review

There are two themes which comprise the literature review for this paper, namely: the importance of mathematics in tertiary education, and the evidence concerning the relationship between ATAR scores and first year university academic performance. These themes will now be explored.

The importance of mathematics in tertiary education

The study of mathematics has been frequently cited as highly important for a range of disciplines in tertiary education, including engineering, business and finance (Hine et al., 2016) as well as agriculture, pharmacy and economics (Nicholas et al., 2015). In addition, mathematical competency is considered an integral component of many scientific and clinical undergraduate degrees (Hall & Ponton, 2005; Koenig, Schen, Edwards & Bao, 2012; Nakakoji & Wilson, 2014), and an ability to apply mathematical and statistical thinking in the context of science is an issue requiring urgent attention (Belward et al., 2011). Specifically, mathematical skills and knowledge have been regarded by scholars as essential for students undertaking university study in health sciences (Hine, Anderton & Joyce, 2015; Anderton, Evens & Chivers, 2016) and nursing (Galligan, Loch & Lawrence, 2010; Wright, 2007). McNaught and Hoyne (2011) suggested that those mathematical skills, which can be applied broadly across various courses, include representation, interpretation, reasoning, problem solving, and analytical skills.

While the importance of mathematics for tertiary education has been firmly established within the literature base, researchers have also underscored how university success depends on the level of mathematics studied at secondary school (Nicholas, Poladian, Mack & Wilson, 2015). For instance, researchers at an Australian university found considerable differences within a cohort of first-year students enrolled in a health science degree (Hine et al., 2015) and in health sciences degrees (Anderton, Hine & Joyce, 2017). Irrespective of gender, it was determined in both projects that those students who had studied a more difficult mathematics pathway at secondary school attained a significantly higher GPA than those who had taken an easier mathematics pathway. In the United States, Sadler and Tai (2007) suggested that the 'two pillars' supporting academic success within college science are high school study in the same science discipline (e.g. human biology, chemistry) and an advanced study of mathematics. Concerning the latter discipline, these researchers noted that students who take high school calculus average better grades in college science than those who stop at pre-calculus (Sadler & Tai, 2007).

Canadian-based research highlighted how the amount of time students spent learning mathematics in their final years of secondary school correlated strongly with their academic performance in a first-year calculus course (Kajander & Lovric, 2005).

Evidence between ATAR scores and first year university academic performance

Secondary school academic performance has been consistently heralded as a highly predictive measure of university academic performance (Harackiewicz, Barron, Tauer & Elliot, 2002; McKenzie & Schweitzer, 2001; Nicholas et al., 2015). Within the context of Australian universities, studies have reported that students achieving higher ATAR scores outperform those students with lower ATAR scores (Everett & Robins, 1991; Mills, Heyworth, Rosenwax, Carr & Rosenburg, 2008; Murphy, Papanicolaou & McDowell, 2001). In particular, commentators have identified a positive correlation between ATAR scores and university academic success across first-year (Messinis & Sheehan, 2015), primary education (Wright, 2015), and health science (Hine et al., 2015) degrees.

In Western Australia, Year 12 students can take as many as six (but no fewer than four) subjects that can be counted towards the Tertiary Entrance Aggregate (TEA). Since 2008, the TEA has been calculated by adding any student's best four scaled subject scores, plus a 10 per cent bonus of a student's best Language Other Than English (LOTE) scaled score. From 2017, students taking mathematics methods and/or mathematics specialist courses will receive a 10 per cent bonus of their final scaled score in those courses, highlighting the recognised importance of studying more difficult mathematics courses. The calculated TEA is then converted to an ATAR, which can range from 0 to 99.95 and reports the ranking position of any student relative to all other students. According to Western Australia's Tertiary Institutions Service Centre (TISC), the ATAR takes into account the number of students who sit the Western Australian Certificate of Education (WACE) examinations in any year, as well as the number of people of Year 12 school-leaving age in the total population (TISC, 2016).

Context

From 2010 to 2015 inclusively, Year 12 students in Western Australia were able to use one or two mathematics courses of study, from a possible six courses of study, in calculating their ATAR. Of these six courses, a majority of students annually choose to study one of either: 2C2D Mathematics (2C2D MAT), 3A3B Mathematics (3A3B MAT) or 3C3D Mathematics (3C3D MAT). For the purposes of this papers, these three courses will be referred to as elementary (2C2D MAT), intermediate (3A3B MAT), and advanced (3C3D MAT) mathematics courses. Since a majority of WACE students consistently select these courses of study for tertiary entrance, the researchers have purposively sampled first-year health science students who completed elementary, intermediate, or advanced mathematics courses. These three courses of study are tabulated below in Table 1, along with the amount of class time per school year allocated for teaching students particular topics within each of the three mathematics strands (Number and algebra; Measurement and geometry; Statistics and probability) (SCSA, 2007).

Table 1: WACE Courses of study 2010-2015: Elementary,
Intermediate, and Advanced level mathematics

Course	Elementary	Intermediate	Advanced
Number and algebra	*(51 hours)* - Estimation and calculation - Functions and graphs - Equivalence, equations and inequalities - Finance - Patterns	*(58 hours)* - Estimation and calculation - Functions and graphs - Equations and inequalities - Patterns - Finance - Calculus	*(45 hours)* - Estimation and calculation - Functions and graphs - Equations and inequalities - Calculus
Measurement and geometry	*(20 hours)* - Coordinate geometry - Networks - Measurement	*(16 hours)* - Rate - Measurement - Networks - Reason geometrically	*(28 hours)* - Rate - Measurement - Reason geometrically
Statistics and probability	*(39 hours)* - Quantify chance - Interpret chance - Collect and organise data - Represent data - Interpret data - Conduct chance experiments	*(36 hours)* - Quantify chance - Interpret chance - Collect and organise data - Represent data - Interpret data	*(37 hours)* - Quantify chance - Interpret chance - Represent data - Interpret data

Methods

Participants

First-year students from five different health science degrees were included as participants in this study. The participants comprised first year students (N = 128) enrolled in Biomedical Science, Exercise and Sports Science, Health and Physical Education, Physiotherapy, Nursing, and Science degrees from 2013-2015. Student pre-university admission data including completed level of mathematics at high school, and results of completed level of mathematics were obtained. Ethical approval to obtain student demographic data, including previous secondary school subjects, was granted by the Human Research Ethics Committee at The University of Notre Dame Australia (Fremantle campus).

First year academic performance measures

Students from health science degrees were assessed for academic performance by means of a recorded GPA at the completion of their first year of tertiary studies. Full-time students completing normally scheduled units for the first time were included in mean GPA calculations for each year cohort. For GPA calculations, student unit results were

awarded a 0 (Fail, <50), 1 (Pass, 50-59), 2 (Credit, 60-69), 3 (Distinction, 70-79) or 4 (High Distinction, 80-100).

Data analysis

Data analysis was conducted using the *Statistical Package for Social Sciences* (SPSS) software, version 22 (IBM corporation). Firstly, a Pearson product-moment correlation matrix was constructed to explore correlations between GPA, ATAR, and secondary school mathematics result. Then an initial one-way univariate analysis of variance (ANOVA) was conducted to investigate the main effects of two descriptive independent variables; 'degree', and 'completed level of mathematics at secondary school', with GPA as the dependent variable. A second one-way ANOVA was created to investigate the effect of two numerical independent variables, 'result of completed level of mathematics at secondary school', as well as the student's ATAR, against degree. For both ANOVAs, if main effects were observed, Tukey post-hoc tests were used to investigate the simple effects (i.e. between-degree differences). A *p*-value threshold of <.05 was considered to be statistically significant.

Results

Relationships between secondary school mathematics result, ATAR and GPA

To determine if mathematics was a significant variable to investigate within our population of students, secondary school mathematics results (irrespective of course) were assessed for a potential correlation with academic performance measures. The results show that a significant correlation between secondary school mathematics result, ATAR, ($r = .806$, $p = <.001$), and GPA ($r = .502$, $p = <.001$) was observed for this cohort. Moreover, when examining GPA, the moderate correlation observed between secondary school mathematics result and student ATAR was very similar, warranting mathematics competency for further investigation (Table 2).

Level and result of mathematics studied relate to academic performance

Descriptive statistics for all three independent variables are shown in Table 3. Overall, the cohort consisted of students from five separate degrees (N=128) within the health science disciplines. Figure 1 shows the comparative completed level of mathematics in secondary school for mathematics result, ATAR, and GPA, with a positive trend towards Stage 3C3D for these variables.

Level of mathematics studied affects student performance in secondary and tertiary education

For 'completed level of mathematics at secondary school', students who completed the advanced mathematics course at secondary school had a significantly higher ($p < .05$) GPA than both intermediate and elementary mathematics courses. No significant

difference was observed between elementary and intermediate mathematics courses (Figure 1).

Table 2: Assessment of correlation between secondary
school mathematics result, ATAR and GPA

		Maths result	ATAR	GPA
Maths result	Pearson correlation (*r* value)	-	.806	.502
	Significance (2-tailed)	-	<.001	<.001
GPA	Pearson correlation (*r* value)	.502	.533	-
	Significance (2-tailed)	<.001	<.001	-

Table 3: Summary of student mathematics level and
academic performance measure by individual degree

Degree	Maths level (n)	Maths results		ATAR		GPA	
		Mean	SD	Mean	SD	Mean	SD
Overall	Elementary (18)	55.6	7.5	68.6	8.5	1.7	0.5
	Intermediate (79)	60.7	7.6	80.8	8.7	2.0	0.6
	Advanced (31)	71.9	7.6	91.7	6.0	2.6	0.8
1. Biomedical Science	Intermediate (5)	64.3**(a)	7.8	85.6**(a)	9.4	2.2**(a);	0.5
	Advanced (13)	74.1	5.5	92.7	4.6	*(b) 2.9	0.5
2. Exercise and Sports Science	Elementary (5)	59.0	2.7	71.0	4.3	1.3	0.3
	Intermediate (19)	59.8	4.8	79.4	5.7	1.8	0.7
	Advanced (2)	67.7	1.4	81.5	5.5	2.8	0.3
3. Physical Education	Elementary (5)	57.6	8.5	70.2	9.0	1.8	0.3
	Intermediate (6)	53.4	6.7	72.5	2.4	1.8	0.2
	Advanced (1)	55.4	0.0	84.0	0.0	1.8	0.0
4. Nursing	Elementary (8)	52.3	7.5	66.0	9.4	1.9	0.63*(c)
	Intermediate (35)	59.3	7.2	78.1	8.3	2.1	0.6
	Advanced (3)	68.9	9.6	87.7	7.9	2.6	0.6
5. Physio-therapy	Intermediate (14)	67.4**(a)	6.7	91.5**(a)	2.8	2.0	0.5
	Advanced (12)	72.3	7.6	93.9	4.3	2.3	1.0

n = number of students enrolled; SD = standard deviation; * = significantly higher than other degrees (p <.05); ** = (p <.01); (a) Maths result for Biomedical Science is significantly higher than Exercise and Sports Science, Physical Education, and Nursing; (b) Maths result for Biomedical Science is significantly higher than Physiotherapy; (c) Maths result for Nursing is significantly higher than Physical Education.

Between-degree GPA associated with mathematics level completed at secondary school

The first ANOVA revealed significant main effects for both independent variables; 'degree' (p < .05) and 'completed mathematics level at secondary school' (p < .01), with GPA as the dependent variable. Simple effects were investigated using Tukey post-hoc analyses, which revealed significant within-group differences for 'degree', as Biomedical Science had a significantly (p < .05) higher GPA against all other degrees, and Exercise
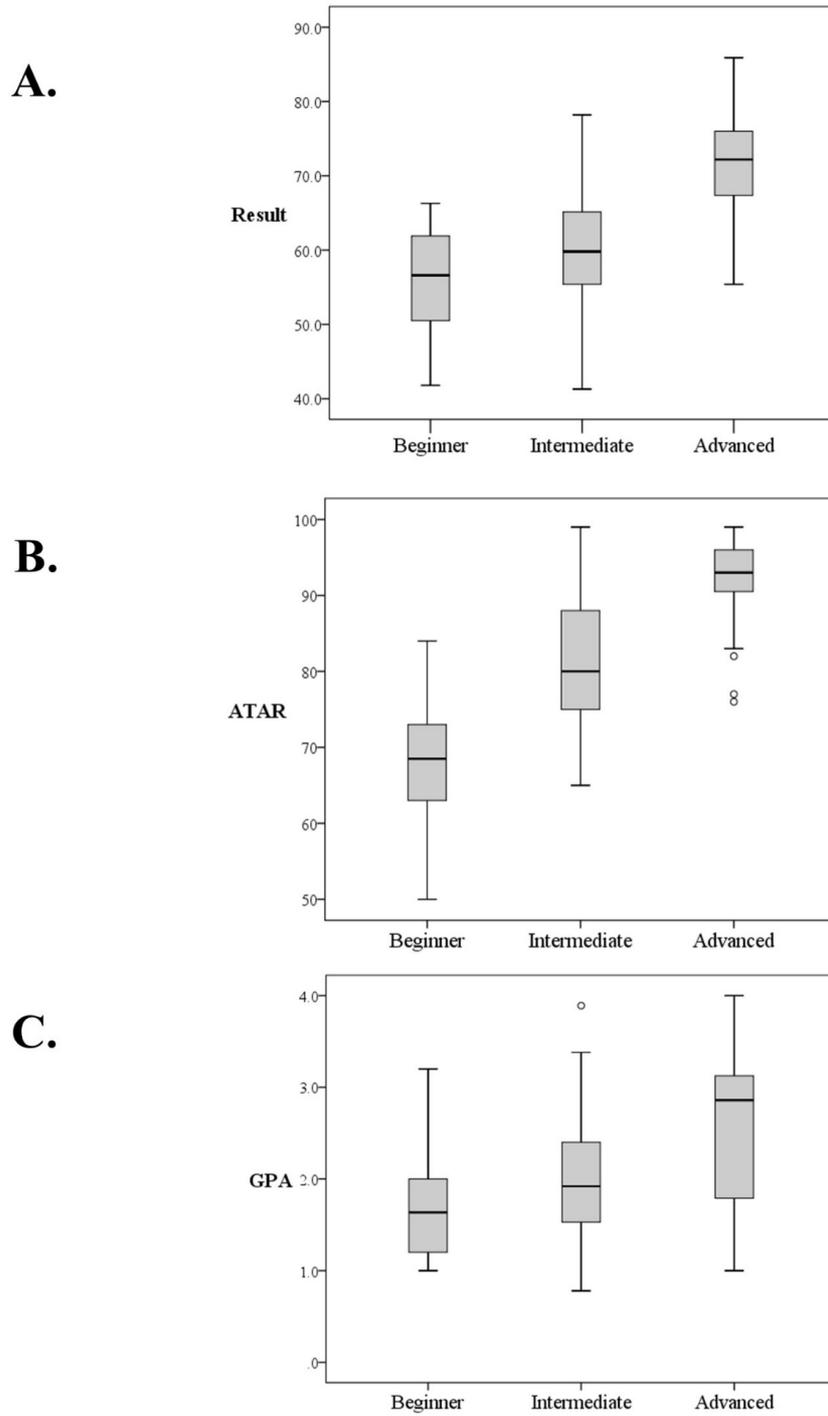
Figure 1: Boxplots summarising level of mathematics studied in secondary school and (A) mathematics result, (B) ATAR, and (C) GPA at the completion of first year

and Sports Science had the lowest GPA of the five degrees. Significant within-group differences for 'completed mathematics level at secondary school' reported that those students who studied advanced mathematics had a significantly (p < .01) higher GPA than students who had studied intermediate or elementary mathematics. No significant difference was reported between elementary and intermediate mathematics.

Finally, the second one-way ANOVA revealed significant between-degree main effects for both independent variables, 'result of completed level of mathematics at secondary school' (p < .01) and 'ATAR' (p < .01) with GPA as the dependent variable. Tukey post-hoc analyses of simple effects revealed Biomedical Sciences had significantly (p < .05) higher secondary school mathematics result over all other degrees, except for Physiotherapy. Physical Education was shown to have the lowest result of completed level of mathematics at secondary school score. For ATAR, Physiotherapy had significantly (p < .01) higher scores than all other degrees, apart from Biomedical Sciences (p > .05).

Discussion

The current study aimed to investigate if GPA differed between the five degrees offered in Health Sciences at The University of Notre Dame Australia (Fremantle campus), and if GPA was associated with the level of mathematics studied at secondary school. This aim was investigated using an ANOVA to examine the between-degree differences in GPA and the level of mathematics studied at secondary school. A second ANOVA was used to investigate the between-degree differences in ATAR and result of mathematics level studied at secondary school. Student ATAR was investigated as a correlate for GPA at the completion of first year in health science degrees. In the study, ATAR showed a moderate correlation with first year GPA, in agreement with numerous studies across education (Wright et al., 2015) and health science disciplines (Anderton et al., 2016; Mills et al., 2009). It has been reported that the level of mathematics course studied during secondary school is associated with overall ATAR scores (Anderton et al., 2017; Hine et al., 2015); therefore, the authors set out to determine if the mathematics level studied at secondary school was associated with student academic performance achieved at University, particularly in a degree specific manner.

The results from the present study determined that the mathematics level studied by students entering university (directly from secondary school) significantly impacted on their performance in first year. Specifically, students who had previously studied advanced mathematics had a significantly higher first-year GPA over students studying either intermediate or elementary mathematics. Unsurprisingly, student competency in mathematics, and the mathematics level studied in secondary school, has previously been reported as a correlate of university success (Hine et al., 2015; Hourigan & Donoghue, 2007; Mills et al., 2009; Rylands & Coady, 2009). Another finding of this study agrees with these comments. When correlating level of mathematics studied and the corresponding result of that level of mathematics undertaken, those students who completed a lower level of mathematics did not attain a higher result, and those who completed a higher level of mathematics did attain a higher result [$r(128) = .56, p < .01$]. This is shown in Figure

1A. While linking achievement in mathematics and science has anecdotally been observed for some time, entering the first year of university with a high level of mathematics may allow students to comprehend subject matter in more applied university courses such as those in science disciplines (Nakakoji & Wilson, 2014). Biomedical Sciences and Physiotherapy had the highest percentage of students completing advanced mathematics at secondary school (72% and 46%, respectively). Exercise and Sports Science, Physical Education, and Nursing were all between 7% and 8%. The mathematics level previously studied is also a strong predictor for performance in first year anatomy and chemistry units (Anderton et al., 2016), which are particularly important for Biomedical Science and Physiotherapy students.

With regards to ATAR, students studying Physiotherapy entered university with significantly ($p < .01$) higher scores than all other degrees, apart from Biomedical Sciences ($p > .05$). Further, students from both these degrees displayed significantly higher GPAs at the completion of first year. As mentioned previously, a higher percentage of students entering into Biomedical Science and Physiotherapy degrees had previously studied more difficult mathematics, suggesting a possible cause for academic variability between degrees. While each of these degrees vary in theoretical and practical content, Biomedical Science students typically favour aspects of study relating to medical courses, such as anatomical dissections (Anderton et al., 2016). A high proportion of students undertaking Biomedical Sciences are using this degree as alternate entrance into Medicine. This would support the higher mathematics level previously studied for students undertaking the Biomedical Science degree. In comparison, students in other health science degrees may be more inclined to study broader aspects of the human body, involving human participants and peer-based activities (Anderton et al., 2016).

The results from the present study provide evidence linking the performance in mathematics level and academic success in degree studies, associated with a more focused structure and higher ATARs. One possible explanation for this is that participation in intermediate and advanced mathematics courses can encourage higher-order thinking skills, allow students to critically analyse situations, and extend their capacity to use mathematical concepts abstractly in real-life situations (Belward et al., 2011; McNaught & Hoyne, 2011). These required skills correspond to the associated careers of Biomedical Science and Physiotherapy students. As previously mentioned, the majority of students undertaking Biomedical Science are using this degree as an alternate pathway into medicine. Potential career earnings for the five degrees in this study report Biomedical Sciences and Physiotherapy average salaries at $100K+ and $70K+, respectively. These are reported to be greater than Physical Education ($60K+), Sports Science ($55K+), and Nursing (31K+) (Salary Comparison, 2017). It is therefore clear that undertaking a higher level of mathematics at secondary school not only relates to university performance, but also beyond.

Finally, students studying Biomedical Sciences and Physiotherapy attained a significantly ($p <. 01$) higher result in completed level of mathematics at secondary school, than students in the other three degrees. It is also important to note that both Biomedical Sciences and Physiotherapy degrees reported a greater percentage of students completing

advanced mathematics than the other three degrees. The higher secondary school mathematics results scores of these students show they are more capable at understanding mathematics principles at a higher level, than students from the other three degrees, who recorded lower secondary school mathematics result scores from a lower level of mathematics studied (elementary or intermediate) (Hine et al., 2015; Hourigan & Donoghue, 2007; Mills et al., 2009; Rylands & Coady, 2009). As previously mentioned, those students who completed a lower level of mathematics did not attain a higher result, and those who completed a higher level of mathematics did attain a higher result. The similar findings for mathematics result with that of GPA and ATAR show a widening gap in academic achievement, dependent on the level of mathematics studied at secondary school that students enter university with. It could be suggested that modification of teaching and university courses to 'narrow' this gap could be considered, although factors such as known career path, study load, socio-economical bracket, and reasons for undertaking a tertiary education are outside the scope of this study.

The findings of this study should be considered along with some limitations. Firstly, this study was limited to school leavers only, who enter university immediately after finishing secondary school. However, in doing this, the authors were able to standardise the mathematics entry pre-requisites that may have differed from international and mature age students. Secondly, a positive and significant correlation existed between level of mathematics studied and the corresponding result [$r(128) = .56$, $p < .01$], indicating that those who undertook a higher level of mathematics obtained a higher result than those who undertook a lower level of mathematics and scored a lower result. However, despite this result it cannot be implied that a result in the lower level course is equivalent to the same result in a higher level course. Thirdly, although ATAR entry score for each degree differs, the level of difficulty between-degree cannot be objectively measured. Finally, and while this study examined the relationships between GPA, ATAR and level of mathematics completed, the authors acknowledge that a lower GPA or ATAR may not be solely attributable to mathematical background or ability.

Conclusions

This study agreed with the current literature regarding the significant declining participation rate in secondary school mathematics within Australia, with students electing to study a more basic level of mathematics, when comparing first-year performance of students studying five different health science degrees. Students opting to study a lower level of mathematics at secondary school achieved lower scores than students opting to take a higher level of mathematics, and also achieved a lower first year university GPA. This sharp decline in higher-level mathematics enrolments impacts upon first year university performance and beyond, into employment. The between-degree comparison of mathematics performance also is in accord with the literature, pertaining to the "use" of mathematics in the areas of future study and employment. For example, the greater success in mathematics performance for Biomedical students may be linked to students using this degree as a pathway to studying medicine, a career with future earning potential higher than the other degrees. While the lack of advanced mathematics participation may

be due to self-perception of difficulty (McPhan et al., 2008), and a lack of interest in pursuing mathematics at university, the present study highlights, and reiterates, the importance of mathematics in health science courses. In doing so, the findings highlight to university teaching staff that students enrolled in a health science degree have commenced their tertiary education from significantly varied mathematical backgrounds. Cognisance of such variety may behoove university teaching staff to create and make available supplemental mathematical resources to support student learning. For example, and in line with the recommendations of Hine (2015), such support could be in the form of massive open online courses (MOOCs) which can be accessed flexibly in terms of participation, with the possibility of asynchronous group interactions from peers.

It is hoped that the findings of this study will be useful to those personnel principally responsible for advising prospective entrants wishing to undertake study in a health science degree. For instance, the findings regarding mathematics and ATAR can inform the University's marketing approaches to senior secondary students, particularly those who intend commencing a health science degree. Furthermore, these findings can be used by staff working in secondary schools to counsel appropriately those students in lower secondary school (particularly Year 10 students) who are already considering subject selections for senior secondary school and for university entrance. Looking to the future, the researchers intend tracking the cohort of this study through to degree completion, in an attempt to investigate longitudinally the relationship between GPA, ATAR and secondary mathematics completed. Additionally, a further research topic has been identified for the researchers to explore the associations between GPA and scores in other subjects (i.e. other than mathematics) used to calculate a student's ATAR. Such investigations could provide additional insight into a between-degree comparison involving secondary mathematics and GPA.

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