# Secondary School Mathematics and Science Matters: Academic Performance for Secondary Students Transitioning into University Allied Health and Science Courses

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## Abstract

The literature strongly indicates that secondary school performance is highly predictive of university performance. Moreover, scholars have identified that successful performance in university mathematics and science courses depends on the level of mathematics studied in secondary school. This paper investigated the extent to which particular mathematics and science courses (e.g. Stage 2; intermediate and Stage 3; advanced) completed at secondary school affected the Grade Point Average (GPA) of 521 first-year Health Science, Physiotherapy and Nursing students within an Australian university. Based upon a statistical analysis of student performance (secondary Australian Tertiary Admissions Ranking (ATAR) score & first-year university GPA), the authors used a general linear model to investigate which secondary science and mathematics courses were associated with higher first-year university GPA. The key findings of this quantitative research project were that: the level of secondary mathematics studied, studying physical science courses at secondary school, and the completion of both advanced level mathematics and science courses were all associated with higher first-year university GPA.

## Introduction

The importance of mathematics and science within the Australian educational system is a well-established axiom in the literature (ACARA, 2009; Office of the Chief Scientist, 2014). Frequently, these disciplines have been increasingly acknowledged as essential to national prosperity, economic growth, and global competitiveness (McPhan et al., 2008). Within a higher education setting, scholars underscore how various mathematical skills can be applied across a broad range of courses (Hall & Ponton, 2005; McNaught & Hoyne, 2011). At the same time, the Australian Learning and Teaching Council (ALTC, 2010) outlines clear statements on suggested learning outcomes for Australian science graduates, particularly regarding the use of quantitative skills. Despite this importance, empirical studies report that within Australia, competency standards of post-compulsory secondary (Office of the Chief Scientist, 2012a; Tytler, 2007) and tertiary (Lee & Anderson, 2014; Maltas & Prescott, 2014) students are in a state of decline. Various studies have indicated that competency in secondary mathematics and science is a good predictor for academic achievement at university (Hine Anderton, & Joyce, 2015; Green, Brown & Ward, 2009; Hein, Smerdon, & Sambolt, 2013); however, within an Australian context, which specific level of mathematics and science

subjects completed at secondary school and how they contribute to academic performance at university is unknown.

**The Importance of Mathematics and Science**

Scholars have highlighted the significance of producing a mathematically and scientifically literate society (Rennie, Goodrum & Hackling, 2001). Hine et al. (2016) underscored that an understanding of mathematics is crucial in laying a solid foundation for post-secondary study in a range of disciplines, including engineering, business and finance. Additionally, mathematical skills and knowledge have been considered essential for university courses in health sciences (Anderton, Evans, & Chivers, 2016; Hine et al., 2015), and nursing (Galligan, Loch & Lawrence, 2010; Wright, 2007). In particular, McNaught & Hoyne (2012) suggested that mathematics provides students with a range of valuable skills – representation, interpretation, reasoning, problem solving, and analytical skills – which can be applied broadly across various courses. Equally, scientific literacy is regarded as a high priority for all citizens (ACARA, 2009; Rennie et al., 2001). Furthermore, Rennie et al. (2001, contended that developing scientific skills and knowledge helps people:

> *…to be interested in, and understand the world around them, to be skeptical and questioning of claims made by others about scientific matters, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being* (p.455).

Within Australia, Science, Technology, Engineering and Mathematics (STEM) and STEM-related careers are frequently exhorted as critical to economic growth and global competitiveness (McPhan et al., 2008; Office of the Chief Scientist, 2014). For instance, the Office of the Chief Scientist (2012b), asserted:

> *Mathematics, Engineering and Science (MES) are fundamental to shaping the future of Australia, and the future of the world…Our future lies in creating a high technology, high productivity economy; to innovate and to compete at the high-end of provision. To do so, the technical skills and scientific awareness of the entire workforce must be raised. The number of MES graduates needs to increase to allow industry to expand in these areas. Yet our current performance is wanting, and compare poorly to our leading Asian neighbours* (p.12).

In a similar vein, Wilson and Mack (2014) stressed that economic and industry experts predict that all new economies will be built on the foundations of mathematics and science.

**Competency Challenges**

Despite the significance attributed to the study of mathematics, the mathematical competency of Australian undergraduate students is declining (Belward et al., 2011; Brown, 2009; Wilson & Mack, 2014). Moreover, studies conducted within Australia indicate falling enrolments in post-compulsory secondary (OCS, 2012a; Tytler, 2007) and tertiary courses (Lee & Anderson, 2014; Maltas & Prescott, 2014), particularly within mathematics and science. Hassan (2008) observed that students entering Australian universities struggle particularly in science, engineering and mathematics degrees; Rylands and Coady (2009) found more recently that Australian universities are reporting a distressingly large proportion of first-year students failing mathematics, statistics, or physics. At a senior secondary school level, and with the exception of entry mathematics, enrolments in science and mathematics courses have "been declining in real terms, for the greater part of the past two decades and continued to do so in 2012" (Kennedy, Lyons & Quinn, 2014, p. 44). Moreover, these declining enrolments at secondary school are accompanied by students increasingly opting for lower levels of study in

mathematics and the 'softer' sciences, e.g. psychology (Dow & Harrington, 2013; Kennedy et al., 2013). There is also concern that compared with other nations (e.g. Singapore, Shanghai-China), the standard of science literacy in Australian secondary schools is slipping (OCS, 2012a). As such there are calls for the state of mathematics and science education within Australian schools and universities to be redressed (Dow & Harrington, 2013).

**What Influences University Performance?**

Scholars have consistently reported that secondary school academic performance is highly predictive of university performance (Harackiwicz, Barron, Tauer, & Elliot, 2002; McKenzie & Schweitzer, 2001; Nicholas, Poladian, Mack, & Wilson, 2015). In the Australian system, students with high Australian Tertiary Admissions Ranking (ATAR) scores out-perform students with lower scores (Everett & Robins, 1991) at university. For example, a positive correlation between ATAR scores and university academic performance has been observed across first year (Messinis & Sheehan, 2015), primary education (Wright, 2015), and health science (Hine et al., 2015) degrees. The use of a Grade Point Average (GPA) to calculate and report university performance is common practice, and across a wealth of studies, GPA has been used as a controlled covariate to gain insights into other relationships (Bacon & Bean, 2006). Specifically, research findings suggest that competency in university mathematics courses (Poladian & Nicholas, 2013; Rylands & Coady, 2009) and university science courses (Armstrong, Fielding, Kirk, & Ramagge, 2012; Nicholas et al., 2015; Sadler & Tai, 2007) depend on the level of mathematics studied at secondary school. For instance, Hine et al. (2015) found considerable differences within a cohort of first-year university students enrolled in a health sciences degree. Irrespective of gender, it was determined that those students who had studied a more difficult mathematics pathway at secondary school had a significantly higher GPA than those who had taken an easier mathematics pathway. Similarly, research conducted by both Anderton et al. (2016) and Green et al. (2009) concluded that particular secondary school science courses are associated with academic performance of first-year university students enrolled in bioscience degrees. However, it is unknown the extent to which specific mathematics and science courses influence specific university courses, in particular when addressing ATAR and GPA performance, and based on the level of mathematics and science subjects completed at secondary school.

In the United States, Sadler and Tai (2007) established that the 'two pillars' supporting university and college science were the study of mathematics and relevant science specialist subject as the most influential prior learning for attainment in biology, chemistry and physics. Other studies have reported a positive relationship between secondary school mathematics and university science attainment (McNaught & Hoyne, 2011; Nicholas et al., 2015). A meta-analysis of more than 80 studies conducted across all grade levels in the United States indicated strongly that indicators of secondary and post-secondary academic performance were strongly correlated with achievement in mathematics, English and science (Hein et al., 2013). On a related theme, Nakakoji and Wilson (2014) examined the relationship between attainments in mathematics and science courses taken within first year university. These authors concluded that prior learning in the examined science was the best predictor of later science attainment, but that mathematics is also a strong predictor of science achievement across biology, engineering, molecular bioscience and physics (Nakakoji & Wilson, 2014).

## Aims

There were two broad aims for this research project. The first aim was to investigate the extent to which particular mathematics and science courses (e.g. Stage 2; intermediate, Stage 3;

advanced) completed at secondary school affected the GPA of first-year Health Science students within an Australian university. Within this aim, the authors wished to examine:

- the association between students' completed level of secondary mathematics with their first-year GPA score of an allied health and science degree;
- the association between students' completed level of science at secondary school with first-year GPA score of an allied health and science degree; and
- the combined effect of students undertaking at least one advanced mathematics course *and* one advanced science course in secondary school, to see if a relationship existed with first-year GPA.

Based upon a statistical analysis of student performance (secondary ATAR & first-year university GPA), the second broad aim was to investigate which secondary science and mathematics courses were associated with higher first-year university GPA, using a general linear model (GLM).

## Methods

### Participants

First-year students from five different allied health and science degrees were included in this project. The data comprised first year students (n=521) enrolled in Biomedical Science, Exercise and Sports Science, Health and Physical Education, Physiotherapy, Nursing and Science degrees from 2013-2015. Students enrolled in each of these degrees undertake a variety of health-based units in their first year, with common units studied including structural and functional anatomy, physiology, and cellular biology. Student demographic data, pre-university admission data and mode of entrance were obtained for this project. Stage 2 is classified as intermediate level mathematics and science in the Australian curriculum. Stage 3 is classified as advanced level mathematics and science at the 3A3B level, and higher, 3C3D level. Students were classified as school leavers on obtaining entry into university with a valid ATAR score. Ethical approval to obtain student demographic data, including previous secondary school subjects, was granted by the Human Research Ethics Committee at the University.

### First-Year Academic Performance Measures

Students from allied health and science degrees were assessed for academic performance by means of a recorded grade point average (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). For the first aim, descriptive statistics were obtained for percentage of students entering university with a completed intermediate or advanced level of mathematics or science. Group differences in academic performance were analysed using an independent t-test (mathematics) or one-way ANOVA (science) with a $p$ value threshold of $<0.05$ considered statistically significant. For the second aim, a GLM was used to identify the significant advanced mathematics and science courses, and how much they influenced ATAR,

to assess secondary school performance, followed by a second GLM where GPA was used to assess first-year university performance.

## Results

### Students entering allied Health and Science university degrees

Within the school-leaver population entering university, the proportion of first-year students completing science and/or mathematics ATAR courses was recorded (Table 1). Enrolling into science and allied health degrees, a higher proportion of these students had completed human biology at secondary school, in comparison to other science courses. Fewer than 65% of students enrolling into a science or health discipline, completed advanced mathematics (61.4%).

**Table 1. Percentage of Students Entering University from Secondary School with Advanced Mathematics or Science**

| Secondary school subject | **2013 (%)** | **2014 (%)** | **2015 (%)** | **Average (%)** |
|---|---|---|---|---|
| *Chemistry* | 33.3 | 23.4 | 28.6 | **28.4** |
| *Physics* | 16.7 | 9.6 | 10.7 | **12.3** |
| *Human Biology* | 60.9 | 67.0 | 70.2 | **66.0** |
| *Biology* | 11.5 | 8.1 | 9.5 | **9.7** |
| *Mathematics 3A3B* | 44.2 | 46.7 | 49.4 | **46.8** |
| *Mathematics 3C3D & Specialist 3C3D* | 14.1 | 18.3 | 11.3 | **14.6** |

### Secondary School Mathematics Can Influence First Year GPA

To determine if studying advanced mathematics in secondary school had an effect on first-year university GPA, student pre-entry data for advanced mathematics (3A3B & 3C3D) were collected. Overall, and in all cohorts, mean GPAs for students with or without prior advanced mathematics (3A3B) education was not shown to be significantly different (Figure 1A). In contrast, students entering university following the completion of advanced mathematics (3C3D) in secondary school, consistently performed significantly better ($p < 0.001$) in all year cohorts (Figure 1B). Allied health and science students entering university with advanced mathematics (3C3D), as an ATAR course, reported a 0.5 higher GPA, in comparison to students without.

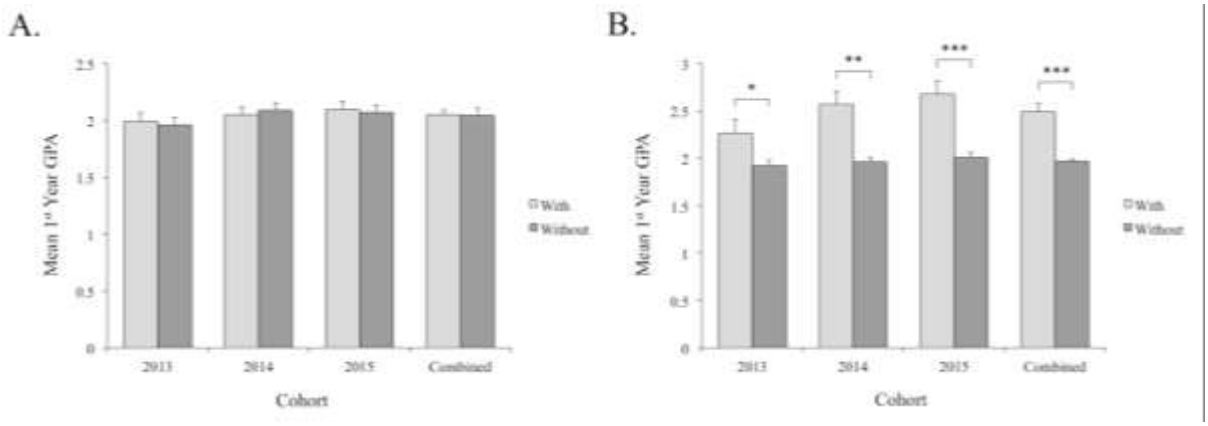


**Figure 1: First Year Grade Point Average in Allied Health and Science Degrees**.

Students were classified into groups on the basis of the level of mathematics studied in their final year of secondary education. First year grade point average of students entering university (2013-2015) with /without studying (A) Mathematics 3A3B or (B) Mathematics 3C3D/Specialist Mathematics 3C3D. Data shown are the mean ± standard error; **p*<.05, ***p*<.005, ****p*<.001.

### Physical Science Courses in Secondary School Can Influence First Year GPA

The four ATAR science courses in Western Australian secondary schools with the highest enrolments comprise: Biology, Human Biology, Chemistry and Physics, with the majority of school-leaver students in this project entering allied health and science degrees with a human biology background (66%; Table 1). Completion of physical sciences (Chemistry and Physics) in secondary school showed significant (Chemistry, $p < 0.001$; Physics, $p = 0.031$) benefit for students' first-year GPA (Figures 2B & 2D). Allied science health and science students in this study entering university with Chemistry and Physics as ATAR courses would score a 0.4 and 0.2 GPA (respectively) higher, in comparison to students without (Figures 2B & 2D). The completion of Human Biology did not significantly change first year GPA although, a positive trend was reported ($p = 0.080$). However, students who completed Biology reported a significant ($p = 0.032$) negative association with first year GPA, reporting a score of 0.2 lower, than students who had taken other science courses. (Figures 2A).

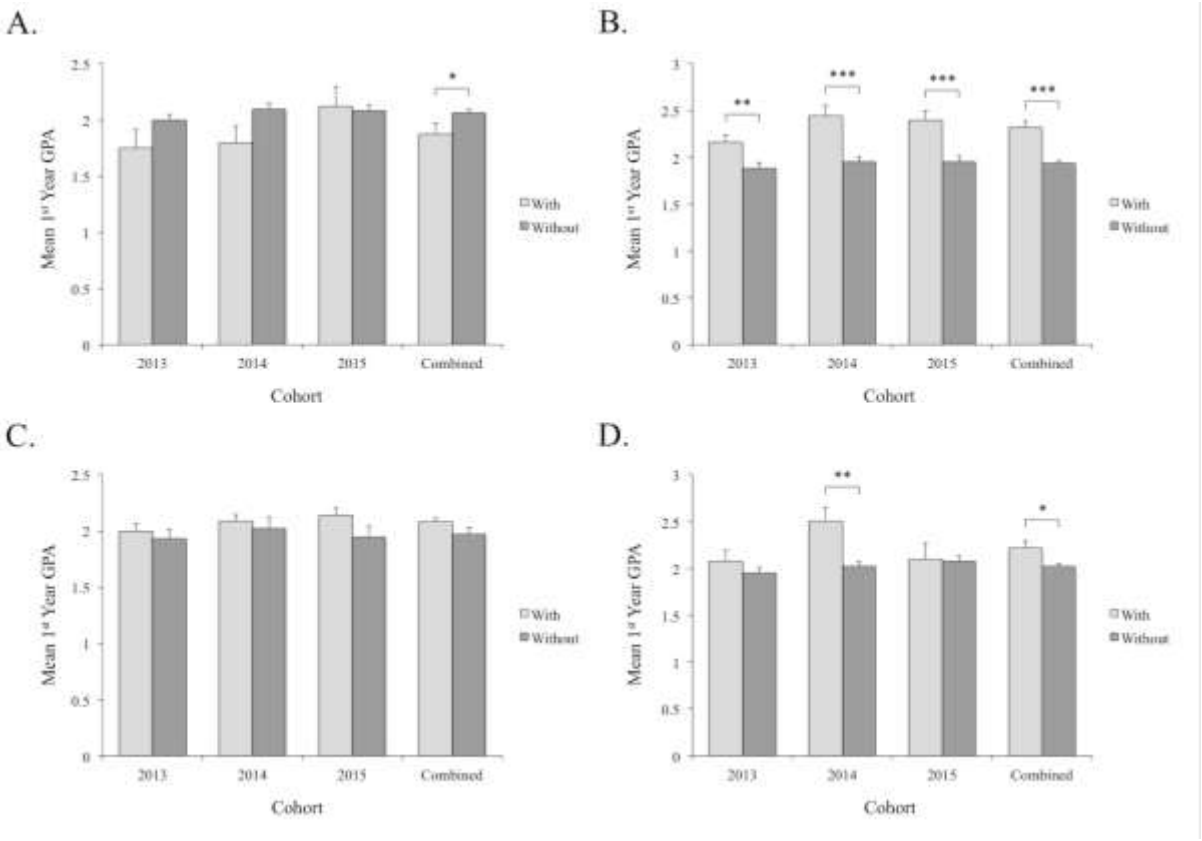


**Figure 2: First Year Grade Point Average in Allied Health and Science Degrees, following the Completion of (A) Biology, (B) Chemistry, (C) Human Biology, or (D) Physics Courses of Study.** Data shown are the mean ± standard error; **p*<.05, ***p*<.005, ****p*<.001.

**Completion of Advanced Mathematics and Science Results in Increased First-Year GPA**
Following the identification of key secondary school courses of study that appear to prepare students for allied health and science degrees, this project focused on students who have completed science and mathematics courses. Student completion of at least one advanced mathematics course, and one advanced science course (excluding biology), was used as a measure of adequate preparation for first-year allied health and science degrees. It was reported that 67% of students had undertaken at least one advanced science course (with the exception of biology), and one advanced mathematics course, whereas 33% of students had only completed either one advanced science (exception of biology), *or* one advanced mathematics course. Significant differences in GPA between those with, and those without, advanced science and mathematics courses were observed in all three cohorts ($p < 0.001$).

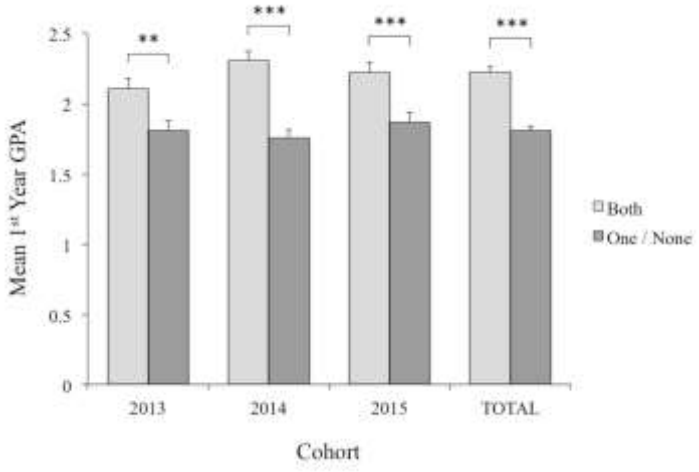


**Figure 3: The Impact of Concurrent Secondary Advanced Mathematics and Advanced Science Study on First Year University Grade Point Average**.

Students were classified into two groups, those who completed at least one advanced mathematics and one science subject concurrently (both), and those who did not complete both subjects concurrently, and may have completed advanced mathematics alone, a science subject alone, or neither (One/None). Data shown are the mean ± standard error; *$p$<.05, **$p$<.005, ***$p$<.001.

**GLM for the Prediction of Student ATAR and First-Year GPA**

Following the identification of certain science and mathematics courses as significant factors resulting in academic performance in allied health and science degrees, this project sought to determine the strength of association of each course with ATAR and first-year university GPA. Firstly, student ATAR was used as the academic outcome. Using a GLM, Chemistry (2.8; $p$ = 0.005), advanced mathematics (3A3B) (5.2; $p$ < 0.001), and advanced mathematics (3C3D) (12.2, p < 0.001) were identified as predictors of school ATAR (Table 2). For example, the results from this model indicate that completing advanced mathematics (3C3D) and Chemistry (3A3B) courses allowed students within this study score an ATAR of 15 points greater than a student without these courses.

**Table 2. Final Model Parameter Estimates: Predictors of Academic Performance (Year 12 ATAR Score)**

| Variable | | β coefficient | Std. Error | Significance |
|---|---|---|---|---|
| (Intercept) | | 76.259 | .6369 | <0.001 |
| Mathematics 3C3D | Yes | 12.215 | 1.3795 | <0.001 |
| | No | 0a | . | . |
| Mathematics 3A3B | Yes | 5.226 | .8987 | <0.001 |
| | No | 0a | . | . |
| Chemistry 3A3B | Yes | 2.802 | .9916 | 0.005 |
| | No | 0a | . | |

*Comparison category set to zero

**Table 3. Final Model Parameter Estimates: Predictors of Academic Performance (first year GPA)**

| Variable | | β coefficient | Std. Error | Significance |
|---|---|---|---|---|
| (Intercept) | | 1.679 | .0571 | <0.001 |
| Mathematics 3C3D | Yes | 0.453 | .0826 | <0.001 |
| | No | 0a | . | . |
| Chemistry 3A3B | Yes | 0.367 | .0675 | <0.001 |
| | No | 0a | . | . |
| Human Biology | Yes | 0.293 | .0611 | <0.001 |
| | No | 0a | . | . |

*Comparison category set to zero

To determine if similar courses were predictive for allied health and science degrees, first-year GPA was used as the research outcome. The GLM identified Chemistry (0.37; $p < 0.001$), Human Biology (0.29; $p < 0.001$), and Mathematics 3C3D (0.45, $p < 0.001$) as associated with academic achievement (Table 3). This finding report that students taking the above mentioned courses will perform 1.11 points (out of 4) better in first-year allied health and science GPA.

## Discussion

The first broad aim of this project was to investigate the relationship between secondary school mathematics and science achievement on first-year performance (GPA) within allied health and science university degrees. The authors investigated the association between firstly, completed level of mathematics, and then secondly, completed level of science at secondary school with first-year GPA score of an allied health or science degree. Next, authors investigated the combined effect of students undertaking at least one advanced mathematics course *and* one advanced science course in secondary school, to see if a relationship existed with first-year GPA. The second broad aim utilised a GLM to explain the variance in ATAR, and then GPA using advanced mathematics and science courses. This was done to better understand student academic development from the completion of secondary school through to the completion of a first-year allied health or science degree at university.

Firstly, students having completed, or not undertaken advanced mathematics (3A3B), did not have significantly different GPAs upon completion of their respective first-year allied health or science degree at university. However, students entering university having completed advanced mathematics (3C3D) reported significantly higher GPAs, than those who had completed advanced mathematics (3A3B), or lower. These results conform to previous research outlining the importance of Mathematics as a positive influencer of academic performance in university courses (Hine et al., 2016; Green et al., 2009), specifically in health science relates courses (Anderton et al., 2016; Hine et al., 2015).

Second, when investigating the completed level of science and its association with GPA, dissimilar findings were reported. Those students who completed physical sciences (Chemistry & Physics) were shown to have significantly higher GPAs than those students who did not complete these subjects. However, while students who completed Human Biology reported a positive trend towards higher GPAs than those students who did not complete this subject at secondary school, students who completed Biology did not show a similar trend. Moreover, students who completed Biology at secondary school were placed at no benefit towards obtaining higher GPAs upon completion of their first-year allied health or science degree. This particular finding has been presented in previous research where, students who studied Chemistry and Physics at secondary school were found to have a better tertiary performance, than those who studied biology, which reported a negative effect on tertiary performance (Schwartz, Sadler, Sonnert, & Tai, 2008).

Schwartz et al. (2008) underscored that physical science courses enhanced tertiary performance due to the methods used to teach these subjects. To illustrate, tertiary Chemistry and Physics courses were taught in ‘depth’, aimed at students developing an advanced understanding of specific concepts, whereas Biology was taught in ‘breadth’, i.e. using an approach to canvass a wide, general understanding of the course. It was suggested that broader coverage (breadth) of a course lead to a negative university performance, compared to more focused subjects taught within a discipline that encourages the development of a deeper understanding of the structure of the discipline (Schwartz et al., 2008). It may be considered that the use of ‘depth’ of content in tertiary courses, as opposed to ‘breadth’ is more STEM-career specific, in that

students are undertaking a degree for a career, rather than to finish secondary school with the relevant prerequisites for tertiary entry. This important finding supports STEM and STEM-related careers which are critical to economic growth and global competitiveness (McPhan et al., 2008; OCS, 2014).

Third, the researchers investigated the combined effect of students undertaking at least one advanced mathematics course *and* one advanced science course in secondary school, to see if a relationship existed with first-year GPA. It was reported that students who had completed *both* an advanced mathematics and science course had significantly higher GPAs, (0.3 - 0.55) than those student who only had either advanced mathematics *or* science, or neither ($p$ <0.001). This has been found by previous authors who indicated strong correlations with post-secondary school success and achievement in mathematics and science (Hein et al., 2013). Importantly, it has been reported that these similar findings explain the benefit of entering first-year university with a high level of mathematics *and* science as being able to comprehend subject matter easier in more applied university courses such as, engineering and molecular bioscience (Nakakoji & Wilson, 2014). The allied health and science degrees in this project would also be considered as applied courses due to the prior knowledge of mathematics and science students utilise within units, and the level of practical assessments completed.

The second broad aim of this project investigated how students progressed from secondary-school level (Year 12 ATAR) through to the completion of first-year university (GPA). The Year 12 ATAR GLM reported advanced mathematics (3C3D) as the strongest predictor of ATAR, followed by advanced mathematics (3A3B), and Chemistry (3A3B). For example, completion of both advanced mathematics (3C3D) and Chemistry (3A3B) would give a Year 12 student a 15 point higher ATAR than a Year 12 student who had not selected these courses. The two strongest associated variables being mathematics also outline previous authors' recommendations that an understanding of mathematics is crucial in laying a solid foundation for post-secondary study in a range of disciplines (Hine et al., 2016). The GLM also reported Chemistry as the third strongest associated variable of ATAR, which was reported for the second aim as the strongest influencer of first-year GPA at university. This finding suggests that studying Chemistry at a Year 12 level would translate into positive academic performance at a tertiary level, a finding that supports an in depth approach towards secondary study of advanced science courses (Schwartz et al., 2008).

The first-year GLM found similarities with the Year 12 ATAR GLM, with two subjects also reported as being associated with first-year GPA. Advanced mathematics (3C3D) was again reported as the strongest associated variable with GPA, with Chemistry (3A3B) reported as the second. Human Biology was reported as being the third. Human Biology is not to be confused here with Biology, which was found to be negatively associated with GPA. Human Biology would relate to an allied health or science degree specifically with courses such as Biomedical Science. The importance of the two GLMs sharing similar mathematics and science subjects shows a trend towards positive academic performance at both secondary school and university. This finding is important as it may assist in the development or modification of education pathways from secondary school to university for courses outside of allied health and science. More specifically, the instructional approaches used by educators to teach science and mathematics - both at secondary and university levels - can be further tailored to maintain student interest, enhance specific learning needs, and reduce attrition rates. Studies throughout the world demonstrate that performance in final year secondary education correlates to university attrition rates (Battin-Pearson et al., 2000), university grades (Richardson, Abraham,

& Bond, 2012), and beyond, employment performance (Carr, Celenza, Puddey, & Lake, 2014), and salary (Roth & Clarke, 1998).

At the same time, some limitations of this project have to be acknowledged. Firstly, the sample cohort was drawn from a single Australian university. Consequently the findings may have limited generalisability to other contexts nationally and internationally. Secondly, the authors only looked at whether students had completed particular ATAR courses, and not the score obtained. From a secondary school perspective, students are placed into particular ATAR courses based on their prior achievement and general aptitude; with this foreknowledge, the authors assumed that because of students' enrolment into an allied health science courses they would have completed a minimum of Stage 2 ATAR science and Stage 2C2D mathematics. As such, broadening the analysis of secondary school achievement data to include all enrolled allied health science students allowed the researchers broader scope to establish statistical relationships and examine anomalies, rather than to rely solely on the analysis of threshold marks or scores (e.g. only those above 75%). In addition, looking for student course completion allowed for a simpler and clearer statistical analysis to be conducted. Based on the findings of this study, future research into how university GPA progresses through a student's tertiary career, as well as how GPA differs between tertiary degrees would be of interest.

## Conclusion

In conclusion, the level of completed mathematics in secondary school has been shown to be consistently and widely related to university academic performance. However, few studies have investigated the effect of the completed level of science in secondary school and university performance, let alone a combination of both areas. This project has particular importance within the Australian tertiary system in relation to STEM and STEM-related careers, highlighted as being critical to economic growth and global competitiveness.

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