# Mathematics for first-year success

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#### Abstract

Successful completion of tertiary courses within Health Sciences and Biomedical Sciences relies on competency in mathematics. Competency, and, confidence with mathematics, is innately connected. Most students enter University courses by obtaining the requisite Australian Tertiary Admission Rank (ATAR) score for their chosen course. However, increasingly, students also enter via "alternative entry pathways". Such students could be at a disadvantage compared to those who have studied mathematics throughout high school. To test this idea we implemented a diagnostic assessment pilot study for literacy (n = 269) of midyear entry students across six Schools and a low cognitive mathematics test on a smaller cohort of students (n = 31) who had completed the literacy test and were enrolled in courses within the School of Health Sciences on the University of Notre Dame Australia's Fremantle campus. The data shows that in contrast to expectations the "alternative entry pathway" students that had completed the bridging course scored better in the reading test compared to ATAR or Cert IV graduates. In addition, Cert IV and TEP graduates performed comparably in the mathematics test compared to ATAR students but the overall performance of all student groups in the mathematics test was well below expectation. As universities move towards Post Entrance Literacy Assessments (PELA), the need for parallel Post Entrance Numeracy Assessments (PENA) warrants further research, based on the results of this study.

### **Theoretical underpinnings**

In some university courses, mathematics is an overt and important requirement for success (e.g. Bachelor of Biomedical Science). Mathematics skills are also important within many courses in which mathematics may appear a less obvious component (e.g. Bachelor of Referring to higher education students, Lau (2003, p. 2) notes: Outdoor Recreation). "Students who lack the basic and fundamental skills, especially in mathematics and writing, are finding it difficult to cope with the normal course workload". Furthermore, Waycaster (2001) found, in a study of five community colleges, that developmental mathematics was positively associated with student retention. Mathematics skills are important for higher education students (Hall and Ponton, 2005) for a wide range of reasons, including computational skills, data handling, problem solving, reading research reports and critical thinking skills. Fike and Fike (2008, p. 81) note: "All basic academic skills (reading, writing, and mathematics) are essential for college-level success." Whilst at times the terms 'academic literacy' and 'academic literacies' (Henderson & Hirst, 2006) are used with a focus on reading and writing, mathematics is as important for student success in higher education.

The traditional entry point to university was an upper school suite of subjects, linked to the area of future study. For many years university courses had stated 'prerequisite subjects', whereas most universities now list 'recommended' subjects, rather than prerequisites.

Secondary schools often recommend subject selections at upper secondary designed to maximise their Australian Tertiary Admission Rank (ATAR), to gain course entry. At times, students undertake upper school subjects with limited connection to their future study plans, purely to maximise their ATAR score. Therefore, an ATAR score 'alone' is not a predictor of success in various courses. Thomas, Henderson & Goldfinch (2009) contend that performance in specific subjects would be a better indicator than just the overall score. For example, a student may achieve a high ATAR score, but their individual score in subjects such as mathematics and physics are likely to be a better predictor of their success in a mechanical engineering course.

It is now common for students in Australia to enter university from a wide variety of 'non traditional' entry points (Coaldrake, 2001). Large numbers of Australian university entrants meet 'minimum entry requirements' through the Special Tertiary Admittance Test (STAT), Technical and Further Education (TAFE) certificates and diplomas, and university run or sponsored 'bridging courses' (Cullity, 2007). "Portfolio entry" requires potential students to present evidence of nominated selection criteria, usually at interview, and is increasingly common in Australian universities. Secondary schools often encourage students to consider an alternative entry pathway to university as an option to the traditional upper school subjects, and to sitting external exams.

The issues around mathematics for university entrants are not new phenomena. More than 20 years ago, there was evidence of declining numeracy standards within students attending universities (Chapman, 1988). Further, these concerns were not, and are not, specific to the university cohort alone. As noted, by Paulos (1990), there was long standing evidence of declining numeracy standards within the community at the end of the 1980's. There have been declining numbers of students taking higher level mathematics as upper school subjects in Australia (Dobson, 2006).

There are well recognized, commonly held associations within the general population (including students) towards mathematics. Mathematics success and failure is intrinsically linked to psychological dispositions (Usher, 2009; Pajares, 2001). According to Bandura (1997) self-efficacy is an individual's belief in their capacity to manage situations. These beliefs determine how an individual perceives a task, and are not related to actual skill level. High self-efficacy increases motivation, task focus and effort, and decreases negative thinking and anxiety (Bandura, 1997). Students with high levels of self-efficacy use higher order thinking strategies and persevere with tasks (Pajares, 1997). Self-efficacy beliefs vary according to the subject matter, and beliefs can depend on experiences within different subject areas (Waldman, 2003). Student anxiety levels and confidence predict Mathematics performance better than standardised measures of quantitative ability (Ironsmith, Marva, Harju & Eppler, 2001).

The UK William's Report (2008) noted that: "The United Kingdom remains one of the few advanced nations where it is socially acceptable – fashionable, even – to profess an inability to cope with mathematics." It is considered socially odd to like mathematics – it attracts an image of being an intellectual, or a 'nerd', an almost guarantee of social ineptitude (Ginsberg, 1997). Some students are reluctant to engage with mathematics, but have developed effective mechanisms to work around this. There is a much smaller but significant group who suffer from mathematics anxiety. There are many definitions of mathematics anxiety, including:

Mathematics Anxiety is defined as feelings of tension and fearfulness that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations. (Curtain-Phillips, 2003, p. 19)

This anxiety negatively impacts on self-esteem, inhibits intellectual functioning and interferes with performance (Shapka & Keating, 2003). Sufferers experience significant levels of distress and impairment when dealing with mathematics (Arem, 2003). As in other phobias, the 'mathematics anxious' experience impacts on their lives in real and tangible ways (Curtain-Phillips, 2003). High anxiety reduces working memory span and this leads to high rates of computational errors (Ashcraft & Kirk, 2001).

Students may actively choose to avoid mathematics within their secondary school years, prior to coming to university, not through a lack of ability, but rather their dislike of the subject, and through negative teaching and learning experiences over time (Williams, 2008). This disposition, however, may leave them disadvantaged when the skills inherent to mathematics (for example, problem solving, analytical reasoning and critical thinking) are essential to their tertiary studies. It is possible that student reluctance to engage with mathematics is leading to subject selections which exclude mathematics subjects, or increases the likelihood of 'lower' courses being chosen (Dobson, 2006). Whilst limited mathematics experience prior to tertiary enrolment will not necessarily be detrimental to meeting the requirements for undergraduate enrolment, it may well leave students underprepared for the mathematics demands within their studies.

## Context

The Academic Enabling Support Centre (AESC) was established on the Fremantle campus of UNDA in semester one 2010. This facilitated data collection and professional dialogue on student performance in a range of areas encompassing literacy, vocabulary and mathematics. The data collected by the AESC, during semester one, 2010, indicated that students who sought assistance were often the more competent students; less able students were less likely to seek support. More than 600 students across the campus enrolled in a free, academic support course, additional to their studies, during semester one, run by the AESC. At the end of the semester one, 2010, AESC staff analysed the results of the lowest performing first-year students across the University (n =85) and only 3 of those (85) students had enrolled in an AESC academic support course.

The mid-year entry cohort was always significantly smaller in size (with approximately 350 mid-year entrants to undergraduate study in semester 2, 2010), and anecdotally noted each semester by staff as more problematic. That is, staff indicate that mid-year entrants are more likely to have difficulty with their course work, and need greater support and encouragement in the early stages of their undergraduate study. This has been deductively linked to the higher proportion of alternative entry pathway students who commence in semester two each academic year.

The University made the decision to pilot a diagnostic test for literacy at the commencement of semester two, 2010. Across six Schools, the results of 269 commencing students were analysed, focusing on reading comprehension, vocabulary and essay writing skills. All tested students completed self-assessments prior to the testing, and a comparison was made between students' self-perception and test results. Students' results were of cause for concern in both reading and writing. More than half the tested students were below the benchmark in reading comprehension and essay writing. As a specific example, 55% of the School of Nursing

entrants were below the benchmark in writing (McNaught & Alliex, 2011). Between 60% - 80% of semester two entrants (depending on course) were from alternative entry pathways, which included bridging courses, Certificate IV TAFE studies, STAT, and university transfers. Generally, male students and those from alternative entry programs had a poor alignment between their self-assessments and results; they tended to overestimate their skills and appeared to lack an awareness of their skill-set on entry.

The larger study led to a secondary study, which is the basis for this paper. AESC staff discussed whether the same, rather disappointing, results in literacy would be paralleled or different if mathematics was tested on the same students. As a result, the students within the Tertiary Enabling Program (TEP), a UNDA semester-long bridging course, were tested using an 18 question, multiple choice format, mathematics test. The decision was made to reuse the same test on some of the Health Science students who had completed the literacy test. Given that entrants to TEP seldom met minimum entry requirements for direct undergraduate entry (thus the reason for undertaking a bridging course) it was expected that Health Science students would outperform the TEP cohort.

Of the 40 students commencing a Health Science course at the UNDA (Fremantle campus) in semester two, 2010, 66% entered their course via an alternative entry pathway. One quarter of the students had not taken traditional upper school subjects, completing instead 'wholly school assessed' courses, and attained minimal entry requirements by completing a Certificate IV from TAFE. Notably none of these Certificate IV entrants had completed a 'higher' level mathematics course through to the end of high school; conversely, nearly all had completed the 'lowest' possible course, or none at all. The implications of this emerged through this study.

Competence and confidence with mathematics is of innate importance to all Health Sciences courses. At UNDA, the School of Health Sciences offer courses in Health and Physical Education (Primary and Secondary), Exercise Sports Science, Preventive Health, Biomedical Science and Outdoor Recreation. Whilst all of the Health Science courses require competency in mathematics, some courses, such as Biomedical Science, require relatively sophisticated mathematical knowledge and skills. Whilst a mathematical subject in applicant's background is encouraged it is not a prerequisite for University entry into any of the courses and as a result, it is possible to enrol without any formal mathematics training during secondary education.

## Results

The three-part literacy assessment tool was trialled on a total of 40 first year Health Science students. The literacy assessment was completed in the second week of semester two 2010, in the usual tutorial time, for the core Health Sciences literacy unit, CO115 Academic Research and Writing in Health Sciences. In the first week of semester, in the same course, the same students had completed a self-assessment profile on their literacy skills, and basic demographic data had been collected. The mathematics assessment was completed in week four by 33 students in the same course. The mathematics test was not completed by all students, for a range of reasons. It was largely a pedagogically focussed, spontaneous response, to better inform teaching practice, rather than a planned trial, and only certain tutorial groups were involved. Students were invited to participate, and all students were willing to complete the test in the tutorial time. Not all students had completed the self assessment processes in week one, the literacy tests in week two, and the mathematics

assessment. The sample group for analysis comprised 31 students, for whom all the relevant data was available.

The results of the 31 students were analysed in a range of ways. Of the 31, there were 19 males (61%) and 12 females (39%), which was not dissimilar to the overall gender balance in the core literacy unit, CO115, which had 50% males and 50% female in semester two, 2010. By entry point, 12 students (39%) had entered using an ATAR score; 11 students (35%) had entered using from the University's Tertiary Enabling Program (TEP) bridging course; the remaining 8 students (26%) had entered using TAFE Certificate IV course. These entrypoints were also reflective of all students in CO115.

Of the 12 ATAR students, the range of scores was from 71.0 - 85.8, with an average ATAR of 77.0, representing 'solid scores' in a course with a minimum ATAR entry point of 70.0. The TEP bridging course students were all students who had completed Year 12 at secondary school, with most having taken an ATAR pathway, yet not achieving the minimum ATAR entry score for direct undergraduate entry. Four of the 11 TEP graduates had completed 'wholly school assessed' (WSA) courses of study in Year 12. The semester-long TEP course requires the completion of seven units focused on academic literacy, but included a unit of mathematics and a human biology unit for the Health Science pathways. Of the 8 Certificate IV graduates, 7 had completed a course specifically related to Health Sciences, predominantly in the areas of sport development and fitness related programs. The one student with a non-related course completed a Certificate IV in Screen and Media (Film and Television).

The mathematics test was made up of 18 multiple choice questions, each with four possible answers. The test did not allow students to use calculators. The questions were conceptually not more difficult than would be expected to be completed by Year 9 students. The key understandings assessed were:

- Addition and subtraction of three-digit numbers
- Addition of fractions with uncommon denominators
- Calculating area of a rectangle
- Calculating capacity
- Calculating time
- Calculations based on a calendar
- Converting common decimals to fractions
- Division of decimals
- Faces and edges in 3D shapes
- Identifying 4 sided shapes
- Identifying mathematical patterns
- Interior angles in 2D shapes
- Multiplication of decimals and whole numbers
- Negative numbers
- Probability
- Subtraction of numbers ending in zero

This test had been developed for the University's AESC by experienced secondary mathematics teachers, for use with the TEP students, as a broad screening tool. All commencing TEP students had completed the test in their first week of tutorials. Eighty (80)

TEP students had completed the test, and the average mark was 51%. The range of marks was widely distributed, with the lowest performing student achieving 10%, and the highest performing student achieving 90%. Detailed question-by-question error analysis had been completed, to inform teaching staff of the major need areas for students, over the semester ahead. The test also served to provide students with an indication of their current skill set, but had no bearing on their marks and results in the unit.

In looking at the wide range of comparisons possible, the decision was made to compare the performance of each Health Science student's score in the reading component of the literacy test, and their score on the mathematics test. The Health Science students had performed consistently in the reading, whereas, in both the vocabulary and writing sections, their results had been widely distributed and were less consistent to the results of the whole cohort (269 students) tested in literacy across six Schools (faculties). The reading test involved a short piece of non-fiction text, and required the students to complete six multiple choice questions based on the text. The test had a low cognitive load and of the 269 students tested, the average score was 5/6, 83%. The Health Science students were below the whole cohort average, and this group of 31 students have the same average as the whole Health Science cohort, at 65%.

Whilst it had been hypothesised that the Health Science students would perform better on the mathematics assessment than they had on the reading assessment, this was manifestly not the case. Most Health Science students (77%) performed better in reading than in mathematics. Their average score for mathematics was 51%, with a 65% average for reading. Three students (10%) were critically low (<50% in mathematics and/or reading) in reading, whereas 10 students (32%) were critically low in mathematics. Of the three students who were critically low in reading, two were also critically low in mathematics; the third student performed significantly better in the mathematics than the reading. This third student (mathematics 61% and reading 33%) had the second highest ATAR score within the group, of 85.7; results which are incongruous to that ATAR score.

		TEP Graduates	CERT IV
	ATAR n =12	n =11	Graduates n=8
MATHS	53%	52%	47%
READING	64%	70%	63%

 Table 1: Average test scores, by course entry point

The lack of relationship between performance and entry point is particularly interesting (Table 1). Given that an ATAR student must have passed an appropriate English course to meet minimal entry requirements for UNDA, this is not a requirement for either TEP or Certificate IV graduates. As a result it was anticipated that their ATAR entry point would have been advantageous in a reading assessment. However, TEP graduates outperformed ATAR entrants, and Certificate IV graduates had an average reading test score only 1% less than the ATAR entrants (Table 1).

A question-by-question analysis revealed the most common mathematical errors occurred with calculating angles (97% having the incorrect answer) followed by calculating with time (84% incorrect), identifying shapes (81% incorrect), probability (81% incorrect), adding fractions (68% incorrect) and calculating the area of a rectangle (also 68% incorrect). Due to the high common error rates on these questions, the test was administered to six current Year 9 students, then a class of Year 12 (n = 27) 'middle' mathematics students, and the error rates were significantly lower for all the school students in the sample tests. (All Year 9 and 12 students assessed achieved a minimum of 50%; the average for the Year 12 students was 68%). Overall, the average for both groups, TEP students (not TEP graduates) and Health Sciences students, resulted in the same average score of 51%.

## Discussion

The results of the Health Science students on the mathematics test were alarming. Whilst the test was administered to a relatively small sample of only 31 of the mid-year entry students, it is possible that similar results would be obtained by testing a larger cohort, both within Health Sciences, and potentially across other faculties. Given the importance of mathematical skills in all Health Science courses, students with a low mathematics results are likely to be disadvantaged during their course work. Several core units within their course require a level of mathematics knowledge well beyond the cognitive difficulty of this test. Moreover, mathematics proficiency is associated with problem-solving skills and reasoning, essential in many non-numerical tasks that will be encountered in course work.

Only three students achieved the top mark of 67%, which should be considered an 'average' performance score considering the low cognitive demand of the test. This assumption was supported by the observation that Year 9 and Year 12 students achieved a higher mean score than the Health Science students. The lowest mark achieved by one of the six Year 9 students was 61%, significantly better that the Health Science cohort average of 51%. It remains of serious concern that 32% of the Health Science students had a 'critically low' score in the mathematics assessment.

The results were so disappointing that speculation was given to the students perhaps not treating the assessment seriously. The test was administered to the students by an experienced academic, with a positive working relationship with the students. They were observed to be well-engaged during the test period, albeit that the academic noted a number of students using strategies which were age-inappropriate, such as counting on their fingers, or mouthing when calculating. These phenomena are also seen in other mathematics testing around the University, and may well indicate a lack of mental computational skills, and a lack of automaticity with number recall. It is also possible that these students have become calculator dependent during their secondary schooling, with only recent initiatives, from 2009 onwards in Western Australia, that Year 12 examination papers in mathematics contain both calculator and non-calculator sections.

A number of staff in the School of Health Sciences, involved in the testing process, were initially very disappointed with the results from the literacy tests, and had been 'quietly confident' that the students would perform better in the mathematics test. The academics who viewed the mathematics test agreed that the cognitive load was not high; and a number indicated that they considered the content to be equivalent to 'middle school' material, and appropriate to Years 9 and 10 students in generalist mathematics courses. Thus, the results of the mathematics were a serious disappointment for the academic staff, and created the quandary of 'where to from here?' in responding to the identified needs of the group. The

results challenged long-held and general assumptions that the incoming Health Science students were a mathematically capable group. However, other academics in the School were less surprised, given students difficulty, and palpable lack of enjoyment, in third-year units with a significant mathematics load.

The need to develop a Health Science specific mathematics screening test, for all incoming undergraduate students, is a work in progress. In parallel, the need to have support courses available to students is an imperative if the results of these students are replicated in future semesters. As a first step, in response to the results, an optional, twelve hour, summer term course on 'basic mathematics' is available to students, through the AESC. The students achieving a result of 50% or less have been contacted, to encourage their enrolment. Consideration is being given to a generic first-year 'essential mathematics' course for all incoming Health Science students.

That ATAR students did not significantly outperform alternative entry pathway students in the reading and mathematics tests was a significant surprise in the results. In reading, the ATAR students outperformed the Certificate IV graduates by one percentage point (based on average scores) and achieved poorly in comparison to the TEP entrants. Likewise, whilst their mathematics scores were slightly higher than TEP or Certificate IV graduates, the ATAR students, despite high entry scores, were still a serious cause for concern mathematically. Again, questions about dependence on calculator work, remains an issue that warrants investigation. A student in Western Australia can achieve an ATAR without a mathematics course being taken, but in the case of the 12 students in the sample, all had taken at least some form of mathematics to Year 12. This project did not look at their performance in their mathematics course, nor the composition of subjects they studied which led to their ATAR score; both would be interesting to explore in future research.

The results indicate a need for dialogue between secondary schools and the higher education sector. That students exiting schools appear to lack fundamental skills in mathematics is a serious issue, which necessitates communication and information sharing. From the earliest phases of schooling, significantly more resources are positioned to support students struggling with literacy, than numeracy (Ginsburg, 1997). It is common for university preparation programs to focus far more on literacy, than on numeracy. Generic skill courses, available to all undergraduate students, and offered at nearly all universities, are commonly around research skills, literacy and information technology, and seldom address numeracy. Whilst a short literacy course (e.g. a three hour workshop on a particular reading strategy) can be highly effective as an intervention strategy, the remediation process for mathematics is more complex. Moreover, it is unlikely that university entrants will keenly embrace additional mathematics classes. It is anticipated that it would be a challenge for academic support centres on university campuses to market mathematics courses, given the likely reluctance to engage in such programs. For a student who has some level of anxiety about their mathematical performance, enrolling in such a course would be personally confronting.

This study looked at one group of students, in one course, from one university. The study is limited and deserves replication on a broader scale. Anecdotal collegial conversations around the data in this test indicate that the problem is not limited to this group, course or University; rather that is it is systemic. This warrants further research and exploration.

#### Conclusion

Whilst 'post entry literacy assessments' (PELA) are becoming common in Australian universities, 'post entry numeracy assessments' (PENA) are rare, and unlike PELA, which is common to all undergraduate entrants, it would appear that PENA are used within specific courses only. Given the innate nature of mathematics to virtually all areas of study, it may well be that PENA is worth broader consideration. Given too, that mathematics provides students with a range of broadly applicable skills, such as representation and interpretation, reasoning, problem solving and analytical skills, the importance of mathematics to a wide range of courses (e.g. nursing, physiotherapy, medicine, science, geology, architecture, engineering, education etc) warrants discussion and consideration. It is unwise to assume student prior knowledge, and screening tests are potentially useful. If academics assume that Literature students will have strong writing skills, or Physiotherapy students a background in physics and/or human biology, units of course work can be premised on fallacious ideas, which work to the detriment of both staff and students. This study demonstrated that one particular group of students were 'at risk' with mathematics; it cannot be generalised to other groups without the use of PENA and data analysis. It is also quite possible that the phenomenon is repeated in other courses, in other institutions, and this warrants investigation.

The stimulus for this study was the disappointing literacy test results for Health Science students; however, their lower mathematics results left their low results in reading 'appearing' less problematic. However, the contention is that overall, this cohort group is likely to experience difficulties with future studies based on their entry reading and mathematics score, and that intervention is essential. Failure at the tertiary level is an expensive process (financially, emotionally and academically) for students (Peelo, 2002), and linked to student attrition (Fisher & Engemann, 2009). The majority of students who were flagged at risk through both reading and mathematics tests were performing poorly by the end of their first semester, and one had failed all five units. This powerfully demonstrates the importance of not only identification, but intervention. For higher education, the complexity is that intervention is usually an option for students to take up, not mandated; therefore, navigating towards intervention requires a strategic response. Universities may well need to consider policy and regulation changes to make support programs compulsory. There appears little value in identifying 'at risk' students without being able to implement an appropriate response. Ethically, once the weakness is identified, a professional response is required both for quality teaching and learning, and also for the pastoral care of students.

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