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# Year 12 Students and Higher Mathematics: Emerging Issues

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In order for young Australians to contribute to economic prosperity and remain competitive in a global market place, participation in higher and further education is essential. In this context, participation in mathematics, and in particular, higher mathematics, is an important prerequisite for young Australians to enable them to develop the range of skills that underpin a scientifically literate workforce. This is a report on a study in progress focusing on the fact that participation in mathematics study at higher levels to Year 12, and in universities in Australia, is in decline. We provide data on the specific nature of this decline and explore emerging issues that need to be investigated including reasons why students choose to and do not choose to participate in higher-level mathematics.

## Introduction

Industries and businesses worldwide have emphasised the importance of producing employees who are both mathematically capable and trained.

> Mathematics is a key science for the future, through its enabling role for science, engineering and technology. This is illustrated by dramatic advances in communications, bioinformatics, the understanding of uncertainty, and dealing with large data sets. (Lemaire, 2003, p.1)

This point is reiterated by the Australian Academy of Science (AAS) (2006). Mathematical sciences are seen as being fundamental to the economic and social well-being of nations. Mathematics and statistics are important discipline areas for Australia, not only for the scientific and engineering base of the country, but also in other areas such as finance and economics (Australian Council of Deans of Science, 2007).

The utilitarian and aesthetic values of mathematics have also been given prominence. Increasingly, the discipline provides powerful tools to understand, investigate and make predictions in the solution of a range of problems. As Phillipe Tondeur, former Director of the Division of Mathematical Sciences at the USA National Science Foundation, has noted:

> The opportunities for the mathematical sciences at the beginning of this century are fantastic. This century is going to witness one of the unprecedented pervasiveness of mathematical thought throughout the sciences and our learning culture. In a data-driven world, mathematical concepts and algorithmic processes will be the primary navigational tools. (Lemaire, 2003, p.2)

Despite such exhortations from influential members of the global community about the critical need to support citizenry who are mathematically literate, the quality and level of participation of young Australians in mathematics continues to be a real concern, particularly in regard to the participation in higher-level mathematics courses at secondary school level. This concern is articulated by the Australian Council of Deans of Science (2007, p.2):

> Intermediate, and especially, Advanced Mathematics students are essential for a strong science, research and innovation capacity. The statistics at hand indicate that number in these areas are shrinking and students are instead electing to take Elementary Mathematics.

## Context

The *Third International Mathematics and Science Study* (TIMSS) conducted in 1994/1995 showed that no country performed significantly better than Australia (Lokan & Greenwood, 2001) at all levels of schooling. Analysis of 2002/3 TIMMS results indicated that there was no significant difference in the performance of 4$^{th}$ and 8$^{th}$ graders in mathematics (Thompson & Fleming, 2004). However, a number of other countries show a significant improvement over this period, raising their position relative to that of Australia. Likewise, PISA scores for 2000 revealed that 15 year-old Australian students performed well in comparison to other OECD countries in questions that focussed on mathematical literacy (OECD, 2001). Interestingly, over the period of these reports, a stable number of students continued to enrol in Year 12 mathematics as shown in Table 1 (column 5).

Table 1: Year 12 mathematics students as percentages of Year 12 students (Barrington, 2006, p. 3)

| | Advanced mathematics students % of Year 12 | Intermediate mathematics students % of Year 12 | Elementary mathematics students % of Year 12 | Total mathematics students % of Year 12 |
|---|---|---|---|---|
| 1995 | 14.1 | 27.2 | 37 | 78 |
| 1996 | 13.5 | 26.9 | 37 | 78 |
| 1997 | 13.5 | 27.1 | 39 | 79 |
| 1998 | 12.7 | 26.1 | 39 | 78 |
| 1999 | 12.3 | 25.1 | 41 | 79 |
| 2000 | 11.9 | 25.0 | 47 | 83 |
| 2001 | 11.3 | 24.2 | 45 | 81 |
| 2002 | 11.1 | 23.4 | 46 | 80 |
| 2003 | 11.8 | 23.5 | 47 | 82 |
| 2004 | 11.7 | 22.6 | 46 | 80 |

However, while the overall percentage of student enrolling in Year 12 mathematics remained high (about 80%), the percentage figures for advanced mathematics have been on the decline. This is in contrast to the steady increase in the percentage of students enrolling in elementary mathematics. Forgasz's (2006) parallel analysis also reflects the above pattern and trend.

Even though schools in Australia have experienced an increase in retention rates of students into post-compulsory education and a subsequent increase in enrolments in mathematics courses, enrolments in advanced mathematics courses continue to decline in relation to less challenging courses (Board of Studies NSW, 2006).

The corporate and public sectors expect that graduates from science, engineering and allied fields will have the skills in mathematics to add intellectual value to products and innovations. Dr Philip McCloud from Roche Products, in an open letter to Dr Nelson the then Federal Minister for Education, sought support for endeavours to increase the number of graduate statisticians in Australia. He claimed that the viability of the biometrics industry in Australia is threatened, 'because Australia is failing to produce sufficient statistics graduates' (McCloud, 2007, p. 9). He further claimed that:

> … only three of the major pharmaceutical companies have so far chosen to establish large Biometric departments in Australia. We cannot expect other companies to follow this example, if Australia cannot supply sufficient statisticians to meet the needs of these leading companies. (McCloud, 2007:9)

In 2003, the OECD Education report showed that only 0.4% of Australian university students graduated with qualifications in Mathematics or Statistics, compared with an OECD average of 1% (AAS, 2006).

**Statistical data on mathematics participation**

While the above contexts provide anecdotal evidence of less than satisfactory levels of student participation in mathematics, there is a need to consider statistical data that would shed more light on these reported trends. Tables 2 and 3 show the enrolments figures for science and technology courses for the years 1989-2002. The figures for mathematical sciences have been in decline with the trend being particularly evident when we consider enrolment in all degree courses.

Table 2: Enrolments 1989 - 2002 in Science & Information Technology Courses, by Field, All Students (All degrees)

| **Course Group** | | | | | | **Growth 1989 - 2002** | |
|---|---|---|---|---|---|---|---|
| | **1989** | **1993** | **1997** | **2001** | **2002** | **No.** | **%** |
| General/Other Science Courses | 22554 | 32646 | 31293 | 32112 | 33161 | 10607 | 47.0 |
| Life Sciences | 15698 | 20488 | 28196 | 23896 | 25126 | 9428 | 60.1 |
| Mathematical Sciences | 4045 | 4590 | 4086 | 2703 | 2787 | -1258 | -31.1 |
| Physical Sciences | 6378 | 8048 | 8264 | 6047 | 5634 | -744 | -11.7 |
| All Science Courses | 48675 | 65772 | 71839 | 64758 | 66708 | 18033 | 37.0 |
| IT Courses | 13897 | 21004 | 27991 | 56474 | 61446 | 47549 | 342.2 |
| Science & I/T | 62572 | 86776 | 99830 | 121232 | 128154 | 65582 | 104.8 |

Source: DEST Aggregated Data Sets (Dobson, 2003).

Table 2 shows that among the seven courses that were analysed in the DEST study, enrolments in both mathematical and physical sciences were the only areas to decline. Furthermore, the drop in mathematical sciences is more than double of that for physical sciences. The trend evident in these two subjects is not surprising as, in general, students who wish to pursue subjects in the physical sciences such as physics and chemistry are expected to have a high level of understanding of advanced mathematics concepts. While the enrolments in all the other courses have increased, the increase in IT-based courses has been significant. The key question arising from these data is whether those with mathematical/scientific capability are taking up studies in ICT and Science/ICT courses at the expense of mathematical and physical sciences?

Table 3 shows enrolment figures for the same courses as in Table 2 but is limited to Bachelors degree programmes. The trend is similar to that indicated by Table 2. However, the percentage decline in mathematical and physical sciences is higher than that in Table 2. This suggests the drop in student enrolment is more severe at the undergraduate levels and there is an urgent need to investigate reasons underlying this decline.

Table 3: Enrolments 1989 - 2002 in Science & Information Technology Courses, by Field, Level of Course: Bachelor (Pass)

| **Course Group** | | | | | | **Growth 1989 - 2002** | |
|---|---|---|---|---|---|---|---|
| **Number** | **1989** | **1993** | **1997** | **2001** | **2002** | **No.** | **%** |
| **Bachelor (Pass)** | | | | | | | |
| General/Other | 19563 | 26924 | 24923 | 28253 | 29163 | 9600 | 49.1 |
| Life Sciences | 11345 | 14596 | 20754 | 17041 | 18232 | 6887 | 60.7 |
| Mathematical Sciences | 3227 | 3418 | 2993 | 1808 | 1780 | -1447 | -44.8 |
| Physical Sciences | 4117 | 4843 | 4860 | 2429 | 2418 | -1699 | -41.3 |
| All Science | 38252 | 49781 | 53530 | 49531 | 51593 | 13341 | 34.9 |
| Information Technology | 8970 | 14665 | 21027 | 40662 | 44455 | 35485 | 395.6 |
| Science & I/T | 47222 | 64446 | 74557 | 90193 | 96048 | 48826 | 103.4 |

Source: DEST Aggregated Data Sets (Dobson, 2003).

If the course enrolment patterns outlined above present a bleak picture for the study of mathematics at Australian universities, the trend is equally spectacular for the *completion* of the Mathematics and Sciences degrees in which students were enrolled. Table 3, shows that the completion figures for Australian students (as opposed to Overseas students) has been on the decline during the 1989-2001 period. The level of course completion by overseas students was considerably higher than domestic students in all the courses under consideration.

Table 4: Course Completions: 1989 – 2001 - Science & Information Technology Courses by Course Group and Domestic/Overseas Students

| Course Group | 1989 | 1993 | 1997 | 2001 | Growth 1989 - 2001 No. | Growth 1989 - 2001 % |
|---|---|---|---|---|---|---|
| **General/Other** | | | | | | |
| Domestic | 4606 | 6498 | 6344 | 6346 | 1740 | 37.8 |
| Overseas | 142 | 400 | 275 | 604 | 462 | 325.4 |
| **Life Sciences** | | | | | | |
| Domestic | 3268 | 4000 | 6123 | 5230 | 1962 | 60.0 |
| Overseas | 62 | 244 | 463 | 448 | 386 | 622.6 |
| **Mathematical Sciences** | | | | | | |
| Domestic | 710 | 838 | 831 | 563 | -147 | -20.7 |
| Overseas | 45 | 98 | 100 | 90 | 45 | 100.0 |
| **Physical Sciences** | | | | | | |
| Domestic | 1075 | 1304 | 1638 | 1531 | 456 | 42.4 |
| Overseas | 49 | 143 | 228 | 202 | 153 | 312.2 |
| **All Science** | | | | | | |
| Domestic | 9659 | 12640 | 14936 | 13670 | 4011 | 41.5 |
| Overseas | 298 | 885 | 1066 | 1344 | 1046 | 351.0 |
| **Information Technology** | | | | | | |
| Domestic | 1983 | 3291 | 3922 | 7785 | 5802 | 292.6 |
| Overseas | 144 | 698 | 1722 | 6428 | 6284 | 4363.9 |
| **Science & Information Technology** | | | | | | |
| Domestic | 11642 | 15931 | 18858 | 21455 | 9813 | 84.3 |
| Overseas | 442 | 1583 | 2788 | 7772 | 7330 | 1658.4 |

Source: DEST Aggregated Data Sets (Dobson, 2003).

Taken together, the patterns of results in Tables 3 and 4 indicate that young Australians do not enrol and complete degrees in Mathematical science courses at a level that would be on par with other courses and students.

## Emerging Issues

The above set of statistics about Australian participation in the study of higher mathematics raises a number of questions concerning reasons behind students' decisions for enrolling or declining to enrol in advanced mathematics subjects. We examine these below.

### *Lack of career information*

Students moving from compulsory schooling into post-compulsory education are required to make important decisions regarding which subjects to study and which to discontinue. The choice to continue with science, mathematics or technology in their final years of schooling has consequences for their subsequent tertiary options and career opportunities. For most students, however, this relationship between mathematics, tertiary study and career remains largely unimportant and poorly understood. Potential mathematics students appear to know little about future career options and a career in mathematics is perceived as not being very lucrative when set against a backdrop of social pressures to earn income (Aldous, 2007). Smith (2004, p. 4) cites a 'lack of awareness of the importance of mathematical skills for future career options and advancement' as a possible factor contributing to the decline in mathematical enrolments at post-compulsory schooling in the United Kingdom.

*Lack of quality and qualified teachers*

The future of mathematics based disciplines, at schools and at tertiary level, depends at least in part on the experiences of secondary school students in their mathematics classrooms. In this regard, the quality of teaching and teacher's knowledge and attitudes seems to be an area of concern in students' selection of mathematics subjects. Students are quoted as being impressed and inspired by teachers who really understand the subject, and respond negatively to teachers who seem to not know what they're teaching (Ayres, Dinham & Sawyer, 2000). Although the above statistics did not consider students' attitudes to mathematics, it is reasonable to conclude that the likelihood of a student pursuing further studies in mathematics would be influenced by their experiences in mathematics classes at secondary school. Students' comments lead Raison and Etheridge (2006) to comment about the 'savvy' nature of high school students that they are more than capable of assessing the qualifications, comfort and ease of their teachers with respect to their knowledge of the subjects they are teaching.

The continuing pattern of teachers with less than an optimal level of qualifications to teach high school mathematics is contributing to the larger issue of declining enrolment. A national study, released in October 2006 revealed that one in 12 (8%) high school mathematics teachers have not studied mathematics at tertiary level (Harris & Jensz, 2006). Three in four schools experience difficulty recruiting suitably qualified teachers for mathematics classes, and the impending retirement of the baby boomer generation is set to exacerbate this situation (Department of Science Education and Training, 2003). The recommendations of the report on the Preparation of Mathematics Teachers in Australia, prepared for the Australian Council of Deans of Science, call on state and federal governments, as well as secondary and tertiary education authorities, to ensure that sufficient numbers of suitably qualified teachers of mathematics are available to nurture future generations of school students (Department of Science Education and Training, 2003; Harris & Jensz, 2006; Ramsey, 2000).

The problem of shortage of specialist mathematics teachers is not limited to Australia. Referring to a similar situation in the United Kingdom, Smith (2004) commented that 'ensuring the future supply of sufficient young people with appropriate mathematical skills' is one of the most important challenges for teacher education in the United Kingdom. These shortcomings were attributed to long-term decline in the numbers of young people continuing to study mathematics beyond high school.

*Primary Teaching of Mathematics and Science*

There are data to suggest that many primary teachers feel under-equipped to teach mathematics and science. The Australian Primary Principals Association (APPA) recently released *The Charter on Primary Schooling* (2007) which detailed the pressures primary teachers feel under due to both the overcrowding of the primary school curriculum and teachers' lack of preparedness to teach science and mathematics. APPA called for a narrowing of the primary school curriculum to four main curriculum areas, including mathematics and science to enable greater attention to be given to these areas. In August 2007, the APPA also released a commissioned study *In the Balance: The Future of Australia's Primary Schools* (Angus, Olney & Ainley, 2007). Based on data collected from a random sample of 160 Australian primary schools, the study found primary teachers devote only 3 per cent of their time to the teaching of science and 18 per cent of their time teaching mathematics. The concern is that if primary students receive an insufficient grounding in mathematics and science in primary school, this will cause difficulties in secondary school, resulting in lower achievement, disengagement and a reluctance to pursue higher-level studies in these subjects. It is for these reasons that Dinham has advocated a degree of specialisation in primary teacher training and teaching, with specialist mathematics/science teachers (Dinham, 2007).

*Lack of access to advanced high school mathematics courses*

Available statistics show that not all potential students of higher-level mathematics courses have equal access to these courses at the schools they attend. An Australian wide study of mathematics teachers states that only 64% of schools now teach advanced mathematics, a situation brought about by fewer students wanting to take it up (Illing, 2007). The direction of the link between student enrolment pattern and schools' offerings needs further investigation. However, it is clear that the above situation presents a dilemma for students in secondary schools that do not include higher mathematics subjects in their school curriculum. These students could be disadvantaged because those who wish to enrol in the more advanced mathematics subjects are unable to do so.

*Lack of appropriate university prerequisites*

There is a lack of consensus as to the cause and effect of some students entering university with a less than adequate background in mathematics. It seems that 'Australian universities are lowering mathematics prerequisites and this is undermining enrolments in high school mathematics' (AAS, 2006, p. 9) while at the same time offering remedial courses for first-year students to help them cope with their degree. It is a matter for speculation whether offering stricter prerequisites would result in more students undertaking mathematics at an advanced level in Year 12, or whether students would not apply for courses with those prerequisites.

*Lack of understanding of the role of mathematics*

The role of tertiary education providers in fostering a greater level of uptake of advanced mathematics subjects by Year 11 and 12 students is another issue that falls within the general purview of the declining interest and enrolment in Australia. It is suggested that higher education in the mathematical sciences can contribute by developing in all students a sense of the *embeddedness* of mathematics in the broader science enterprise (Lemaire, 2003). It would seem that the community at large tends to place emphasis on science and science-related subjects without sufficient attention to the mathematics that drives scientific understanding of students. The greater community awareness of the role of science in career options may contribute to the perception that mathematics, particularly higher mathematics, is not an important requirement for entry into and success in science-based careers. In a review conducted for the Chancellor of the Exchequer, Robert (2002) concluded that many young people in the United Kingdom have a poorly informed view of career opportunities arising from the study of science, including mathematics.

*Declining participation is a global phenomenon*

International data show that concerns about decline in the number of graduates with majors in mathematics are not restricted to Australia. For example, between 1992 and 1999 the proportion of US full-time mathematics graduate students dropped by 26.5% (Wickware, 2007), and that fewer than half of the graduate students in mathematics programs across the United States are US citizens, down from 75% in the 1970s. Similar trends have been reported in the United Kingdom, where, for example, it was observed that in the last five years, mathematics' overall share of A-level students in the United Kingdom has declined by about 7,000 students (Smith, 2004). This report suggested that less than 10% of young people in England were studying mathematics after the age of 16, and of these less than 10% went on to do mathematics degrees.

*Lack of access to university mathematics courses*

The decline in student enrolment in higher mathematics at school level appears to have an impact on the activities of university mathematics departments in Australia. The Group of Eight universities have lost almost a third of their permanent staff in mathematical science departments in the last decade (AAS, 2006). Only four Australian universities have sufficient staff to teach mathematics to users of mathematics and statistics but also to those doing advanced study in the field (Ferrari, 2007). The increasing age of the workforce, the brain drain and closure of departments compound the situation.

## Concluding comments and directions for future study

Preliminary work thus far has identified a number of core areas that researchers need to focus on in future studies on student enrolment in higher mathematics. Each of the above concerns is important and needs to be the investigated in order to tackle the macro issue of understanding and reversing the enrolment patterns that are emerging from the analysis that has been presented here. Our view is that the study of students' understanding of, and views about, the role of advanced mathematics in their career choice will provide multiple insights into the other issues. We are designing a study in which a cohort of Year 10 students in NSW secondary schools will be surveyed and interviewed about their attitudes to and experiences of mathematics, and their plans for enrolment in mathematics in the future, including Years 11 and 12.

Thus, our study will focus on the following key questions:

- Why are students electing to enrol in elementary mathematics courses rather than those at advanced level?
- Do capable young people choose to study mathematics courses that are less demanding? If so why?
- On what beliefs and advice do students base their subject choices?
- Would students choose differently if they believed that a career in the mathematical sciences offered exciting and profitable opportunities?
- Would student choice be influenced if teachers and careers advisors informed them that science graduates whose major area of study was mathematics will have a higher employment rate?

It is hoped that such a study will help identify underlying reasons for students' participation in high level mathematics and offer directions for course offerings at tertiary institutions.

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