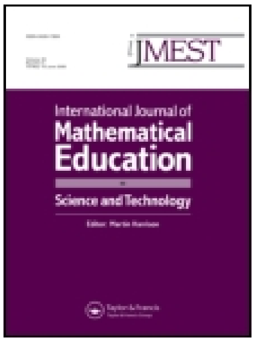

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Mathematical sciences in Australia

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This article investigates enrolment trends in mathematical sciences in Australian universities. Data has been difficult to extract and the coding for mathematical disciplines has made investigation challenging. We show that the number of mathematics major undergraduates in Australia is steadily declining though the number studying mathematics-based subjects is steady.

Keywords: Australia; university mathematics; trend data

1. Introduction

Mathematics plays a crucial role in modern societies. Professor Terence Tao, Australia's only Fields medallist has noted:

> 'The technologies of the future, for instance with regards to gene sequencing, climate change, or new energy technologies, will rely on mathematics even more. If Australia is to become competitive in these areas and create new technologies rather than merely use existing ones, it will need large numbers of workers who are not only trained in the technical aspects of their field, but have the ability to adapt and refine their skills to handle these new challenges and opportunities [1].'

Mathematics is used to solve problems in many industries such as science, engineering, finance, economics and medicine. One could argue that mathematics is running the modern world. Today's world boasts advancements in technology most of which rely on sophisticated mathematical content [2]. The applicability of mathematical skills often results in labels being placed on mathematical applications by their application area, for example engineering or science. Mathematics becomes an invisible achiever and the importance of mathematical sciences can be lost to the community at large.

This article summarizes the situation in Australia in mathematical sciences for the years 2001–2007. In Australia, the term 'mathematical sciences' is used to encompass mathematics, statistics and the range of mathematics-based disciplines. Where we use 'mathematics' it should be read in this more inclusive sense [3]. The article will provide a commentary on the statistical changes over the years and provide some explanations for the trends. This article will also highlight some of the consequences that these trends have brought about. It was not possible to directly compare data from before 2001 because the counting methodology and the classification system changed.

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1.1. *Overview of Australian education context*

Australia is a commonwealth comprising of six states, two territories and a federal government. The population is around 21 million and the majority of students complete high school. School education is run by the States and universities predominantly by the federal government. There are separate school boards – or equivalent – in each state, which design and administer their own curriculum and end of school examinations. The 38 universities offer degrees within a qualifications framework and choose the structure of disciplines and programmes that is suitable for their student body. The largest universities attract around 40,000 students and offer a wide range of programmes. Teachers are trained at universities with a Bachelor of Education or a bachelor degree in a discipline plus a 1-year Diploma of Education or a 2-year Masters of Education.

1.2. *Relevance of study*

'Mathematics is critical to economic prosperity' [4]. The Australian Academy of Sciences report [5] affirmed this by stating that:

> '... mathematical sciences are critical to Australia's economic competitiveness and quality of life ... Mathematical sciences are generic and enabling technologies ... [and are] essential to the prosperity of many value-adding industries in Australia.'

In spite of this 1996 report, which clearly articulated the need to provide a strong mathematical science base in Australia, by 2006 international reviewers found that: 'Australia's distinguished tradition and capability in mathematics and statistics [was] on a truly perilous path [3]'. The Review documented that the number of Year 12 students taking the more advanced mathematics subjects was declining; only 0.4% of Australian university students majored in the mathematical sciences compared with an Organization for Economic Co-operation and Development (OECD) average of 1%; there was a narrowing mathematical research base; and a worsening supply of adequately qualified teachers of mathematics [3].

The purpose of this article is to highlight that, in spite of the importance of the mathematical sciences, fewer students are enroling in mathematics as a major subject. The decline has continued even after the 2006 Review and this article will highlight some reasons as to why this is so.

Hall, in 'The crisis in math in Australia' [6], described the importance of mathematical ideas to industry but also highlighted the paradox that there was no 'mathematical industry' although virtually every 'application' area, required or could benefit from mathematicians and statisticians to increase efficiency. This comment illustrates a difficulty with mathematical sciences. While it contributes to virtually all industries, the forms of its contribution are not as transparent as say, a mining engineer to a mining project. As a result, it is harder for mathematicians to form a community and equally as difficult for the community to see the value in mathematics. This problem has been identified by many mathematicians including Krantz [7], as having a bearing on the declining enrolments in mathematics worldwide.

2. Data

The data for this article comes mainly from the Australian government Department of Education, Employment and Workplace Relations (DEEWR) and data gathered from Australian universities and reported in the *Gazette* of the Australian mathematical society.

The main methodological concern in this article has been the fact that tertiary mathematics as a discipline in itself is not immediately recognizable in the Australian education statistics. Instead, mathematics is usually buried in Natural and Physical Science, Economics and Finance and other such areas of study. It is also a possible reason for the perceived decline in mathematics undergraduates in Australia.

2.1. *Assumptions and limitations*

Our attempt to map patterns in mathematics numbers in Australia proved to be challenging. National enrolment and graduation data mostly failed to identify mathematics as a field of study in its own right. It was also interesting to note how there was seemingly no reference or public interest in regards the lack of availability of significant statistics about undergraduate study in mathematics.

In making our deductions, we rely on the assumption that a mathematician is any person whose primary area of study and research is the field of mathematics. This includes a student who completes university with a major or degree in mathematics. For the purpose of this article, the degree or major has to be in at least one of the following subjects; actuarial studies, applied mathematics, mathematics – general; operations research; pure mathematics and statistics.

2.2. *Undergraduate numbers*

Data from the website of the DEEWR have been compiled for Figure 1 for the years 2001–2007 [8]. An EFTSL is an effective full-time student load and is the main unit of measurement consistent across universities in Australia. For example, a full year of study is one EFTSL so if a student takes one subject of mathematics out of a full year's load of eight subjects, then they will count as one-eighth of an EFTSL. Consequently 18,000 EFTSL will correspond to many more actual bodies studying mathematics subjects. Commencing students refers to students who have enrolled in a mathematics unit for the first time, Bachelor degrees studies refers to undergraduate study or first degree study [8].

Figure 2 shows data derived from Universities Australia unit record data (2001–2007) as provided by DEEWR Higher Education Statistics Unit [9]. These data are not openly available on the DEEWR web site and have been extracted by the statistics unit for the purposes of this article.

2.3. *Graduate destinations*

Graduate Careers Australia (GCA) works with government and universities on graduate employment issues in Australia [10]. GCA has representatives from universities and government, as well as graduate recruiters, and has been in existence for over 40 years operating as a not-for-profit company. GCA runs a survey each year of graduates of all universities in Australia which asks about employment status and salary. It is called the Graduate Destination Survey. Universities use the data to ascertain the appropriateness of their programmes and the sectors that graduates are moving into. The survey produces more data than are available. For example, graduates list the employers that they are

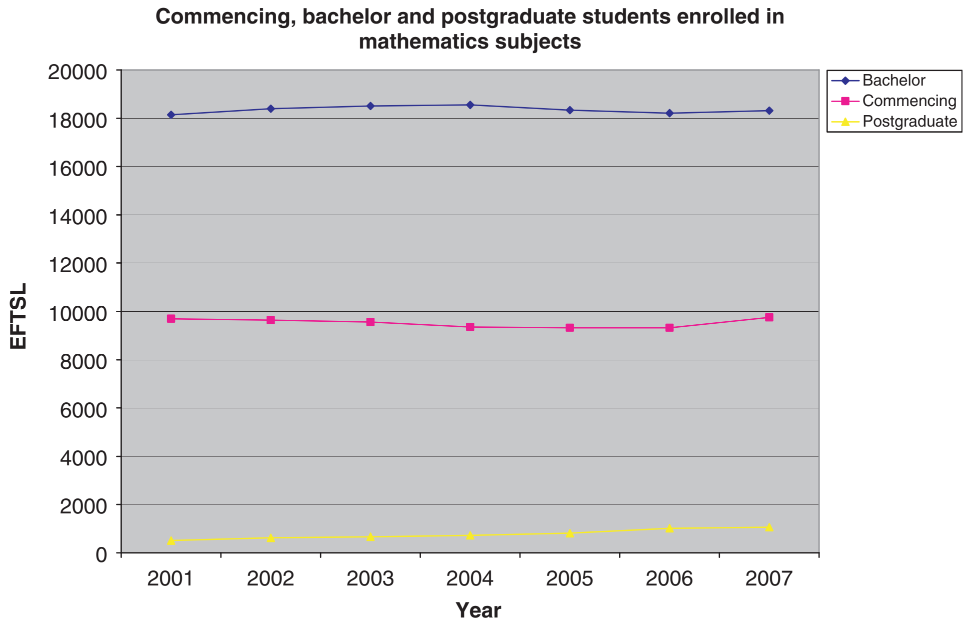

Figure 1. Commencing students who have enrolled in a mathematics unit for the first time), bachelor (undergraduates doing any mathematics subject) and postgraduate students in mathematics subjects [8].

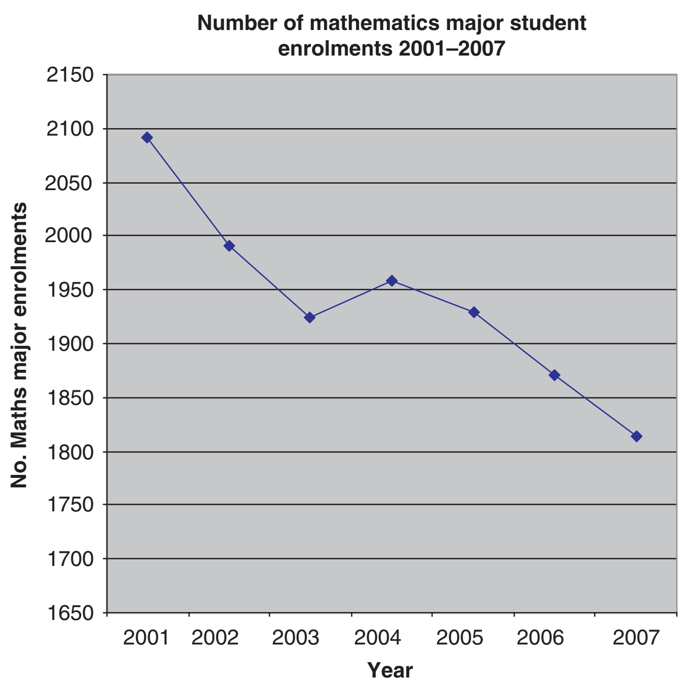

Figure 2. Australian enrolled undergraduate students with a major in mathematics [9].

Table 1. Industry sectors of mathematics graduates for 2007 [10].

Government	17.0%
Health	2.2%
Education	9.6%
Private	65.2%
Other	5.9%

working with but these data are not available for universities at this stage. It is also difficult to look at trend data because the surveys have changed over the years of collection.

The Government Graduate Destination surveys of 2007 show that of the mathematics graduates who wanted full-time employment, 80.8% were employed full time and 19.2% were seeking full-time employment, as compared to an average full-time employment rate of 84.5% for all graduates. This suggests that there is 3.7% more unemployment among mathematics graduates as compared to the average graduate, and this at a time of general high employment and skill shortages. Table 1 shows the sectors where mathematics graduates were employed.

The Australian Government graduate destination surveys of 2007 also show that in all the graduate fields surveyed, the starting salaries for mathematics graduates in employment was slightly above average with a wage of $A46,000 as compared to the average graduate wage of $A43,000. Graduates engaged in engineering and related technologies by analogy earned an average of $A51,200 [10]. Moreover, while the number of students EFTSL enrolment numbers in mathematical sciences in 2007 were 2211, for engineering and other technologies they were 8395. Mathematically capable students may be being enticed by higher employment and higher renumerating career paths [8].

2.4. *Postgraduate numbers*

Although this article does not analyse the trends in postgraduate numbers, statistics and commentary about research degree numbers are available in Johnston [11]. Figure 1 also shows the number of postgraduate research and coursework students per year between 2001 and 2007. Johnston [11] shows that the number of honours mathematics graduates in the 5-year period from 1997 to 2001 was only three-quarters of what it had been in the previous 5 years.

2.5. *Mathematics teacher training*

There are no uniform requirements for the training of mathematics teachers in Australia. Teacher registration is administered by the state authorities. There is, however, federal agreement that teachers should have a 4-year qualification. Since the late 1980s, this has usually meant a Bachelor of Education for primary teachers and a degree plus a graduate diploma of education for intending secondary teachers. In recent years, there has been a trend to 4-year ‘double’ degrees. These consist of 2 years of a normal degree programme and 2 years of education studies. While graduates may have, for example, a bachelor of science awarded, these courses involve a year less discipline content than a stand-alone degree.

Teachers are registered on the basis of having completed a 4-year course and principals largely decide what they will teach. An analysis of primary teacher education courses by the Australian Mathematical Sciences Institute showed a lack of mathematical content or competency assessment [12]. There appears to be some shortfall in the number of primary teachers available overall and it is not possible to measure the percentage who have appropriate mathematical content knowledge. The data are not collected. The situation is complicated by some states teaching Year 7 in primary schools and having five years of secondary schooling compared with six in others.

There is a clearer picture at the secondary level. A report prepared by the Australian Council of Deans of Science documented that leading teachers in schools believed that teachers at the upper secondary should have a major or above and teacher qualifications [13]. They were less sure about qualifications for junior secondary and more dissatisfied with teacher preparation for those years. This may partly relate to the need to use teachers who have not trained as mathematics teachers due to teacher shortages. A third of those teaching at junior and middle school level did not have a mathematics method.

The shortfall in the number of graduating secondary mathematics teachers is likely to worsen in the light of the declining number of graduates. Mathematics occupies about 14% of the timetable in secondary schools. Teachers are usually encouraged to have at least two teaching methods, so Schools of Education should aim for well in excess of 14% of their cohort graduating competent to teach mathematics. The mismatch between the specialty subjects of graduating teachers and the reality of the school timetable are illustrated in a 2006 DEST report showing the combined first and second methods in mathematics just exceeding 14% [14]. This compared with 44.5% who had method studies in Studies of Society and the Environment and 35.8% for science.

The high figure for science hides an aspect of current enrolments in university science courses. It is possible to complete a science degree without taking any mathematics or statistics courses. This is especially true of the biological sciences in spite of the quantitative nature of modern biology. Thus, the high science figure masks a shortage of specialist chemistry and physics teachers and also the fact that many general science teachers have insufficient mathematics to teach it in the junior secondary years with confidence.

3. Discussion

3.1. *Factors influencing the study of mathematics in higher education*

Demographics influence the numbers of people available for higher education. The population of 15–17-year olds in Australia is around 850,000. Of the potential cohort around 40% are in higher education. The numbers who then decide to pursue mathematics are low as compared to the intake in other disciplines. This results in a decline in students taking mathematical sciences in university and the number who come out of the mathematics pipeline is significantly low. For example, Figure 2 shows that between 2001 and 2007 the number of Australian students enrolled in mathematics as a core as opposed to a supplementary subject were between 1800 and 2100. These figures are very small in proportion to the number of students enrolled in undergraduate studies in Australian universities.

Another factor leading to the decrease in mathematics undergraduates is higher participation rates in optional school-level mathematics. In Australia students can choose to opt out of taking mathematics in high school from Year 11. This liberty has been a critical filter of prospective mathematics undergraduates as increasingly more students opt out of taking advanced and intermediate mathematics in high school and as a consequence prematurely restrict themselves from pursuing mathematical science in university [15].

Arguably the most influential factor in the decrease in mathematics undergraduates in Australia is the community's perception that mathematics is not useful in the marketplace. In fact, this negative perception even exists among mathematics students [16]. This lack of understanding, and devaluation of the applicability of mathematical science in the wider community, results in prospective undergraduate mathematics students being lured into pursuing programmes that are seemingly more practical such as engineering and commerce. Actuarial Studies, for example, is often taught in Commerce faculties and places are sought after by talented mathematics students. One could argue that there is a transference of mathematical skills and talent to larger, more visible and lucrative application areas such as engineering, commerce and information technology as opposed to an actual reduction in the number of mathematicians in Australia.

Directly linked to this transference is the media's negative portrayal of mathematics and mathematicians. Gould [17] put forward that the media plays a significant role in introducing prospective students to career choices. He concluded that Australian media was doing mathematics and the larger community a great disservice by failing to acknowledge its relevance and importance in every day life. The media's failure to show mathematician role models can also contribute to the lack of interest in mathematics in the younger generation. Gould gave, as an example, the increase in students enroling in forensic science after the free to air screening of the programme *CSI: Crime Scene Investigation*. The programme, though fictional, provided role models and career insight to prospective students. Mathematicians in the media on the other hand are usually portrayed as white middle-aged men with poor social skills – hardly a future one would voluntarily choose! As a result, students are instead choosing to pursue careers that have attractive remuneration packages and social prestige, such as law, medicine, psychology and business studies.

Closely aligned to this is student interest and enjoyment of mathematics or, more accurately, lack thereof. Mathematics is often parodied as having the 'Brussel Sprouts effect' [17]. The Brussels sprouts effect refers to the negative connotations associated with the study of mathematics and by analogy, it is good for you and yet few people choose to consume it.

Another notable factor is the inherent difficulty in the study of mathematics. Eccles and co-workers [18–20] proposed that educational, enrolment and career choices were directly related to two sets of beliefs: the individual's expectations for success, and the importance value that the individual placed on the task. Because of the perceived difficulty of the study of mathematics, students seem to be less confident in their ability in mathematics and as such are less likely to select mathematics subjects over other subjects. Moreover the community's negative outlook about the applicability of mathematics results in prospective mathematics placing little value on mathematics, both as a discipline of study and as a career choice.

Some commentators have suggested that there are sufficient mathematics graduates for the Australian workforce and argue that there is no need to expand places. This is because the Australian Government Graduate Destination surveys of 2007 show that of the mathematics graduates who wanted full-time employment, 80.8% were employed full time and 19.2% were seeking full-time employment [10]. Many of us would argue that some mathematics graduates are not prepared for the workplace and that mathematics graduates may lack sufficient computing and work readiness skills. This is an area where universities can change the curriculum to assist graduates to be able to apply their mathematical knowledge in the workplace [21].

Another factor affecting the numbers in mathematics can be explained by findings from an Australian study of first-year tertiary mathematics students across five universities. This study found that the most powerful factor motivating students to enrol in first year mathematics was that it was a pre-requisite to a non-mathematics course [22]. This suggests that of the 18,000 EFTSL who appear to be taking mathematics, in reality only 1814 are core mathematical students – and as such only 1814 remain in the pipeline.

3.2. *Consequences for industry and teaching*

As outlined earlier, the obvious consequence of the low numbers studying mathematics is that there are few students coming into the discipline and very few coming out as mathematicians. For example, at the University of Sydney, Australia, Taylor [2] reported that there were more than 2500 students studying mathematical sciences in first year, 200 completed mathematics or statistics majors and 25 studied a fourth year of honours. As a result, limited numbers of mathematicians are available to enter the workforce, leaving industries such as engineering with an unmet demand for such graduates.

The lack of mathematicians also has an impact on industry and immigration as the workforce looks beyond Australian borders for candidates with suitable mathematical skills. Australia has been able to import good mathematicians especially from Eastern Bloc countries and Asia.

Also, according to survey results on graduate destinations by the Australian Government, only 9.6% of mathematics graduates go into education as a career path [10]. This can be attributed to the comparatively low wages teachers get as opposed to how they are renumerated in the private industry.

3.3. *Teacher supply*

The number of students graduating in mathematics and statistics in Australia will not improve until the opportunity to learn improves in schools. The problem begins in primary schools with the shortage of teachers and then moves to the junior secondary. 'The knock-on effect is that the number of students going on to study advanced mathematics is drying up, which will not only hit research and professions such as engineering, but also dry up the pool of qualified mathematics teachers that are desperately needed to ensure there are enough school children taking up intermediate and advanced maths into senior school' [23].

Until recently, the problem of mathematics teacher shortage was largely perceived as confined to schools in remote areas, some rural regions and the lower socio-economic parts of the major cities. This is no longer the case. Schools in relatively affluent areas of Melbourne – for example – have reported that they have not been able to attract qualified teachers. They have then been forced to drop electives and enrichment classes for Year 10 students in spite of student demand. As a result they now find that not enough students select the most advanced Year 12 mathematics subjects, to justify offering it. The schools are big schools by Australian standards with around 1500 students. The Deans of Science study found that just 64% of schools were in a position to offer the most advanced Year 12 mathematics course [13].

The downward trends in the number of students studying advanced level Year 12 subjects and majoring in mathematical sciences suggests that various attempts to attract more graduates to careers in teaching will not be sufficient to solve the current staffing problems in schools. In the short term, there must be opportunities for teachers to up-grade their skills and there must be financial support for career change professionals who want to teach mathematics. However, considerable work is needed to devise courses appropriate to both of these groups. It is important to address teachers' knowledge levels as well as pedagogical needs in the courses offered to career change professionals.

There is now agreement that Australia will have a national curriculum in mathematics and planning has begun. This will be an opportunity to delineate mathematical expectations of students for each year of schooling and therefore should be a guide to expectations of teachers' content knowledge.

4. Conclusion

'Mathematical science has developed a rich and intrinsic culture that . . . now reach[es] far beyond the physical sciences and engineering; into medicine, commerce, industry, the life sciences, the social sciences and to every other application that needs quantitative analysis [5].' Unsurprisingly, the decline in mathematics undergraduates in Australia is causing concern among academia.

While the mathematics 'pipeline' metaphor has been critiqued by researchers such as Herzig [24] and Adelman [25], research and statistics suggests that it in fact exists. As such, mathematicians, industry and the larger community need to take an active role in educating the community by nipping the sources of negative mathematical perceptions in the bud, if they want to curtail the decline in undergraduate participation in the mathematical sciences. This article serves to illustrate that factors influencing senior high school mathematics and tertiary participation in mathematics can successfully be predicted and dealt with. We ought to use this information to secure a prosperous economic future for Australia and the global market. Moreover, we should recognize the significant contribution mathematics has made, and will continue to make, in the modern world.

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