

THE CONTINUING DECLINE OF SCIENCE AND MATHEMATICS ENROLMENTS IN AUSTRALIAN HIGH SCHOOLS

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Is there a crisis in Australian science and mathematics education? Declining enrolments in upper secondary Science and Mathematics courses have gained much attention from the media, politicians and high-profile scientists over the last few years, yet there is no consensus amongst stakeholders about either the nature or the magnitude of the changes. We have collected raw enrolment data from the education departments of each of the Australian states and territories from 1992 to 2012 and analysed the trends for Biology, Chemistry, Physics, two composite subject groups (Earth Sciences and Multidisciplinary Sciences), as well as entry, intermediate and advanced Mathematics. The results of these analyses are discussed in terms of participation rates, raw enrolments and gender balance. We have found that the total number of students in Year 12 increased by around 16% from 1992 to 2012 while the participation rates for most Science and Mathematics subjects, as a proportion of the total Year 12 cohort, fell (Biology (-10%), Chemistry (-5%), Physics (-7%), Multidisciplinary Science (-5%), intermediate Mathematics (-11%), advanced Mathematics (-7%) in the same period. There were increased participation rates in Earth Sciences (+0.3%) and entry Mathematics (+11%). In each case the greatest rates of change occurred prior to 2001 and have been slower and steadier since. We propose that the broadening of curriculum offerings, further driven by students' self-perception of ability and perceptions of subject difficulty and usefulness, are the most likely cause of the changes in participation. While these continuing declines may not amount to a crisis, there is undoubtedly serious cause for concern.

INTRODUCTION

Is there a crisis in Australia's science and mathematics education? There has certainly been significant media coverage of this issue over the last few years, though the evidence provided appears confusing and at times even contradictory. A study commissioned by Australia's Chief Scientist concluded that all the main high school sciences were experiencing continuing and dramatic declines (Goodrum, Druhan, & Abbs, 2011). However, the scale of those reported declines has since been questioned (Ferrari, 2011)

leading to confusion over the actual figures. Whatever their true scale, it is clear that government and industry bodies believe that these declines in science and mathematics education need to be addressed.

At the senior high school level a number of reports (e.g. Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Hackling, Goodrum, & Rennie, 2001; Hassan & Treagust, 2003) point to either a decline in science education enrolments in Australia or, at best, zero growth over the long term. Studies into the state of Mathematics (Barrington, 2006;



Thomson, 2009) have reported similar levels of decline in participation.

The trends reported in Australia have been echoed to various extents in a number of countries across the globe including England and Wales (Smith, 2011), France (Charbonnier & Vayssettes, 2009), India (Garg & Gupta, 2003), Israel (Trumper, 2006), and Japan (Schleicher & Ikeda, 2009) thus suggesting that the causes of the changes may go beyond national and cultural borders.

It is important to resolve these conflicting messages and clarify the state of enrolment trends in high school Science and Mathematics courses. This is especially so given the increasing requirement for citizens to make informed decisions about socio-scientific issues such as renewable energy production, coral reef degradation or climate change. Furthermore, analyses of previous trends in Australia are now several years old and it is crucial that policy and planning initiatives are based on the most accurate and up to date information. This is especially true given the expense of education and the current context of funding (Kelly, 2013).

This paper provides a fresh analysis of Australian senior high school Science and Mathematics enrolment trends over the last two decades, based on recent state and territory enrolment data. The trends in the participation rates are discussed both individually and in the wider context of school Science. Some of the confusion surrounding the trends is clarified and we show that enrolments in the majority of Science and Mathematics courses are continuing to decline. To fully understand these trends requires a deeper analysis than can be offered in this paper; however some general conclusions and recommendations are offered.

BACKGROUND

To understand the context of senior school enrolments in Australia requires an overview of the education systems across the country. There are presently ten recognised school-leaving qualifications administered by eight individual state and territory governments and one international organisation (Masters,

Forster, Matters, & Tognolini, 2006). Depending on jurisdiction, students variously start secondary schooling in either Year 7 or Year 8, aged 12 or 13 years old, and are legally required to remain in compulsory education, employment or training until the age of 17. Prior to 2010, the compulsory school age varied between 15 and 17 on a state-by-state basis. Across all states and territories, English, Mathematics and Science are compulsory subjects until the end of Year 10 and English remains compulsory in Years 11 and 12 except in the Australian Capital Territory (ACT). Students generally select a further three to five other subjects from those offered by individual schools to complete their senior studies. Alternative curricula such as the International Baccalaureate (IB) add a layer of complexity, with IB enrolments accounting for around 0.8% of total Year 12 enrolments in 2012. Throughout this paper we have used the term enrolment to mean students who have enrolled in a school in Australia in their final year of education and have been presented for matriculation to their state education body. Enrolment does not necessarily refer to successful completion of the course.

An important issue to consider in interpreting enrolment trends is the classification used to refer to the multitude of course options across disparate educational jurisdictions. The classification of the “core” science subjects, Biology, Chemistry and Physics, across Australia is fairly straightforward and consistent. However, other Science courses have been included in historical analyses and categorised variously at different times (Table 1). In this paper we also consider the groupings Earth Sciences and Multidisciplinary Science. We note that while Hassan and Treagust (2003) and Ainley et al. (2008) included Psychology as a Science course, its unavailability in some high population states and its promotion elsewhere as a social science have led us to exclude it from this discussion for the sake of clarity.

Classification of Mathematics courses has proven to be equally complex.

The declines seen in most subject areas have been occurring for two decades; do even small declines now amount to a crisis?

Courses tend to be defined depending on their content or on their pathways to tertiary education. Table 2 shows the historical classification of the Mathematics courses and their general content. Although these categories seem clear-cut, to categorise a particular Mathematics course fairly requires analysis of the content of

course syllabus which, in some cases, is very difficult. Furthermore, a subset of elementary Mathematics courses is not able to be included in the calculation of Australian tertiary admission ranks (ATAR). For the purposes of this analysis the Elementary Mathematics group is therefore split into Background Mathematics and entry Mathematics.

PREVIOUS STUDIES OF AUSTRALIAN SCIENCE AND MATHEMATICS ENROLMENTS

Dekkers, de Laeter and Malone (1986) began a systematic process of tracking Year 12 student enrolments in Science and Mathematics with follow up studies at the turn of the millennium (Dekkers & de Laeter, 2001; Dekkers & Malone, 2000). These reports showed that as the proportion of students continuing beyond post-compulsory education increased, Science enrolments slowly but steadily climbed to a peak around 1992 before falling away towards the end of the decade. They also found that Intermediate Mathematics enrolments followed a very similar pattern to Science enrolments, coinciding in their peaks in 1992, yet Advanced Mathematics enrolments declined

SUBJECTS ANALYSED	DEKKERS AND DE LAETER (2001)	HASSAN AND TREGUST (2003)	AINLEY, KOS AND NICHOLAS (2008)	KENNEDY, LYONS AND QUINN (2013)
Biology				
Human Biology	✓	✓	✓	✓
Chemistry	✓	✓	✓	✓
Physics	✓	✓	✓	✓
Geology	✓	✓	✓	
Environmental Science				✓
Agriculture	✓			
Alternative Science	✓			
Physical Science				✓
General Science		✓	✓	
Other Sciences				
Psychology		✓	✓	

Table 1: Science subjects historically analysed by previous researchers.

DEKKERS, DE LAETER AND MALONE (2000) CLASSIFICATION	BARRINGTON (2006) CLASSIFICATION	KENNEDY, LYONS AND QUINN (2013) CLASSIFICATION	GENERAL COURSE CONTENT
Low	Elementary	Background	Terminal Mathematics courses that are not designed for further tertiary study and do not contribute towards tertiary admissions rank.
		Entry	Terminal Mathematics courses that are not designed for further tertiary study yet do contribute to the calculated tertiary admissions rank.
Intermediate	Intermediate	Intermediate	Mathematics courses that provide a satisfactory knowledge-base for tertiary courses requiring minimal understanding
High	Advanced	Advanced	Mathematics courses that provide a specialised knowledge-base for tertiary studies in courses such as engineering and physical science.

Table 2: General classifications of Australian high school Mathematics courses.



steadily through the period. Hassan and Treagust (2003) expanded on these studies by considering the declines in Science and Mathematics in the context of other key learning areas (KLA).

Dekkers et al. (1986) attributed much of the observed increases in both Science and Mathematics enrolments to increased retention, particularly female retention, into Year 12. Some researchers (e.g. Hassan & Treagust, 2003; Hackling et al., 2001) suggested that course content and financial and career incentives may be key to understanding the subsequent declines. However, studies by Lyons & Quinn (2010) and Thomas (2000) suggest that the declines were likely to be a consequence of diversification; both of the academic and career aspirations of the expanded Year 12 cohort and the associated diversification of curriculum offerings, including the introduction of alternative and vocational courses. Forgasz (2006b) noted that declines in Mathematics appeared to be part of a trend away from more specialised Mathematics courses towards elementary courses, rather than a decline in total enrolments.

Ainley et al. (2008) extended these Science trends to 2007 and showed that from 2000 the actual numbers of students enrolled in Year 12 Science courses appeared to be very slowly recovering. However, while the number of students in Science classes grew slightly, this increase was vastly outstripped by the increasing numbers of students completing Year 12. This was reported as a continued decline in terms of student participation rates in Science.

Barrington and Brown (2005), Barrington (2006) and Forgasz (2006b) continued previous work on Mathematics enrolments, showing that downward trends in both Intermediate and Advanced Mathematics continued to 2004, while in elementary courses enrolments continued to increase. Forgasz (2006a) reported large differences in enrolments in Intermediate Mathematics between states and concluded that variation in student expectations of different courses may be key to explaining the observed decline in enrolments at the intermediate level. In her view,

the mathematical ability required of students studying at the intermediate level in some states was much greater than at the elementary level, yet this was not necessarily equitably rewarded in their final marks. Barrington (2013) showed that while enrolments in Advanced Mathematics seemed to be reasonably stable, the trend for students to select Elementary Mathematics in preference to Intermediate has persisted.

Does the decline in STEM suggest a weakening of Australia's academic prowess or a strengthening through diversity?

METHODS

Data Collection

State and territory curriculum authorities publish raw enrolment data annually for every Year 12 course in a variety of forms including media guides and annual reports to government, and the national statistics presented here were compiled from these individual raw data sets. The year 1992 was selected as a Science base level as the work of Dekkers and de Laeter (2001) had already shown this as the year in which participation rates peaked and retention rates from Year 10 to Year 12 stabilised at around 75%. There were also major curriculum changes in a number of states and territories around this time, so inclusion of data from earlier years would not clarify the enrolment trends of the twenty-first century. The year 1994 was selected as the base level for Mathematics enrolments (in keeping with Barrington and Brown (2005)) since categorising courses prior to this is unreliable due mainly to course designations in Victoria (Vic).

Definitions and Constraints

Each of the different state and territory boards offers Science subjects under slightly different titles. In this study, enrolments for Biology also include enrolments for Human Biology. Some boards offer Geology, Environmental Science, and Earth and Environmental Science; and here these are grouped under the term Earth Sciences. Similarly, some less specialised Science courses such as Senior Science in New South Wales (NSW), Integrated Science in

Western Australia (WA) and Science21 in Queensland (Qld) are available, and are here grouped as Multidisciplinary Science.

To allow for valid comparisons between states and over time (due to variations in course curricula), only enrolments in the highest level course available (see Table 3) are included in this analysis. Even though this data collection context is slightly different to that of earlier researchers, results presented here are consistent with earlier works (Ainley et al., 2008; Barrington, 2006). Slight differences sometimes arise due to the definition of enrolment; however, variations between different data sets for the core Science subjects are within $\pm 2\%$.

In this analysis we present both the raw enrolment numbers and the subject participation rates, the latter being the proportion of the total Year 12 cohort enrolled in a particular course. While both methods have the advantage of being readily understood, it should be noted that the increasing Year 12 overall cohort numbers can mask underlying trends in individual subjects.

Science and Mathematics subjects are often reported as being gender biased in their enrolments (Fullarton, Walker, Ainley,

& Hillman, 2003). In these analyses, the sex ratio is presented as the proportion of female enrolments in a particular course.

Australian Year 12 students can and often do enrol in multiple Science courses; however, because of the way enrolments are reported by the states and territories it is not possible to determine reliably the number of students enrolled in multiple courses. A similar issue exists in determining the total enrolment numbers for Mathematics as intermediate enrolments often include the advanced enrolment numbers. Consequently an overall participation rate for Science or Mathematics can neither be accurately determined nor reasonably estimated.

RESULTS OF THE ANALYSIS OF THE ENROLMENT TRENDS

Overall school participation and retention

Figure 1 presents the overall enrolment numbers for Year 8, Year 10 and Year 12 students and retention rate from Year 10 into Year 12 from 1992 to 2012.

Figure 1 shows that in general terms the number of students in Year 12 has risen year-on-year as a consequence of a

STATE OR TERRITORY	KEY LEARNING AREA (KLA)	NAME OF HIGHEST LEVEL OF SUBJECT INCLUDED IN ANALYSIS IN 2011
New South Wales (NSW)	Science	Higher School Certificate (HSC) – 2 unit
	Mathematics (Advanced)	HSC – Extension 2
Queensland (Qld)	Science	Authority Subjects – Year 12
	Mathematics (Advanced)	Authority Mathematics C – Year 12
South Australia (SA) / Northern Territory (NT)	Science	South Australian Certificate of Education (SACE) / NTCE - Stage 2 (20 Credits)
	Mathematics (Advanced)	SACE / NTCE - Stage 2 (20 Credits) Specialist Mathematics
Tasmania (Tas)	Science	Tasmanian Certificate of Education (TCE) – Level 3
	Mathematics (Advanced)	TCE – Level 3 Mathematics Specialised
Victoria (Vic)	Science	Victorian Certificate of Education (VCE) – Unit 4
	Mathematics (Advanced)	VCE – Specialist Mathematics Unit 4
Western Australia (WA)	Science	Western Australian Certificate of Education (WACE) – Unit 3B
	Mathematics (Advanced)	WACE – Mathematics: Specialist Unit 3D
Australian Capital Territory (ACT)	Science	T-Accredited – Major
	Mathematics (Advanced)	T-Accredited – Mathematics Double Major

Table 3: Highest levels of Year 12 science and advanced mathematics subjects analysed in this paper, by state and territory.



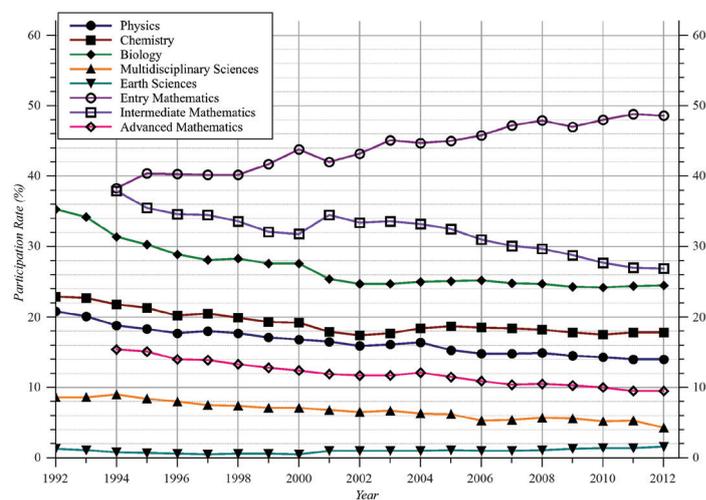
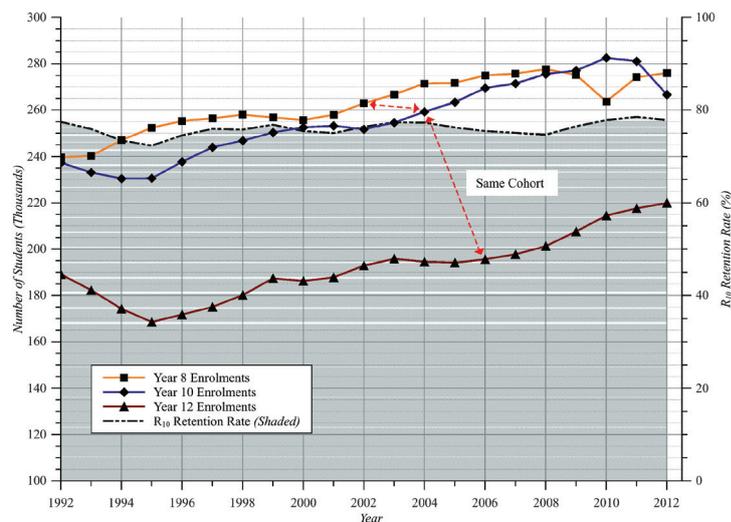
rising school population in Year 10. The Year 12 data were compiled from total examination candidature from the state and territory qualification authorities. The Year 8 and Year 10 enrolments were compiled from Australian Bureau of Statistics (ABS) data (ABS, 2013). The total number of Year 12 enrolments in 2012 was 219,907 compared with 189,041 in 1992. Throughout most of the period the R_{10-12} retention rate (the proportion of students retained into Year 12 from the parent Year 10 cohort) remained fairly stable at around 75% (standard deviation 1.4%) before increasing from 2008 onwards. This increase in R_{10-12} retention is most likely either a consequence of the move by all state and territory governments to increase the general school leaving age to 17 years old (Council of Australian Governments (COAG), 2009) or of an increase in overseas students migrating to Australia to complete pre-university studies (Department of Immigration and Citizenship (DIC), 2011).

Most previous studies, including Dekkers and de Laeter (2001), used Year 8 as the base line for retention rates as historically this has been the first common year of secondary school. As can be seen by comparing the Year 8 and Year 10 lines on Figure 1, which follow almost identical trends, the R_{8-12} and R_{10-12} retention rates could be used interchangeably until 2008. However, post-2008 we choose to use the R_{10-12} retention rate as Year 10 represents the end of compulsory education in most KLAs and takes into account the swelling of the Year 10 cohort compared to the corresponding Year 8 group.

It is also worth noting the significant dip in student numbers in 2010 (Year 8) and 2012 (Year 10). This is due to a shortfall of around 10,000 students in Western Australia caused by the so-called "half-cohort"; a consequence of an increase to the school starting age by six months in that state in 2001 (ABS, 2010). This should cause a corresponding dip in the 2014 Year 12 datasets.

Participation rates, enrolments and sex ratios of individual subjects

Figure 2 shows changes in participation rates of Science and Mathematics subjects from 1992 to 2012.



It is clear that all the subjects analysed show declines in their individual participation rates except Earth Sciences, which exhibits marginal growth, and Entry Mathematics which shows steady growth. The major part of these declines occurred prior to 2002 and the rate of decline has been generally lower in subsequent years. The enrolment trends for individual courses will be discussed in detail in the following sections. For clarity we will discuss changes in participation rates in terms of the total Year 12 cohort, rather than changes within individual courses.

Figure 3 shows the changes in absolute student numbers for Science and Mathematics subjects over the same period.

As can be seen from this figure, the number of students enrolled in most

Figure 1 (top): Overall national enrolment numbers (left hand axis) for Year 8, Year 10 and Year 12 with retention rate (right hand axis) from 1992 to 2012.

Figure 2: Participation rates for Science and Mathematics subjects, 1992-2012.

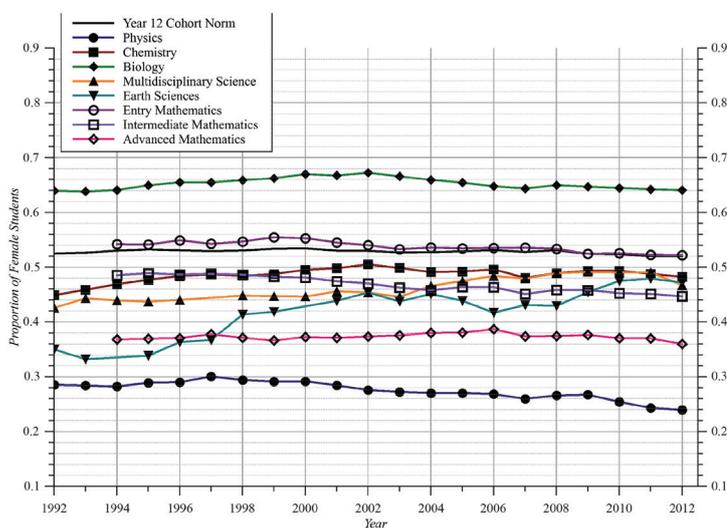
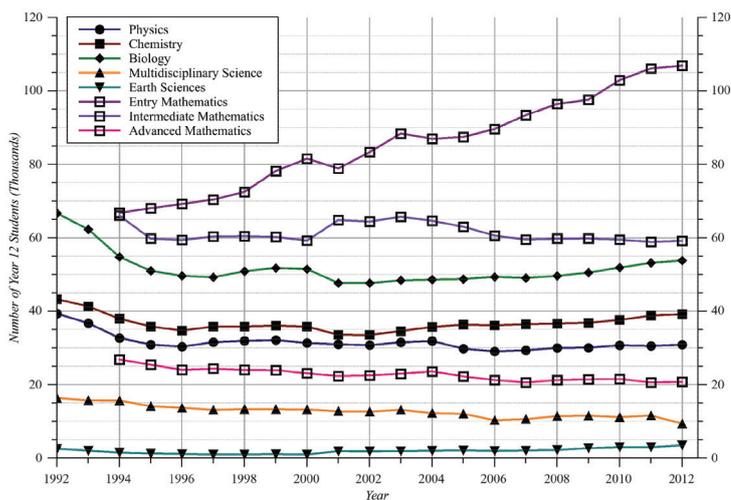


Figure 3 (top): The numbers of student enrolments in Science and Mathematics courses, 1992-2011.

Figure 4: Subject sex ratios showing the number of female students per 100 males within each course from 1992-2012.

of these courses declined markedly between 1992 and 1996 before recovering slightly. From 2001 the number of students studying Entry Mathematics has risen dramatically, the number studying Biology, Chemistry and Earth Sciences has risen slightly while the numbers enrolled in Physics, Advanced Mathematics and Multidisciplinary Science have continued to decline slightly. Intermediate Mathematics witnessed an increase in enrolments in 2001 followed by a steady decline.

Figure 4 shows the sex balance within each of the subjects displayed as the proportion of female enrolments. It is important to recognise that a sex ratio of 0.50 does not necessarily represent equity; the sex ratio of the cohort as

a whole must also be considered. The shaded area on this graph indicates the subjects with a male enrolment bias and the corresponding line indicates equality.

This figure shows that from 1992 to 2012, Chemistry, Multidisciplinary Science and Earth Science have tended towards sex equality while Physics, Biology and Advanced Mathematics have retained and in some cases strengthened their respective sex biases. Entry Mathematics has been the subject closest to the cohort norm in terms of equality of sexes throughout the study and from 2005 has been almost indistinguishable from the norm.

Trends in Physics enrolments

It is apparent from Figure 2 that the proportion of Year 12 students studying this subject has steadily declined each year from 21% in 1992 to just 14% in 2012. This is a change of -7 percentage points compared with the 1992 levels of participation and -2 percentage points when compared to 2002; i.e. a percentage change of -33% compared to 1992 or -12% compared to 2002.

In the same period, the number of students enrolled in Physics courses declined from around 39,000 in 1992 to around 31,000 in 1996 (Fig. 3). This level of enrolment remained reasonably stable until 2004 but then fell by a further 2000 students over two years. Since then Physics enrolments have been very slowly growing to the present level of 30,877. In relative terms, the present number of enrolments represents just 76% of the 1992 numbers.

Figure 4 shows that Physics has the largest proportion of male students and that this proportion has become steadily larger. In 2012, the sex ratio was 0.25 which equates to approximately three male students for every female.

Trends in Chemistry enrolments

Participation rates for Chemistry (Fig. 2) have been in general decline across the period of study from a high of 23% in 1992 to 18% in 2012. Ainley et al. (2008) suggested that Chemistry participation may have turned a corner and started to recover, but Figure 2 shows that the



recovery in participation rates between 2002 and 2005 was short lived and the steady decline has continued. This is a decline of -5 percentage points on 1992 levels or an increase of +1 percentage point when compared with 2002; i.e. a percentage change of -22% compared to 1992 or +2% when compared with 2002.

Figure 3 shows that absolute enrolments in Chemistry declined steadily by 10,000 students over the period 1992 to 2002 from an initial level of around 43,000. Since this date, enrolments have continued the gradual rise identified by Ainley et al. (2008) and in 2012 reached 39,187 students. The present enrolments account for 90% of the 1992 numbers or a 17% gain on the 2002 figures.

Chemistry exhibits fairly good balance between the sexes with the sex ratio relatively stable around 0.49 since 1995 (Fig. 4). This equates to around 26 males for every 25 female students.

Trends in Biology enrolments

The participation rates for Biology (Fig. 2) from 1992 to 2002 dropped from 35% to around 25% and mirrored the trends in raw enrolments (Fig. 3). However, since 2002 the participation rates have been relatively stable, only falling to 24.5% by 2012. This is a change of -10 percentage points compared with 1992 or -0.5 percentage points with respect to 2002; i.e. a percentage change of -31% compared with 1992 or -1% compared with 2002. This can be accounted for as the increases in raw Biology enrolments (Fig. 3) were only slightly outstripped by the increases in the total Year 12 cohort.

Biology has remained the most popular Science subject throughout this period. Enrolments were around 67,000 students in 1992 and declined steadily to approximately 48,000 in 2002 (Fig. 3). There has since been steady improvement with enrolments reaching 53,802 in 2012. The 2012 enrolment figures represent 81% of the 1992 numbers or a gain of nearly 13% on 2002.

Female students have consistently shown a preference for Biology over their male peers throughout the period of study. The sex ratio tended even further towards females reaching a peak of 0.67 in 2004 (Fig. 4) but has since moved back

slightly. In 2012 the sex ratio was 0.65; this indicates that there were around nine females enrolled for every five males.

Trends in Earth Science enrolments

Participation rates (Fig. 2) in Earth Sciences have been reasonably stable from 1992-2012 and follow a very similar pattern to raw enrolment numbers (Fig. 3). In 1992 Earth Sciences had a participation rate of 1.3% which fell to a low of 0.5% in 2000 before climbing to a level of 1.6% in 2012.

Throughout the period of study, Earth Sciences have attracted the fewest enrolments of all the mainstream Science courses. However, while enrolments declined from 1992 to less than 1,000 students in 1996, they have been slowly increasing since to 3,470 in 2012 as shown in Figure 3.

The apparent changes in sex balance of this group of subjects can be a little misleading as slight variations in enrolment patterns can have visually large effects on the sex ratio due to the small cohort size. Some of this volatility can be explained by the introduction of additional courses in the Earth Sciences group by a number of states and territories to complement the more traditional Geology-like courses. Figure 4 shows that Earth Sciences have been predominately male-biased but post-2006 the sex balance has been trending towards equity. In 2012, the sex ratio of 0.47 represents nine female students for every ten males.

Trends in Multidisciplinary Science enrolments

Participation rates in the courses comprising the Multidisciplinary Science category have followed the common trend and have suffered a steady decrease over the period falling from around 9% in 1992 to 4.3% in 2012 (Fig. 2).

Actual enrolment numbers show a long, slow decline from around 16,000 in 1992 to a low of around 10,000 in 2006 (Fig. 3). More recently enrolments had appeared to recover, yet in 2012

Does your school show similar trends in Science and Mathematics to the rest of the country?

they fell to a new low of 9,386. The 2012 enrolments represent 59% of the 1992 or 74% of the 2002 numbers.

Multidisciplinary Science shows a slight male bias, but from 2005 onwards this balance has been tending towards equity. In 2012, there were 22 females per 25 males represented by a sex ratio of 0.47 (Fig. 4).

Trends in Entry Mathematics enrolments

As can be seen in Figure 2, Entry Mathematics has followed a very different trend to all the other subjects analysed in this paper. Participation rates have steadily increased from 38% in 1994 to around 49% in 2012. This represents a change of +11 percentage points on the 1994 levels or +5 percentage points on the 2002 levels; i.e. a percentage change of +27% compared with 1994 or +13% compared with 2002.

Figure 3 shows that the actual number of students enrolled in Entry Mathematics has risen from around 67,000 in 1994 to 106,900 in 2012. The rate of increase in enrolments has been fairly steady over the 20 years of the analysis, excepting the significant drop in 2001. This can be accounted for entirely by a drop in the New South Wales enrolments, which coincided with significant syllabus changes and reorganisation in this state. The 2012 enrolment numbers represent an increase of 60% on the 1994 enrolments or 28% compared with 2002.

Entry Mathematics has traditionally had a slight female bias. Over the period of these analyses this has tended towards equity and from 2008 the sex ratio has been almost indistinguishable from the Year 12 cohort norm; in 2012 the sex ratio was 0.522 while the cohort norm was 0.520. This equates to eleven females per ten males.

Trends in Intermediate Mathematics enrolments

Figure 2 shows that Intermediate Mathematics is almost the reverse image of Entry Mathematics. Participation rates have steadily fallen from 38% in 1994 to 27% in 2012. This is a decline of -11 percentage points on the 1994

baseline or a decline of -7 percentage points on 2002 participation rates; i.e. a percentage change of -29% compared to 1994 or -11% compared to 2002.

In terms of raw enrolments, Intermediate Mathematics has been remarkably stable showing virtually zero growth over the 20 years of this analysis. 1995 marked the beginning of a six year stretch where the total number of students was around 60,000. In 2001, there was a significant increase to 65,000, which coincides with the syllabus overhauls in NSW and the subsequent increase in state enrolments. From 2003, the total number of enrolments declined to the historic level of around 60,000 by 2007 and in 2012 there were 59,144 enrolments.

Although total enrolments have remained relatively steady, the sex balance of the course has changed slightly. Intermediate Mathematics has shown a male bias that has become slightly stronger over time. In 1994, the sex ratio was 0.37 while in 2012 it was 0.35, equating to eight females for every ten males.

Trends in Advanced Mathematics enrolments

As can be seen in figure 2, Advanced Mathematics has followed a similar trend to Physics and to some extent Chemistry. Participation rates have steadily declined from around 16% in 1994 to 9% in 2012. This is a change of -7 percentage points compared with the 1994 participation levels or -3 percentage points on the 2002 data; i.e. a percentage change of -39% compared to 1994 or -19% compared to 2002.

Figure 3 shows that raw enrolment numbers declined from around 27,000 in 1994 to a low point of 20,600 in 2007. Since this time, enrolments have been relatively static with 20,789 enrolments in 2012. This corresponds to 77% of the 1994 levels or 93% of the 2002 data.

The sex balance within Advanced Mathematics, as shown in Figure 4, has been remarkably stable throughout the period at 0.37, representing six female students per ten males. This dropped slightly in 2012 to 0.35 corresponding to 14 female students for every 25 males.



DISCUSSION

At first glance, the National Partnership Agreement on Youth Attainment and Transitions (Council of Australian Governments (COAG), 2009) would suggest that from 2012 onwards there should be an increase in the R_{10-12} retention rate (Fig. 1), caused by a swelling of Year 12 as students became required to remain in full time education, training or employment until the age of 17. This overall swelling could be expected to comprise students who would have traditionally left school at Year 10 and who may not be academically inclined towards science and mathematics in Year 12. If this change in cohort profile is correct, there should be a corresponding drop in the participation rates for Science and Mathematics (Fig. 2). However, we observe neither an increase in retention in 2012 compared to previous years nor any significant change in the rate of decline in subject participation rates excepting Multidisciplinary Science which is caused by a drop in raw enrolment numbers (Fig. 3). This apparent anomaly can be traced to the cessation of Multi-Strand Science in Qld (Qld Studies Authority (QSA), 2013). After one cohort, the change to the school-leaving age appears to have had no direct effect on the number of students completing Year 12 with a traditional credential; whether this will change over the next five to ten years remains to be seen.

The sex ratios presented in Figure 4 show that some subjects show a definite bias towards one sex or the other. This is particularly clear in Physics and Advanced Mathematics. Discussion of the complex and multi-faceted potential reasons for this bias is beyond the scope of this paper but there is a strong research field exploring the reasons for women leaking from the STEM 'pipeline'. (see e.g. Clark Blickenstaff (2005)). As shown in Figure 4, most subjects have remained fairly consistent in their sex balance since 2002, except for Biology and Physics which have shown changes towards proportionally fewer females and Earth Science and Multidisciplinary Science

which have shown changes towards proportionally more females. Figure 3 suggests that in the case of Biology this change has been brought about by an increasing number of males electing to do the subject, and conversely in Earth Science an increasing number of females choosing the course. However, examining Multidisciplinary Science leads to the conclusion that fewer students overall, and males in particular, are choosing this subject. A similar story can be seen in the Physics data; students in 2012 are overall less likely to study Physics than in 2002 and female students are even less likely to do so than their female counterparts in earlier cohorts. The factors lying behind these trends are likely to be a combination of personal relevance, interest, difficulty and cultural characteristics (Lyons, 2006), but the granularity of the data analysed here is too coarse to allow this to be examined further.

A potential explanation for the falling subject participation rates is that students who previously may have enrolled in two or more Science courses are now studying only one (Calderon, Dobson, & Wentworth, 2000; Lyons & Quinn, 2010) due to the breadth of choice currently available. In 2012 the New South Wales Board of Studies (NSWBoS) offered examinations in 124 different courses and levels (NSWBoS, 2012). If this explanation is correct, then while individual subject trends may show continuing declines, the overall health of science, as measured by the number of students with some exposure to science at the upper secondary level, may still be satisfactory. This hypothesis is interesting yet cannot be easily examined using the available data as combinations of subjects are not published by the various states and territories. The Longitudinal Surveys of Australian Youth (LSAY) reports issued by National Centre for Vocational Education Research (NCVER), formerly issued by the Australian Council for Educational Research (ACER), offer an opportunity to examine this further (Fullarton et al., 2003) yet the demographic profile of the sample remaining in LSAY by Year 12 is not a perfect match for the Year 12 cohort as

a whole. Further analysis is required in this area if the effects of combinations of subjects on overall participation rates are to be understood.

As is evident in Figure 2, there is symmetry between the participation rate trends of Entry and Intermediate Mathematics; the mean participation rate of these two courses has remained fairly constant at $38 \pm 1\%$ over the entire period from 1994 to 2012. This suggests that the growth in Entry Mathematics is not a result of an increased proportion of Year 12 students studying mathematics, but is a consequence of students selecting a non-calculus course (entry) in preference to a calculus-based course. It can also be seen that both Entry and Intermediate Mathematics courses have become slightly more male-biased over time. Combining this with the declines seen in Advanced Mathematics could suggest that students of both sexes are abandoning Advanced Mathematics in favour of Intermediate, while the changes from Intermediate Mathematics see male students selecting Entry Mathematics while females elect no Mathematics. This summary is necessarily coarse due to the granularity of the data but supports the findings of Mack and Walsh (2013) in relation to girls in NSW and needs further investigation at the national level.

Chinnappan, Dinham, Herrington and Scott (2008) suggested that the declines in Advanced Mathematics then could be due to many reasons including a lack of potential career information and a lack of understanding of the role of mathematics in science. A study by McPhan, Morony, Pegg, Cooksey, and Lynch (2008) suggested that the blockers towards student enrolments in Mathematics are unsurprisingly similar to those in the Sciences namely; self-perception of ability, perceptions of difficulty and usefulness, previous achievement, and interest and liking of mathematics. The very close mirroring of the trends in Physics and Advanced Mathematics seen in Figure 2 are suggestive of common causation. Arguably, students may be assessing the utility value of Year 12 courses and then selecting courses at a level appropriate to their immediate needs (e.g. university

entrance scores) rather than their future aspirations. The selection of courses is further complicated by the tertiary course information made available to students through the Universities Admissions Centre (UAC). The entries in the 2013–14 UAC (NSW/ACT) guide for example often make reference to Mathematics as *assumed knowledge* yet do not state the level of mathematical expertise required by the student in order to succeed in a particular course. Limited mathematical background results in students struggling to make adequate progress once they reach university (Brown, 2009).

CONCLUSIONS AND RECOMMENDATIONS

Participation in Science and Mathematics courses by Australian Year 12 students, with the lone exception of Entry Mathematics, has been declining in real terms for the greater part of the past two decades and continued to do so in 2012. The magnitude of this rate of decline has been less in recent years than prior to 2002, but continues steadily. It is important that these enrolment trends continue to be monitored and updated regularly so that accurate and current documentation of the trends is maintained.

While the declining participation rates in Advanced and Intermediate Mathematics are relatively straightforward to track, it is not a simple task to determine where these students are going. Due to the tiered nature of mathematics education it could be assumed that the Advanced Mathematics students are simply dropping a level to Intermediate Mathematics. Yet this is easier to hypothesise than understand and is made particularly difficult by the abundance of Mathematics courses available across the country that are not easily comparable. In order to understand

Do your students perceive Science and Mathematics in Years 11 and 12 to cost them more in effort than they are worth for their future career paths? Why?



the true state of school mathematics, it is essential that the states and territories agree on the definition of the content of each level of the Mathematics offerings so that overall enrolment numbers for each of these category can be distilled and the overall health of the subject be discerned.

The available Year 12 curriculum has significantly broadened throughout the period covered by this analysis creating an increased range of subjects from which students can choose. There is some suggestion that responses to systemic changes such as the transition away from prerequisite courses by universities, a reduction in the minimum number of required subjects in some states and territories, and the clever choice of courses to maximise a student's tertiary admissions rank may have combined to encourage students, who may be considering a career in science or engineering, to select courses primarily on the basis of immediate interest rather than as a foundations for future needs. The analyses presented in this article can neither support nor refute this argument and a more extensive analysis across a wider selection of subjects is needed to investigate this further.

Ultimately, these analyses show that participation in post-compulsory school Science and tertiary-enabling Mathematics continues to decline. Is this a crisis? We hesitate to describe it as such, since the continuing declines are very gradual. However, should government, industry and the educational sector be alarmed by these trends? Yes. If school STEM is to continue to be a cornerstone of creating scientifically aware and literate citizens then it is important to understand why students are electing not to continue the study of school science. Examining enrolment data can only

What could you do in your classroom to promote the uptake of Science and Mathematics in Years 11 and 12?

reveal the general trends in this regard. Further investigation with the students in compulsory science education is required to understand why, when and how they make the decision to turn away from Science courses and to also understand what they elect to study to replace them.

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