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Australian enrolment trends in technology and engineering: putting the T and E back into school STEM

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Abstract There has been much political and educational focus on Science, Technology, Engineering and Mathematics (STEM) in Australian schools in recent years and while there has been significant research examining science and mathematics enrolments in senior high school, little is known about the corresponding trends in Technologies and engineering. Understanding these subjects is essential for educators and policy-makers alike if Australians are to embrace the challenges of an innovation economy. We have collected raw enrolment data from each of the Australian state and territory education departments from 1992 to 2014 and analysed this across five Technology and Engineering subject areas. We also consider some of the relationships between these subject areas and other areas of the STEM equation. The results of these analyses are discussed in terms of absolute enrolments, participation rates and sex balance. We have found that the total number of students in Year 12 increased year on year and that this growth is echoed, to a lesser extent, in the participation rates for design technology, food technology and engineering. Digital Technologies however, grew rapidly until 2000, after which time it has been in steady decline. We identify that while the trends mostly show growth, there is a concerning male bias to many of these subject areas. We suggest that the broadening of the upper high school curriculum, confusion surrounding vocational training enrolments, and gamesmanship of the university entrance system, may be contributing to the limited growth observed. Finally, we identify a number of important areas for further research in this key learning area.

Keywords High-school · Technology · Digital technology · Engineering · STEM · Gender · Enrolment trends

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Introduction

The status of Science, Technology, Engineering and Mathematics (STEM) in Australia has been the focus of much political discussion and many education initiatives in recent times. STEM is being lauded as the driving force of the Australian economy over the next 20 years (Commonwealth of Australia 2015b) and a National STEM School Education Strategy (Education Council 2015) has recently been established. Much has therefore been made of the need to produce more STEM-proficient students in Australian high schools. Indicative of the activity around STEM education, one recent national survey found over 250 different extra-curricular school STEM programs available around the country (Office of the Chief Scientist 2016), while another survey of Australian employers indicated that 45% expected their demand for STEM skills to grow by 2020 (Deloitte Access Economics 2014).

In the current national discussion surrounding STEM, the term itself tends to be used in two different contexts. Those more familiar with the origins of the STEM movement understand it as an integrated, interdisciplinary approach to student learning coupled with real-world applications and contexts (Lederman and Lederman 2013; Tsupros et al. 2009). The integrated conception of STEM, while becoming more popular, is still relatively rare in Australian schools. By contrast, as the term STEM has become more common in political and public discourse there has been a greater tendency for it to be used as a convenient catch-all for the four fields, individually or collectively, and across the school, university and industry domains.

When the term STEM is used casually in relation to schools, engineering and technology are often overlooked; the former because it is not commonly taught as a stand-alone subject, and the latter because the 'Technologies' key learning area (KLA) encompasses such a wide range of subjects from software design to food technology. Science and mathematics tend to take centre-stage in research focus and much public commentary, while engineering and technology wait in the wings. This is likewise the case with research on participation in school subjects (e.g. Barrington and Brown 2005; Dekkers and de Laeter 2001; Kennedy et al. 2014), most likely because Technologies subjects are classified variously in different states and territories, and consequently national enrolment trends are very difficult to track and collate.

Two reports from the Australian Council for Educational Research (ACER) provide some enrolment data up to 2007. Fullarton et al. (2003) identified that in 2001 computer studies had the highest share of Technologies enrolments, followed by food science and technical studies. Ainley et al. (2008) identified relatively stable Australia-wide participation rates across most technology subjects from 1996 to 2007 with the notable exception of computer studies—where national enrolments peaked at 25% of the Year 12 cohort in 2001, then fell rapidly towards 14.5% in 2007. Their report also noted that food and home science enrolments increased from almost 5 to 8% over the period of their analysis. Since these reports however, little has been done to monitor or explore further changes. Engineers Australia's annual Statistical Overview (Kaspura 2015) has as one of its foci the transition of students from schools to university courses in engineering. While discussing trends in school mathematics and science, this engineering-focussed report does not focus specifically on trends in school Technologies subjects.

On the international stage digital technologies (variously described as computer science, ICT, and computing) has garnered much of the attention within the Technologies KLA. Most published research focuses on the university sector, where there are indications of declining enrolments and high attrition in some contexts. For example, Brinda et al. (2009) noted that only 7.6% of university entrants elected to major in computer science and over a third of these failed to complete their courses while Vegso (2008) reported decreased enrolments during the early 2000s of as high as 60% in computer science in US colleges. The few studies reporting trends in upper secondary schools similarly point to concerns about enrolments. For example, the low levels of enrolments in digital technology courses in New Zealand in the mid 2000s (Bell et al. 2010) resulted in the adoption of Digital Technology Guidelines to formally define a computer science curriculum in schools (Ministry of Education 2010). In a USA study, Carter (2006) attributed declines in tertiary computer science primarily to students having an inaccurate (or no) perception of what computer science entails, because of an inadequate to the field in high schools.

Hence, with the implementation of the *Australian Curriculum: Technologies* on the horizon, it is important to update our knowledge of the enrolment patterns in Technologies and establish an enrolment benchmark at this point. It is also significant that we take this snapshot now at this stage of the school STEM movement, as the school approach to STEM often uses technological and engineering contexts to provide real-world examples and applications for the scientific and mathematical knowledge and thinking valued by employers and society. Furthermore, the analyses of previous trends are now nearly a decade old and it is crucial that effective policy, planning and initiatives are informed by the most accurate and up to date information. In particular, if the adoption of the National STEM School Education Strategy (Education Council 2015) is to be effective then it is essential that the current educational landscape be well mapped. By putting the 'T and E' back into the STEM enrolment picture, stakeholders can begin to see similar and contrasting characteristics and trends with mathematics and science enrolments.

This paper provides an analysis of Australian senior high school (Years 11 and 12) Technologies and engineering enrolment trends over the last two decades. The raw data were collected from each of the eight state and territory departments of education, catalogued and collated to create the most up-to-date national Year 12 enrolment database available. The trends in the participation rates are discussed here both in terms of individual subject areas and in the wider context of the Technologies KLA. We show that while there are some areas of enrolment growth, there are also some areas of decline. Taking a STEM perspective, we also report on our exploration of patterns with respect to science and mathematics enrolments to identify any apparent relationships for future investigation. To fully understand the causes of and relationships between these trends requires a deeper analysis than can be offered in this paper; however some general conclusions and recommendations are offered here.

Background

In the Australian education system the majority of students commence high school (Years 7–12) at age 12 or 13, and are legally required to remain in compulsory education, employment or training until the age of 17. In practice this requirement has resulted in a majority of students (85.6% of females and 77.4% of males) completing Year 12 studies (Australian Bureau of Statistics 2015). The federally administered Australian Curriculum, Assessment and Reporting Authority (ACARA) has responsibility for the production and dissemination of the Foundation (also known as Kindergarten) to Year 10 curriculum which is then interpreted and implemented by the state and territory education departments. School curricula and exit qualifications are the responsibility of the eight state and territory governments and variously consist of four to six subjects, usually including English as a mandated course. In 2014, 1.1% of students completed the externally administered International Baccalaureate Diploma Programme as an alternative to the state based leaving qualification. Within this complex curriculum model, the Technologies KLA is a mandatory component for all students until the end of Year 8 when it takes on many elective forms including specific engineering courses in some jurisdictions.

One of the issues to be considered in understanding enrolment trends is the classification used to refer to the broad range of course options available across the Technologies KLA and across the various educational jurisdictions. ACARA defines two distinct subjects within the Technologies curriculum: F-10—digital Technologies and design and technology—each with a number of learning contexts (ACARA 2015). In Years 11 and 12 these subjects are built upon by the states and territories into a wide range of separate courses. Following consultation with ACARA's Technologies Project Officer (J. King, personal communication, 12 July 2015) we have elected to include five course areas within this analysis. Although there are many specific courses, these five *course areas* are available to students, in approximately comparable form, across all eight jurisdictions (except for food and fibre production in Tasmania and The Australian Capital Territory), and therefore can be used to represent the breadth of the KLA in the final years of school. Over the last 20 years however, the availability, nomenclature and content of the Year 11 and 12 courses offered by the different states and territories have changed significantly. Table 1 shows the courses (as offered in 2014) included in each course area. We note that Ainley et al. (2008) included hospitality studies as a separate grouping, yet we have excluded it from our analyses due to its offering in many states and territories only as a vocational learning area partly outside the formal control of schools. We have also decided to include agricultural science (in the food and fibre production subject area) and computer science (in the digital technology subject area) in our analyses in keeping with ACARA recommendations, even though some states and territories regard these courses as part of the science KLA in Years 11 and 12. Since around 2001, Vocational Education and Training (VET) courses have also been recognised as equivalent to school-based courses as part of a student's exit qualification. Many of these VET courses fall into the subject areas of the Technologies KLA, however, the naming and classification of these courses has varied so much across the period of research, and appears so inconsistent between jurisdictions, that these students cannot be reliably included in the following analyses.

Methods

Data collection

Each year the state and territory curriculum authorities collect raw enrolment numbers for every Year 12 course, in various forms. The national statistics presented here are manually compiled from these individual raw data sets supplemented with additional publicly available data from other organisations (e.g. International Baccalaureate Organisation). As outlined in Kennedy et al. (2014), the year 1992 was selected as a suitable reference-level for science enrolments as previous work (Dekkers and de Laeter 2001) had shown this as the year in which Year 10–12 retention rates began to stabilise at around 75%. These

Table 1 Offered Year 11 and 12 courses across the technologies key learning area by subject areas and jurisdiction as at 2014

Jurisdiction	Australian curriculum: technologies F-10				Engineering *(engineering thinking focus)*
	Digital technology *(computer programming and use foci)*	Design technology *(design and use of technology foci)*			
		Design technology	Food technology	Food and fibre production	
New South Wales (HSC 2 unit)	Information processes and technology Software design and development	Design and technology Industrial technology Textiles and design	Food technology	Agriculture	Engineering studies
Victoria (VCE unit 4)	Information technology—IT applications Information technology—software development	Product design and technology	Food and technology	Agricultural and horticultural studies	Systems engineering
Queensland (authority subject)	Information processing and technology Information technology systems	Technology Studies Graphics	Home economics	Agricultural science	Engineering technology Aerospace studies
South Australia/Northern Territory (stage 2: 20 credits)	Information technology Information processing and publishing	Design and technology—communication products Design and technology—material products	Food and hospitality Nutrition	Agriculture and horticulture	Design and technology—systems and control products
Australian capital territory (T-accredited)	Information technology T	Design and technology T Textiles and fashion T Design and graphics T	Food Science and management T	No equivalent	Engineering studies T
Tasmania (level 3)	Computer science 3 Information systems and digital technologies 3	Electronics 3 Computer graphics and design 3 Housing and design 3 Technical graphics 3	Food and nutrition 3	No equivalent	No equivalent
Western Australia (stage 3)	Computer science Applied information technology	Design Materials design and technology	Food science and technology	Animal production systems	Engineering studies Aviation

analyses of Technologies enrolments complement our recent analyses of science and mathematics enrolments (Kennedy et al. 2014) and share the same reference year.

Definitions and constraints

In order to allow valid comparisons to be made between states and over time, only enrolments in the highest level Year 12 courses available in each subject area (see Table 1) are included in this analysis. Although this data collection context is slightly different to that of Ainley et al. (2008), there is general agreement between the results presented here and this earlier work. Additionally, this is the same context adopted in our earlier work (Kennedy et al. 2014) allowing for the direct comparison of these enrolments with those of the Science and Mathematics KLAs.

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 or territory education body. Enrolment does not necessarily refer to successful completion of the course.

In the individual analyses below, we have presented both the raw enrolment numbers and the course area participation rates—the proportion of the total Year 12 cohort enrolled in the courses of a particular Technologies KLA course area. While both approaches have the advantage of being readily understood, the increasing total numbers of Year 12 students can mask underlying trends in individual course areas and so we recommend the use of participation rates for comparison purposes.

STEM courses are frequently reported as being generally biased in favour of enrolment by male students (e.g. Clark Blickenstaff 2005; Hill et al. 2010). To investigate this aspect, the female-male balance of the different course area cohorts is presented below as the number of female students per 100 males enrolled in a particular course. This measure will be referred to as the sex ratio.

Australian Year 12 students are generally unconstrained by the number of courses in which they can enrol in the Technologies KLA. Fullarton et al. (2003) identified that few students take more than one course in the Digital Technologies subject area yet they found it to be a little more common for a student to undertake more than one course from the design and technology subject area. However, due to the unavailability of published, individual level data, it is not possible to reliably determine the number of students enrolled in multiple courses. Consequently any attempt to determine the overall participation rate for the Technologies KLA will always be an over-estimation, and we are not exploring participation in the Technologies KLA overall in this paper.

In order to identify any apparent relationships between courses both within the Technologies KLA and with the wider Science and Mathematics KLAs a series of graphical correlation analyses were performed using the *R* statistical environment (R Core Team 2014). The *pairs.panels* function in from the *Psych* library (Revelle 2014) was used to produce Scatter Plot Matrices (SPLOM) of the pair-wise course participation rates (Figs. 5–8). Course areas are plotted on the diagonal with pair-wise scatterplots, linear regression lines and 95% confidence ellipses below the diagonal. The pair-wise correlation coefficients (r) are printed above the diagonal. In order to determine if a particular pair-wise trend is both statistically significant and statistically meaningful (Bryhn and Dimberg 2011), a two-tailed t-statistic was calculated using the Pearson correlation coefficient and the number of samples according to the method outlined by Lowry (2016). This was used to assess each pair-wise correlation against the null hypothesis (H_0) that the two retention rates are not dependent on each other. A *p* value was then determined using the Student's t-distribution with the degrees of freedom being determined by the number of data-pairs minus two. Bryhn and Dimberg (2011) argue that a trend should be considered statistically meaningful if both the coefficient of determination (r^2) is greater than 0.65 and the trend is statistically significant to at least the 95% confidence level.

However, it is important to recognise that a statistically meaningful pair-wise correlation between two course areas does not by itself necessarily indicate the presence of common factors. The course area participation rate data are in reality time-series data which could reasonably be expected to show some level of inter-correlation simply as a result of the time trend itself. An additional indicator of the existence of common exogenous variables affecting two or more course areas would be a statistically meaningful relationship between the course area participation rates after being detrended; that is after the time based growth described by the linear regression line is removed leaving only the random effects that cannot be attributed to time. If both course area participation rates vary randomly together and in-phase, that is, if there is a statistically meaningful positive correlation between their residuals, then this may be an indication of the existence of a common underlying exogenous variable(s). If the correlation between the residuals is a statistically meaningful negative correlation then this may be an indication of the existence of a causal relationship between the course areas, although the direction would be indeterminate from the simple model.

Results and discussion of enrolment trend analyses

Overall school participation and retention

Figure 1 presents the overall enrolment numbers for Year 10 and Year 12 students and the retention rate from Year 10 into Year 12 from 1992 to 2014. The Year 12 data are a result of total examination candidature statistics and the Year 10 data are based on Australian Bureau of Statistics data (Australian Bureau of Statistics 2015). In general terms, Fig. 1 shows that the total number of Year 12 students has risen year on year in response to a growing Year 10 population. The R_{10-12} retention rate (the proportion of students retained into Year 12 from the parent Year 10 cohort) has risen steadily since 2008 from its historical level of around 75% to the 2014 level of 81%. The corresponding R_{8-10} retention rates (not shown: the proportion of students retained into Year 10 from the parent Year 8 cohort) have been slightly in excess of 100% since 2008 (102% in 2014) suggesting that this increase in R_{10-12} retention is likely a consequence of both the rising of the general school leaving age to 17 years old (Council of Australian Governments (COAG) 2009) and of immigration.

As we noted in Kennedy et al. (2014) the significant dips in student numbers in 2012 (Year 10) and 2014 (Year 12) are due to the so-called "half-cohort" in Western Australia; a consequence of an increase to the school starting age by 6 months in that state in 2001 (Australian Bureau of Statistics [ABS] 2010).

Participation, enrolments and sex ratios of individual subjects

Figure 2 shows the changes in the participation rates across the course areas of the Technologies KLA from 1992 to 2014.

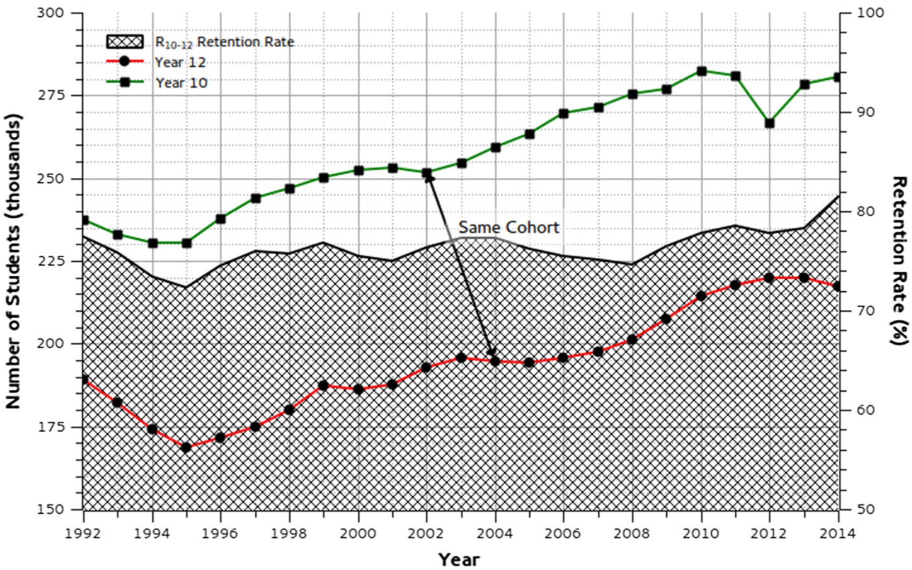


Fig. 1 Overall national enrolment numbers (*left hand axis*) for year 10 and year 12 with retention rate (*right hand axis*) from 1992 to 2014

It is clear that while most Technologies course areas show very slight growth since 2000, digital Technologies have suffered significant declines. This is the inverse of the pre-2000 pattern, where all areas were steady or in slow decline except for digital Technologies, which were on the rise. Significantly, all of these course areas account for a very small proportion of Year 12 enrolments with design technology (10.9% in 2014) being the largest contributor. From a STEM perspective, it is interesting to note that this participation rate is reasonably comparable to the participation rate reported for advanced mathematics (9.5% in 2012) reported by Kennedy et al. (2014).

Figure 3 shows the changes in absolute student numbers for Technologies course areas over the same period. As can be seen in this figure, the number of students enrolled in most of these course areas has risen steadily between 1992 and 2014 excepting digital Technologies which witnessed plummeting enrolments post 2000, and food and fibre production where enrolments have declined very slowly since 2000.

Figure 4 shows the sex ratio within each of the course areas displayed as the number of female students per 100 males. Figure 4 (lower) shows the same data but focussed on those subjects with a sex ratio less than 150 per 100. It is important to recognise that a sex ratio of 100 does not necessarily represent equity as the sex ratio of the cohort as a whole, which tends to be slightly female biased, must also be considered. The shaded area on this graph indicates the subjects with a male enrolment bias and the corresponding boundary line indicates equality.

This figure shows that over the period 1992–2014, food and fibre production has tended towards sex equality, although this is possibly overemphasised by the small enrolment numbers, while all other areas have retained or strengthened their respective traditional sex biases.

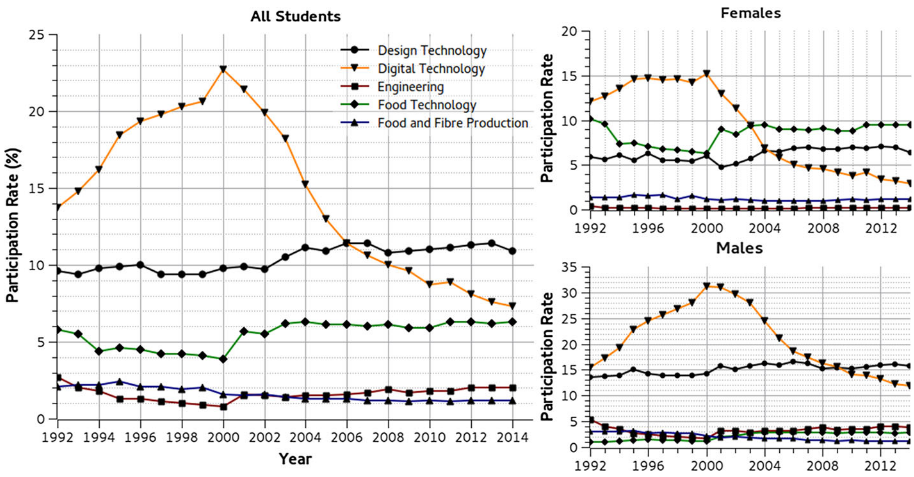


Fig. 2 Overall participation rates (*left*) for subject areas in the technologies key learning area, 1992–2014 and broken down by student sex (*right*)

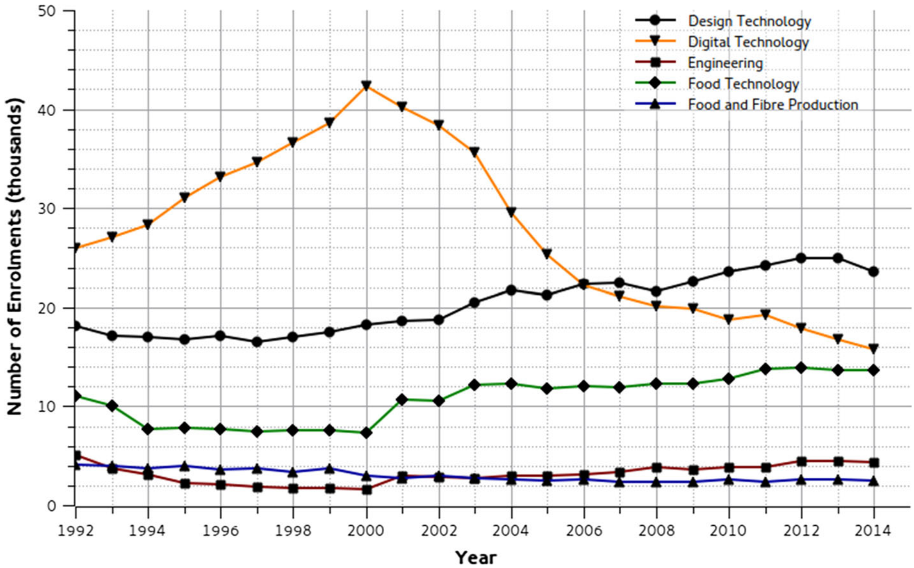


Fig. 3 Student enrolment numbers for subject areas in the technologies key learning area, 1992–2014

Trends in design technology enrolments

The design technology course area incorporates a wide range of school-based courses with a strong design element (Table 1). As identified by Fullarton et al. (2003), it is likely that some of the enrolments in this course area can be attributed to the same student and so the following participation is likely to be a slight overestimation. It is apparent from Fig. 2 that the proportion of Year 12 students electing to study this course area remained steady from

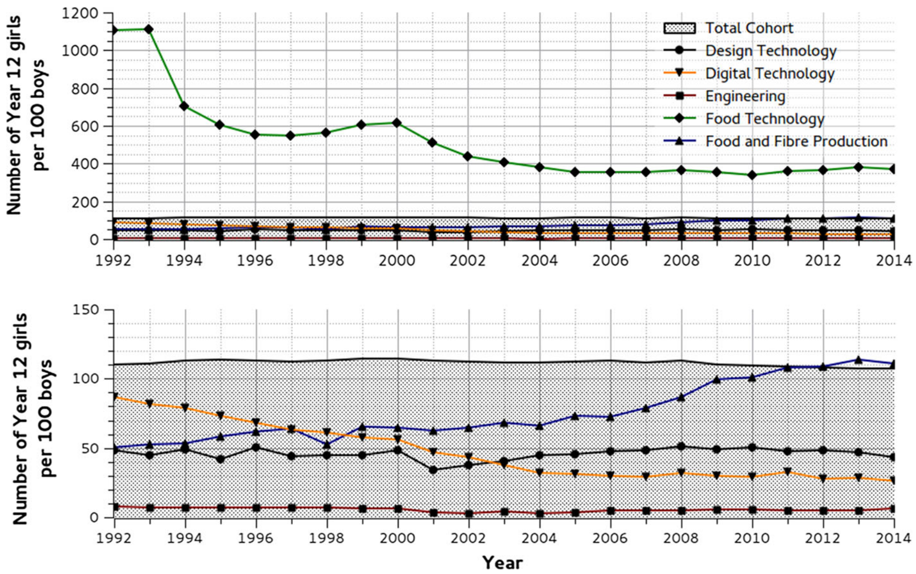


Fig. 4 Subject sex ratios showing the number of female students per 100 males within each technologies subject area from 1992 to 2014. Showing all subject areas (*upper*) and truncated to male-biased subject areas (*lower*). The *shaded region* indicates cohort-parity between the sexes

1992 to 2000 at around 9.6% before rising to around 11.1% by 2005. Participation has again been reasonably steady since then and was 10.9% of Year 12 students in 2014.

In the same period, the number of students enrolled in design technology courses rose from around 18,000 in 1992 to around 25,000 in 2013 (Fig. 3). This level of enrolment has dropped slightly to around 23,500 in 2014 but there is no evidence to suggest this is the beginning of any long term decline. In relative terms the present number of enrolments represents 130% of the 1992 numbers.

Figure 4 shows that design Technologies has consistently been a male dominated course group and the sex ratio has not changed significantly over the period of analysis. In 2014, the sex ratio was 44 females per 100 males.

Trends in digital technology enrolments

Participation rates for courses in the digital technology course area demonstrated a significant increase in enrolments throughout the 1990s (Fig. 2). Following a peak of 23% in 2000, participation rates have declined markedly to the current level of just 7% in 2014. This current level represents 47% of the 1992 levels or one-third of the peak level. Interestingly, the declines observed in the national data are only seen in the records of three jurisdictions—New South Wales (NSW), Victoria and the Australian Capital Territory (ACT)—while other areas have recorded slight growth or static enrolments. Together these three jurisdictions account for around 60% of the total Year 12 cohort numbers, thus explaining the size of the drop seen in the national data post 2000.

Figure 3 shows that absolute enrolment numbers in digital Technologies increased steadily from 26,000 to 42,000 in 2000 before falling rapidly to just 15,000 in 2014. The sex balance in digital Technologies has become steadily more male biased over time (Fig. 4) changing from 87 females per 100 males in 1992 to just 26 females per 100 males in 2014. This emphasises the decrease in female participation in digital Technologies where just 2.9% of the female Year 12 cohort, just 3300 students nationwide, studied this course area in 2014; this is one-fifth of the peak female participation rate of 15,000 students recorded in the year 2000.

Trends in engineering enrolments

Engineering has had a consistently low participation rate across the whole period of analysis. Participation rates for engineering courses (Fig. 2) declined slowly between 1992 and 2000, falling from 3 to 1% mirroring absolute enrolment numbers. Post-2000 however, participation has increased again and was at 2% or 4300 students in 2014.

Female students have consistently been under-represented in the engineering subject area and there has been no significant change in the sex ratio over the period of analysis. The sex ratio (Fig. 4) was 6 females per 100 males in 2014, compared to a ratio of 7 per 100 in 1992.

Trends in food technology enrolments

The food technology course area has incorporated a large variety of courses over the years including home economics. Food technology courses are the only courses to have consistently demonstrated a female bias in their enrolments over the period of analysis (Fig. 4). In 1992 there were 1100 females per 100 male students and by 2014 this had fallen to 370 females per 100 males. A large part of this change can be attributed to the nearly 300% increase in male participation rates between 2000 and 2014 (Fig. 2), although the male participation in this course area is still low in comparison to others. Participation rates (Fig. 2) fell gradually between 1992 and 2000 but have since recovered steadily. The participation rate of 6.3% in 2014 represents a 150% increase on the minimum participation of 3.9% in 2000. Raw enrolment numbers have mirrored the participation rate trends and courses in food technology accounted for 13,600 enrolments in 2014 (Fig. 3),which is an increase of 6300 on the low point of 7300 in 2000.

Trends in food and fibre production enrolments

Courses in the food and fibre production course area are classified variously across Australia. In some jurisdictions they include courses such as agricultural science, and in others they are described as agriculture and horticultural studies. This variation in naming conventions, together with the removal of these courses by some states, means this course group is difficult to monitor. However, participation in food and fibre production (Fig. 2) appears to have been in steady, yet persistent, decline since 1995. In 1995, enrolments amounted to a participation rate of 2.4%, which has halved to 1.2% in 2014. Raw enrolment numbers show a long, slow decline from around 4000 in 1992 to just 2500 in 2014 (Fig. 3). Food and fibre production enrolments traditionally had a male bias (Fig. 4), yet from 2009 have been almost at parity. In 1992 the sex ratio was 50 female students per 100 males while in 2014 it was 110 females per 100 males, which is slightly above the cohort norm of 107 per 100. This change is a result of the declining enrolments in this course area being almost entirely comprised of male students (Fig. 2). Between 1992 and 2014, male enrolments fell from 2700 to 1200 while female enrolments remained static at around 1300 enrolments.

Fig. 5 Correlation scatterplot matrices showing the relationships between **a** participation rate and **b** residuals following linear detrending for design technologies, engineering, food technologies food and fibre production and overall year 10–year 12 student retention rate for 1992–2014. The course areas are on the diagonals with pair-wise Pearson correlation coefficients above the diagonals and bivariate scatterplots below ▶

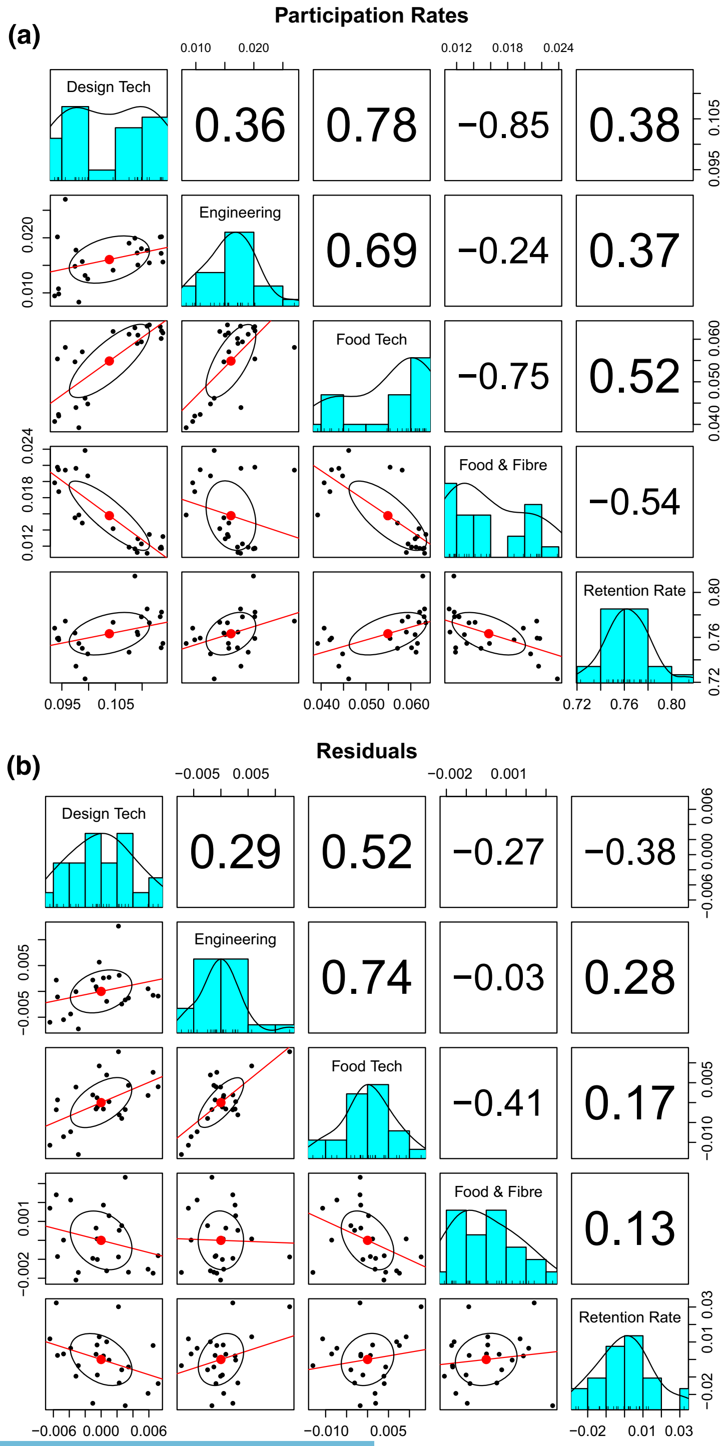
Patterns in enrolment trends

Participation rates for three of the subject areas (design technology, food technology and engineering) in the Technologies KLA (Fig. 2) demonstrate small increases over the period of analysis and these all follow apparently similar trends. These similarities pose the question, "is there a common underlying factor driving these changes?" A correlation analysis of the participation rates (Fig. 5a) shows that there is a moderate to strong correlation between a number of these course areas. The strong positive correlations between food technology and engineering ($r = 0.69$, $t(21) = 4.32$, $p = 0.0003$) and food technology and design technology ($r = 0.78$, $t(21) = 5.80$, $p < 0.0001$) participation rates pose the question of whether these are trends are being driven by similar factors. Consideration of the residuals after detrending (Fig. 5b) suggests that participation in engineering and food technology ($r = 0.74$, $t(21) = 4.97$, $p < 0.0001$) are likely to be being driven by similar underlying factors whereas the trends in design technology and food technology ($r = 0.52$, $t(21) = 2.82$, $p = 0.010$) are likely the result of unrelated external factors. However, as these results narrowly fail to meet the criteria of being statistically meaningful (Bryhn and Dimberg 2011) these findings are to be approached cautiously.

There are moderate positive correlations of the retention rates in these same three course areas with the overall R_{10-12} retention rate (Fig. 5a). However, analysis of the residuals (Fig. 5b) suggests that these might be spurious correlations rather than indicative of the growth being due to the increased retention of students into Year 12. It is likely that these trends are also being confounded by the incomplete picture of VET enrolments thus preventing the actual scale and cause of the observed growth from being reliably determined.

Perhaps surprisingly for Australia, which generated 2.4% of its gross domestic product amounting to \$46bn in 2010–2011 from agriculture (Australian Bureau of Statistics 2012), food and fibre production has shown a small yet consistent decline as a school based course area in Year 12. The participation rate for food and fibre production shows statistically significant, strong negative correlations (Fig. 5a) with both food technology ($r = -0.75$, $t(21) = -5.17$, $p < 0.0001$) and design technology ($r = -0.85$, $t(21) = -7.36$, $p < 0.0001$) as well as a moderate negative correlation with the retention rate ($r = -0.54$, $t(21) = -2.93$, $p = 0.0081$). Analysis of the residuals (Fig. 5b) reveals no statistically significant relationships and so it can be inferred that enrolment changes in this course area are being driven by different influences than the other courses analysed. Most likely is the rise in VET courses as part of Year 12 qualifications. For example, in 2014 in Victoria, 1202 school students completed VET courses in agriculture and horticulture, compared to 228 students who entered for the examinable agriculture and horticultural studies (unit 4) course; this is a ratio of 5.3:1. In 2001, this same ratio for Victoria was 1.2:1. If these Victorian examples are comparable across the country as a whole—published data are unclear in this regard—then this transition to VET is a significant influence on enrolments in comparable, examinable course areas, that warrants thorough research.

Digital technologies exhibits a unique pattern in enrolments (Fig. 2) showing strong growth throughout the 1990s yet falling sharply post 2000 to the current point. Figure 6


(a)
Participation Rates
Design Tech
Engineering
Food Tech
Food & Fibre
Retention Rate
0.36
0.78
-0.85
0.38
0.69
-0.24
0.37
-0.75
0.52
-0.54
(b)
Residuals
Design Tech
Engineering
Food Tech
Food & Fibre
Retention Rate
0.29
0.52
-0.27
-0.38
0.74
-0.03
0.28
-0.41
0.17
0.13

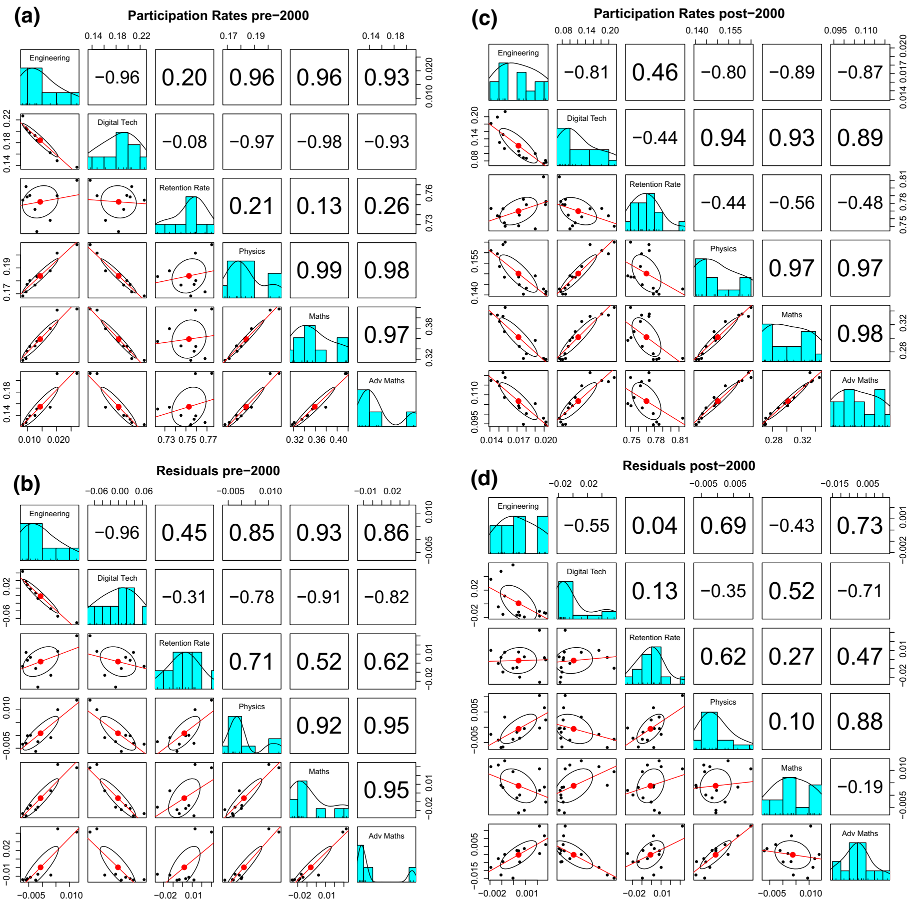


Fig. 6 Correlation scatterplot matrices showing the relationships between (**a**, **c**) participation rate and (**b**, **d**) residuals following linear detrending for engineering, digital technologies, overall year 10 to year 12 student retention rate, physics, mathematics and advanced mathematics for (**a**, **b**) 1992–2000 and (**c**, **d**) 2000–2014. The course areas are on the diagonals with pair-wise Pearson correlation coefficients above the diagonals and bivariate scatterplots below

shows that within the Technologies KLA, digital technologies only shows a statistically significant, strong negative correlation with Engineering which is apparent both pre-2000 (Fig. 6a) (r = −0.96, t(7) = −9.93, $p < 0.0001$) and post-2000 (Fig. 6c) (r = −0.81, t(14) = −4.81, $p = 0.0004$). Analysis of the residuals reveals that a statistically meaningful, strong negative correlation existed between digital technologies and engineering before 2000 (Fig. 6b) (r = −0.96, t(7) = −9.33, $p < 0.0001$) but that this relationship became less strong post-2000 (Fig. 6d) (r = −0.55, t(12) = −2.26, $p = 0.0436$). This strongly suggests the existence of an external factor that promoted digital technologies at the expense of engineering prior to 2000 but that flipped direction and weakened after the turn of the century. While the bursting of the *Dot-Com bubble* in 2000 could reasonably be expected to show an effect on enrolments from 2002 onwards (allowing for the 2 year lag between enrolment and matriculation), the exact cause of the sudden change in trend cannot be determined reliably. However, this observed turning point coincides with the renewal of course syllabi in many states and territories, the recognition of VET as part of Year 12 qualifications, and also the broadening of the curriculum as a whole to provide wider choice to students. For example, between 2000 and 2001 the total number of available courses across NSW, the ACT, and Victoria (excluding languages other than English), rose by 15% from 187 to 216. The availability of VET courses, a significant number of which were in the Technologies KLA, also increased in this period. However, the difficulty of aligning national VET data with school-based data again prevents definitive conclusions being made regarding scale and cause.

Commonalities with the sciences and mathematics

The knowledge and skills developed in school science and mathematics courses, in particular physics, mathematics and advanced mathematics, are complementary to the knowledge and skills required by some of the Technologies courses such as engineering and digital Technologies. By combining the Technologies KLA participation data presented here with our prior analyses of the science and mathematics KLAs (Kennedy et al. 2014), which we have extended to 2014, we are able to reveal some interesting correlations between course areas. There are very strong, statistically significant, negative correlations between each of physics ($r = -0.97$, $t(7) = -10.37$, $p < 0.0001$), mathematics($r = -0.98$, $t(7) = -12.45$, $p < 0.0001$) and advanced mathematics ($r = -0.93$, $t(7) = -6.62$, $p = 0.0003$) with digital Technologies pre-2000 (Fig. 6a), which become strong positive correlations when only considering the post-2000 data (Fig. 6c) (physics ($r = 0.94$, $t(12) = 9.14$, $p < 0.0001$), mathematics ($r = 0.93$, $t(12) = 9.08$, $p < 0.0001$), advanced mathematics ($r = 0.89$, $t(12) = 6.76$, $p < 0.0001$)). Consideration of the residuals reveals strong correlations pre-2000, indicative of a common underlying factor, yet much weaker residual correlations post-2000 except for advanced mathematics. This pattern in the trends suggests there was a move away from the traditional science and mathematics course areas towards the modern digital technologies during the 1990s. However, following the turning point when digital technologies began its decline, rather than return to these traditional course areas, students instead transitioned into other course areas in other KLAs from both digital technologies and physics and mathematics. This may be suggestive of a similar set of underlying driving factors affecting the declining participation rates in digital Technologies, physics, mathematics and advanced mathematics.

Engineering shows a strong positive correlation (Fig. 6a) in participation rate with physics ($r = 0.96$, $t(7) = 9.74$, $p < 0.0001$), mathematics ($r = 0.96$, $t(7) = 8.78$, $p < 0.0001$) and advanced mathematics ($r = 0.93$, $t(7) = 6.89$, $p = 0.0002$) when considered prior to 2000. Again the strong, statistically significant correlations between the residuals (Fig. 6b) suggests that the trends in these four course areas were being driven by similar external factors during the 1990s. Considering the post-2000 data separately (Fig. 6c), all three courses reveal strong negative correlations with engineering (physics ($r = -0.80$, $t(12) = -4.65$, $p < 0.0006$), mathematics ($r = -0.89$, $t(12) = -6.71$, $p < 0.0001$), advanced mathematics ($r = -0.87$, $t(12) = -6.15$, $p < 0.0001$)). Physics and advanced mathematics also show strong positive correlations with engineering in their residuals (Fig. 6d) suggesting that at least some students may have opted to study engineering in place of physics or advanced mathematics at the school level. Examination of raw enrolment numbers between 2000 and 2014 shows that nationally engineering rose by around 2800 students while physics, mathematics and advanced mathematics fell by 300, 450 and 1800 respectively. In the same period the Year 12 cohort expanded by 31,000 students. It is unrealistic to suggest that the rise of engineering in schools, particularly considering its relatively limited offering in schools, is the sole cause of the reported physics and mathematics declines, but it is reasonable to speculate that some of the additionally retained students may have elected to study physics and mathematics in the applied form of engineering rather than in their traditional forms.

Emerging issues and implications

The sex ratios presented in Fig. 4 show a strong bias towards male students for most of the courses analysed. The clear exception to this is food technology, which is strongly biased towards female students. These ratios, which have for design technology and engineering been fairly static, are strongly suggestive of the effects of cultural stereotypes on enrolment decisions.

As already discussed, the movement towards parity of the sex ratio in food and fibre production has been driven by the decline in male enrolments rather than an increase in female enrolments (2700 male enrolments in 1992–1200 enrolments in 2014 compared with 1360–1330 for female enrolments in the same time). However, enrolment numbers in this course area are too low to be able to draw meaningful conclusions about the underlying factors causing this change in enrolment patterns among male students.

The huge apparent drop in female:male sex ratio in food technology is due to the increase in male enrolments rather than a substantial decrease in female enrolments. In 1992, male enrolments accounted for 1.2% of the cohort, and by 2014 these had more than doubled to 2.8%. Contrastingly, female enrolments had risen by less than a third from 7.3 to 9.5% in the same period. This difference in the rate of change has led to the dramatic change in sex ratio which could possibly be associated with underlying changes in cultural and media stereotypes.

However, perhaps of greatest challenge to our understanding of STEM participation is the change in sex ratio in digital Technologies. Between 1992 and 2014 the sex ratio fell from just under parity to only one in five students being female. This change has been driven by a decline in female participation rates from 12 to 3% of the Year 12 cohort, compared to a decline in participation by males from 15 to 12% in the same period. This result comes despite many programs and initiatives aimed specifically at growing the number of females entering digital careers (Office of the Chief Scientist 2016), and the societal normalisation of gaming and technology usage among female adolescents (Brand and Todhunter 2015). Consideration of these national sex based trends alongside other research in this area suggests that the reverse effect identified by McLachlan et al. (2016) between participation rates in digital technologies courses in schools and day-to-day technology could likely have a more significant effect on female students than on males. It would be of great interest to repeat this data collection across a number of international jurisdictions. Comparisons of the national enrolment trends thus revealed would be invaluable in shedding light on the underlying socio-cultural factors driving these changes. However, an analysis of this scale is beyond the scope of this study.

The steep decline in female participation in school digital technology subjects presents a complex and seemingly intractable puzzle (Zagami et al. 2015). For example, we currently do not understand the extent to which the decline from near parity to near gender marginalisation over 22 years was associated with curriculum changes across the

Technologies KLA, or to broader sociocultural influences. As Zagami et al. (2015) argue, all the most obvious hypotheses have been explored and initiatives to counter each have been developed, yet we appear no nearer to closing the gap. It is hoped that the detailed enrolment data contributed by our study will assist researchers in exploring this issue further.

Overall, participation in most areas of the Technologies KLA by Australian Year 12 students represents a small, but growing proportion of the total cohort. While this growth is heartening, the low absolute numbers of students studying engineering and the continuing decline of participation rates in digital Technologies should be of particular concern to a nation that aspires to “embrace new ideas in innovation and science, and harness new sources of growth to deliver the next age of economic prosperity in Australia” (Commonwealth of Australia 2015a). The available Year 12 curriculum has significantly broadened throughout the period covered by this analysis, creating a far greater range of subjects from which students can choose. There has also been a tendency in some states and territories to reduce the minimum number of subjects required for a leaving qualification. Additionally, there has been an apparent increase in students “gaming the system” (Matters and Masters 2014; Tisdell 2014) with regard to their course selection in order to maximise their tertiary admissions rank.

In addition to a broadened Year 12 curriculum, a cursory glance at almost any school prospectus suggests that there has been a corresponding broadening of elective courses in Years 9 and 10 (although definitive statistics are unavailable). As courses in the Technologies KLA cease to be compulsory from Year 9 onwards—unlike science and mathematics—it is reasonable to suggest that this increased competition is partially responsible for the lower levels of participation in Year 12; it being relatively less likely that a student will choose to pick up a discipline in Year 11 that they dropped in Year 9 than one similar to a course that has been studied during Year 10.

The strong male bias evident in most of the technologies course areas is echoed in our study of science and mathematics enrolments (Kennedy et al. 2014). Given the policy-aim of producing STEM-proficient graduates, it could be argued that the sex-ratio of STEM courses should be of greater concern to policy makers than enrolment numbers in the STEM disciplines: the participation rate for most technologies, science and mathematics courses has been relatively stable for the five cohorts since 2010. If the STEM disciplines have found their new equilibria levels with regards to the broader curriculum, policy makers might usefully ask what opportunities might exist to promote further female engagement in the domain without negatively affecting male student engagement.

Ultimately, these analyses reveal that participation in technology-based courses is growing in most areas, albeit slowly. However, given the focus on school STEM of the last few years and the assertion that STEM can be a cornerstone of creating technologically aware and literate citizens then it is important to understand why more students are not electing to study Technologies at school. Phrased like this, it makes the collapse of enrolments in digital Technologies of particular concern especially given the pervasiveness of computers and the future needs for computational thinkers. However, examining enrolment data can only reveal the general trends and further investigation is required to understand why, when and how they make the decision to turn away from technology courses and to also understand what they elect to study to replace them.

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