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STEM Pathways: The impact of equity, motivation and prior achievement

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Abbreviations

ACER	Australian Council for Educational Research
ASCED	Australian Standard Classification of Education
ESCS	economic, social and cultural status (index of)
FiF	First in Family (to attend university)
HE	Higher Education
ISEI	International Socio-Economic Index of Occupational Status
LSAY	Longitudinal Surveys of Australian Youth
MCEETYA	Ministerial Council on Education, Employment, Training and Youth Affairs
NCSEHE	National Centre for Student Equity in Higher Education
PISA	Programme of International Student Assessment
RRR	Regional, Rural and Remote
SES	Socioeconomic status
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in International Mathematics and Science Study
WIL	Work Integrated Learning
WINTA	Women in Non-Traditional Areas
WPLS	Widening Participation Longitudinal Study
VET	Vocational Education and Training
Y03	The LSAY cohort who commenced in 2003, age 15

Executive summary

Science, technology, engineering and mathematics (STEM) skills are promoted by the Australian Government as pivotal for Australia's economic prosperity and meeting future workforce requirements (Timms et al., 2018). Whether particular equity groups are able to participate in STEM has implications for the future labour market outcomes of these groups and their contributions in an area seen as vitally important for innovation and prosperity.

This study, developed with the support of a National Centre for Student Equity in Higher Education (NCSEHE) Research Grant, is framed around three core research questions:

1. How do the STEM pathways of equity groups and non-equity groups differ?
2. What factors facilitate equity group students participating in university STEM courses?
3. Do the factors influencing young people's university STEM participation differ between equity groups and non-equity groups?

The study uses data tracking a cohort of young people from age 15 to 25 to explore these core questions. This data is drawn from the Longitudinal Surveys of Australian Youth (LSAY) and from the Programme of International Student Assessment (PISA). The study offers new insights into STEM pathways for young people in equity groups as they progress from secondary school, through post-school education and into the workforce. The equity groups of focus in this study are people from Low socioeconomic status (SES) backgrounds, Non-metropolitan areas, First in Family to enrol at university and Women in Non-Traditional Areas (WINTA).

In the analysis of **pathways into and through STEM for equity groups**, the findings from this study show:

- Lower relative transition rates into higher education for most equity groups, meaning that a smaller proportion of equity group cohorts go on to study STEM in university.
- Of those young people in equity groups who do make the transition to university, the proportion who enrol in a STEM field is similar to the average across all university entrants – with approximately one in four university commencers enrolling in a STEM field (except for women, see below).
- For women entering university, the transition rate into a STEM field is about half the rate of the national average. Less than one in eight women from this cohort who commenced university did so in a STEM field.
- Once enrolled in STEM at university, equity group students tend to have lower completion rates by age 25. In general the STEM completion rates for equity groups are lower than the completion rates for other fields of education (except for women, see below). This was especially the case for students from Low SES backgrounds, where one third of this group had not completed their STEM degree by age 25.
- For women in STEM fields, completion rates at university are very high compared with national averages and other equity groups, and unlike other groups, STEM completion rates for women are comparable to rates of completion in other fields.
- When it comes to transition into a STEM occupation, fewer than one in three STEM university commencers go into a STEM occupation, and for students from Low SES backgrounds and women in STEM the transition rate is even lower, at one in four.

Results of further analyses to explore the **factors that contribute to the outcomes**, specifically for entry into university, focussed on exploring subject selection in senior secondary school, mathematics achievement in secondary school, and attitudes towards mathematics and school. The analyses found:

- While mathematics achievement at age 15 is a very strong predictor of entry to university, it did not necessarily differentiate pathways into STEM for equity groups or others in the cohort.
- Among equity groups, participation in two higher level mathematics subjects in senior secondary school was notably lower compared to the non-equity group in the analysis. Furthermore, analysis of participation in mathematics and science in senior secondary school showed that for those without two or more subjects in this area, the prospects of subsequently studying in a STEM field was low.
- Instrumental motivation in mathematics (as measured through PISA at age 15) was a significant predictor of subsequent higher education study in a STEM field for the cohort as a whole and all equity groups (especially Low SES), even when controlling for mathematics achievement and other background factors.
- Self-concept in mathematics (as measured in PISA at age 15) was also a significant predictor of higher education participation in STEM – but only for Low SES, First in Family and women. This outcome was not apparent for the non-equity group or Non-metropolitan students.

These results open the door to future research to better understand the transition points and pathways of young people in equity groups pursuing STEM. They also provide evidence for future policy implementation. In particular, given the influence on decision-making in relation to further STEM study, interventions targeted at fostering self-concept and instrumental motivation are crucial, even before students are at age 15 and particularly with students from equity groups.

Recommendations

The findings from this study have potential implications for policy and practice in relation to three important areas of the student lifecycle – early and middle years of schooling; senior secondary school; and assisting entry into the STEM workforce. Opportunities to influence these three points in the lifecycle so as to improve outcomes for students from under-represented groups include:

- In the early and middle years of schooling, building mathematics programs and encouraging pedagogical approaches that *focus on demonstrating the practical importance of mathematics*, with the aim of increasing instrumental motivation in mathematics. Increasing instrumental motivation has been shown to significantly increase likelihood of pursuing STEM among equity groups, especially students from Low SES backgrounds.
- In the senior years of schooling, policies and interventions to encourage university participation among under-represented groups should continue and be refined to ensure the range of opportunities through higher education are understood. Being able to demonstrate the benefits of mathematics competency across a broad spectrum of employment and practical problem solving issues is of particular importance in increasing the flow of higher education entrants into STEM fields.
- In the later years of university, opportunities for work placements, internships and/or Work Integrated Learning (WIL) in STEM fields is critical for developing pathways into the STEM workforce. Strong developments in this area across science in Australia, led by the Australian Council of Deans of Science has seen significant change in recent years (https://www.acds-tlcc.edu.au/wil-guide-for-science/). Given this growing confidence and know-how in universities, and the work already underway for Women in STEM, further widening the focus on opportunities for equity groups, particularly Low SES students should be a challenge taken up in the future.

Introduction

Science, technology, engineering and mathematics (STEM) skills are promoted by the Australian government as pivotal for Australia's economic prosperity and meeting future workforce requirements (Timms et al., 2018). Whether particular equity groups are able to participate in STEM has implications for their future labour market outcomes. Unfortunately, there is evidence that certain equity groups are underrepresented in the field. For instance, 2018 course enrolment data show that while women are 61 per cent of non-STEM course completers from the university and VET sectors, women represent only 23 per cent of STEM course completers (Australian Government Department of Industry, Science, Energy and Resources, 2020). An understanding of STEM pathways, and the factors associated with these pathways, have important implications for the nature and timing of equity initiatives.

This study investigates the STEM pathways of four equity groups – Non-metropolitan, Low SES, First in Family, and Women In Non-Traditional Areas (WINTA). The analyses in this study examine how experiences of people in these equity groups differ from others. Specifically, this research describes the type of STEM education and occupational pathways undertaken by young people in Australia, tracking these pathways from early adolescence into the workforce. This study particularly investigates factors established in the research literature to be important determinants associated with pursuing higher education STEM – namely, a STEM 'profile' or STEM 'identity'.

This study also provides results for students who are not included in the four equity groups of this study. For ease of discussion, this group is labelled the 'non-equity' group, although this group does include young people from other equity groups—such as Indigenous young people.

This research, developed with the support of a National Centre for Student Equity in Higher Education (NCSEHE) Research Grant, is framed around three core research questions:

1. How do the STEM pathways of equity groups and non-equity groups differ?
2. What factors facilitate equity group students participating in university STEM courses?
3. Do the factors influencing young people's university STEM participation differ between equity groups and non-equity groups?

To explore these research questions, the report details a synthesis of existing literature relating to the barriers and enablers to pursuing STEM pathways, and the extent to which evidence exists relating to different patterns of equity and non-equity groups in this regard. This review can be found in the Background section that follows. The report then details the approach and findings of analyses of data from the Longitudinal Survey of Australian Youth (LSAY) and the Programme of International Student Assessment (PISA) (which has data linked to LSAY). These analyses develop new insights into STEM pathways for equity groups, based on the tracking of LSAY participants from secondary school, through post-school education and into the workforce (essentially from age 15 to age 25). The report concludes with a discussion addressing the research questions and exploring implications of these findings for policy, practice and future research.

Background

Setting the context

Student engagement and participation in STEM study is a topical issue in Australia. At a time when the STEM workforce is considered essential for maintaining national innovation and economic growth, the country is also faced with declining student enrolments in STEM subjects and courses (Education Council, 2018). Among young people in Australia, the main pathway from school is into higher education and then work (Ranasinghe et al., 2019), and this also applies to STEM pathways (Anlezark et al., 2008). However, 'leakage' occurs at each stage in the STEM pipeline, highlighting the importance of measuring STEM *pathways* rather than 'point-in-time' participation. For example, the proportion of students expressing an interest in science careers declines as students progress through school (Gore et al., 2017), and substantial numbers of young people leave STEM at each transition between secondary school, post-school study, initial employment, and beyond (Anlezark et al., 2008; Australian Academy of Science, 2019).

A number of key characteristics have been linked to STEM participation at various stages in the STEM pipeline from school to work, such as higher prior achievement, high self-efficacy, high self-concept, lower levels of mathematics anxiety, and positive interest and career aspirations. Research on equity groups and STEM has primarily focused on gender, although other equity groups are sometimes also considered. This research suggests that equity group membership is associated with a number of the key factors linked to 'leakage' from the STEM pipeline (Anlezark et al., 2008; Gore et al., 2017; Thomson et al., 2004, 2008). However, this area is still relatively unexplored, and less attention has focused on tracking the STEM pathways of a range of equity groups, or on the interplay between equity group membership, these factors, and STEM pathways.

The STEM profile

Individuals pursuing the STEM pathway – at school, in higher education and in the STEM workforce – tend to have a similar motivational profile and pattern of prior achievement. In particular, commitment to the STEM pathway is more likely when individuals have experienced success, or performed well, in STEM subjects at school (Marsh et al., 2019; Tytler et al., 2008). Studies like the Trends in International Mathematics and Science Study (TIMSS) and the Programme of International Student Assessment (PISA) illustrate the particular motivational profile associated with higher performance during secondary school education. Australian students who perform at higher levels in STEM areas at school tend to report higher levels of self-concept, self-efficacy and value in STEM subject areas and report lower levels of mathematics anxiety (in relation to mathematics performance) (Thomson et al, 2013; Thomson, De Bortoli & Underwood, 2017; Thomson, Wernert, et al., 2017). PISA and TIMSS results also show that higher performance in STEM at school is associated with career aspirations in STEM related areas. Thomson, De Bortoli and Underwood (2017) reported in the 2015 cycle of PISA that the percentage of 15-year-old Australian students with the highest scientific literacy, who also aspired to be in science-related careers when they were 30, was more than three times larger than the percentage of students with the same aspirations who had the lowest levels of scientific literacy (48% versus 14%, respectively). Watt et al. (2017) found that mathematics achievement and mathematics self-concept for females and mathematics interest for males in Year 9 had the largest influences on STEM career aspirations in Year 11.

Research suggests that the 'STEM profile' at the early adolescent stage – higher levels of self-concept, value and achievement, and lower levels of anxiety in relation to STEM subjects – may be a crucial determinant of persistence with STEM (Wang & Degol, 2013). Transitions from higher education to the workforce have also been highlighted with Anlezark et al.'s (2008) analysis of LSAY data finding that the largest drop in participation along the

STEM pathway occurred between higher education and the workforce – only one third of students who studied STEM in higher education went on to pursue a STEM career. While this type of finding suggests that this 'leakage point' on the STEM pathway should be the key target for interventions designed to encourage more individuals to choose STEM careers, it cannot be considered in isolation of other developmental patterns. Anlezark et al. (2008) also found that over three quarters of individuals in a STEM career had pursued this pathway by completing Year 12 STEM subjects, followed by STEM higher education before moving into the STEM workforce. However, motivation and patterns of achievement in Year 9 influenced the choice to study Year 12 STEM subjects, suggesting that the critical point of this STEM pathway was in early adolescence. In an analysis of the LSAY data that focussed on the Y03 cohort, Parker et al (2014) found that students' decision to enrol in a STEM course at university was predicted by their levels of mathematics self-concept at age 15. Other studies have supported this trend to emphasise that the key characteristics driving students' trajectory along the STEM pathway, or away from it, are evident at the age of 14 or 15 (DeWitt & Archer, 2015; Marsh et al., 2019; Tytler et al., 2008).

If the STEM profile in early adolescence is a key determinant of persistence along the STEM pathway, then factors that encourage or discourage the development of this profile should be investigated. Discussion in this area has moved to the importance of cultural and social capital present in students' lives that provide the opportunities to foster the STEM profile and educational opportunities more broadly (Devlin, 2013; Tytler et al., 2008). Others have investigated the issue through the concept of a STEM identity based on the rationale that the development of a STEM identity is a prerequisite condition for pursuit of a STEM pathway. Factors influencing the development of this identity exist in the home and school environment but also include the media and the type and amount of exposure children have to STEM role models (Steinke, 2017). Across the literature, some of the important cultural and social capital/experiences required to foster the STEM identity in early adolescence are exposure to high quality STEM teachers and pedagogy at school, support from family and career advisors, and an awareness of the STEM opportunities in the workforce (Marginson et al., 2013; Tytler et al., 2008). Understanding that these experiences/factors can shape the STEM identity or discourage it in early adolescence is useful for initiatives designed to promote engagement and participation with STEM. It is also useful for identifying the barriers to equity groups' participation in STEM pathways.

Equity groups and opportunities for development of the STEM profile

School and adolescent-related factors

Literature reviewed for this study suggests equity groups are often underrepresented among those who display attitudes and achievement patterns characteristic of the STEM profile in early adolescence. For instance, PISA and TIMSS findings show that Australian students from lower SES backgrounds and non-metropolitan areas tend to perform at significantly lower levels on assessments of mathematics and science (Thomson et al., 2019; Thomson, Wernert et al., 2017). Furthermore, analyses of LSAY data suggests that students from lower SES backgrounds are also less likely to participate in science study post-age 16 than students from higher SES backgrounds (Cooper et al, 2020). Results for gender are more variable with some data showing that boys outperform girls in mathematics and the majority of data showing no significant difference in boys and girls performance in science assessments (Thomson et al., 2018; Thomson, De Bortoli & Underwood, 2017; Thomson, Wernert, et al., 2017). Findings also indicate that students from lower SES backgrounds, non-metropolitan areas and female students report significantly lower levels of self-confidence or ability beliefs in mathematics and science, and female students experience significantly higher levels of mathematics anxiety (Thomson, De Bortoli & Underwood, 2017; Thomson et al., 2013; Thomson, Wernert, et al., 2017). Using LSAY data from the Y03 cohort, Watt et al. (2017) found that for female students STEM-related career aspirations in Year 11 were predicted by mathematics self-concept beliefs in Year 9.

Students in equity groups may be less likely to exhibit the characteristics typical of a STEM profile in early adolescence because of limited opportunities or limited exposure to the cultural and social capital required for these characteristics to develop. For instance, some studies show that students from lower SES backgrounds show greater rates of absenteeism, suggesting this could be a reason for patterns of lower achievement as these students have less classroom opportunities to learn (Panizzon et al., 2018; Thomson, De Bortoli & Underwood, 2017).

More prevalent are arguments and evidence that students within low SES and non-metropolitan equity groups lack the STEM resources and qualified STEM teaching during their secondary schooling necessary for STEM engagement (Tytler et al., 2008). For instance, Murphy et al. (2019) note that “curricular and pedagogical choices can have a significant impact on the [STEM] dispositions and academic success” of female, non-metropolitan and disadvantaged students in Australia (p. 126). The problem of drawing in and retaining high quality and qualified STEM teachers is documented Australia-wide. However, teacher shortages are more common in non-metropolitan areas and for schools with larger numbers of lower SES students (Panizzon et al., 2013; Watt et al., 2012; Watt et al., 2007). These shortages not only limit students’ experience of high quality and engaging STEM pedagogy but can impact on educational choices, with research showing that teachers can significantly shape students’ future subject decisions and career paths (Quinn & Lyons, 2016; Tytler et al., 2008).

Furthermore, Fraser et al., (2019) note that rural schools are often understaffed and lacking in resources and links with STEM industry, which can result in students and parents being less informed and aware of STEM opportunities in life. Teachers at these schools are often unable to access professional development opportunities to develop their STEM teaching pedagogy (Townsend et al., 2017). In addition to the importance of teachers in influencing students’ motivation and career aspirations – the critical role of career advisors has also been emphasised in developing students’ awareness of STEM pathways, particularly for equity groups like women (Anlezark et al, 2008; Broadley, 2015).

The social and cultural capital or experiences of students within the first in family equity group are difficult to assess as research on their achievement and motivation in early adolescence would have to be retrospective. However, the literature on low SES and non-metropolitan students illustrates that these equity groupings are not mutually exclusive; they intersect with each other and overlap with the first in family group. For instance, first in family students or those who come from non-metropolitan locations are more likely to come from lower SES backgrounds (Devlin, 2013; Fraser et al., 2019; Li & Carroll, 2017; Quinn & Lyons, 2016). The experience of first in family students could then be similar in terms of exposure to limited cultural and social capital and opportunities to form a STEM identity.

Women, as an equity group, can be considered differently given they are a larger and more diverse grouping. Research on women having limited experiences or restricted exposure to the cultural and social capital likely to encourage a STEM identity and STEM profile has been widely explored (e.g. Steinke, 2017). Studies have shown that STEM gender stereotypes endorsed by students or parents – particularly in mathematics – and socialisation processes can contribute to the development of negative STEM attitudes (Eccles et al., 1984; Gunderson et al., 2012; Good et al., 2012).

Workforce transitions

Early adolescence may be a formative period for the development of the STEM profile. However, the experiences of equity groups during STEM higher education and in the workforce are also important for successfully transitioning individuals into long-term STEM careers. Data from the 2016 Australian census illustrates that 14 per cent of individuals in STEM qualified occupations are women compared with 50 per cent in non-STEM occupations (Australian Government Department of Industry, Science, Energy and Resources, 2020). Large numbers of women do not move on to the STEM workforce following STEM higher education courses, particularly in the areas of mathematics, engineering and physical sciences (Reid et al., 2016). Furthermore, it is unclear whether this attrition point is determined by factors during higher education participation or at an earlier educational stage.

In addition, some research suggests that first in family students and students from non-metropolitan areas are at greater risk of considering dropout in higher education at the beginning of course study, while women in STEM courses are at less risk as are students from lower SES backgrounds, but only when academic achievement is taken into account for the latter group (Li & Carroll, 2017). On the other hand, Wilson et al. (2013) found no difference in the percentage of students from metropolitan and non-metropolitan backgrounds indicating an intention to withdraw from their STEM university course at the end of the first year of study. They suggested that “attrition traps” (p. 84) may be more likely at earlier educational stages.

Within the STEM workforce, the experiences of women have also been studied, with findings suggesting that these experiences are not equitable to those of men. Li et al. (2016) found that women in the STEM workforce were less likely than men to be fulfilling roles that used their STEM qualifications and were more likely to be an at earnings disadvantage compared to women working in the non-STEM workforce.

Gaps that this study can address

While PISA and LSAY data have been used to examine equity groups’ mathematics and science beliefs, attitudes, performance, and aspirations in secondary school (e.g. Schmid, 2019; Thomson et al., 2004), and one study has looked at pathways into STEM occupations among persons who attended secondary school in the 1990s (Anlezark et al., 2008), these data have not been used to examine STEM pathways from school to employment among cohorts of young people or across a range of equity groups.

This study explores these gaps. It is aimed at helping build a more comprehensive understanding of equity groups and their STEM pathways, providing additional insight for policy and practice. In particular, the findings have the potential to highlight areas where schools can help mitigate the effects of disadvantage on university STEM participation, as well as having implications for careers guidance and advice at school, and university outreach activities.

Methods

At the core of this project is the Longitudinal Surveys of Australian Youth (LSAY). Different elements of this data, focussing on the ‘Y03’ cohort (that is people who were 15 years old in 2003 and then surveyed annually up to the age of 25), informed the findings of this study. Within the LSAY Y03 cohort is the linking of data from the Programme of International Student Assessment (PISA), which was undertaken by this cohort when they were 15 years old. The contextual data collected through the LSAY survey instruments and PISA, as well as the academic achievement data collected through PISA are all used in this analyses.

Details relating to the data, definitions and approaches to analyses are discussed in the sections below. What is perhaps not apparent is that while these data provide a rich array of information, using them in the way that has been done for this study – i.e. charting specific, filed related pathways over a ten-year period – is complex. As discussed in the later parts of the report, the analyses developed here offer a new insight into the pathways of young people through STEM, informed by an equity lens.

Data

As noted above, this project is based upon quantitative analysis of data from LSAY. Key strengths of LSAY for this project are: it comprises representative samples of young people including both higher education participants and non-participants; it is longitudinal; and it comprises a wide the range of data collected in secondary school and across the post-school years. The background section of this report includes a number of studies that LSAY has been used in for exploring STEM outcomes and for exploring pathways of equity groups. This study uses LSAY to delve into both of these areas at the same time.

LSAY participants initially participate in the Australian component of PISA at age 15, and are interviewed annually until age 25. PISA/LSAY samples are designed to provide high levels of precision at the national and state levels in Australia. The sampling is also designed to collect representative data for some equity groups – particularly in relation to non-metropolitan students and those from low socioeconomic backgrounds.

The LSAY samples, like most longitudinal studies, lose participants over time. The impact of this is notable for LSAY in particular, given the participants are highly mobile young adults. Attrition weights are calculated each year to account for the loss of participants, in addition to the PISA weights that were originally assigned. These weights consider each participant’s family structure, the higher level of parents’ education, country of birth, year level, intended occupational level, education program orientation, Indigenous background, sex and home location (Rothman, 2007).

LSAY collects detailed information on: equity group membership; achievement and subjects while at school; post-school plans, aspirations and pathways; and a wide range of attitudes and beliefs. In this study, one cohort is examined: y*oung people who were 15 years old in 2003 and surveyed annually up to age 25 in 2013 (Y03)*.

It is recognised that recent school leavers (the population for this research project) are not representative of all higher education students, and that equity students are more likely than non-equity students to enter university as mature age students. However, recent school leavers can provide important insights into university STEM pathways, including specific barriers faced by young people from equity groups. LSAY contains rich data on both university students and persons who do not attend university (unlike higher education administrative data and higher education survey data, which are restricted to university students), making it ideally placed for the investigation of factors which facilitate or act as barriers to STEM participation by young people from equity groups.

Key dataset in analysis for this study

Across a range of different LSAY cohorts, the Y03 dataset was chosen for analysis in this study due to a range of factors. As is detailed in the finding section that follows, data from this cohort in particular enabled nuanced analysis specific to the focus on STEM and the breadth of the questions being explored in this research. Such data is not necessarily available in other LSAY cohorts. Of particular interest to this study, and as a justification for the Y03 focus, this LSAY cohort:

- completed contextual survey items at age 15 about attitudes beliefs and aspirations towards mathematics (including mathematics anxiety, self-concept, self-efficacy, and interests, perceived usefulness of mathematics for career)
- completed the Programme for International Student Assessment (PISA) at age 15, in a year when PISA included a focus domain on mathematical literacy
- is larger than other cohorts across its multiple waves, therefore enabling analyses based on specific sub-populations – which is particularly important for exploring equity group pathways and outcomes, as well as analyses into particular fields of education and occupation.

While there are strong sampling designs to account for the original distribution of participants and attrition, our analysis is based on the raw data only. This report does not focus on statistically comparable findings to account for differences between groups in their STEM pathways. The attrition weights that are calculated for the PISA and LSAY samples do not account for differential attrition by the equity groups separately. Rather than assume that the sampling weights that can be applied will ameliorate the differential sampling in the original selection of students for PISA, we have chosen to use the data unweighted to indicate the pathways taken by each group—which, in some cases may be so small that weights may in fact distort the experiences of a few cohort members.

Variables and definitions

Summary of variables

The list below gives an overall indication of the variables available for use in this analysis based on the LSAY Y03 cohort. The definitions and discussion in this section that follow, focus on the first two main dot points to explain and define these variables.

- Equity group indicators:
  - First in family
  - Low SES
  - Non-metropolitan
  - WINTA
- STEM Pathways, incorporating:
  - School STEM participation (in STEM subjects at Year 12)
  - Higher Education STEM courses (to age 24)
  - Occupation in STEM (at age 25)
- Mathematical and science literacy at age 15 (PISA)
- Attitudes beliefs and aspirations:
  - General (including attitudes towards school, post-school plans, occupational aspirations, university applications and preferences)
  - Mathematics (including mathematics anxiety, self-concept, self-efficacy, and interests, perceived usefulness of mathematics for career)
  - Stated reasons for participating/not participating in tertiary STEM course (for persons who had studied Year 12 maths or science at age 19).

Equity group measures

Low socioeconomic status (low SES)

The low SES group in this study comprises LSAY/PISA participants in the lowest quartile of the index of economic, social and cultural status (ESCS). This index was created on the basis of the following variables: the International Socio-Economic Index of Occupational Status (ISEI); the highest level of education of the student's parents, converted into years of schooling; the PISA index of family wealth; the PISA index of home educational resources; and the PISA index of possessions related to 'classical' culture in the family home.

Non-metropolitan (Regional, rural and remote)

Regional, rural and remote students are those who attended schools in non-metropolitan areas. The former Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) agreed on eight geographic classifications; two of these are considered metropolitan areas for the project: Metropolitan Zone Mainland State Capital City Regions and Metropolitan Zone Major Urban Statistical Districts. All other classifications are used to describe students from regional, rural and remote locations (RRR).

Students in LSAY are sampled on the basis of their school. Schools are selected for participation in PISA based on jurisdiction and geographic location within the jurisdiction.

First in Family (FiF)

First in family students are those whose parents have not been awarded a bachelor degree or higher. Data for deriving this variable is available through the PISA and LSAY contextual surveys instruments.

Women in Non-Traditional Areas (WINTA)

The broad definition used by the Australian Department of Education, Skills and Employment for Women in Non-Traditional Areas (WINTA) includes a broad range of fields across STEM and Non-STEM disciplines.[1] Due to the focus specifically on STEM in this study, for the WINTA group, we created a specific 'WINTA STEM' and 'WINTA Non-STEM' categories within the WINTA equity group based on the STEM definitions detailed below. This allowed us to restrict our analysis to gender participation in STEM areas - at school, in tertiary education, and the workforce. Participation in non-STEM WINTA fields was used in identifying pathways relating to course of study changes.

STEM pathways

Defining STEM:

There is no agreed upon definition of STEM fields of education or STEM occupations. The narrowest definitions are limited to the fields of science (including mathematics), IT, and engineering. The broadest definitions also include health; architecture and building; and agriculture, environmental and related studies.

This report uses the STEM definition used by the Office of the Chief Scientist (Leigh et al 2020), which includes the following

- Natural and Physical Sciences
- Information Technology
- Engineering and Related Technologies
- Agriculture, Environmental and Related Studies.

[1] https://www.ncsehe.edu.au/wp-content/uploads/2020/11/NCSEHE-Briefing-Note_2019-20_Final.pdf (see page 3)

However, we acknowledge that some fields excluded from our definition, such as health, may also involve STEM knowledge and skills.

STEM school subjects

- Senior secondary mathematics subjects in each state were assigned to two levels: lower level (equivalent to Essential Mathematics or General Mathematics) and higher level (equivalent to Mathematical Methods or Specialist Mathematics), based upon the classifications provided by Forgasz (2006) and McMillan and Edwards (2019) (see Appendix 1 for details).
- Senior secondary science, technology and engineering subjects are detailed in Appendix 1.
- Students who studied two or more science or higher level mathematics subjects in Year 12 were classified as STEM students.

STEM higher education

The STEM higher education study variables used in this report relate to the field of education at the commencement of the first bachelor degree, and for the ‘course change’ analysis, the field of education of the new course of a student.

The first variable used in relation to STEM studies in higher education, used in the analysis of three of the equity groups: low SES, non-metro and first in family groups, and in the non-equity group analysis, is based upon the STEM fields used by the Chief Scientist (Leigh et al 2020) and includes a separate category for health.[2] The variable has three categories:

- **STEM** (Australian Standard Classification of Education (ASCED) broad fields: 01 Natural and Physical Sciences (includes Biological Sciences); 02 Information Technology; 03 Engineering and Related Technologies; 05 Agriculture, Environmental and Related Studies);
- **Health** (ASCED broad fields:06 Health);
- **Other fields** (ASCED broad fields: 04 Architecture and Building; 07 Education; 08 Management and Commerce; 09 Society and Culture, 10 Creative Arts; 11 Food, Hospitality and personal Services; 12 Mixed Field Programs).

The second variable, which is used specifically in the WINTA analyses, distinguishes between:

- **WINTA fields which have a STEM** orientation (ASCED broad fields: 01 Natural and Physical Sciences (including Biological Sciences); 02 Information Technology; 03 Engineering and Related Technologies; 05 Agriculture, Environmental and Related Studies);
- **WINTA fields which do not fall into the STEM** definition used in this report (ASCED broad fields: 04 Architecture and Building; 08 Management and Commerce; 0919 Economics and Econometrics);
- **Non-WINTA fields** (ASCED broad fields: 06 Health; 07 Education; 09 Society and Culture (excluding 0919 Economics and Econometrics), 10 Creative Arts; 11 Food, Hospitality and personal Services; 12 Mixed Field Programs).

STEM occupations

The classification of STEM-qualified occupations in the *STEM Equity Monitor* by the Department of Industry, Science, Energy and Resources (2020) was used to classify occupations at age 25 as STEM or non-STEM. In this classification, STEM-qualified

[2] This approach has also been used in various other reports, such as ABS (2014), and DISER (2020).

occupations are those where the majority of people in the occupation reported a qualification in a STEM field of education in the 2016 Census of Population and Housing[3]. To add further nuance to the definitions, using the 2016 Census, the Monitor splits occupational groupings for STEM to identify those requiring a university-level qualification, those requiring a VET qualification and those that had a mix of university and VET level qualifications within the workforce.[4] Health fields are similarly categorised in the *Monitor*. For the purpose of this study, the key groupings included in the analysis are as follows:

- University STEM-qualified: >=50% of the occupation's working population have a university STEM qualification.
- Mixed STEM-qualified: >=50% of the occupation's working population have a STEM qualification in either VET or university.
- University Health-qualified: >=50% of the occupation's working population have a university Health qualification.
- Mixed Health-qualified: >=50% of the occupation's working population have a Health qualification in either VET or university.

Analysis approach

Research Question 1 is addressed using LSAY data on education and labour force activities to map pathways into and out of STEM, from senior secondary school through to age 25. Comparisons are drawn between the pathways of equity groups and non-equity groups. Each group for analysis is based on their bachelor study classification, with the emphasis on those who entered STEM study at university.

Exploring Research Questions 2 and 3 entails in-depth analysis of one key aspect of STEM pathways – university STEM participation – measured up to age 24/25. Multivariate techniques described below and in the discussion were employed in order to understand the influences on university STEM participation, and how these differ for particular equity groups and non-equity groups.

LSAY cohort by equity group

The LSAY Y03 data that was available to undertake the analyses required in this study included 3,343 LSAY Y03 cohort members. At the outset, the characteristics of each member of the cohort were examined and, where a person fit the relevant definition they were allocated to an equity group for this project, with some allocated to more than one group. There were 1,384 cohort members who could not be assigned to an equity group; they had attended a school in a metropolitan area, their SES level was in the top three quartiles, at least one of their parents had attained a bachelor degree or higher, and they were not women who had enrolled in a non-traditional area. For the purpose of this study, this group is considered the 'Non-equity group.' The number in each equity group—and those not in the non-equity group are shown in Table 1.

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[3] This classification is similar to that used by Anlezark et al (2008) to analyse LSAY data. However, reflecting Anlezark et al's broader definition of STEM, they also classified architects, urban and regional planners, architecture, building and surveying technicians and health occupations as STEM occupations.

[4] https://www.industry.gov.au/data-and-publications/stem-equity-monitor/methodology#--stemqualified-occupations

Table 1. Number of LSAY Y03 cohort members, by equity group

	TOTAL (n)
All cohort members	3343
Non-metropolitan	856
Low SES	491
First in Family	1026
WINTA	1725
Not in an equity group	1384

Notes: A cohort member can appear in more than one equity group (non-metropolitan, low SES, first in family or WINTA). Cohort members in the 'non-equity' group may be members of equity groups not discussed in this report.

Multinomial logistic regression

To examine research questions 2 and 3 in this study – that is, exploring some key factors that might influence participation in STE – the PISA contextual questionnaire undertaken by the Y03 cohort was used. There were eight variables from the PISA contextual questionnaires chosen for use in models to explore these influences. Other variables were available in the LSAY data set, but preliminary analyses showed that the variables listed below were the most likely to show significant effects, particularly after examination of the relationships among all variables.

- ANXMAT Mathematics anxiety
- ATSCHL Attitudes towards school
- BELONG Sense of belonging to school
- INSTMOT Instrumental motivation in mathematics
- INTMAT Interest in mathematics
- MATHEFF Mathematics self-efficacy
- SCMAT Mathematics self-concept
- STUREL Student-teacher relations at school.

Using these variables, a multinomial logistic regression analysis was run separately for each of the following groups:

- persons who attended secondary school in a non-metropolitan area ('Non-metro')
- persons who were from a low socioeconomic group ('SES')
- persons who were the first in their families to attend university ('FiF')
- women who enrolled in non-traditional areas ('WINTA')
- persons who did not belong to any of the categories above ('non-equity').

The analyses used three different outcomes:

- entry into STEM fields at bachelor level
- entry into non-STEM, health-related fields at bachelor level
- entry into other fields (non-STEM, non-health) at bachelor level.

For the WINTA group there were different program entry (outcomes): WINTA STEM, WINTA non-STEM and all other programs.

Other variables included in the model were PISA achievement scores, and participation in science and mathematics subjects in senior schooling.

Further detail relating to these analyses are embedded in the discussion in the Findings section of this report.

Findings

The analysis and findings of this study are discussed below in two main sections, each exploring research questions outlined in the introduction of this report. The first section details the pathways into and out of STEM for the Y03 LSAY cohort, tracking each member from the age of 15 through to age 25. The second section details analysis into the factors that might be influencing participation in STEM at university, including analysis to examine if there are different influences across equity groups.

Pathways into STEM: from school to work

A key benefit of using a longitudinal study is the ability to follow pathways over time. In this section, analysis of LSAY is undertaken to examine the following research question:

- How do the STEM pathways of equity groups and non-equity groups differ?

Exploring pathways of thousands of young people over a ten-year period opens a myriad of options for analysis. Based on the resources and data available for this study, the focus has been on tracking the pathways described in the diagram below (Figure 1).

This figure is intended to guide the discussion of pathways that follows. Pathways explored include subjects undertaken in senior secondary school; university entry and field of study; changes of course and completions; and occupation at age 25.

The most complexity in this model relates to the movement into, through and within STEM in higher education – specifically chosen as a focus given the objectives of this study. As indicated in the figure, the pathways discussion relating to post-school studies covers overall field of education for bachelor level, and then within the STEM fields, explores changes into and out of STEM (represented by the rectangles in the diagram).

The analysis below first explores the proportion of the Y03 cohorts entering university by field of course. It then examines the extent to which studying science and mathematics subjects in senior secondary school has an influence on the choice of field of study at university. STEM pathways are then discussed in relation to changes in course during study, and completion of university. This section of the analysis concludes by looking at the occupational outcomes for equity groups among those in the cohort who studied in a STEM field at university.

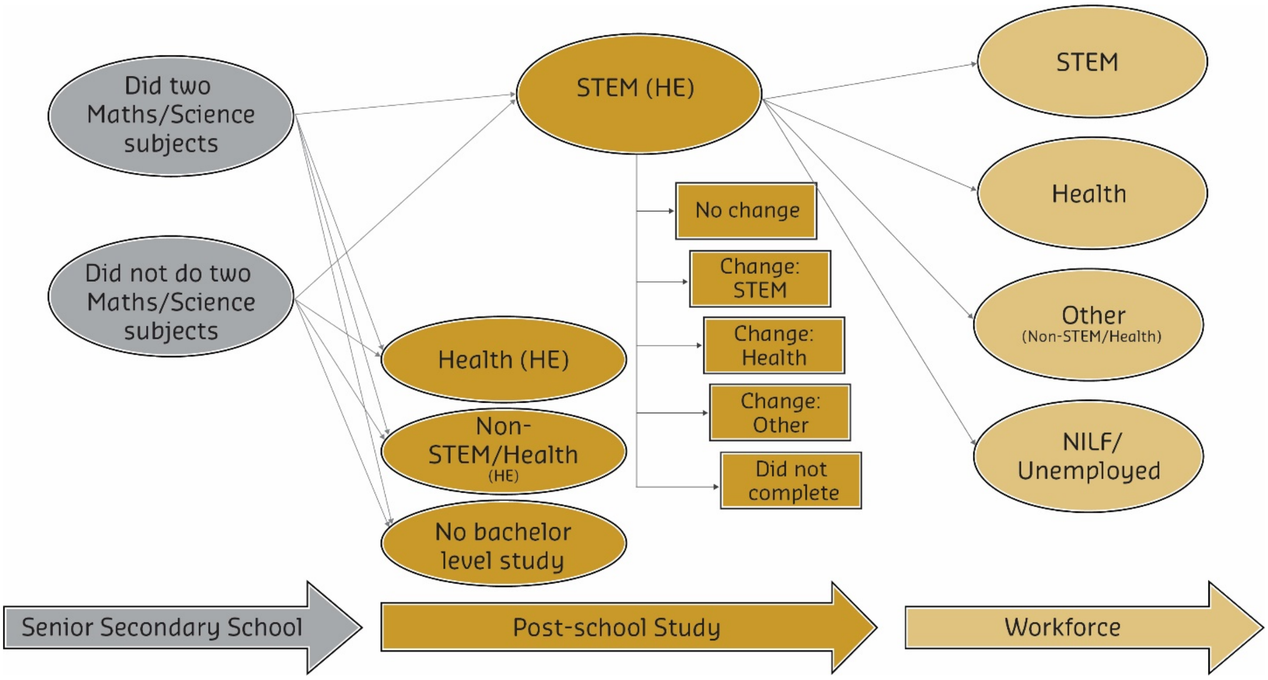


Figure 1. Pathways from secondary school into post-school study (bachelor level up to age 24) and into employment (age 25)

Pathways to university entry

Table 2 shows the distribution of entry to university among the LSAY cohort, with details showing the spread by field of study for each equity group and the non-equity groups. Overall the figures show 18.9 per cent of cohort members entered a STEM bachelor field. Comparison across the equity groups at this level is difficult in this context given that the First in Family (FiF) are only an equity group by the very fact that they are enrolled in university, and for the WINTA group the analysis is exploring slightly different pathways. However, among the Non-metropolitan and Low SES groups, the proportion of students who did not go on to higher education is larger than the average across the whole cohort, and this reflects lower overall proportion of these groups represented in STEM fields in higher education. The Low SES group in particular has a notably lower proportion who went on to study a STEM field at university.

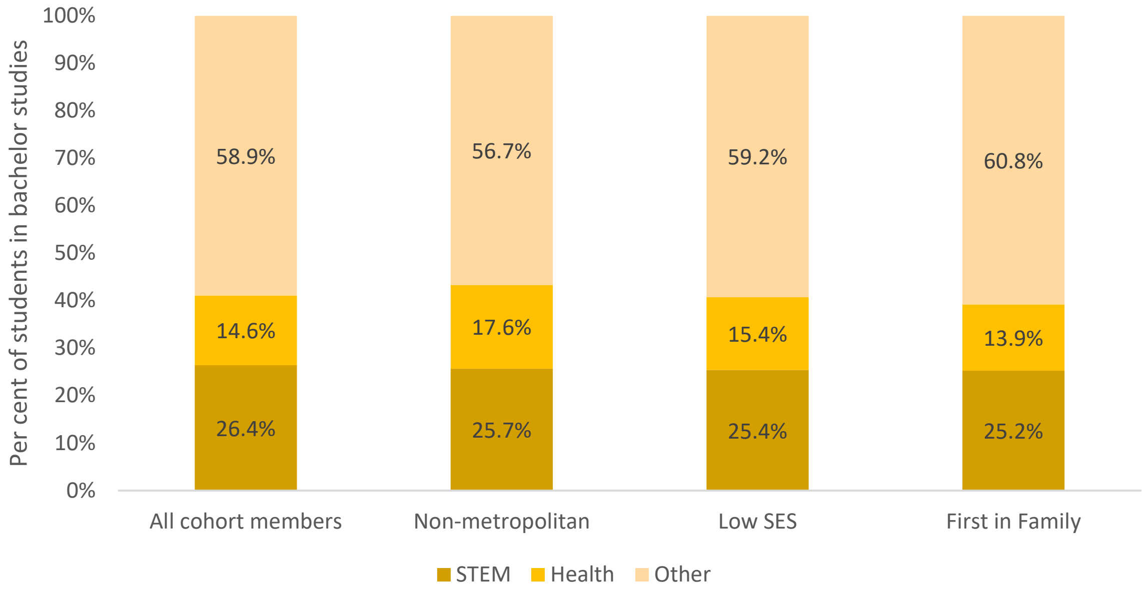
For the WINTA group analysis, the data show that fewer than 10 per cent of women go into a university STEM field, and more than half go into a university course in a non-WINTA area.

Table 2. University entry of LSAY cohort members, first bachelor-level post-school study by equity group and field

	Bachelor-level study					
	STEM	Health	Other	No study	Total	Total (n)
All cohort members	18.9%	10.5%	42.1%	28.5%	100.0%	3343
Non-metropolitan	17.5%	12.0%	38.7%	31.8%	100.0%	856
Low SES	13.4%	8.1%	31.4%	47.0%	100.0%	491
First in Family	25.2%	13.9%	60.8%	N/A	100.0%	1026
	WINTA STEM	**WINTA Non-STEM**	**Non-WINTA**	**No study**	**Total**	**Total (n)**
WINTA	9.3%	15.3%	53.4%	22.0%	100.0%	1725

Notes: A cohort member can appear in more than one equity group (non-metropolitan, low SES, first in family or WINTA). Cohort members in the 'non-equity' group may be members of equity groups not discussed in this report.
For the FiF group, there are no cohort members in 'no study' because this is an equity group that only applies to those enrolled in higher education.

Figure 2 displays the spread of field of study choices among those who enrolled in a bachelor degree for all groups except WINTA. It shows that for the LSAY Y03 cohort, there appears to be no substantial difference in the rate of enrolment in a STEM course between equity groups and across the whole cohort, with about one quarter who started university enrolling in a STEM course.



Notes: A cohort member can appear in more than one equity group (non-metropolitan, low SES, first in family or WINTA). Cohort members in the 'non-equity' group may be members of equity groups not discussed in this report.

Figure 2. Distribution of fields of study for students enrolled in bachelor-level study, LSAY Y03 cohort

It is important to highlight that pathways into university are far from linear, and for the LSAY Y03 group, the analysis below shows that transition directly from school to higher education is not a pathway followed by all. Overall, 15 per cent of those in LSAY Y03 who enrolled at university in a STEM field at some time before the age of 25 deferred entry. Deferral patterns were lower than the average for Low SES, First in Family and WINTA groups. However, young people from non-metropolitan areas deferred at close to twice the average rate (Table 3).

Table 3. Percentage of STEM entrants who deferred entry in the first year after school, by STEM field and equity group

STEM field	Equity Group				
	Non-metro	Low SES	First in Family	WINTA	No group
Natural and Physical Sciences	33.3%	5.9%	14.3%	10.4%	14.5%
Information Technology	27.3%	0.0%	0.0%	0.0%	0.0%
Engineering and Related Technologies	20.5%	13.3%	6.3%	6.7%	20.0%
Agriculture, Environmental and Related Studies	21.1%	0.0%	0.0%	26.7%	22.2%
All STEM fields	27.3%	7.1%	9.6%	10.0%	14.7%

Influence of secondary school subjects and STEM university pathways

Table 4 shows the percentage of students from each equity group who studied two mathematics or science subjects in secondary school. These percentages are shown for all members of the LSAY Y03 cohort in this study ('All'), and for those who entered a STEM course at bachelor degree level ('STEM').

For each of the groups examined, STEM entrants more frequently studied two mathematics and science subjects at school compared to all in the group. Among equity groups, more than one-half of cohort members who subsequently undertook STEM study at university had studied two science subjects while in senior secondary school.

It is also important to note that the study of science or higher-level mathematics at senior secondary did not preclude entry to a STEM field at bachelor level. Overall, 11 per cent of cohort members who went into STEM did not take a science subject in senior secondary, and 28 per cent did not take a higher-level maths subject.

Table 4. Percentage of students who studied two mathematics or science subjects in secondary school, by post-school study and equity group, LSAY Y03

Subjects	Study Group	Equity Group				
		Non-metro	Low SES	First in Family	WINTA	No group
Two Maths/Science	All	38.2%	28.6%	45.4%	37.1%	38.7%
	STEM	75.3%	69.7%	76.8%	78.8%	83.9%
Two Science	All	26.1%	18.2%	28.1%	23.9%	24.2%
	STEM	57.3%	51.5%	54.1%	56.9%	54.8%
Two Higher Maths	All	7.2%	4.9%	9.7%	5.8%	9.5%
	STEM	21.6%	18.2%	21.2%	21.8%	34.2%

While Table 4 shows the percentage of cohort members who had studied two mathematics or science subjects at school—including those who entered STEM courses—Table 5 shows how many of those who had studied two subjects then went into a STEM course at bachelor level. Within the equity groups, around 20 per cent had taken two mathematics subjects at school, but of those who did take two maths subjects, around one-half then went into a STEM course at university. Among the WINTA group, however, only one-third who had taken two higher-level maths subjects went into a STEM course. Similarly, lower rates of 'conversion' from secondary school for those studying two or more science subjects or a maths and science subject are seen in the WINTA category compared with all other groups. This is in general because many went into a non-STEM WINTA field, such as economics.

Table 5. Percentage of students who had studied two mathematics or science subjects in secondary school and entered STEM study at university, by equity group, LSAY Y03

Subjects	Equity Group				No group
	Non-metro	Low SES	First in Family	WINTA	
Two Maths/Science	34.7%	32.9%	42.9%	19.7%	31.2%
Two Science	38.6%	38.2%	48.8%	22.1%	32.6%
Two Higher Maths	52.5%	50.0%	54.5%	34.3%	51.9%

The PISA assessments undertaken in secondary school at age 15 include questionnaires that collect information on students' attitudes towards school and the major domain on each cycle's assessments. For the Y03 cohort, the major domain was mathematics, and the attitude questions—in addition to questions about attitudes toward school and a sense of belonging to school—asked about interest in mathematics and instrumental motivation in mathematics, mathematics self-efficacy, mathematics anxiety and mathematics self-concept. For this study, two of these attitude scales highlight differences between those entering STEM at university and others in secondary school. STEM entrants across all equity groups scored higher than other entrants and non-entrants on instrumental motivation, and lower on mathematics anxiety (Table 6). On the more general school-related scales, there was little difference among the university entrants, with those not pursuing higher education scoring lower on those scales.

Table 6. Mean scale scores on two mathematics-based attitude scales, by post-school study and equity group, LSAY Y03

Subjects	Study Group	Equity Group				No group
		Non-metro	Low SES	First in Family	WINTA	
Instrumental Motivation in Mathematics	STEM	0.54	0.54	0.55	0.47	0.55
	Health	0.25	0.16	0.29	0.31	0.33
	Other	0.01	0.11	0.05	-0.03	0.02
	None	0.04	0.01	- -	-0.14	-0.04
Mathematics Anxiety	STEM	-0.58	-0.33	-0.54	-0.36	-0.66
	Health	-0.22	-0.11	-0.28	-0.18	-0.39
	Other	-0.13	-0.03	-0.11	-0.08	-0.15
	None	-0.05	0.03	- -	0.14	-0.02

University completion - STEM and other fields

For the members of the Y03 cohort who went on to study at university, by the time they were 25, about four out of every five had completed a degree. Confirming prior research in this area (see for example a NCSEHE report by Edwards & McMillan, 2015), equity group students in this cohort had lower completion rates than the cohort average – with the exception of WINTA group members. Table 7 shows that on average STEM university entrants were slightly less likely to complete their degree by age 25.

Among equity groups, those who commenced a STEM field bachelor qualification from the Non-metropolitan, and Low SES groups were less likely than other university commencers to complete their studies. Low SES STEM and Health commencers were also notably more likely to still be in study for their first degree at age 25 compared with those in other equity groups, and the average across this cohort. The WINTA STEM group tend to have bucked the general trend in university completions, with their rate of completion high, and very similar to those in the WINTA non-STEM and the Non-WINTA fields.

Table 7. University completion status of LSAY Y03 cohort at age 25, by equity group and field of initial bachelor degree

Equity group	Bachelor Course	Still studying	Completed	Did not complete	N
Non-metro	STEM	11.3%	71.3%	17.3%	150
	Health	9.7%	83.5%	6.8%	103
	Other	12.4%	70.6%	17.0%	330
Low SES	STEM	15.2%	66.7%	18.2%	66
	Health	17.5%	80.0%	2.5%	40
	Other	11.7%	70.8%	17.5%	154
First in Family	STEM	12.7%	71.8%	15.4%	259
	Health	12.6%	78.3%	9.1%	143
	Other	9.8%	72.9%	17.3%	623
WINTA	WINTA STEM	6.3%	80.6%	13.1%	160
	WINTA non-STEM	9.8%	80.7%	9.5%	264
	Non-WINTA	8.5%	81.1%	10.4%	920
No group	STEM	11.1%	76.9%	12.1%	199
	Health	7.1%	88.3%	4.5%	154
	Other	8.8%	84.5%	6.8%	502
All cohort members	STEM	10.1%	76.4%	13.4%	632
	Health	9.1%	84.3%	6.6%	350
	Other	9.5%	78.3%	12.2%	1406

Alternative pathways - course changes and completion of STEM study

Not all students complete study in the field that they commenced. University students change their course of study for a range of reasons. Some commence a course because they did not get their first preference and change as soon as possible. Some find that the course they are studying is not what they had expected, then look for other courses.

Approximately one in six cohort members who commenced in a STEM field changed their field of study while at university. Among the equity groups examined, the non-metropolitan students were the least likely to change their field of study following commencement at university. As shown in Table 8, for most groups, the majority of those who started in a STEM field and made a change during their study changed to another STEM field.

Among those who did change from a STEM field, 35 per cent of non-metropolitan students switched to a health field. Close to one-half (43 per cent) of those in the ‘non-equity’ group transferred to a non-STEM/non-health field, and 43 per cent of women transferred to a non-WINTA field. A small number of cohort members made more than one change of field during their university careers.

Table 8. Percentage of STEM entrants who changed their field of study after the first year of bachelor degree study, by new field and equity group

	Equity Group					
	Non-metro	Low SES	First in Family	No group	WINTA	
At least one change	13.3%	18.2%	17.4%	18.6%		17.5%
Of those who changed, the change was into…						
Different STEM field	45.0%	50.0%	55.6%	56.8%	Other STEM	50.0%
Health field	35.0%	25.0%	22.2%	0.0%	Other WINTA	7.1%
Other field	20.0%	25.0%	22.2%	43.2%	Non-WINTA	42.9%
Number of changes	20	12	45	37		28

Table 9 explores the outcomes for students who commenced in a STEM field and who changed or did not change field during their degree, by equity group. The number of students for some groups is very small, and therefore must be viewed with caution. Nonetheless, the general pattern across the whole table is that for students who commenced in a STEM field and made a change during their degree, their rate of completion is slightly higher than for those who did not. Of the LSAY Y03 cohort that commenced in a STEM field and changed their course during their university study, 80 per cent completed their bachelor degree study. Of those who did not change course, 76 per cent completed their bachelor degree study.

The Table 9 figures show that this more positive outcome is particularly consistent for STEM commencers who changed into another STEM field during their degree. In every group in this table, the 'change into another STEM' students have higher completion rates than the 'no change' students. For example, among the Low SES group, for those who commenced STEM and continued in the field they commenced in, 65 per cent had completed their degree by age 25, while for those who had changed to a different STEM field during their degree the completion rate was 83 per cent.

Table 9. Completion status of STEM field of study cohort members by type of course change and equity group, at age 25

Equity group	Change	Completion status: Still studying	Completed	Did not complete	N
Non-metropolitan	No change	11.5%	68.5%	20.0%	130
	Into another STEM	11.1%	88.9%	0.0%	9
	Into Health	0.0%	100.0%	0.0%	7
	Into Other	25.0%	75.0%	0.0%	4
Low SES	No change	16.7%	64.8%	18.5%	54
	Into another STEM	16.7%	83.3%	0.0%	6
	Into Health	0.0%	66.7%	33.3%	3
	Into Other	0.0%	66.7%	33.3%	3
First in Family	No change	13.6%	70.6%	15.9%	214
	Into another STEM	8.0%	76.0%	16.0%	25
	Into Health	0.0%	90.0%	10.0%	10
	Into Other	20.0%	70.0%	10.0%	10
WINTA	No change	6.8%	78.8%	14.4%	132
	Into another STEM	0.0%	85.7%	14.3%	14
	Into a WINTA Non-STEM	0.0%	100.0%	0.0%	2
	Other	8.3%	91.7%	0.0%	12
No group	No change	9.9%	77.2%	13.0%	162
	Into another STEM	9.5%	81.0%	9.5%	21
	Into Health	-.-	-.-	-.-	0
	Into Other	25.0%	68.8%	6.3%	16

Occupation and relevance to STEM degree at age 25

Once their study was completed, most cohort members entered the labour force. While the initial employment after university may not necessarily be the ‘career job’ they expect to have as a result of their university studies, exploring occupation outcomes at this point is still useful.

At the age of 25, 22 per cent of all LSAY Y03 cohort members who had first enrolled in a STEM course at university were working in an occupation that required university STEM qualifications. Another 9 per cent were in occupations with mixed-STEM qualifications. One-half were working in occupations that did not require STEM or Health qualifications. Four per cent were either unemployed or not in the labour force (NILF).

In Table 10 these rates are displayed for the equity groups in this study. Across the groups, these percentages varied, with cohort members from the Low SES and WINTA groups less often employed in university STEM-qualified and Mixed-STEM qualified occupations.

Table 10. Occupation group of cohort members who commenced STEM study at university, by equity group

Occupation group	Equity Group				No group
	Non-metro	Low SES	First in Family	WINTA	
University STEM-qualified	24.0%	18.2%	21.6%	15.6%	26.6%
Mixed STEM-qualified	6.0%	6.1%	10.4%	7.5%	13.1%
University health-qualified	8.0%	12.1%	5.0%	13.8%	4.0%
Mixed health-qualified	0.0%	0.0%	0.0%	0.6%	0.0%
Other group	54.0%	54.5%	49.0%	52.5%	47.2%
Studying (not working)	6.0%	6.1%	8.5%	5.6%	5.0%
NILF/Unemployed	2.0%	3.0%	5.4%	4.4%	4.0%
N	150	66	259	160	199

Note: Occupation information in 2013 was not available for all cohort members.

What factors facilitate equity group students participating in university STEM courses?

The second and third research questions for this study explored factors facilitating university participation in STEM. The analyses undertaken to examine these issues again uses the LSAY Y03 cohort, and in particular examines contextual survey data and assessment results from this cohort's participation in PISA in 2003. The questions being explored in this section are:

- What factors facilitate equity group students participating in university STEM courses?
- Do the factors influencing young people's university STEM participation differ between equity groups and non-equity groups? For example:

Influences on pathways into STEM

As detailed in the Methods section, members of the cohort were each given an 'outcome' in relation to their post-school study destinations. The analyses for this section of the study then used PISA and LSAY data to look back at these different outcomes and examine the extent to which there were factors measured in these instruments that could help explain the trajectory of students based on the following different outcomes:

- entry into **STEM** fields at bachelor level
- entry into non-STEM, **health-related** fields at bachelor level
- entry into '**Other fields**' (non-STEM, non-health) at bachelor level
- did not go into higher education study.

Further, for the WINTA group there were different program entry (outcomes): WINTA STEM, WINTA non-STEM and all other programs.

School achievement and subject choices

The first variable explored in relation to influencing factors was **school achievement in mathematics** using the PISA 2003 focus domain scores for mathematical literacy. Results indicated that all members of the LSAY Y03 cohort who entered university had higher scores on the mathematics assessment in PISA in 2003 when compared with the 'did not go to higher education' group. Detailed analysis within the university entrant groups indicated that this score alone did not distinguish substantially between the different fields of study taken by these three enrolment groups. In other words, mathematics achievement was not necessarily a useful predictor of STEM pathways.

Examining achievement linked to STEM pathways of equity groups was also undertaken. There were some analyses that indicated a statistically significant difference between the STEM entrants and the 'Other fields' entrants when mathematics achievement is used as a covariate, but the differences are small and not meaningful enough to be considered worth publishing. For example, for one equity group, an increase of ten score points on the PISA scale in mathematics increases the odds ratio for STEM enrolment by three percentage points. However, once other variables are included in the models, the influence of mathematics achievement becomes non-significant.

Information on the **subjects studied in senior secondary school** by LSAY cohort members were then included in the models. These data did not offer any additional information, indicating that students who enter university study similar subjects while in secondary school, and that the factors that lead them to university study are similar to the factors that lead them to senior secondary school study. In particular, most students study mathematics in senior secondary (it is often required in state curricula), and many take a science subject.

Attitudes, motivation, anxiety and other influences

Given that the initial modelling undertaken did not show a strong link between prior achievement in mathematics, or the undertaking of science and mathematics in senior secondary school on entry into STEM fields at university, it was necessary to develop models that included other contextual data.

Based on the PISA context survey undertaken by this cohort, the study was able to explore the potential influences of a range of other factors. As discussed in the methodology section, eight variables from the PISA contextual questionnaires were chosen for use in models to further explore influences on STEM participation at university. These variables were chosen based on a preliminary set of analyses across a wider range of survey questions. They are:

- mathematics anxiety
- attitudes towards school
- sense of belonging to school
- instrumental motivation in mathematics
- interest in mathematics
- mathematics self-efficacy
- mathematics self-concept
- student-teacher relations at school.

Analyses incorporating answers to these contextual questions, and controlling for other variables were conducted using multinomial logistic regression to identify factors associated with differences in university enrolment. For these analyses, enrolments into 'Other fields' (i.e. non-STEM, non-Health fields) were used as the reference group to compare to entry into a Health field or entry into a STEM field. The outcome variable was enrolment in a bachelor degree.

Logistic regression analyses are interpreted using odds ratios. Table 11 shows the statistically significant variables for each group associated with entry into STEM and entry into Health (detailed tables with the full parameter estimates for each equity group are included in Appendix 2). Each figure in Table 11 is the odds ratio; that is, the odds of enrolling in a STEM field or a Health field as opposed to *not* enrolling in a STEM or Health field, compared to enrolling in an Other fields degree as opposed to *not* enrolling in an Other field. An odds ratio of 1.0 indicates no difference between the groups being compared. A figure greater than 1.0 indicates an increase in the odds ratio for each one-point increase in the variable's scale; a figure lower than 1.0 indicates a decrease in the odds ratio.

For example, among the non-metropolitan group, the variable, 'Instrumental motivation in mathematics' (or INSTMOT) has an odds ratio of 1.580 associated with entry into a STEM field. This means that the odds ratio increased by 58 per cent for each increase in the INSTMOT score calculated in PISA 2003.

Table 11. Summary showing significant variables for each group analysis, LSAY Y03 cohort

Other fields (non-STEM, non-Health) as reference	Non-metro	SES	FiF	WINTA	No group
STEM fields					
ANXMAT Mathematics anxiety	0.661	- -	- -	- -	0.776
ATSCHL Attitudes towards school	- -	0.631	0.814	- -	- -
BELONG Sense of belonging to school	- -	- -	- -	- -	0.713
INSTMOT Instrumental motivation in mathematics	1.580	2.661	1.653	1.542	1.770
INTMAT Interest in mathematics	- -	- -	- -	- -	- -
MATHEFF Mathematics self-efficacy	- -	- -	- -	- -	1.660
SCMAT Mathematics self-concept	- -	1.615	1.825	1.720	- -
STUREL Student-teacher relations at school	- -	- -	- -	- -	- -
Health fields					
ANXMAT Mathematics anxiety	- -	- -	- -	- -	0.645
ATSCHL Attitudes towards school	- -	- -	- -	0.845	- -
BELONG Sense of belonging to school	- -	- -	- -	- -	- -
INSTMOT Instrumental motivation in mathematics	- -	- -	- -	- -	1.499
INTMAT Interest in mathematics	1.622	- -	- -	1.472	- -
MATHEFF Mathematics self-efficacy	- -	- -	- -	- -	- -
SCMAT Mathematics self-concept	- -	- -	1.395	- -	- -
STUREL Student-teacher relations at school	- -	- -	- -	- -	- -

Note: The figures above are the Exp(B) from the nominal logistic regression analyses. Only statistically significant exponents are shown. See Appendix 2 for full estimates by equity group.

The analyses showed that among the equity groups and the students in no equity group, **instrumental motivation in mathematics** (INSTMOT)—a composite index that captures students' motivation to learn mathematics because they perceive it as useful to them in the future—was statistically significant when examining the difference between university entrants in STEM fields and entrants in Other fields. Among all groups, an increase of one on this scale increased the odds ratio by more than 50 per cent.

Among equity groups, when examining the difference between entrants into STEM fields and entrants into Other field, the difference in INSTMOT is greatest for the low SES student group, with an odds ratio of 2.66, suggesting those from this background who have an interest and also see the value of mathematics are more than two and a half times more likely to pursue a STEM field than an Other fields pathway. As noted above, the odds ratios are also high among each of the equity groups as well as the non-equity group. When examining the difference between entrants into Health fields and entrants into Other fields, the difference in INSTMOT is evident for the non-equity group only.

Of the other variables in the models, **mathematics self-concept** (SCMAT) was statistically significant for the comparison between Other fields entry and STEM entry, for three groups:

low-SES, First in Family and WINTA; it was also statistically significant for entry into Health fields among First in Family students.

For the variable **mathematics anxiety** (ANXMAT), the results show that higher levels reduced the odds ratio of entry into STEM for Non-metropolitan students, and for the non-equity group, that is, young people in the LSAY Y03 cohort with higher levels of mathematics anxiety more frequently entered an Other program than a STEM program at bachelor level. Interestingly, this variable was not statistically significant in the other equity groups.

In terms of the other variables explored in the table above and their link to further study in a STEM field, **attitudes to school** made a difference for the Low SES and First in Family groups; where a negative attitude reduced the odds ratio of likelihood of studying STEM by 20 to 40 percent. Finally, for the equity groups, **sense of belonging**, i**nterest in mathematics**, and **student-teacher relations at school** were not statistically significant.

Discussion

STEM participation is an important issue, gaining prominence in the past few years among Australian education ministers who have highlighted the need to stop a decline in student enrolments in STEM, which is seen as an economic and innovation driver for the future of the Australian economy (Education Council, 2018).

The analyses in this study above offer insight into an area that has not previously been examined in this way. While prior research has been undertaken examining pathways and achievement in mathematics and science at school (Schmid, 2019; Thomson et al., 2004) and into the workplace (Anlezark et al., 2008), these studies have not explored the pathways and outcomes in STEM among students from disadvantaged backgrounds.

Where under-represented groups have been explored in recent research on STEM, it has primarily been in relation to gender, although even then, studies have tended to focus on one or other end of the STEM pipeline (i.e. school subject choice, or workplace entry) rather than pathways through a number of transition points.

The use of LSAY data for this study has enabled analysis of transition points across the STEM pipeline for young people from age 15 to age 25 in four equity groups – Low SES, Non-metropolitan, First in Family, and Women in Non-Traditional Areas. The key discussion points relating to these findings are outlined below in relation to the three main research questions set for this study. The discussion section finishes by outlining the limitations of the research and discussing possibilities for further research in this area.

Exploring the research questions

Research Question 1: How do the STEM pathways of equity groups and non-equity groups differ?

We know from prior research that Australian students from Low SES and Non-metropolitan backgrounds perform at significantly lower levels on assessments of mathematics and science (Thomson et al., 2019; Thomson, Wernert et al., 2017). Prior analysis of LSAY has also shown that Low SES background students are less likely to participate in science study beyond age 16 than other students (Cooper et al, 2020).

The analyses for this study, confirms these findings, but also looked further. The findings detailed earlier build on the work of Cooper et al, and show that as a result of lower participation in science and mathematics, the likelihood of progressing to higher education in a STEM field is lower. Our findings show that among equity groups, participation in two higher level mathematics subjects was notably lower than for the non-equity group in the analysis. Furthermore, analysis of participation in mathematics and science in senior secondary school showed that for those without at least two subjects in this area, the prospects of subsequently studying in a STEM field was low.

Overall, the entry rates to university for many equity groups are low relative to national averages and non-disadvantaged groups (CSHE, 2018), and the findings for the equity groups in the LSAY cohort examined in this study confirmed this. However, the findings of this analysis in relation to STEM participation show that among those who do go to university, the proportion who choose a STEM pathway is similar regardless of equity group (excluding WINTA). Essentially, about one in four university students from Low SES, First in Family and Non-metropolitan backgrounds enrol in a STEM field – a similar figure to the national average.

However, for women, the findings here confirm those of others (for example, Eccles et al., 1984; Gunderson et al., 2012; Good et al., 2012; Steinke, 2017), showing that transition rates from school to university STEM fields is relatively low. Among the LSAY Y03 cohort, less than one in ten women went on to study a WINTA STEM field at university – this is despite the fact that on the whole, the university transition of women in this cohort was notably higher than for men. Overall, among the members of the LSAY cohort who went into university, women were about half as likely to enter a STEM field than any of the other equity groups explored in this study.

A more positive outcome in terms of WINTA STEM was found in this study at the other end of the university cycle, where the data showed that for those women who do enter a STEM field, the completion rates are very high in comparison to other equity groups as well as being above the overall average for the cohort. As discussed earlier, Li & Carroll (2017) found that women in STEM were not at risk of high attrition when academic achievement was controlled for, and the new findings in this study suggest that on average most in this equity group are successful in their transition through university. The key caveat here is that this outcome only occurs once the choice to study STEM has been made; as noted above, the 'attrition traps' (Wilson et al., 2013) for women are certainly prevalent prior to university entry.

Completion of STEM courses for other equity groups were found to be lower than average, and also lower than for some other fields within each group. For example, only two in every three Low SES students from the LSAY Y03 cohort who enrolled in a STEM field at university had completed their degree by age 25. This is low compared with Low SES students studying in Other fields (71 per cent completion), Low SES students in Health (80 per cent) and the overall average for the cohort who studied STEM (76 per cent). The Non-metropolitan students and First in Family students also had low STEM completion rates in comparison to the average for the whole cohort. While prior research by Wilson et al (2013) suggested that at the end of first year, students from equity groups did not intend to withdraw from their course at a greater rate than other students, the findings in this study suggest that further down the track these intentions are not always fulfilled.

For those who do commence a STEM course at university, the data in this study shows that another substantial 'leakage point' in the pipeline occurs in the transition into work. With the caveat that this data tracks outcomes only up to age 25 and that careers take some time to establish, the findings relating to the occupations of the LSAY Y03 cohort at age 25 offer interesting insight. In line with the findings of Anlezark et al. (2008), across this whole cohort, about one in five (22 per cent) of those who commence a STEM course went into a STEM university qualification-related occupation, and a further 9 per cent entered a 'mixed STEM' occupation (that is an occupation which has a mixed workforce of university and VET qualifications). Among equity groups, analysis in this study shows that the transition rates into STEM occupations was mixed. The Non-metropolitan and First in Family groups had similar overall STEM occupation uptake as the average across the cohort, but for Low SES and WINTA STEM students, the rate of entering a STEM occupation was notably lower. Among the Low SES and WINTA groups, less than one quarter (24.3 per cent for Low SES, 23.1 per cent for WINTA) of those who had commenced a STEM course at university were employed in a STEM occupation (university or mixed qualification) by age 25. For the WINTA group, this again confirms analyses by others, including Reid et al. (2016) who note that the 'pipeline leakage' for women is particularly prominent in the areas of mathematics, engineering and physical sciences.

Overall in relation to Research Question 1, the research in this study shows that achieving positive outcomes in STEM participation among equity groups is most prominently an issue in the transition from school into university, and the transition from university into the STEM workforce. In general, fewer differences were specifically identified in relation to school subject take-up and progression once in university for equity groups in STEM. That is not to say that disadvantage doesn't exist at these points for these groups, just that these issues do not seem to be substantially 'worse' within the STEM fields. For transition to STEM occupations for those who undertook a STEM university qualification, the low take-up rates among some equity groups are indicative (or similar to) the low rates across all those who studied STEM in this cohort, but even worse for those from Low SES backgrounds and women who studied STEM.

Research Question 2: What factors facilitate equity group students participating in university STEM courses?

In addition to tracking pathways and examining specific movement between transition points among the LSAY Y03 cohort, this study examined factors relating to achievement, motivations and attitudes towards STEM of young people – an area with very little prior research, especially in relation to equity groups.

This study identified a few notable factors that specifically impact STEM participation among equity groups. Key to these findings was the analysis of PISA data for the LSAY cohort. This cohort had undertaken PISA in a year when the ‘focus domain’ was mathematical literacy, thus enabling a strong and nuanced analysis suited to the STEM-focus of this research.

The study found that while mathematics achievement at age 15 was a very strong predictor of entry to university, it did not necessarily differentiate pathways into STEM for equity groups or across the whole cohort. However, the results from the PISA context survey did show some specific factors influencing the participation in university STEM courses. Multinomial logistic regression analyses highlighted that instrumental motivation in mathematics and mathematics self-concept were relatively strong factors in predicting the likelihood of students, including those in equity groups, to go on to study STEM at university. These were relatively strong predictors among most equity groups, and the latter tended to only be a predictor for equity groups. Each of these concepts are outlined below.

Instrumental motivation in mathematics is measured in PISA as the extent to which a student sees the utility of mathematics for their future studies and work. In a number of survey questions in PISA, students are asked whether they think mathematics is important to improve career prospects and to undertake further study, as well as whether they think learning mathematics and making an effort is worthwhile for work and study pursuits. The LSAY Y03 analysis in this study identified that positive responses in relation to these questions significantly increased the likelihood that a student would subsequently enrol in a STEM field course.

Mathematics self-concept relates to students’ belief in their own mathematical abilities. In the PISA data analysed in this report, a scale is used to reflect this based on a number of survey questions focussing on students’ perception of their ability in mathematics, such as whether they feel they learn mathematics quickly, whether mathematics is one of their ‘best’ subjects, and whether they understand the ‘most difficult work’ in mathematics. As highlighted by the OECD, mathematics self-concept ‘is an important outcome of education and strongly related to successful leaning’ (OECD, 2013). Given this, it is unsurprising that those who go on to study STEM at university have high mathematics self-concept.

This finding, in combination with the finding for instrumental motivation, supports the idea that a ‘STEM profile’ in early adolescence may be a key determinant for persisting with a STEM pathway (Wang & Degol, 2013). Furthermore, in this study these factors were shown to be relevant for individual equity groups, even after controlling for other factors, including mathematics achievement. These results show that given their influence on decision-making in relation to further STEM, interventions targeted at fostering self-concept and instrumental motivation in mathematics are crucial, even before students turn 15 years of age and particularly with students from equity groups.

Research Question 3: Do the factors influencing young people's university STEM participation differ between equity groups and non-equity groups?

While the discussion above in relation to factors influencing STEM enrolment at university is relatively general in indicating the findings of this study, there are notable nuances in outcomes identified between equity groups and other students, and also across the different equity groups explored here. Given the broader findings discussed above, the focus of the discussion in relation to Research Question 3 is centred around the differences in the two key factors identified – instrumental motivation in mathematics, and mathematics self-concept.

For instrumental motivation in mathematics, the findings in this study showed that this was a significant factor in predicting STEM university study for all equity groups and the non-equity group in the LSAY Y03 cohort. This factor was particularly strong for students from Low SES backgrounds – with each increase in instrumental motivation meaning the odds of a student studying in a STEM field grew more than two and a half times. Other equity groups, and the non-equity group, recorded increases at about one and a half times. As noted above, these findings suggest a focus on improving instrumental motivation in mathematics could potentially have a positive outcome for equity group students in terms of further participation in STEM, particularly students from Low SES backgrounds.

Interestingly, mathematics self-concept was shown as a significant factor for Low SES, First in Family and women entering STEM, but not for Non-metropolitan students or the non-equity group. Increased self-concept in this subject was related to an increased odds ratio for entering a STEM field of between 60 and 82 per cent for the three equity groups. Again, this suggests an area of consideration in improving the proportion of students from these groups entering STEM in higher education.

Limitations and future research

In interpreting the findings of this study, it is important to consider a number of caveats to the research. These are outlined in the dot points below, and also discussed within the detail in the Methods section of the report:

- *Sample size* is an issue with analysis of longitudinal data, especially when cutting the analyses to sub-populations and sub-populations of those sub-populations. For example, a number of the analyses in study were focussed on equity groups, and then among these groups students who pursued STEM in higher education. The LSAY Y03 cohort was chosen as the focus for this analysis for two reasons – the first being the 'focus domain' of mathematics that was included in PISA for this particular cohort (as discussed elsewhere in this report), the other reason is that of all the LSAY cohorts available to analyse over a 10 year period, the Y03 had the most robust sample sizes for the equity groups that were being explored. Where appropriate in the report, caveats around interpretation of results have been included, and 'n's have been inserted into tables where numbers are particularly small.
- *Reduced number of equity groups* were analysed in this work when compared to the Department's list of higher education equity groups. In particular Indigenous Australians and people with disability were not included. For Indigenous Australians, the sample for the Y03 cohort was too small to be able to be published at the level of granularity required. For people with disability, data to examine the outcomes of this group are not available in the LSAY cohort used in this analysis. Future work relating to ensuring larger and identifiable samples in these key groups is underway – for example the development of the Widening Participation Longitudinal Study (WPLS), that is currently in a scoping phase, being led by the Australian Department of Education Skills and Employment.

This study is but one step in helping to shed light on STEM pathways for equity groups. As mentioned above, further work on developing data through the WPLS will no doubt help in expanding the ability to ‘drill down’ further in the data and explore a wider range of student groups. Other more specific things that we would have liked to do to expand this research project – time and resources permitting include:

- analyses of qualitative data relating to choices, support and barriers for students in their senior years of schooling in the LSAY data
- exploration of students who fit into multiple equity groups – to better understand the cumulative impact of equity group membership on the pathways traced in this work
- extension of the multivariate modelling to examine university completions in STEM, and transitions into STEM occupations
- expansion of analysis to understand the postgraduate university pathways being followed among the students who completed a STEM bachelor degree
- further exploration relating to equity outcomes within the STEM field, including disaggregation by ‘high prestige’ fields and ‘high prestige’ institutions.

Conclusion

This research offers new perspective in relation to studies of youth transitions. Its contribution lies in its intertwining of two issues being addressed in parallel in various policy and research projects across Australia – improving the STEM pipeline, and improving educational outcomes for young people in under-represented groups. Focusing on longitudinal data tracking a cohort from age 15 to 25, this study explores pathways and transitions into and through STEM. It then ‘dives deep’ to examine factors such as motivation, anxiety and self-concept in relation to a subject central to STEM success – mathematics – and the extent to which these factors predict future outcomes for students in equity groups.

The study results have shown that within the STEM ‘pipeline’, the transition from school into university, and the transition from university into the STEM workforce are two critical areas where there are ‘leaks’, especially for equity groups, and particularly for women and people from Low SES backgrounds.

The findings also support the idea that a ‘STEM profile’ in early adolescence may be a key determinant for persisting with a STEM pathway (Wang & Degol, 2013). The study has identified that a profile that has a strong emphasis on higher mathematics self-concept and instrumental motivation is strongly associated with the likelihood of entering a STEM field in university – particularly among individual equity groups.

These results open the door to future research to better understand the transition points and pathways of young people in equity groups pursuing STEM. They also provide evidence for future policy implementation. In particular, given the influence on decision-making in relation to further STEM study, interventions targeted at fostering self-concept and instrumental motivation are crucial, even before students turn 15 years of age and particularly with students from equity groups.

Recommendations

The findings from this study have potential implications for policy and practice in relation to three important areas of the student lifecycle – early and middle years of schooling; senior secondary school; and assisting entry into the STEM workforce. Opportunities to influence these three points in the lifecycle so as to improve outcomes for students from under-represented groups include:

- In the early and middle years of schooling, building mathematics programs and encouraging pedagogical approaches that *focus on demonstrating the practical importance of mathematics*, with the aim of increasing instrumental motivation in mathematics. Increasing instrumental motivation has been shown to significantly increase likelihood of pursuing STEM among equity groups, especially students from Low SES backgrounds.
- In the senior years of schooling, policies and interventions to encourage university participation among under-represented groups should continue and be refined to ensure the range of opportunities through higher education are understood. Being able to demonstrate the benefits of mathematics competency across a broad spectrum of employment and practical problem solving issues is of particular importance in increasing the flow of higher education entrants into STEM fields.
- In the later years of university, opportunities for work placements, internships and/or Work Integrated Learning (WIL) in STEM fields is critical for developing pathways into the STEM workforce. Strong developments in this area across science in Australia, led by the Australian Council of Deans of Science has seen significant change in recent years (https://www.acds-tlcc.edu.au/wil-guide-for-science/). Given this growing confidence and know-how in universities, and the work already

underway for Women in STEM, further widening the focus on opportunities for equity groups, particularly Low SES students should be a challenge taken up in the future.

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Appendix 1: Classifications of science and mathematics Year 12 subjects

Table 12. Classification of Year 12 mathematics subjects

State/Territory	Lower level mathematics	Higher level Mathematics
ACT	8 Mathematical Applications	9 Mathematical Methods
	30 Trade and Business Maths	11 Specialist Mathematics
NSW	5 General Mathematics	1 Mathematics
	24 Mathematics Life Skills	22 Mathematics Extension
QLD	2 Mathematics A	3 Mathematics B
	29 Trade and Business Mathematics (incl. Workplace, Practical)	4 Mathematics C
SA/NT	8 Mathematical Applications	10 Mathematical Studies
	9 Mathematical Methods	11 Specialist Mathematics
Tas	21 Mathematics Applied	9 Mathematical Methods
	26 Maths after College	25 Mathematics Specialised
	27 Maths at Work	
VIC	5 General Mathematics	9 Mathematical Methods
	6 Foundation Mathematics	11 Specialist Mathematics
	15 Further Mathematics	
WA	14 Discrete Mathematics	12 Applicable Mathematics
	23 Mathematics in Practice	13 Calculus
	28 Modelling with Mathematics	
	7 Foundations of Mathematics	
	31 Vocational Mathematics	

Sources: Forgasz (2006); McMillan & Edwards (2019); Thomson (2005)

Table 13. Classification of Year 12 STEM subjects (excluding mathematics)

	Subjects
Sciences	
Biological sciences	Biology, Human Biology, Life Sciences
Chemistry	Chemistry
Physics	Physics, Physics (inc. Electronics), Physical Science
Other sciences	
Information technology	
Information technology	
Information technology (VET)	
Engineering	
Engineering	2 Advanced Electronics 3 Aeronautics 27 Engineering Studies 28 Engineering Technology 48 Local Area Mining, 50 Manufacturing & Engineering inc. Engineering Applications, 57 Nautical Studies, 71 Engineering Technology

	Subjects
Engineering (VET) and other related technologies	1 (Intro to) Metal Machining & Fabrication (VET) 4 Agriculture & Horticultural Studies 5 Applied Technology, 6 Automotive / Automotive Technology VET, 7 Automotive SWL (VET), 8 Automotive Technology 9 Automotive Workshop, 13 Composite Materials 14 Computer Assisted Drawing and Design (VET) 15 Computer Graphics & Design 17 Design & Technology 18 Design and Technology (inc. Communication Products, Mater 19 Design Graphics 23 Electronics Servicing SWL (VET) 24 Electronics VET 25 Electrotechnology, 26 Engineering / Engineering Technology VET 36 Graphics 37 Graphics Technology 39 Industrial Skills (inc. Building & Construction, Engineer 40 Industrial Technology 42 Introduction to Electronics 43 Introduction to Electrotechnology VET, 47 Light Manufacturing SWL (VET) 49 Machining & Fabrication (VET) 51 Manufacturing and Engineering (VET) 52 Metal Machining & Fabrication (VET) 53 Metals Technology 54 Metals & Engineering VET (inc. Specialist Studies) 55 Metals & Engineering SWL (VET) 56 Mining SWL (VET) 58 Primary Industries VET (inc. Specialisation Study or Exte 59 Primary Industries SWL (VET) 60 Systems & Technology 61 Systems Technology 62 Technical Graphics 64 Technology Studies 66 Trade Drawing (VET) 70 Other Design and Technology subject 73 Electrotechnology 74 Engineering Studies (VET)
~~Other technology (excluded)~~	~~10 Building & Construction VET (inc Bricklaying, Carpentry~~ ~~11 Building and Construction~~ ~~12 Building Construction & Services SWL (VET)~~ ~~16 Construction VET~~ ~~20 Design in Metal~~ ~~21 Design in Wood~~ ~~22 Design SWL (VET)~~ ~~29 Fabrics, Design & Technology~~ ~~30 Facilities Development and Maintenance (VET)~~ ~~31 Fashion & Textiles~~ ~~32 Food & Technology~~ ~~33 Furnishing (Cabinet Making) VET~~ ~~34 Furniture Design and Technology~~ ~~35 General Workshop (VET)~~ ~~38 Housing & Design~~ ~~41 Interactive Media~~ ~~44 Laboratory Operations (VET)~~ ~~45 Laboratory Skills VET~~ ~~46 Lifestyle & Fashion~~

	Subjects
	~~63 Technological & Applied Studies Life Skills~~
	~~65 Textiles & Design~~
	~~67 Video Production - TV studio/Video location (VET)~~
	~~68 Visual Communication - Photography~~
	~~69 Wood Fabrication (VET)~~
	~~72 General Construction (VET)~~
	~~75 Plastics (VET)~~
Agriculture	
Agriculture	1 Agricultural & Horticultural Science
	2 Agricultural and Horticultural Studies
	3 Agricultural & Horticultural Studies (inc. Agricultural St
	4 Agricultural Science
	5 Agriculture
	6 Agriculture & Horticulture (inc. A & H Management, A & H P
	8 Agriculture/Horticulture (inc. Rural Studies, Animal Husba
	11 Animal Production and Marketing
	19 Farm Practice
	24 Natural Resource Management
	25 Marine and Aquatic Practices (inc. Marine Skills, Aquatic
	26 Marine Studies
	29 Plant Production and Marketing
Agriculture (VET)	7 Agriculture VET
	9 Animal Care SWL (VET)
	10 Animal Production & Enterprise (VET)
	12 Applied Land and Resource Management (VET)
	16 Conservation & Land Management (VET)
	17 Equine Industry VET
	20 Horticulture VET
	27 Pastoral Industries (VET)
	28 Plant Production and Enterprise (VET)
	31 Seafood Industry VET (inc. Aquaculture, Seafood Processin
	32 Seafood Operations (VET)
~~Excluded~~	~~13 Aspects of the Tourism Industry (VET)~~
	~~14 Aviation Studies~~
	~~15 Career & Industry Awareness (VET)~~
	~~18 Extension Studies~~
	~~21 Integrated Learning (VET)~~
	~~22 Intro to SWL - Generic Skills (VET)~~
	~~23 Literacy and Numeracy (inc. Applied Literacy, Consumer Ma~~
	~~30 Reception and Customer Service (VET)~~
	~~33 The Study of Teaching (VET)~~
	~~34 Tourism~~
	~~35 Tourism (inc. Tourism Operations, Tourism Issues)~~
	~~36 Tourism Operations (VET)~~
	~~37 Tourism Studies~~
	~~38 Tourism SWL (VET)~~
	~~39 Transition Education~~
	~~40 Transport & Storage SWL (VET)~~
	~~41 Vocational Community Networking (1 or 2) (VET)~~
	~~42 Vocational Work placement~~
	~~43 Work Education~~
	~~44 Work Education (inc. Vocational Studies, Work studies)~~
	~~45 Work Related Learning- Employment, Enterprise, Community~~
	~~46 Work Studies~~
	~~47 Workplace Background (VET)~~
	~~48 Other subject~~
	~~49 Contemporary Transactions~~
	~~50 Vocational Learning~~
	~~51 Work Readiness~~

Sources: Anlezark et al (2008); Thomson (2005)

Appendix 2: Parameter estimates from nominal logistic regressions

Not in an equity group

Table 14. Parameter estimates - Influence of contextual indicators on bachelor field of study, students not in an equity group of focus in this study, LSAY Y03

Area of study[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
STEM field (bachelor level)	Intercept	-1.694	0.151	126.082	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.571	0.127	20.203	1	0.000	1.770	1.380	2.271
	BELONG Sense of belonging to school	-0.339	0.118	8.162	1	0.004	0.713	0.565	0.899
	MATHEFF Mathematics self-efficacy	0.507	0.124	16.801	1	0.000	1.660	1.303	2.115
	ANXMAT Mathematics anxiety	-0.253	0.126	4.032	1	0.045	0.776	0.606	0.994
Health field (bachelor level)	Intercept	-1.427	0.132	116.129	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.405	0.128	9.979	1	0.002	1.499	1.166	1.927
	BELONG Sense of belonging to school	0.008	0.119	0.004	1	0.947	1.008	0.799	1.272
	MATHEFF Mathematics self-efficacy	-0.148	0.142	1.091	1	0.296	0.863	0.654	1.138
	ANXMAT Mathematics anxiety	-0.438	0.137	10.292	1	0.001	0.645	0.494	0.843

a. The reference category is: Other fields (non-STEM, non-Health) (bachelor level).

Non-metropolitan

Table 15. Parameter estimates - Influence of contextual indicators on bachelor field of study, Non-Metropolitan students, LSAY Y03

Area of study[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
STEM field (bachelor level)	Intercept	-1.307	0.154	71.948	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.457	0.148	9.574	1	0.002	1.580	1.183	2.111
	INTMAT Interest in mathematics	0.225	0.155	2.102	1	0.147	1.253	0.924	1.699
	ANXMAT Mathematics anxiety	-0.414	0.138	9.000	1	0.003	0.661	0.504	0.866
Health field (bachelor level)	Intercept	-1.267	0.144	77.542	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.008	0.161	0.003	1	0.959	1.008	0.735	1.383
	INTMAT Interest in mathematics	0.484	0.173	7.789	1	0.005	1.622	1.155	2.278
	ANXMAT Mathematics anxiety	0.203	0.168	1.458	1	0.227	1.225	0.881	1.702

a. The reference category is: Other fields (non-STEM, non-Health) (bachelor level).

Low SES

Table 16. Parameter estimates - Influence of contextual indicators on bachelor field of study, Low SES students, LSAY Y03

Area of study[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
STEM field (bachelor level)	Intercept	-1.384	0.197	49.334	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.979	0.187	27.244	1	0.000	2.661	1.843	3.842
	ATSCHL Attitudes towards school	-0.460	0.156	8.638	1	0.003	0.631	0.465	0.858
	SCMAT Mathematics self-concept	0.479	0.177	7.310	1	0.007	1.615	1.141	2.286
Health field (bachelor level)	Intercept	-1.538	0.193	63.525	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.164	0.212	0.596	1	0.440	1.178	0.777	1.787
	ATSCHL Attitudes towards school	-0.099	0.180	0.301	1	0.583	0.906	0.637	1.288
	SCMAT Mathematics self-concept	0.057	0.219	0.067	1	0.796	1.058	0.689	1.626

a. The reference category is: Other fields (non-STEM, non-Health) (bachelor level).

Table 17. Parameter estimates - Influence of contextual indicators on bachelor field of study, First in Family students, LSAY Y03

Area of study[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
STEM field (bachelor level)	Intercept	-1.347	0.107	159.377	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.503	0.099	25.744	1	0.000	1.653	1.362	2.008
	ATSCHL Attitudes towards school	-0.206	0.081	6.411	1	0.011	0.814	0.694	0.954
	SCMAT Mathematics self-concept	0.601	0.100	36.353	1	0.000	1.825	1.501	2.219
Health field (bachelor level)	Intercept	-1.644	0.115	203.413	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.102	0.117	0.759	1	0.384	1.107	0.880	1.393
	ATSCHL Attitudes towards school	-0.062	0.098	0.405	1	0.525	0.939	0.775	1.139
	SCMAT Mathematics self-concept	0.333	0.120	7.679	1	0.006	1.395	1.102	1.766

a. The reference category is: Other fields (non-STEM, non-Health) (bachelor level).

WINTA

Table 18. Parameter estimates - Influence of contextual indicators on bachelor field of study, Women in Non-Traditional Areas students, LSAY Y03

Area of study[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
WINTA STEM field (bachelor level)	Intercept	-1.767	0.118	224.545	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.433	0.114	14.503	1	0.000	1.542	1.234	1.926
	ATSCHL Attitudes towards school	-0.120	0.088	1.847	1	0.174	0.887	0.747	1.054
	INTMAT Interest in mathematics	0.068	0.129	0.279	1	0.597	1.070	0.832	1.377
	SCMAT Mathematics self-concept	0.543	0.126	18.465	1	0.000	1.720	1.343	2.204
WINTA non-STEM field (bachelor level)	Intercept	-1.179	0.090	170.352	1	0.000			
	INSTMOT Instrumental motivation in mathematics	0.157	0.099	2.502	1	0.114	1.170	0.963	1.421
	ATSCHL Attitudes towards school	-0.168	0.080	4.432	1	0.035	0.845	0.723	0.988
	INTMAT Interest in mathematics	0.387	0.119	10.500	1	0.001	1.472	1.165	1.861
	SCMAT Mathematics self-concept	-0.095	0.116	0.662	1	0.416	0.910	0.724	1.143

a. The reference category is: Other fields (non-STEM, non-Health) (bachelor level)