

# Promoting girls' and boys' engagement and participation in senior secondary STEM fields and occupational aspirations



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## Abstract

Sufficient numbers of people with science and mathematics qualifications are needed for continuing growth in productivity and industry innovation. The Australian Industry Group (2015, p. 5) cautioned, 'the pipeline of STEM skills to the workforce remains perilous' because participation in sciences and advanced mathematics at school and university is in decline, participation is not comparable with other nations, and our students underperform in major international studies. Gender differences in enrolments and career plans continue to fuel the concern of researchers with interest in gender equity. Many have argued girls prematurely restrict their options by discontinuing particular STEM subjects in adolescence, which has ramifications for women's later wellbeing from economic and psychological perspectives. Much research has concentrated

on whether and how girls/boys are differently motivated in particular learning domains, towards different career aspirations, and how features of the learning environment can promote or diminish their motivations. In the STEPS Study (<http://www.stepsstudy.org>), I have been following longitudinal samples of youth over the past two decades using these frames to examine boys'/girls' motivations in particular subjects; how motivations matter differently for girls/boys; in directing them towards particular purposes and aspirations; and as they are influenced by features of their learning environments.

STEM participation is an issue in Australia, as in the US and many countries of the OECD. There have been two main arguments put forward as to why we should care.

## Economic drivers

Sufficient numbers of people with science and mathematics qualifications are needed for continuing growth in productivity and industry innovation. The Australian Industry Group (2015, p. 5) cautioned, ‘the pipeline of STEM skills to the workforce remains perilous’ because participation in sciences and advanced mathematics at school and university is in decline, participation is not comparable with other nations, and our students underperform in major international studies. In May 2012, the Office of the Chief Scientist published ‘Mathematics, Engineering & Science in the National Interest’ which outlined STEM fields as ‘... critical engines of innovation and growth’. The previous Labour Government publicised ‘New Directions for Maths and Science’ (2007) to improve STEM participation:

For Australia to succeed in a highly competitive global economy, students need to have a strong grasp of basic maths and science and encouragement to pursue careers in this area ... 0.4% of Australian university students graduate with maths and statistics qualifications compared with the OECD average of around 1%. [p. 2]

## Personal affordances

Mathematics has been found to act as a ‘critical filter’, as first proposed by Lucy Sells in 1980, which delimits individual future participation and opportunity

to high-status and high-salary fields of education and occupation. It is also a gendered issue. We need to worry about this not only because women are more likely than men to end up as financially responsible for other dependents (Meece, 2006), but because of their own future career opportunities and life satisfaction. The progressive loss of talent from STEM fields is often referred to as the ‘STEM pipeline’, where the flow slows towards a trickle, and some groups – including girls/ women and those from less advantaged backgrounds – leak out more than others.

## An integrative theoretical framework to study influences on the STEM pipeline

An array of factors at the student, institutional, and broader structural levels impact leaks out of the STEM pipeline. These have primarily been studied within the expectancy-value theory (EVT) of Eccles et al. (Eccles et al., 1983; Eccles, 2005). The most proximal predictors of achievement-related choices are self-beliefs and task values (highlighted red in the figure below). Eccles posits that it is not enough to believe that one *can* do something, one also has to *want* to do it, to decide to pursue it. There are four different task values described by EVT. The first is *intrinsic value*, referred to as interest or enjoyment. Second is *attainment value*, which refers to the personal importance of succeeding in a particular

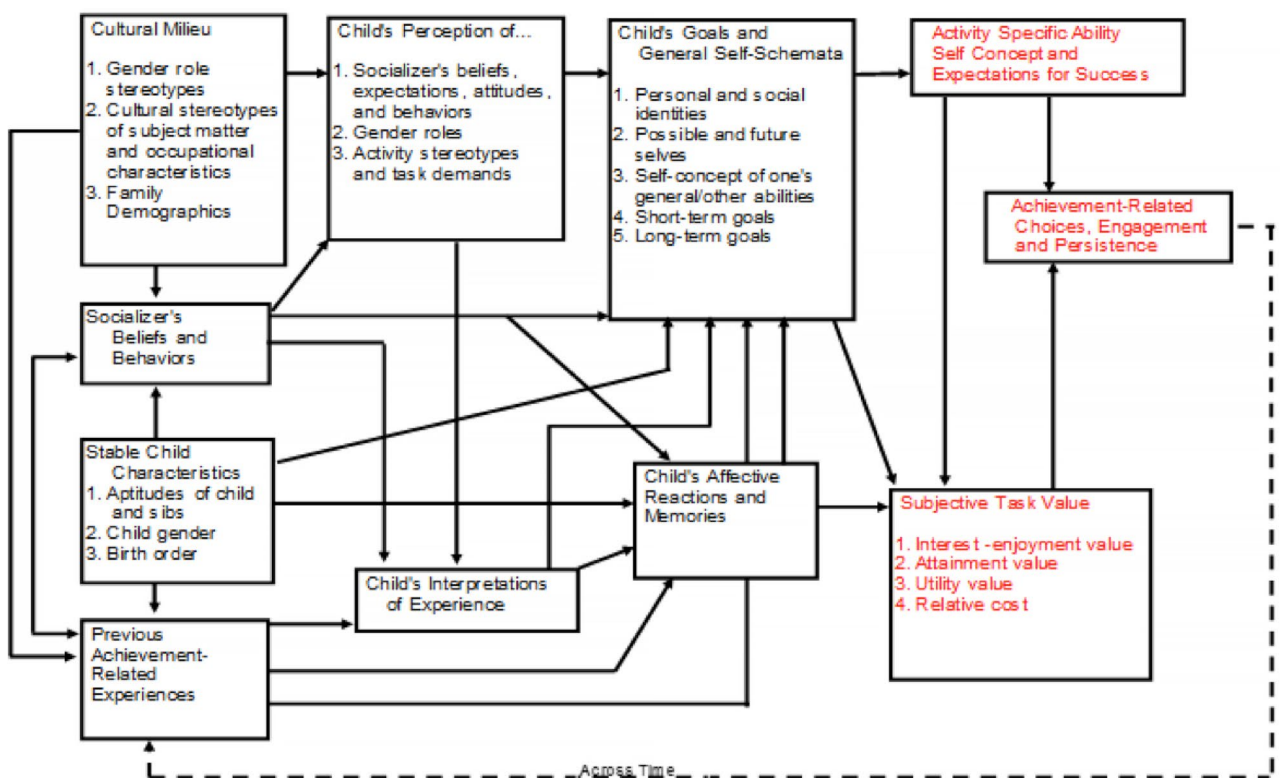


Figure 1 Formulation of the expectancy-value model of achievement choices (Simpkins et al., 2015)

task or domain. *Utility value* is about how useful the task or subject is. Least researched is the negative cost *value*, which would push one away. The first three values should attract a person towards a task or domain. Conversely, different costs should push one away.

## What motivates students in mathematics at school, and beyond?

The first longitudinal Australian study of young adults' STEM motivations, participation, aspirations and outcomes, this first (ongoing) of my two longitudinal STEM STEPS studies began in the mid-1990s. It initially involved 1323 adolescents from three coeducational upper-middle-class government schools in metropolitan

Sydney, matched for socio-economic status by the Australian Bureau of Statistics. Participants spanned grades 7–11 in a three-cohort sequential design (see Watt, 2004), now being followed up 17 years later. This means I can examine long-term outcomes of how their motivations and perceptions during secondary school mattered for actual career outcomes. My second contemporary longitudinal study focuses on sciences as well as mathematics, described in one of the next sections.

## Mathematics participation choices

In the New South Wales mathematics curriculum structure for the Higher School Certificate (HSC) in the 1990s, there were five levels of mathematics: 'Maths in Practice' (MIP), followed by 'Maths in Society' (MIS), '2-unit' (2U), '3-unit' (3U), and the most advanced '4-

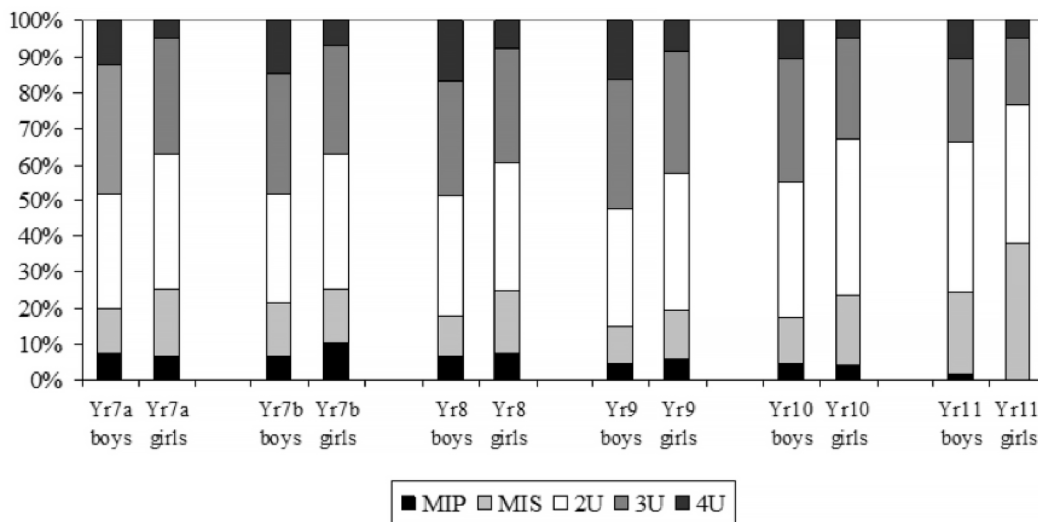


Figure 2 Gendered HSC enrolment choices

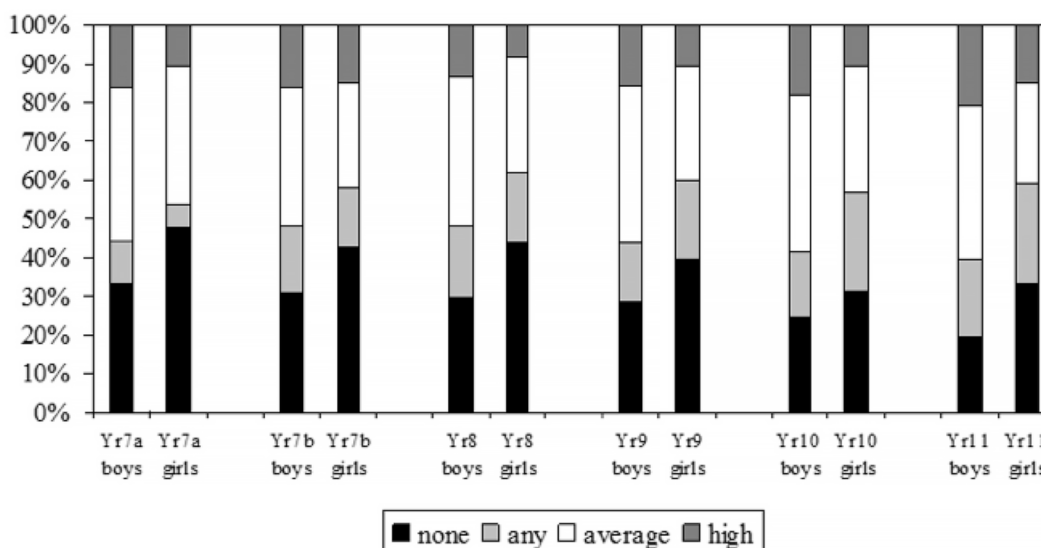


Figure 3 Gendered mathematics-related career plans

unit' (4U) mathematics. Figure 2 left shows proportions of boys and girls aspiring to and, in Year 11, actually undertaking each of those. More boys aspired to and subsequently undertook the most advanced levels of mathematics; vice versa for girls (Cliff's  $\delta$ : 13— .18,  $p < .05$ ). Students' aspirations appeared rather stable from the start of secondary school, and closely resembled later actual enrolments. Gender differences were robust, and statistically significant. Data reflect those at the national level, and resonate with statistics from other countries. In the US, the gender gap in high school mathematics closed mostly because of levers that mean if students opt out, they cut themselves out of university studies, for example.

### Occupational choices

Planned occupations were queried with an open-ended question at each timepoint, coded using the US Department of Labor (1998) Occupational Network Classification system (O\*NET™), into how mathematics-related they were, from 'none' to 'high' mathematical knowledge and skills. Figure 3 shows more girls aspired to careers which were not at all mathematics-related, and more boys aspired to highly mathematics-related careers (Cliff's  $\delta$ : .12— .21,  $p < .05$ ).

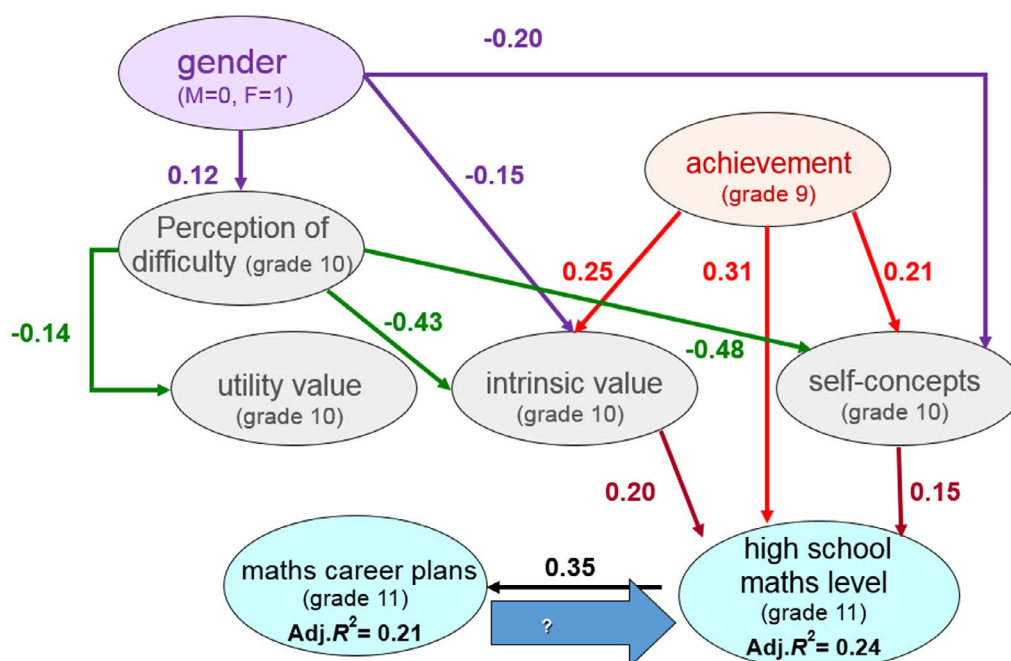
### Influences on girls', and boys', mathematics choices

Why would girls have lower mathematical aspirations? I examined the extent to which expectancies (or self-concepts) and task values could explain differences

over and above achievement. Students responded to survey questions rated from 1 ('not at all') to 7 ('very'). An example self-concept question was, 'Compared with other students in your class, how talented do you consider yourself to be at maths?'; for intrinsic value, 'How much do you like maths, compared with your other subjects at school?'; for utility value, 'How useful do you think mathematical skills are in the workplace?' A path model of estimated influences is depicted in Figure 4. Gender was coded 1=girls, 0=boys; paths from gender convey directional effects for girls (for example, girls considered mathematics to be more difficult than boys). The range of standardised coefficients is 0— 1 (or 0— -1 for negative predictions); only statistically significant paths are shown ( $p < .05$ ).

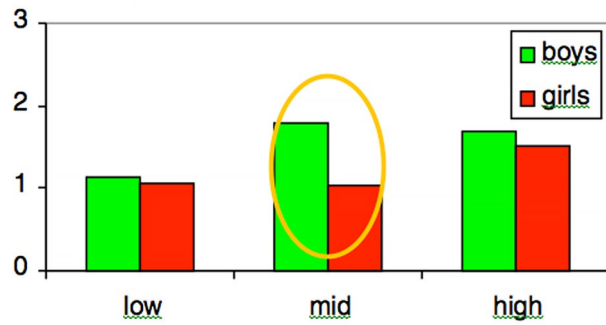
Girls were less interested in mathematics, and thought they were less able, despite equivalent achievement. Higher achievers were more interested, and thought themselves more able. Students who found mathematics more difficult considered it less useful, were less interested, and considered themselves less able. Higher achievers enrolled in more advanced mathematics, as did students who were more interested, considered themselves more able, and aspired to more mathematical careers. It is not entirely obvious which direction this last relationship should go – it is likely students are looking ahead along the pipeline to the kinds of careers involving mathematics and their workplace conditions.

There was no path from utility value to any outcome, but there was an interesting interaction effect. The



**Figure 4** Path model estimating influences on girls' and boys' mathematics choices

circled effect in the figure below highlights that boys who regarded mathematics as moderately useful were as likely as boys who considered mathematics highly useful to aspire to highly mathematical careers (0–3). Whereas, unless girls regarded mathematics as highly useful, they were not likely to aspire to highly mathematics-related careers; girls who thought mathematics was moderately useful were as likely as girls who thought mathematics was low in usefulness to undertake low mathematics-related careers. This suggests many levers to action, such as making connections between different types of mathematical careers and their social uses and values.

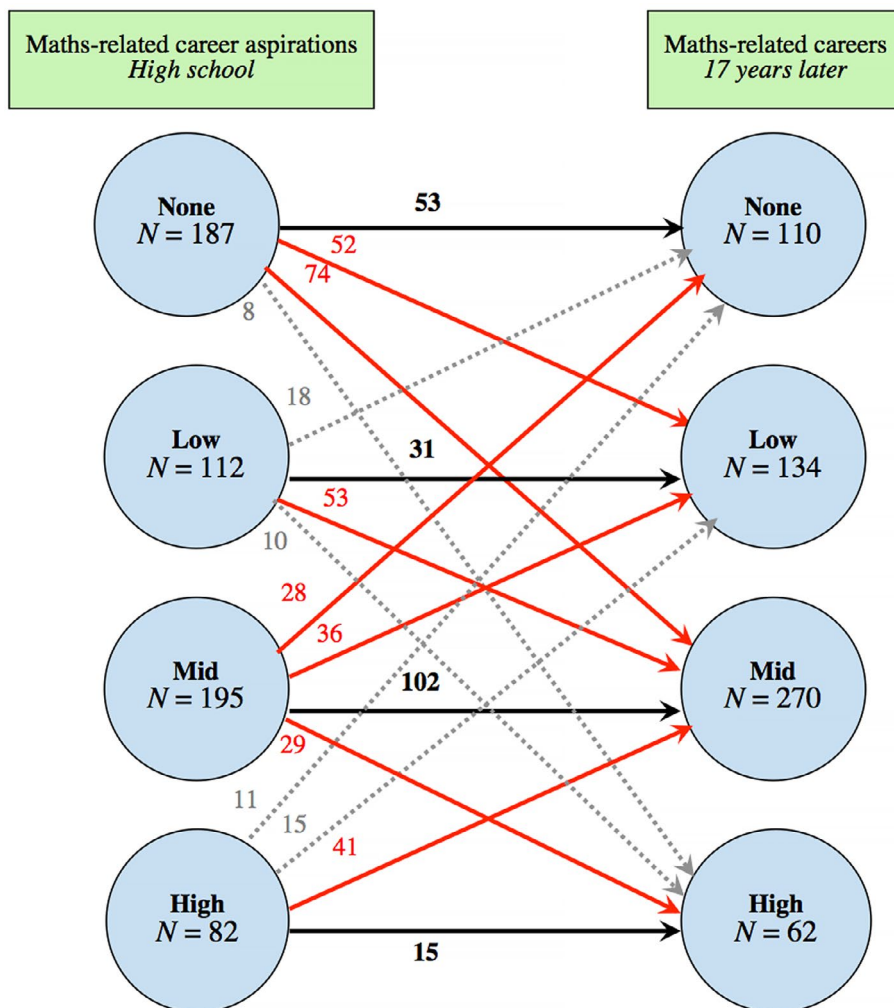


**Figure 5** Interaction effect: Gender X utility value on maths occupational decisions

## How do motivations translate into occupational outcomes?

Despite the fact that the internet did not exist back in the 1990s, I have so far followed up with 643 of the original 1323 participants. The black arrows in the figure

below represent stability paths for same individuals who remained in same categories over time. Red arrows show noticeable 'off-diagonals'; dashed arrows show other atypical pathways. Aspirations (modestly) predicted even long-term outcomes for mathematical careers ( $p = .20$  for boys,  $p = .21$  for girls).



**Figure 6** Correlations between aspirations and careers



## Motivations matter, even 17 years later!

How difficult students had found mathematics, how interested they were, and their self-concepts of ability predicted subsequent mathematical career plans. Green bars in the figure below show that boys who had been more interested, and thought themselves more able, were those who ended up in more mathematics-related careers. The same was true for girls who had thought they were more able at mathematics; girls also experienced a ‘push’ factor – if they had found mathematics difficult, they were less likely to end up in mathematical careers.

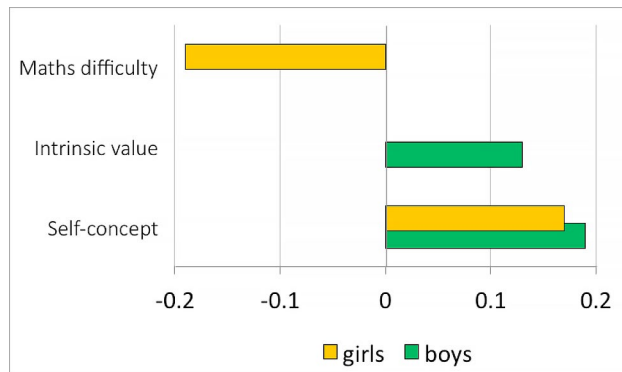


Figure 7 Correlations between motivations and careers

## How do self-concepts and values develop?

If self-concepts and values are so important, we should be concerned with their development. This line of work initially focused on the transition to secondary school, and associated disruption and negative impacts on motivations at that time identified by Eccles, Midgley, Wigfield and colleagues who documented differences in the school environment pre- and post-transition that accounted for those changes – such as disruptions to peer networks, increasing normative assessments, multiple teachers throughout the day for different subjects, and greater curricular differentiation. Concerningly, longer-term longitudinal studies show that this is part of a continuing pattern through secondary school, and students do not ‘recover’ post-transition (see Fredricks & Eccles, 2002, and Jacobs et al., 2002, in the US; Frenzel et al., 2010, and Nagy et al., 2010, in Germany; Watt, 2004, in Australia). Greater realism may explain motivational declines with increased social comparisons and increased normative assessments, but what about the gender differences? Stable magnitudes imply they are in place early on and continue. In the United States, Jacobs et al. (2002) found gender differences in self-concepts as early as grade 2!

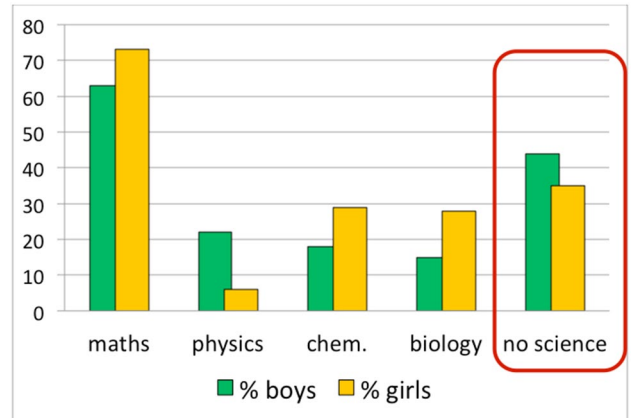


Figure 8 Year 12 STEM participation

## A new ‘contemporary’ longitudinal study: Focus on mathematics and sciences

In a new contemporary longitudinal study, I have been probing sources of mathematics and science motivations among 1172 students from nine Melbourne and Sydney schools, since Year 10 until post-school. I included a mix of government, Catholic and independent schools, coeducational and single-sex, and selective schools. The first striking finding was the high proportion of students undertaking no science in Year 12, or no mathematics (Figure 8). Aspirations towards mathematical or scientific careers were moderate at best (Figures 9 and 10) and declined Years 10–12. There were gender differences for mathematics-related career plans; none for sciences.



Figure 9 Students' maths career plans

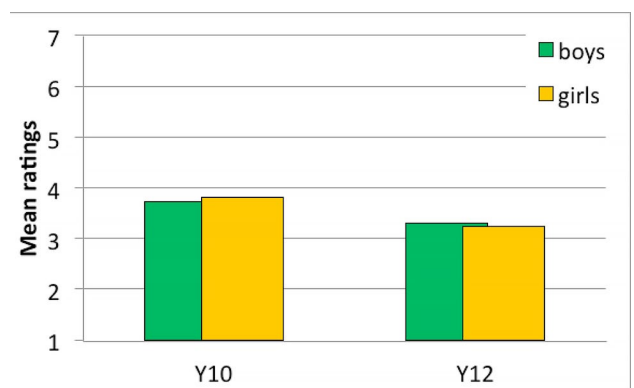


Figure 10 Students' science career plans

## What careers do youth today aim to pursue?

In Year 12, the most popular careers for boys were technology, entrepreneurship and health; for girls they were health, creative arts, teaching and entrepreneurship. Careers more significantly attractive to boys were mathematics, technology, entrepreneurship and trades; careers more attractive to girls were creative arts and teaching. Using a new framework and measure, the Motivations for Career Choice (MCC) scale (Watt & Richardson, 2006), developed with colleague Paul Richardson, grounded in EVT, I measured adolescents' career motivations across a set of 16 factors: ability, intrinsic value, make social contribution, enhance social equity, cognitive challenge, content knowledge match, expert career, autonomy, teamwork, secure progression prospects, family-flexibility, portability, salary, social status, social influences, and easy job.

Most important career motivators for girls and boys were interest, ability and salary; least important were wanting an easy job and social influences. There were no gender differences for motivations related to own abilities, cognitive challenge, prior experiences, salary, status, family-flexibility, autonomy, teamwork, portability, or secure progression prospects. This clearly signals girls do not prefer lower salary or lower status careers. Boys were significantly more motivated than girls by social influences, to pursue an expert career, and for an easy job. Girls were more motivated than boys by their interests, to make a social contribution, and enhance social equity. These differences appear consistent with previous findings that girls and women are more interested in 'social' occupations that allow them to socially contribute and help others.

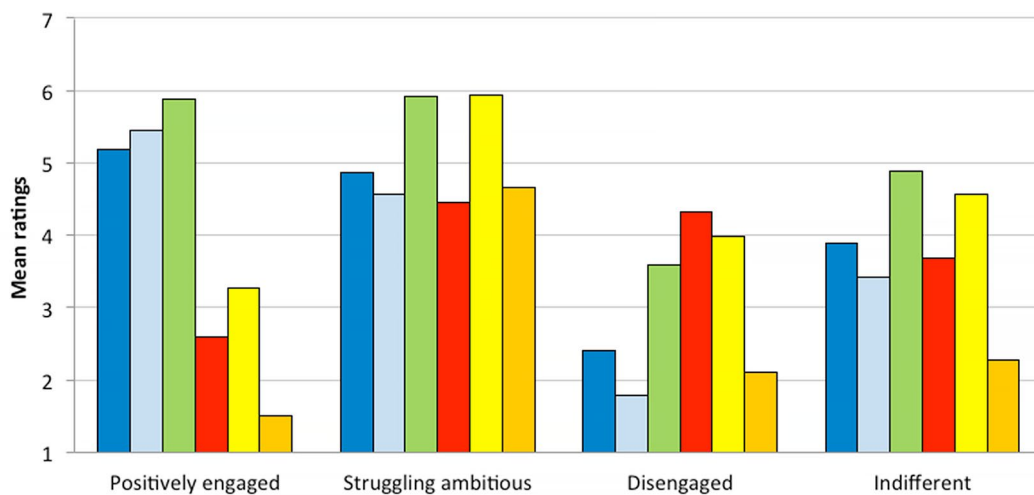


Figure 11 Motivation profile: Maths

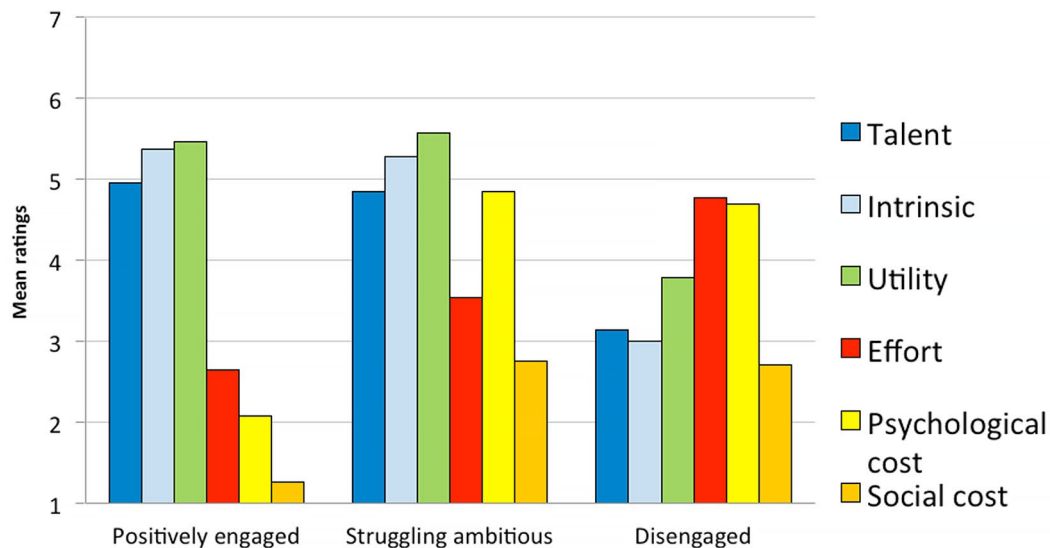


Figure 12 Motivation profile: Science

## Contemporary motivations towards mathematics and science: Including costs

Boys had higher self-concepts in mathematics and science, as well as higher intrinsic and importance values in mathematics. Girls experienced higher psychological cost in both mathematics and science (for example, 'I'm concerned that I won't be able to handle the stress that goes along with studying maths/science'), as well as higher social cost in science (for example, 'I'm concerned that working hard in maths/science classes might mean I lose some of my close friends').

It is probably more important to consider profiles of motivations rather than predictions from individual motivations, because we hold a set of individual attitudes simultaneously when making choices. I have been recently investigating costs, alongside expectancies and values within EVT. I have examined effort cost, psychological cost and social cost, to see whether these factors push people away from STEM, and potential consequences for their own personal wellbeing, such as stress and anxiety and depression.

There were three profiles of students in science. The first cluster was high on positive motivations and low on negative costs. The next was high on both, and the third was low on positive and high on negative. The same three clusters were identified in mathematics, as well as a fourth cluster that was rather undifferentiated. I named them (i) *positively engaged*, (ii) *struggling ambitious*, (iii) *disengaged*, and (iv) – only in mathematics – *indifferent*.

The *positively engaged* and *struggling ambitious* profiles had equally high reported history of results, mathematics/science aspired careers, and aimed marks. The only difference was the high costs perceived by *struggling ambitious*, associated with debilitated psychological wellbeing in terms of depression, anxiety and stress. *Disengaged* had similarly good psychological health to the *positively engaged*. What differentiated them was their low mathematics/science career aspirations, aimed marks and history of results. The low expectancies and values held by the *disengaged* associated with lowered achievement/career-striving, but their perceived low costs bolstered wellbeing. The *indifferent* (mathematics only) had moderately depressed wellbeing, aimed marks and history of results, and rather low mathematics career aspirations. It appears that even moderate perceived costs exert negative effects on achievement striving and psychological health. It is not enough to focus on promoting positive self-concepts and values, we need also to protect against costs.

Including negative cost values alongside typically measured positive expectancies/values enabled identification of students who experience particular combinations of motivations and pressures. Similar profiles for mathematics and science, and coherent

pattern of antecedents and achievement vs. wellbeing outcomes, suggest the types as rather robust, deserving further investigation across contexts and timepoints. Gender differences in mathematics were consistent with entrenched stereotypes – more girls were *disengaged*, and more boys were *struggling ambitious*, consonant with cultural expectations and social pressures. A significant association ( $\chi^2(6) = 44.01, p < .001$ ) indicated a tendency for the same students to be in the same types, thus a possible dispositional base. However, sizeable off-diagonal numbers suggest it is likely we can shift people's motivational profiles, through levers in the curriculum and what happens in the learning environment of classrooms.

## Gender and STEM?

Is it a problem if girls and boys develop different interests and ability beliefs, and choose different pursuits? I believe yes. First, because girls' lower self-concepts (or, boys' inflated self-concepts) translate into patterns of gendered participation that advantage boys' achievement prospects, despite no corresponding achievement differences. Second, ability-related beliefs and values in mathematics affect *non*-mathematical outcomes of societal concern, such as aspired level of education and career prestige. Third, mathematics-related careers associate with career prestige, evidencing mathematics-related career fields as a gateway of concern to researchers interested in social gender equity. Finally, girls do not prefer lower salary or status careers; thus, opting out of advanced mathematics harms their own career goals.

Should equal gender participation be our goal, and for all learning domains? I do not think so. But, when girls' mathematics participation is reduced for negative reasons such as anxiety and lower self-concept, and when those participation choices adversely impact their aspired careers, we need to think carefully about why girls come to hold less positive mathematics motivations than boys. Adolescents often have quite inaccurate ideas of which careers require developed mathematical skills. Therefore, detailed information would be likely to promote girls' interest in mathematics when their preferred careers involve it. If this information could be conveyed by women who are passionate about their work and capable of maintaining a balance between family and work, girls would have positive role models as examples.

Because interests and ability-related beliefs exert important influences on the extent of boys' and girls' later mathematical participation, girls' lower intrinsic value and ability self-perceptions should be of particular concern for future studies and intervention efforts. Eccles and her colleagues have demonstrated that girls are engaged by activities they perceive as socially meaningful, and we have seen that mathematics' importance value impacted



girls' career choices more than boys'. Making explicit connections between mathematics and its social uses and purposes should heighten girls' interest and the importance they attach to it.

### What can educators do?

There is a lot that educators can do. The kinds of learning environments teachers create convey teachers' expectations about what students can achieve and about STEM, which impact students' own self-concepts and values, and consequent career intentions.

A performance structure is one that emphasises competition and results. These teachers will praise high achievement, maybe give awards and prizes, or say who came lowest in the class. Teachers who create a mastery learning environment focus on self-improvement and understanding rather than on how students compare to others. A mastery environment promotes students' self-concepts, STEM values, and related career intentions. Fortunately, mastery climate outweighed performance environments in all eleven cohorts involved in my contemporary study.

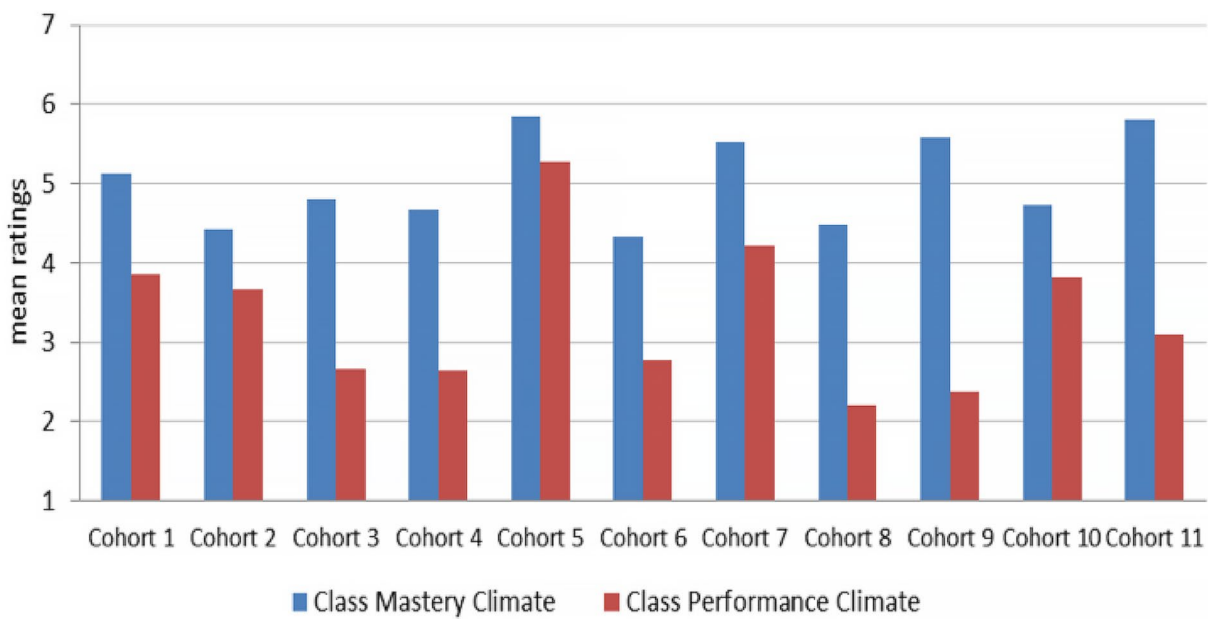


Figure 13 Learning environments for mastery and performance: Maths

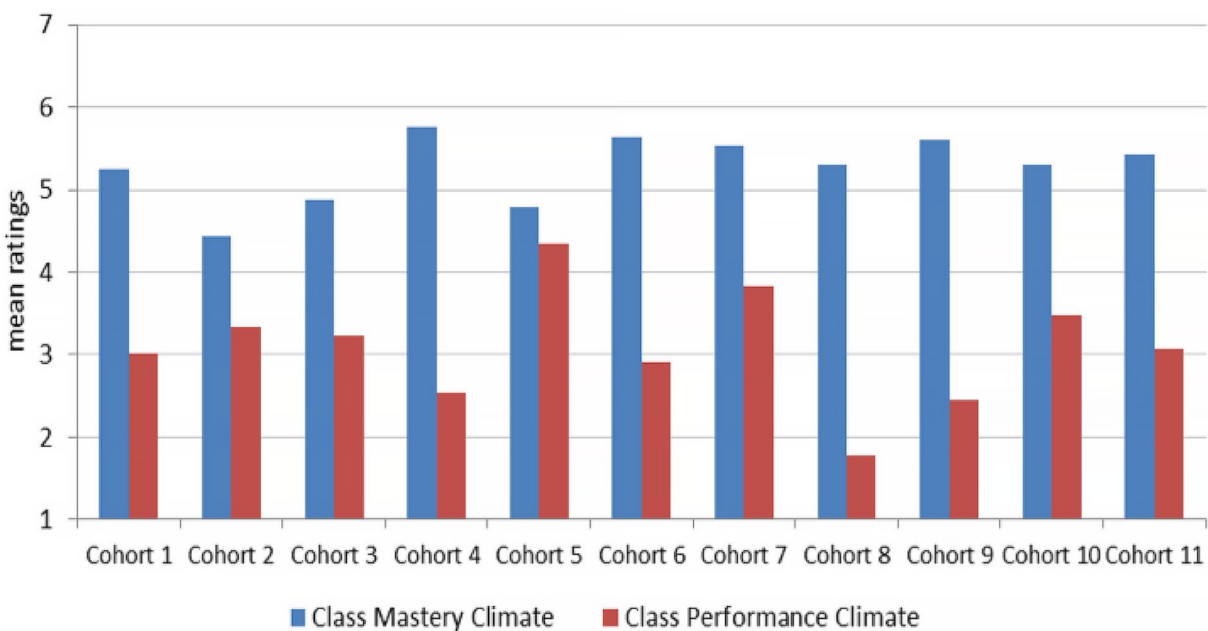


Figure 14 Learning environments for mastery and performance: Science

## Summary and outlook

- The STEM shortage is especially in advanced mathematics and physical sciences, and more pronounced in contemporary data.
- Students, especially girls, are opting out of advanced mathematics and sciences when they perceive a real choice to do so.
- Expectancies and values impact STEM studies and career aspirations.
- Importance value matters, especially for girls; we need to be making explicit connections between the social uses and purposes of science and mathematics for a range of careers.
- Self-concepts and values decline throughout secondary schooling, with a robust gender gap; girls perceive lower talents than their achievements warrant.
- Costs impact wellbeing, even for students with high expectancies, values, achievements and aspirations.
- Aspirations modestly predict actual STEM-related careers; we need more long-term longitudinal studies, and to contrast more different settings as 'natural experiments', particularly where there is high participation in STEM and where girls and women participate to a similar degree to men, to be able to learn from those settings.

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## Acknowledgement

The STEPS Study was supported by Australian Research Council DP110100472 and ARF to Watt, 2011–2015. None of these works would be possible without the many participating schools and students, for whose participation I am most grateful.