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educational and occupational pathways and participation

Keynote Summary:

STEM Participation, Achievement and Beliefs

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ABSTRACT
Sue Thomson was featured as a keynote speaker for the 2021 Network Gender & STEM Conference. She provided a knowledgeable and research-informed presentation on STEM participation, achievement, and beliefs. Given gender differences continue to exist in some areas, she highlighted how females do not enrol in higher mathematics, science or ICT, or move into STEM-based careers to the same extent as males. For example, while the number of people employed as ICT specialists in the EU grew by 36% during the period from 2007 to 2017 (more than 10 times higher than the corresponding increase of 3.2% for total employment), the proportion of women employed in these fields has stagnated. This keynote summary addresses three broad areas that may hold females back from participation in these subjects in school and in entering STEM careers: 1) whether men are better at maths, science, ICT than women, 2) perceived ability – self-confidence and self-efficacy, and 3) cultural beliefs.

KEYWORDS
Gender & STEM; academic achievement; self-beliefs

STEM PARTICIPATION, ACHIEVEMENT AND BELIEFS: THOMSON KEYNOTE SUMMARY

Despite predictions that the demand for STEM professionals across the world will grow at twice the rate of other sectors, and that graduates in STEM disciplines can expect to earn a higher salary than those with degrees in other subjects, men still dominate the field. While women make up around half the whole workforce in both the United States and Europe, participation in the STEM workforce lags far behind. In the United States around one-quarter of STEM workers are women (Martinez & Christnact, 2021), while in the European Union around two in five scientists and engineers but fewer than one in five IT specialists are women (Eurostat, 2021). In Australia around 14 per cent of those in STEM-qualified occupations are women, and this proportion has not changed over the past few years (Department of Industry, 2021). Data from Australia from the Longitudinal Surveys of Australian Youth (LSAY) has shown that among the members of the 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 the study (McMillan et al., 2021). The same report found that while the completion rates for these women are high in comparison to other equity groups studied, there was a substantial 'leakage point' at the transition from study to work, resulting in less than one-quarter of women who had commenced a STEM course being employed in a STEM career by age 25. The 'pipeline leakage' for women is particularly prominent in the areas of mathematics, engineering and physical sciences. There are many reasons proffered for lower participation by women in STEM. Within this summary, three broad areas are discussed: 1) whether men are better at maths, science, ICT than women, 2) perceived ability – self-confidence and self-efficacy, and 3) cultural beliefs.

Genetic differences

STEM jobs are the jobs of the future so we need women to have the same opportunities as men to be employed in worthwhile, well-paid occupations. It matters because we need diversity to solve the world problems that people in STEM will need to address in the future – climate change, limited resources, water shortage, for example. It matters because despite making up half the world's population, women's needs are rarely taken into account – the world has been primarily designed by men, for men, using the "average male" to represent men and women alike (Criado Perez, 2019). There is the argument that lower participation rates in STEM subjects at school by girls reflect genetic differences – boys are just better at maths and science. However, data from Australia's National Assessment Program-Literacy and Numeracy (NAPLAN, Figure 1), the internationally managed Trends in International Mathematics and Science Study (TIMSS, Figure 2), and the Programme for International Student Assessment (PISA, Figures 4 and 5) all show that there are no significant differences in achievement in science at any age level, but some small differences in favour of males at Year 4 and amongst 15-year-old students. These differences are certainly something that we need to pay attention to. However, data from the International Computer and Information Literacy Study (ICILS) and the National Assessment Program ICTL (Figure 6) show that Australian females significantly outperformed Australian males in this area, on average.

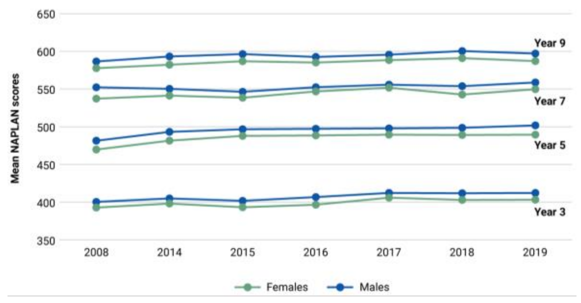

Figure 1. NAPLAN numeracy scores

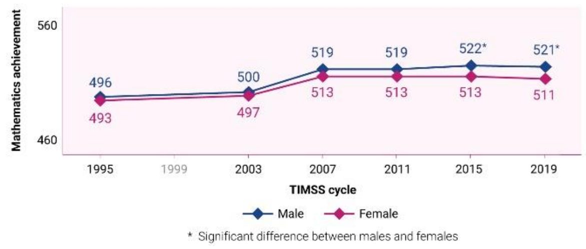

Figure 2. TIMSS Year 4 mathematics

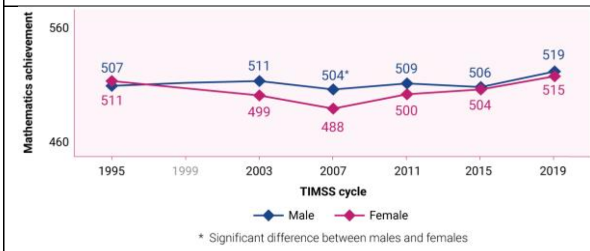

Figure 3. TIMSS Year 8 mathematics

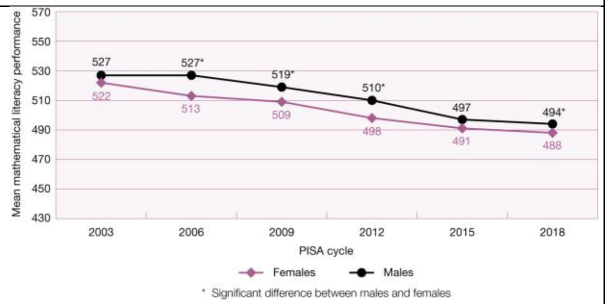

Figure 4. PISA mathematical literacy

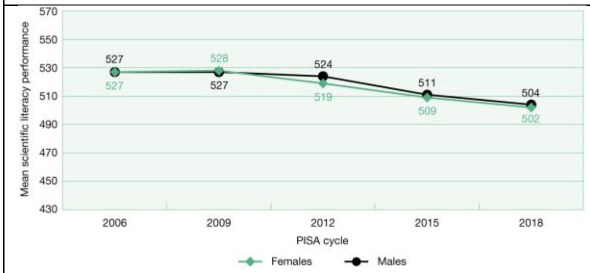

Figure 5. PISA Scientific literacy

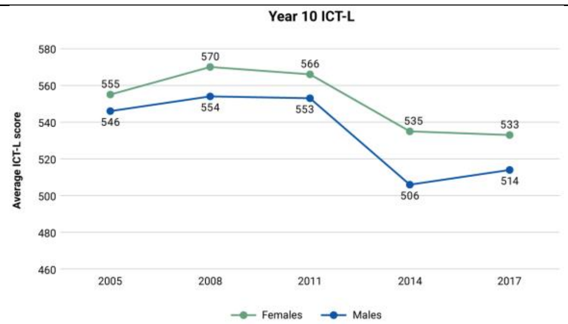

Figure 6. NAP ICTL Year 10

If mathematical, scientific, or computer ability were biologically determined, gender differences would be consistent across countries. This is not the case. There are some differences in favour of males at Year 4 level, but at Year 8 level, however, there are not so many differences, and no large differences in favour of boys. In ICT there are no differences in favour of boys, but plenty in favour of girls (Figure 7). So, are there other reasons that girls aren't continuing in subjects in which they are at least as good as their male counterparts?

	TIMSS								PISA				ICILS	
	Maths (Year 4)		Maths (Year 8)		Science (Year 4)		Science (Year 8)		Maths		Science		ICT	
	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)	No. Countries	Av. Diff (points)
F>M	4	24	7	19	18	19	15	28	10	8	21	12	12	20
M>F	27	10	6	10	7	7	18	11	25	9	2	11	0	
F=M	27		26		33		6				30		2	

Figure 7. International gender differences in TIMSS, PISA and ICILS

Self-beliefs
The influences of family, school, peers, mass media, and the immediate social environment shape the expectations that girls and boys have of success (and their self-concept of their own abilities) together with the value they attach to various subjects and academic domains (Eccles, 1994). These include girls' expectations about success, enjoyment, and perceptions of value of maths. When expectations of success and the value of STEM disciplines are high, girls are much more likely to choose, persist in, and graduate from STEM fields (Eccles & Wigfield, 1995).

A body of empirical research has shown that the relationship between specific domains of self-concept and achievement is dynamic and reciprocal (Marsh & Craven, 2005). Understanding the nature of these relationships is important in informing teaching practice because self-concept is not just an outcome of achievement but also a driver of achievement (Marsh & Craven, 2006). Self-efficacy has been found to be a strong predictor of tertiary entry, and self-concept a strong predictor of STEM course selection (Parker et al., 2014; Watt et al., 2017). Expectancy-Value theory (Eccles et al., 1983) posits that people choose to take on a task, such as studying maths, if they value the task and expect that they can succeed at it.

TIMSS and PISA show strong positive relationships between liking, confidence and valuing mathematics and science and achievement at all year levels, for both males and females. Unfortunately, fewer than half of the Year 4 students surveyed in TIMSS 2019 said that they "very much like learning mathematics" (40% of females and 45% of males), while at Year 8, just 13% of females and 20% of males expressed such a liking. Similar patterns were seen for liking science (50% of females and 52% of males at Year 4, 27% of females and 35% of males at Year 8). Confidence amongst females and males declined substantially between Year 4 and Year 8, with 44% of both females and males saying that they were "not confident" in mathematics. Moreover, 45% of females and 38% of males saying that they were "not confident" in science at Year 8. Only Year 8 students were asked the extent to which they valued mathematics and science. Fewer than half the students surveyed said that they "strongly valued maths", and this was far more evident among females (34% of females and 42% of males), but worryingly, when so much of the work of the future is based on science, just 26% of females and 31% of males said that they "strongly value science" (Thomson et al., 2021).

PISA also asks questions to assess students' self-efficacy, in each cycle specific to the main assessment focus of the cycle. In PISA 2012, the last cycle in which the focus was on mathematical literacy, male students reported significantly higher levels of self-efficacy than females in all countries (OECD, 2013). In Australia, male students' average index score was significantly and substantially higher than the OECD average of zero (0.27), while female students' average index score was significantly and substantially lower than the OECD average (-0.17). The gender difference in Australia was one of the largest internationally. When the PISA mathematics scores of male and female students who were in the top quarter of the self-efficacy index were compared, there was found to be no difference, however, only 20% of females were in the top quarter of this index, compared to 36% of males.

In science (PISA 2015), the findings were less definitive; however, in 41 of the 70 participating countries and economies, males had significantly higher levels of science self-efficacy than females. In just 8 countries, females had significantly higher levels of science self-efficacy than males. In Australia, the average index score for males was again significantly and substantially higher than the OECD average, while the score for females significantly lower than the OECD average. While countries such as Denmark and Germany had the largest gender differences at around 0.3 of a standard deviation, those in Australia were also substantial with about 0.25 of a standard deviation (OECD, 2016). In science, as has often seen to be the case, the gender gap depends on the type of problem or situation that students encounter.

So, on average, male students show substantially higher levels of liking, self-confidence, self-efficacy, and self-concept in both maths and science, and value maths and science more than female students. When females have the same level of self-efficacy as males, their achievement levels are virtually identical. These negative beliefs form substantial barriers to many females engaging in STEM subjects at school and following through into STEM careers. On top of these self-beliefs are a set of cultural beliefs and expectations, and a lack of role models.

Cultural beliefs

A recent Swiss study (Makarova et al., 2019) confirms that gender stereotypes still abound - maths has the strongest masculinity attribution, physics is also strong, while chemistry has the lowest masculinity attribution. The Youth in STEM Survey (National Academy of Engineering, 2008) reported that parents believed that

- Computing or information technology jobs were better suited to men, and were the jobs where STEM skills were the most essential.
- Pharmacy and teaching were the only jobs with essential STEM skills that parents thought were better suited to women.
- Nursing was markedly associated with women, with STEM skills moderately essential.

Clearly there are very strong gender associations with occupations. This inherent bias about how occupations are perceived and positioned is likely to inform students' perceptions of these careers, the opportunities that are available to them and which careers are most suitable to their skillset. A study from the National Academy of Engineering in the United States (YouthInsight, 2021) asked students if they wanted to be engineers: girls were twice as likely as boys to say no. But when asked if they would like to design a safe water system, save the rainforest, or use DNA to solve crimes, the girls answered yes. When students were asked in PISA 2018 about their career expectations at 30 years of age, 41% of females and 34% of males responded with various science-related careers. However, the vast majority of these careers for females was in the area of health professionals (30%), while for males 18% saw themselves in a science or engineering profession and just 11% as health professionals.

CONCLUSION

These gender associations are compounded by what students see in their day to day lives, where they are more likely to see men in STEM teaching roles during their secondary school years (YouthInsight, 2021). If they consider pursuing a STEM course through tertiary education, there are added barriers. Not only are fewer female than male STEM teachers enrolled at tertiary level, but also few of their classmates will be female. A report from Microsoft (2017), among others in the area, stress that both peer group approval and having visible role models for girls have strong impacts on their interest in STEM.

STEM workers play an important role in the world's innovative capacity. They are our engineers, medical scientists, sociologists and informational security analysts. We need diversity in these roles – we need women in these roles.

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Author Note

This Keynote address was presented at the Network Gender & STEM biennial conference, 29-30 July 2021, The University of Sydney, Australia [online]. Both the recorded Keynote and live discussion are accessible here, with permission:
https://youtu.be/ck9hzJavxgE