STEM GENDER GAP

IN SINGAPORE

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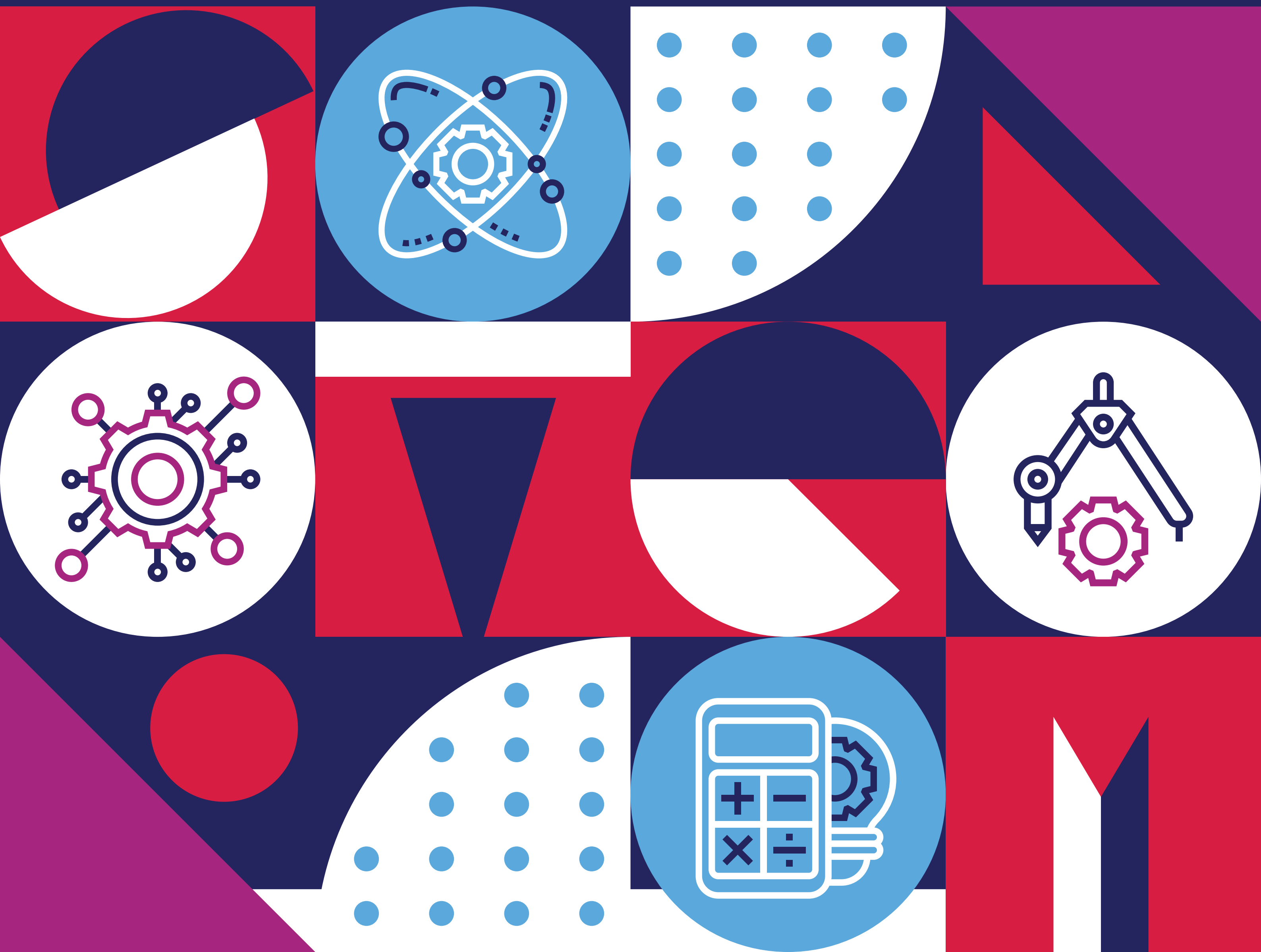

The gender gap in STEM in Singapore

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Abstract

Women are underrepresented in science, technology, engineering and mathematics (STEM) education and careers in Singapore. The lack of gender equity is most apparent in engineering and information technology education, where only 21% and 29% of tertiary graduates are women. This gender imbalance is amplified in STEM related research and development, where women make up only 20% of the workforce. This paper reviews the implications of the gender gap in STEM, particularly as it relates to education and research in Singapore, and discusses possible interventions that could encourage young Singaporean women to pursue careers in STEM fields.

Keywords: Gender, STEM, education, career, interventions

The gender gap in STEM in Singapore

Men have traditionally been viewed as more rational and intellectual than women, whereas women have been seen as inherently less capable of processing the complexities of STEM subjects. Even in recent times, high-profile scientists such as the renowned physicist Alessandro Stumia at Pisa University argued that "physics was invented and built by men" and that the gender gap is due to biological differences rather than sociological factors (British Broadcasting Corporation, 2018). Former Harvard President Lawrence Summers endorsed similar views, stating that the gender gap in STEM is due to men's innate aptitude for science rather than socialization or discrimination (Inside Higher Ed, 2005).

However, there are strong data that refutes these views. For example, various measures and studies indicate that women are quite capable of excelling in a crucial STEM field, information and communication technologies (ICT). Creative output—which measures ICT creations, online creativity, and mobile app creation—is highly correlated with the percentage of female representation in the knowledge workforce ($r > .70$) (Dutta et al., 2018). Some researchers have even found that all-female task groups were more cooperative (Lu et al., 2020) and generated more innovative ideas for information systems than all-male groups (Klein & Dologite, 2000).

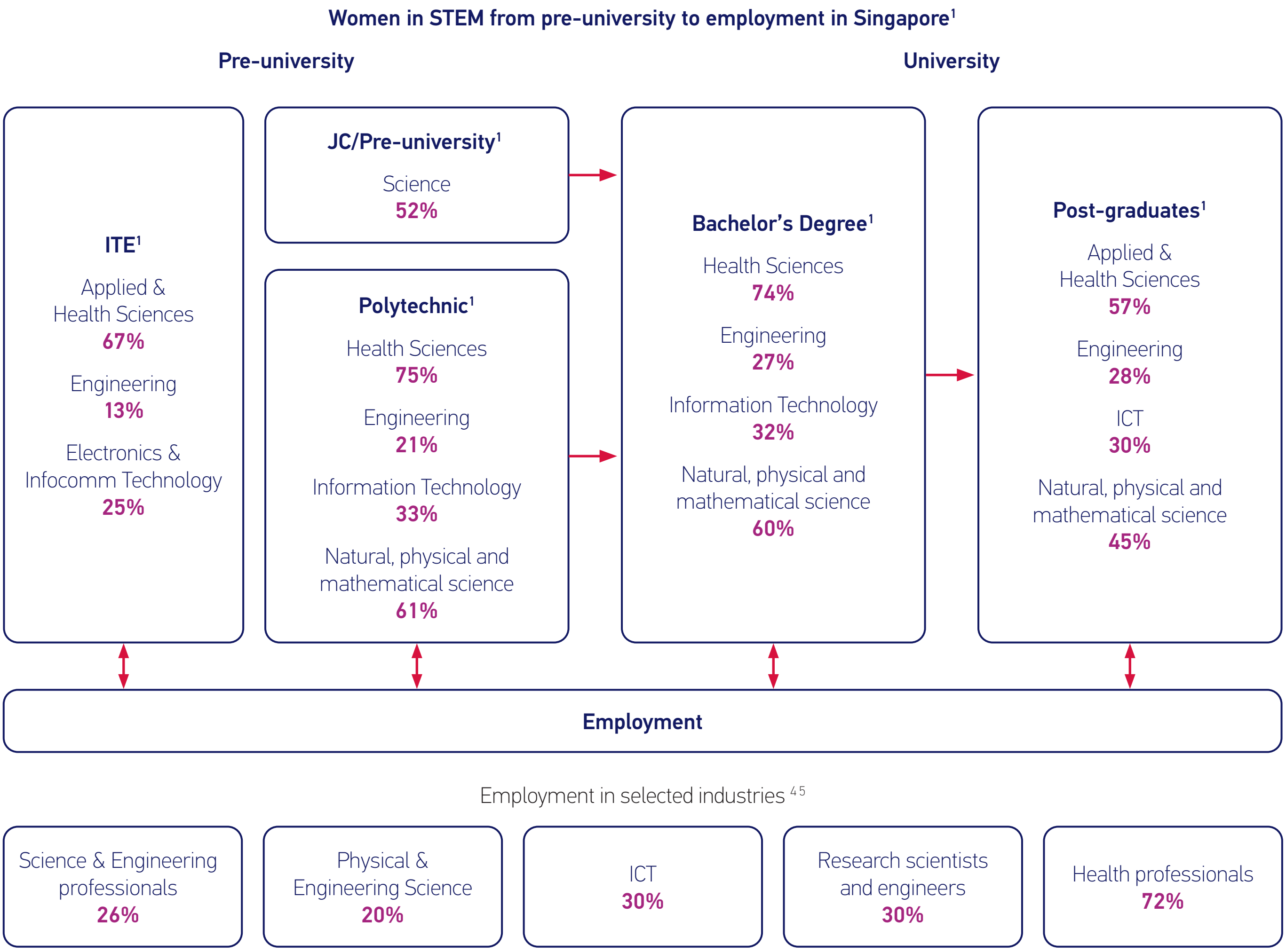
These findings, along with others, also point to a strong reason for bringing more women into STEM: gender equity could lead to more effective solutions, greater innovation, and stronger economies (Lee & Pollitzer, 2016). The European Institute for Gender Equality (EIGE) estimated that closing the STEM gender gap across the E.U. would increase GDP per capita by 2.2-3.0% through increased employment of women in key economic sectors such as finance and information and communication services (The European Union, n.d.).

Yet despite global efforts to narrow the gap, women still account for only 28% of STEM-related researchers worldwide (United Nations Educational Scientific and Cultural Organization (UNESCO), 2015). One obstacle is that biased attitudes favouring men in STEM are endorsed widely by individuals across cultures and age groups (Charlesworth & Banaji, 2019). More broadly, it seems people are motivated to defend their existing social, political, and economic systems (e.g., through stereotyping and ideology) even when it is disadvantageous to them (Kray et al., 2017).

Addressing the STEM gender gap is crucial to Singapore in its transformation to a digital society. Not only does this gender gap mean a loss of human capital in the knowledge workforce, but there are significant consequences for the nation's creative output. Even though Singapore was ranked 8^{th} in the 2019 Global Innovation Index (Cornell et al., 2020), it only ranked 34^{th} in creative output and 36^{th} in the percentage of females employed in knowledge-intensive services.

Unfortunately, the underrepresentation of women in STEM has received considerably less attention in Singapore than in other developed nations. While overall tertiary enrolment may reflect gender parity, statistics from the Ministry of Education (MOE) on enrolment by program in 2020 show otherwise (Figure 1). The average percentage of women in STEM degree programs is 48.25% (74% in health sciences; 27% in engineering; 32% in information technology; 60% in natural, physical and mathematical sciences). National University of Singapore reported that the gender gap is evident at the researcher level with more males being awarded research fellowships and research grants (Ramachandran, 2017). Moreover, 85% of the University's research staff and faculty were aware of the gender gap but only 55% were interested in participating in a program to close it.

Figure 1: The STEM pre-university to career pathway among women in Singapore.



*Data is taken from 2019 or the closest year.

1. Ministry of Education. Education Digest 2020.
2. Statistics Singapore Newsletter March 2016.
3. A-star. National survey of research and development in Singapore.
4. Annual survey on infocomm media manpower 2019.
5. Labour market report release 2020.

Analysis of the gender gap: Possible contributing factors

Research suggests that the shortage of women in STEM is a product of several related but distinct forces. Here is a brief review of some key factors which have been identified.

Self-Perceptions

Research suggests that the shortage of women in STEM is a product of several related but distinct forces. Here is a brief review of some key factors which have been identified.

Motivation

In general, intrinsic and instrumental motivation are linked to higher performance in math and science (OECD, 2013; Pitsia et al., 2017). Intrinsic motivation is the drive to achieve an outcome out of interest or enjoyment; instrumental motivation is the drive to achieve something for external reasons, such as future career opportunities that may lead to higher pay and status (Eccles & Wigfield, 2002). Whereas intrinsic motivation is completely internalized, instrumental motivation is only somewhat internalized into one's self (Burton et al., 2006; Deci & Ryan, 2008).

Instrumental motivation is viewed as an important and acceptable motivator to shape individuals into becoming useful members of Asian societies (Li, 2012). It helps to promote persistence in learning when students are not intrinsically interested in the subject matter (OECD, 2003). However, instrumental motivation can undermine intrinsic interest in learning, with the result that external regulators are experienced as controlling, rather than as facilitators of achievement. Therefore, instrumental motivation is associated with inner pressure and tension (Lens et al., 2012; Liu et al., 2020). A number of studies have found instrumental motivation to be detrimental for students in Asian high-stakes-testing cultures like those of Japan and Singapore, where they are under high personal and parental pressure to succeed (Ho, 2009; Leung et al., 2011; Marginson, 2011; Shen et al., 2014). When instrumentally motivated students are pressed in these ways, they become more easily distracted, less effective with time management, and less positive about learning.

There is some evidence that motivation mediates the relationship between gender and STEM career attainment (Wang et al., 2015). In general, Singaporean boys are more intrinsically and instrumentally motivated to study math and science than Singaporean girls, and view these subjects as more important to their lives (O'Connor-Petruso & Miranda, 2004; OECD, 2013, 2016). Even among high-ability students, boys showed a greater intrinsic motivation in learning science than girls (Caleon & Subramaniam, 2008; Peer & Fraser, 2015). Future research is needed to understand if gender affects the impact of instrumental motivation on interest and performance in STEM subjects.

Gender Stereotypes

Across cultures, people associate math and science with males and arts with females, and the stronger the gender stereotype, the wider the gender gap in math and science achievement (Nosek et al., 2009). Unfortunately, there is a shortage of research on gender stereotypes in STEM in Singapore. Existing studies show that consistent with research from other cultures, primary school boys and girls tend to associate "math" with "boys" (Cvencek et al., 2014). In addition, stronger math-gender stereotyping was associated with higher math self-concept for boys but lower math self-concept for girls, which in turn predicted math achievement (Cvencek et al., 2015). The studies also found that older children are more likely than younger ones to endorse math-gender stereotypes.

School-Age Testing in Math and Science: How Singapore's Girls Compare

Do women have the potential to succeed and excel in STEM fields? One way to address the question is by looking at standardized tests of primary- and secondary-school students.

Singapore participates in two global math and science assessments: OECD's Programme for International Student Assessment (PISA), and the International Association for the Evaluation of Educational Achievement (IEA)'s Trends in International Mathematics and Science Study (TIMSS). PISA measures how well 15-year-old students apply knowledge to real-world situations. TIMMS, sampling students by grade level rather than age, measures how well Primary 4 and Secondary 2 students have learned items from the math and science curriculum (National Center for Educational Statistics (NCES), n.d.). Although Singapore students, as a whole, consistently show excellent scores in both assessments, results by gender differ considerably between PISA and TIMMS (Wu, 2010) (Table 1). Girls generally perform well on these tests, although the results do show some differences by gender.

In PISA, the gender gap appears to be small with a slight male advantage in math and science. However, a closer look at the top end of the performance distribution reveals more boys than girls scoring at Level 6 in both math and science (see Table 2 for percentage of boys vs. girls in each PISA achievement level; OECD, 2019). Although sizable percentages of girls score high, the results are consistent with past research across countries, which likewise shows boys outnumbering girls at the most advanced levels in science and math (Aguinis et al., 2018; Friedman, 1989; Stoet & Geary, 2013).

In TIMMS, girls consistently outperform boys in math, especially at the secondary 2 level (NCES, n.d.). There is a smaller gender gap in science, such as boys and girls perform on par most of the time at both the primary 4 and secondary 2 level. Unfortunately, the breakdown by achievement levels is not reported separately for boys and girls, but there is some evidence that the high-end performance distributions in TIMMS are comparable to PISA (Wu, 2010).

The TIMMS and PISA achievement patterns indicate that gender differences are not equal across domains. In math, girls are better at curriculum-based assessments and boys are better at applying knowledge to solve real-world problems. In science, boys are slightly better than girls in both curriculum-based and real-life application assessments. In addition, the gender gap is greater among high performers, with more boys showing advanced math and science proficiency than girls.

Table 1a. TIMMS assessment scores for Singaporean Primary 4 students by gender (NCES, n.d.).

Year	Maths		Science	
	Boys	Girls	Male	Female
1995	586	595	526	521
2003	**590**	**599***	565	565
2007	**596**	**603***	587	587
2011	604	608	585	581
2015	616	620	590	591

Table 1b. TIMMS assessment scores for Singaporean Secondary 2 students by gender (NCES, n.d.).

Year	Maths		Science	
	Boys	Girls	Male	Female
1995	608	610	587	574
1999	606	603	**578***	**557**
2003	**601**	**611***	579	576
2007	**586**	**600***	563	571
2011	**607**	**615***	591	589
2015	**616**	**626***	597	596

Table 1c. PISA math and science achievement for Singaporean 15-year-old students by gender (OECD, 2019).

Year	Maths		Science	
	Boys	Girls	Male	Female
2009	**565***	**559**	541	542
2012	572	575	551	552
2015	564	564	**559***	**552**
2018	571	567	553	549

Note. Scores that differ significantly are in bold with the asterisk indicating the higher score.

Table 2a. Percentage of students in math proficiency levels in PISA scores, by gender (reported by OECD).

Year	Gender	Below Level 1	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
2009	Boys	3.41	6.77	12.34	17.98	22.56	19.99	**16.95**
	Girls	2.60	6.84	13.94	19.37	23.00	19.98	**14.26**
2012	Boys	**2.93**	**6.82**	12.37	16.59	21.01	20.42	19.88
	Girls	**1.43**	**5.26**	12.04	18.57	22.93	21.63	18.13
2015	Boys	**2.56**	6.08	12.67	19.30	23.75	21.09	**14.56**
	Girls	**1.51**	4.90	12.20	20.81	26.61	22.45	**11.52**
2018	Boys	2.02	5.76	11.02	18.01	24.41	23.46	**15.32**
	Girls	1.61	4.85	11.20	20.13	27.17	22.86	**12.18**

Table 2b. Percentage of students in science proficiency levels in PISA scores, by gender (OECD, 2019).

Year	Gender	Below Level 1b	Level 1b	Level 1a	Level 2	Level 3	Level 4	Level 5	Level 6
2009	Boys	0.36	**3.24**	8.88	16.87	25.21	24.73	15.46	5.26
	Girls	0.20	**1.74**	8.54	18.16	25.57	26.73	15.17	3.90
2012	Boys	0.53	2.32	8.13	16.28	22.63	26.33	16.99	**6.79**
	Girls	0.16	1.34	6.65	17.23	25.34	27.68	16.85	**4.76**
2015	Boys	0.21	2.30	7.71	14.39	22.33	26.59	19.36	**7.11**
	Girls	0.09	1.58	7.26	15.84	24.56	28.93	17.71	**4.03**
2018	Boys	0.22	2.08	7.58	14.64	**23.54**	29.35	**18.17**	4.40
	Girls	0.10	1.44	6.60	15.67	**27.34**	30.00	**15.72**	3.12

Note. Significant differences between percentages of boys and girls in respective levels are indicated in bold.

Women in STEM Tertiary Education and Research

Finally, we look at data on women's progress through higher education into careers in scientific and technical research. The numbers indicate a gradual sorting along gender lines as young people move up the ladder. UNESCO's Institute of Statistics show that females (37.15%) are less likely than males (56.25%) to enroll in a tertiary level STEM program, and that females make up only 20% of the R&D personnel in Singapore (UNESCO, n.d.). UNESCO reported that even though 53% of those who complete undergraduate degrees in STEM are women, the figure drops to 43% at the PhD level and again to 28% at the researcher level (United Nations Educational Scientific and Cultural Organization, 2015). The attrition of women through education levels is commonly termed the "leaky pipeline". Enrolment data from the Nanyang Technological University School of Science (math, physics, biology, chemistry) reflect this trend (Lim, 2019). Women make up 56% of the student population but this drops to 34% at the doctorate level and 26% at the postdoctoral level. In contrast, men increase from 44% at the undergraduate level to 74% at the postdoctoral level.

However, the leaky pipeline metaphor does not explain the entire situation. Women are underrepresented in the College of Engineering at all levels, with relatively few entering the pipeline from the get-go, and the same holds true in Information Technology (Figure 1). This is more consistent with recent analyses of gender differences in the bachelor-to-research career path in STEM in the U.S (Ceci et al., 2014; Miller & Wai, 2015). Women and men there are now equally likely to advance to a PhD degree across all STEM fields, but women remain significantly underrepresented in engineering and computing-related fields.

In short, data tell us that the gender gap is not consistent across STEM disciplines. Women generally prefer STEM studies and careers which are people-oriented (e.g., medical science) over careers which are things-oriented (e.g., many branches of engineering) (Su & Rounds, 2015). STEM fields with large gender gaps in representation such as engineering, computer science and physics also have a strong masculine culture, which is characterized by stereotypes about the field (e.g., that these are not people-oriented fields), negative gender stereotypes (e.g., women are less capable than men in math), and few female role models (Cheryan et al., 2017). These factors have been shown to contribute to women feeling a lower sense of belonging and belief they can succeed in these fields. Accordingly, women show less interest in entering and pursuing a career in "masculine" STEM fields.

However, studies have shown that when women saw STEM careers as providing opportunities to achieve communal goals, they had more positive attitudes towards STEM and were more interested in pursuing a STEM career (Steinberg & Diekman, 2017). Some researchers have also suggested that the underrepresentation of females at the highest levels of math and science reasoning performance is due to the male advantage in spatial ability (Halpern et al., 2007; Wai et al., 2009, 2010). It seems unlikely that this in itself accounts for the gender gap, given that cognitive abilities are affected by a complex interaction between socialization experiences and social and psychological factors, rather than being innate (Ellis et al., 2016; Hyde & Mertz, 2009; Reilly et al., 2017; Van Veelen et al., 2019). Moreover, the gender gap from bachelor's to Ph.D. in all STEM fields has diminished significantly in the U.S., suggesting that females are able to keep up with their male counterparts even at the highest level of academia.

Discussion

This brief review shows that gender differences in STEM-related attitudes and beliefs appear at a young age. Even though girls do better than boys or are on par with them in various national assessment measures, they report lower self-efficacy, self-concept, and motivation. In addition, both boys and girls endorse an implicit bias against women in math and science. These factors contribute to the gender gap in achievement among high performers. The gender gap is apparent at the tertiary and research levels, where women are most underrepresented in STEM fields characterized by a masculine culture.

This review also points to the urgent need for more research on the culture-specific and universal factors contributing to the gender gap in STEM in Singapore, as well as the need for effective population-wide interventions. To our knowledge, MOE does not have specific interventions to encourage girls to develop an interest in STEM subjects and to pursue STEM careers (The Straits Times, 2017). Closing the gender gap can increase employment and productivity of women, increase innovation and research output, and ultimately foster economic growth and societal cohesion institute (EIGE, n.d.; UNESCO, 2015).

Two possible modes of intervention

One possible intervention to close the gender gap is based on the stereotype inoculation model (Shin et al., 2016; Stout et al., 2011). In general, women are more likely than men to define themselves in terms of their close relationships and thus benefit from same-sex role models (Cross & Vick, 2001). In addition, there are gender differences in the sources of self-efficacy. Men tend to build a sense of self-efficacy when they have success experiences, whereas women tend to build it through positive relational experiences (Lee & Kung, 2018; Zeldin et al., 2008). For example, female students who had regular contact with female STEM experts displayed lower implicit gender bias, increased self-efficacy, and a greater sense of belongingness to STEM, compared to female students who met male STEM experts (Blake-Beard et al., 2011). However, mere exposure to same-sex role models may be insufficient to change stereotypes and attitudes. The intervention is most effective when the role model is non-stereotypic and does not conform to negative stereotypes of women in STEM (Cheryan et al., 2011). In addition, female role models are most impactful in recruitment of females to the STEM pipeline (Drury et al., 2011). For those who are already in STEM fields, retention is facilitated by mentorship regardless of the gender of the mentor.

The College Transition Collaborative has also shown that increased feelings of social belonging can lead to improved social integration and higher grades in college (Walton & Wilson, 2018). A social-belonging intervention helps students understand their negative experiences in psychologically adaptive ways. It normalizes feelings of rejection and encourages students to develop a non-depressogenic cognitive style when faced with adversity. Students can then view difficult experiences as due to temporary, specific external causes. First-year female engineering students who received the intervention at the start of the academic year were more socially integrated with their classmates and had better grades at the end of the academic year (Walton et al., 2015). There is evidence that this intervention helps even young children develop higher self-efficacy and greater interest in STEM (Master et al., 2017).

The broader goals

The goal of closing the STEM gender gap fits with Singapore's broader goal of creating a more equitable and meritocratic society, where people are given equal opportunities to pursue their interests, regardless of their demographic status. The former Education Minister Ong Ye Kung emphasized that "the impetus is on us—not just the Government, but all of us— to overcome the limitations of meritocracy and consciously fight against the ossification of social class" (The Straits Times, 2019). This presents a challenge to all members of society to be conscious of and to overcome the sociocultural barriers that prevent women from joining STEM. This spirit of meritocracy and equity also means moving on from the "leaky pipeline" metaphor, as this metaphor assumes that 1) all women who leave academic science "leak out", rather than leave volitionally to pursue other meaningful goals, and 2) there is a linear pathway into STEM, rather than recognizing the increased blending of STEM and non-STEM disciplines (Miller & Wai, 2015). The promotion of women in STEM is thus not simply another checkbox to tick off. It is an endeavor to provide an environment where women have the opportunities to realize their potential, work productively and fruitfully and make a significant contribution to their community.

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