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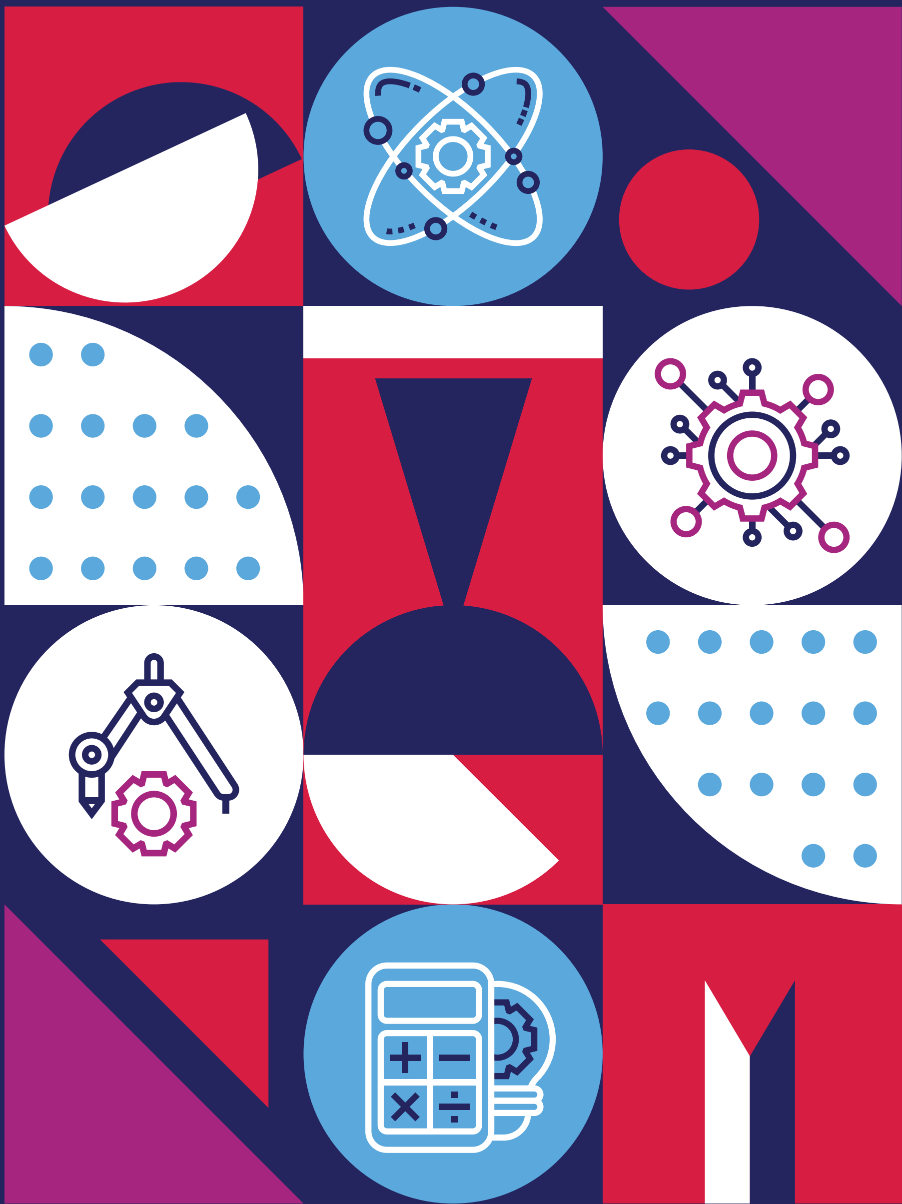
POWERS



# CLOSING THE STEM GENDER GAP IN SINGAPORE

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### Acknowledgement

The work was funded by Ministry of Education through the STEM and Innovation & Enterprise Promotion Programme Grants (#POWERS: the Promotion of Women in Engineering, Research, and Science).

# Executive Summary

As the Singapore government implements policies to economic recovery from the pandemic, it is timely to examine how to close the Science, Technology, Engineering and Mathematics (STEM) gender gap in Singapore as increasing the representation of women in STEM fields is forecasted to boost the business-as-usual annual GDP by 1.9%. In this study, we surveyed a nationally representative sample of Singaporeans to understand the gender gap in STEM careers in Singapore. We found that women who graduated with a STEM diploma or degree (58%) are less likely to work in a STEM field compared to men who graduated with a STEM diploma or degree (70%), despite the majority of women expressing career interests consistent with STEM jobs. Women also acknowledged that there were barriers of inclusion and career advancement for women in STEM. Research has shown that women are more interested in STEM when they believe they belong in and can succeed in STEM. Breaching the gender gap in STEM requires stakeholders to improve belongingness of women in STEM, change gender-based stereotypes and dismantle barriers of participation in the STEM workforce.

## Introduction

For the first time since 2001, Singapore's economy contracted 5.8% in 2020. Singapore's record of strong economic growth has been hit hard by the COVID-19 health pandemic. This is the worst recession since the country's independence in 1965.[1] As the country works toward economic recovery, now more than ever, we need to harness the talents of the entirety of Singapore's potential and tackle the gender inequality in the STEM workforce in Singapore.

In their seminal report on gender inequality in Asia Pacific, McKinsey & Company estimated that improving gender inequality in the workforce can add 5% over business-as-usual GDP or $20 billion to the annual GDP by 2025.[2] They reported that women in Singapore tend to work in lower-growth sectors and in lower paying roles, as compared to men. Notably, one of the key areas of improvement was to increase women's participation in Science, Technology, Engineering and Mathematics (STEM) fields. Increasing representation in high-paying jobs and high growth sectors is estimated to account for 38% to the potential GDP gain (SGD $7.6 billion). The high socio-economic cost of gender inequality in science has led the United Nations Educational, Scientific and Cultural Organization (UNESCO) to declare the gender gap in STEM as one of their priority areas of intervention.[3]

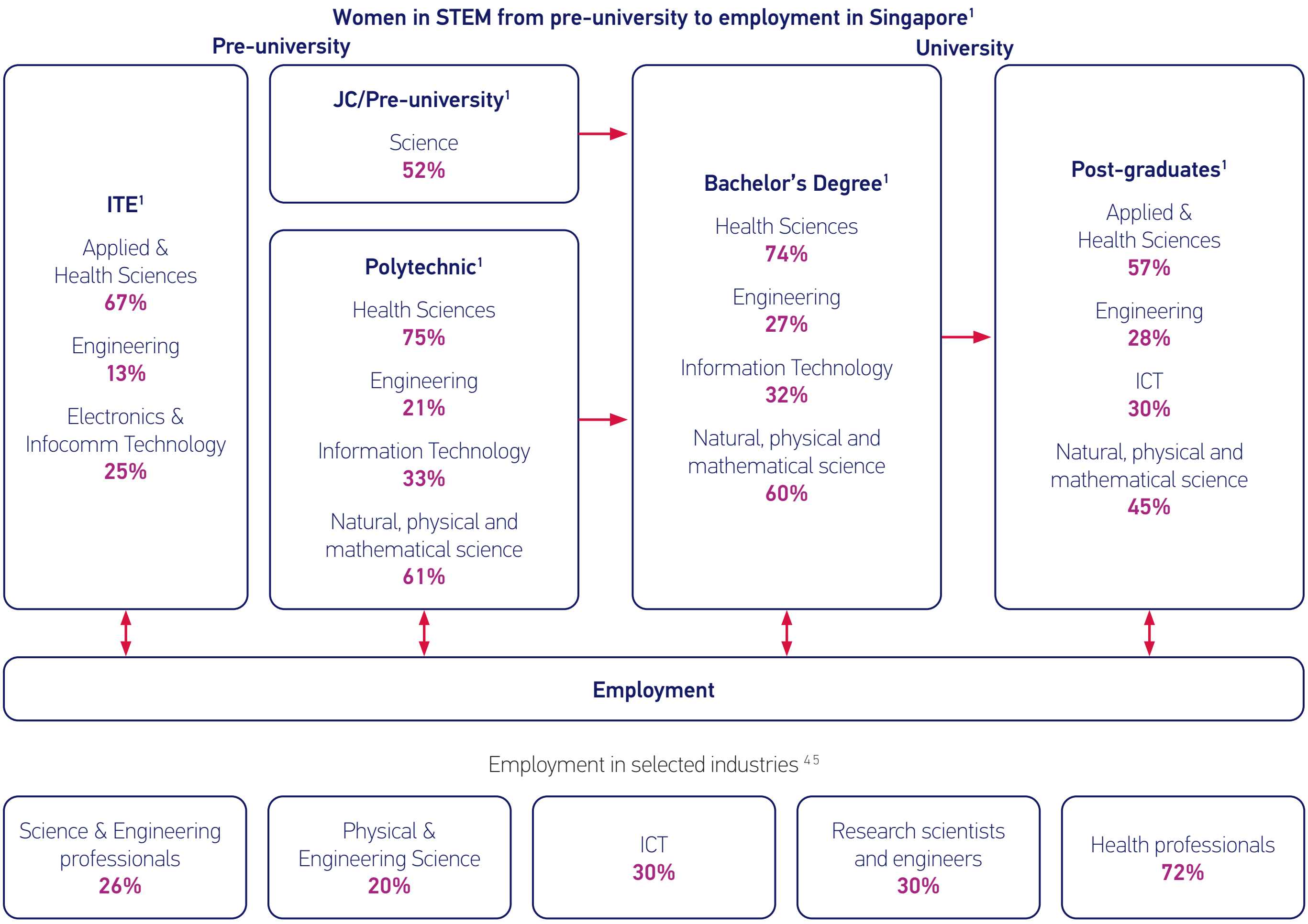
However, few studies have been conducted in Singapore to understand gendered interests and careers in STEM. The aims of this paper are to explore (1) the career pathway of STEM graduates in Singapore; (2) the gender differences in preferred career activities; (3) beliefs about women's belongingness in STEM; (4) the gender differences in STEM self-efficacy (confidence in science and math abilities).

## Gender gaps in STEM education and career

Among diploma holders in Singapore, female graduates accounted for 74% in health sciences and 51% in natural, physical and mathematical sciences. However, across institutes of higher education, there is a 3:1 male-to-female ratio among Singapore bachelor level graduates in engineering and information technology, two crucial areas of Singapore's Smart Nation initiative.[4,5] 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) see Figure 1).[6,7] Singapore women appear to be pursuing only certain types of sciences – namely health and natural sciences (including biology and chemistry), and staying away from engineering and information technology.

The average percentage of women in STEM post-graduate programs is 40% (57% in applied and health sciences; 28% in engineering; 30% in information technology; 45% in natural, physical and mathematical sciences). This means there is an average 8% decrease of women degree holders who go on to complete post-graduate degrees (Master or PhD) across STEM. This decrease has significant implications on the talent pool for research and development careers in all STEM areas, such that only 30% of research scientists and engineers in Singapore are women. [8,9]

**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.

Narrowing the gender gap in STEM can contribute significantly to the development of Singapore's innovation capabilities and the country's economy. The 2019 Economy Survey of Singapore identified innovation as crucial to Singapore's economic development.[10] Given that Singapore's patenting activities (per million of total population) are currently below neighboring nations such as Taiwan, South Korean and Japan, Singapore has the potential to develop its innovation capabilities, particularly in the field of medical technology and biotechnology. Solutions for sustainable development in the 21st century require creativity and innovation in interdisciplinary approaches. Importantly, research has shown that the percentage of women in the knowledge workforce is highly correlated with creativity as they are more likely than men to collaborate when problem solving.[11-13] In addition, the involvement of women in research has been shown to increase the diversity of socially relevant research. Thus, the gender gap in the STEM workforce leads not just a costly reduction in the talent pool, but also in the quality of work.[14] The urgency of economic recovery especially through research and development necessitates the increased involvement of women in STEM.

# The current study

We conducted an online survey to a nationally representative adult sample ages between 21 and 84 years old across Singapore to understand the gender gap in STEM careers.

The data were collected using a nonprobability sampling method. Sample selection was done through quota sampling. Participants were contacted based on the total quota requirements of surveys being run ("live surveys"). Invitations to panel members were then sent out based on the number of participants needed to fill the quota and the known response rate of members of the respective groups. The quota requirements for our study was set according to the national population demographic breakdown of age X gender, and race of Singapore residents.[15] In total, the sampling frame included 14 quota cells and the percentages of participants required per category for our study are provided in Table 1. Race was kept as a separate quota category from the combined age and gender quota category because interlocking quotas would impact feasibility and lead to unintended skews for smaller quota cells.

| | Quota sampling % needed | | Final sample % | |
|---|---|---|---|---|
| Gender X age | Male | Female | Male | Female |
| 21-24 | 3.2% | 3.4% | 3.3% | 4.1% |
| 25-34 | 9.3% | 9.6% | 11.7% | 14.2% |
| 35-44 | 9.8% | 10.2% | 12.8% | 12.3% |
| 45-54 | 9.8% | 10.2% | 12.3% | 7.5% |
| 55+ | 17.0% | 17.7% | 11.7% | 10.1% |
| Race | Male | Female | Male | Female |
| Chinese | 75.0% | | 77.4% | |
| Malay | 13.0% | | 9.7% | |
| Indian | 9.0% | | 8.7% | |
| Other | 3.0% | | 4.2% | |

To improve the representativeness of the estimates and to generate unbiased population estimates, raked weights were created using the SPSS rake extension to ensure that the marginal proportions in the sample matched the national population across gender, race and age. We raked the data on gender X age (10 categories) and ethnicity (4 categories) and used 2019 population statistics as the source for the control totals (Department of Statistics Singapore, 2020). A total of 738 participants completed the study.

### Distribution of respondents (gender)

| | |
|---|---|
| Male | 53% |
| Female | 47% |

### Distribution of respondents (age group)

| | |
|---|---|
| 21-24 | 7% |
| 25-34 | 24% |
| 35-44 | 24% |
| 45-54 | 22% |
| 55+ | 25% |

### Distribution of participants (ethnicity)

| | |
|---|---|
| Chinese | 77% |
| Malay | 11% |
| Indian | 9% |
| Other | 4% |

### Distribution of participants (marital status)

| | |
|---|---|
| Married | 28% |
| In a relationship | 61% |
| Single/divorced/separted/widowed | 11% |

### Distribution of participants (highest education)

| | |
|---|---|
| Diploma | 31% |
| University | 50% |
| Post-graduate | 19% |

### Distribution of respondents (age group)

| | |
|---|---|
| Working full time | 74% |
| Working part time | 8% |
| Full time student | 2% |
| Retired/unemployed/not working | 13% |
| Missing | 2% |

## Distribution of education major

| | |
|---|---|
| Engineering | 21% |
| Science | 7% |
| Technology | 13% |
| Mathematics | 1% |
| Arts | 3% |
| Social science | 12% |
| Business | 39% |
| Education | 2% |
| Other | 2% |

## Distribution of employed (part-time and full-time) participants in each fields of occupation.

| | |
|---|---|
| Engineering | 14% |
| Science | 4% |
| Technology | 12% |
| Mathematics | 0% |
| Arts | 2% |
| Social science | 5% |
| Business | 35% |
| Education | 11% |
| Other | 18% |

## STEM education to career pathway

Participants were asked to indicate their current or desired (if currently not working) field of occupation. Both education majors and fields of occupation were binary coded to STEM vs. non-STEM categories. STEM was defined according to the DHS STEM designated degree program list.[18]

**Table 1. Distribution of STEM educated participants in STEM vs. non-STEM occupations.**

| | STEM occupations (%) | Non-STEM occupations (%) | Significance |
|---|---|---|---|
| STEM educated | 67[a] | 33[b] | $x^2$ (1,717) = 251.03, *p* <.001 |
| Non-STEM educated | 10[a] | 90[b] | |

Note. Groups with different superscripts are significantly different from each other ($p < .05$). The Bonferroni correction was used to adjust for multiple statistical tests.

In general, Singaporeans tend to seek jobs in occupation fields (STEM vs. non-STEM) that match their education major (STEM vs. non-STEM). However, this trend is more prominent among non-STEM educated individuals, with 90% desired to work or were currently working in a non-STEM occupation. By comparison, only 67% of STEM educated Singaporeans desired to work or were currently working in a STEM occupation.

Among STEM graduates (diploma or degree level) who were currently working (part-time or full-time), more men continued on in a STEM career than women. Almost half of the STEM-educated women who had a full-time job worked in non-STEM related occupations.

**Table 2. Distribution of employed (part-time or full-time) STEM diploma/degree educated participants in STEM vs. non-STEM occupations.**

| | Male (%) | Female (%) | Significance |
|---|---|---|---|
| STEM educated | 70[a] | 58[b] | $x^2$ (1,275) = 3.86, *p* <.007 |
| Non-STEM educated | 30[a] | 42[b] | |

Note. Groups with different superscripts are significantly different from each other ($p < .05$). The Bonferroni correction was used to adjust for multiple statistical tests.

## Career activities and interests

The gender stereotype that males are naturally better in STEM than women is found in diverse cultures all around the world.[19] In line with this stereotype, some have argued that the gender gap in STEM careers reflects an innate gender difference in interests.[20] Studies have found that women tend to be interested in person-oriented fields and thus gravitate towards social sciences and medical services, compared to men who tend to be interested in things and investigation.[21] That is, STEM fields with a large gender gap favoring men usually have a high things-orientation and a low people orientation.[22,23] However, the majority of studies published have been conducted in Western cultures and it is unclear whether Asian men and women differ in career interests as the preference for things vs. people is largely driven by socialization forces rather than innate or genetic preferences.[24]

Holland's theory of occupational choice is commonly used to categorize personality types associated with career interests and preferred work environments (Table 3).[25] These personality types are known as RIASEC, with each letter referring to a personality type. The Realistic types are interested in mechanical skills and prefer practical and concrete activities. The Investigative types are interested in math and science activities and prefer investigative and analytical activities. The Artistic types are interested in creative skills and prefer artistic and unusual activities. The Social types are interested in working with people and prefer helping activities. The Enterprising types are interested in leading and directing people and prefer working in positions of responsibility and leadership. The Conventional types are interested in structure and order and prefer routine structured activities. The Realistic and Investigative types are most associated with pursuing STEM careers.[26]

**Table 3. Description of activities, interests and traits by personality types (Taken from Holland, 1996).**

| Type | Activities | Values | Skills | Optimal environment |
|---|---|---|---|---|
| Realistic | Prefers activities involving explicit, ordered or systematic use of objects/tools and avoids educational or therapeutic activities. | Values concrete things or tangible personal characteristics – money, power and status | Acquires manual, mechanical, electrical and technical competencies and deficit in social and educational competencies | A work environment that fosters technical competencies and achievements. Encourages people to see themselves as having mechanical ability and lacking ability in human relations; it encourages them to see the world in simple, tangible and traditional terms. Rewards people for the display of conventional values and goods, money, power and possession. |
| Investigative | Prefers activities involving observational, systematic and creative investigation of physical, biological and cultural phenomena, and avoids persuasive, social and repetitive activities. | Values science | Acquires of scientific and mathematical competencies and deficit in persuasive competencies. | Encourages scientific competencies and achievements. Encourages people to see themselves as scholarly, as having mathematical and scientific ability, and lacking in leadership ability. Encourages them to see the world in complex abstract, independent and original ways. Rewards people for the display of scientific values. |
| Artistic | Prefers activities that are ambiguous, free and unsystematic that involves manipulation of materials to create | Values aesthetic qualities. | Acquires artistic competencies and deficit in clerical or business system competencies. | Fosters artistic competencies and achievement. Encourages people to see themselves as expressive, original, nonconforming, independent; encourages people |

| | | | | |
|---|---|---|---|---|
| | art forms or products. Avoids explicit, systematic and ordered activities. | | | to see the world in complex, independent, unconventional and flexible ways. Rewards people for the display of artistic values. |
| Social | Prefers activities that involves informing, training, developing, treating or enlightening people. Aversion to explicit, ordered, systematic activities involving materials, tools or machines. | Values social and ethical activities and problems. | Acquires human relations competencies (interpersonal and educational) and deficit in manual and technical competencies. | Fosters social competencies. Encourages people to see themselves as liking to help others, understanding of others, cooperative, and sociable; encourages them to see the world in flexible ways. Rewards people for the display of social values. |
| Enterprising | Prefers activities that involves attaining organizational goals or economic gain through people and aversion to observational, symbolic and systematic activities. | Values political and economic achievement. | Acquires leadership, interpersonal and persuasive competencies, deficit in scientific competencies. | Fosters enterprising competencies and achievements. Encourages people to see themselves as aggressive, popular, self-confident, sociable and as possessing leadership and speaking ability. It encourages people to see the world in terms of power, status, responsibility, and in stereotypes, constricted, dependent and simple terms. Rewards people for the display of enterprising values and goals: money, power and status. |
| Conventional | Prefers activities that involve explicit, ordered and systematic manipulation of data, aversion to ambiguous, exploratory or unsystematized activities. | Values business and economic achievement. | Acquires clerical, computational and business system competencies and a deficit in artistic competencies. | Fosters conventional competencies and achievements. Encourages people to see themselves as conforming, orderly, and as having clerical competencies; it encourages them to see the world in conventional, stereotypes, constricted simple, dependent ways. Rewards people for the display of conventional values: money, dependability and conformity. |

## Preferred career interest and activities

Participants were asked to rank 6 career activities and interests based on the RIASEC codes from most favorite to least favorite.[27] Career interests refer to broad domain of interests (e.g., working with people (social); leading, persuading, and directing others (entrepreneurial)) and career activities refer to tasks that people want to do at work (e.g., helping people(social); taking responsibility, providing leadership, convincing (entrepreneurial)).

**Table 4. The top preferred career interests by gender.**

| Career activities | Women | Men | Significance |
|---|---|---|---|
| Realistic | 4% | 6% | $x^2$ (5,730) = 46.45, $p$ <.001 |
| Investigative | 18%[a] | 25%[b] | |
| Artistic | 18% | 14% | |
| Social | 24% | 19% | |
| Entrepreneurial | 12%[a] | 25%[b] | |
| Conventional | 25%[a] | 11%[b] | |

Note. Groups with different superscripts are significantly different from each other ($p$ < .05). The Bonferroni correction was used to adjust for multiple statistical tests.

**Table 5. The top preferred career activities by gender.**

| Career activities | Women | Men | Significance |
|---|---|---|---|
| Realistic | 29% | 26% | $x^2$ (5,728) = 25.78, $p$ <.001 |
| Investigative | 14% | 12% | |
| Artistic | 10% | 8% | |
| Social | 14%[a] | 9%[b] | |
| Entrepreneurial | 16%[a] | 31%[b] | |
| Conventional | 18% | 14% | |

Note. Groups with different superscripts are significantly different from each other ($p$ < .05). The Bonferroni correction was used to adjust for multiple statistical tests.

Overall, Singaporeans preferred practical, hands-on activities working with things that are directed towards economic gain (Realistic type). Singapore men are interested in careers involving leadership (Entrepreneurial) and investigation of science phenomena (Investigative). They prefer work activities which are competitive and enterprising (Entrepreneurial) in a work environment that fosters technical skills directed towards economic and/or political attainment (Realistic). Singapore women are interested in career domains in human/social development (Social), and systematic manipulation of data (Conventional). They prefer practical, orderly and predictable work activities (Conventional) which are directed towards economic achievement (Realistic). More men preferred entrepreneurial career activities and interests than women; more women preferred social career activities and conventional career interests than men.

The comparable percentage of Realistic types between Singapore men and women is counter to previous research in Western cultures which found women tend to be lower on the realistic scale than men.[28] In fact, the percentage of Singapore women in STEM careers is then surprisingly low considering that girls excel in math and science at school, and women gravitate towards work activities and interests which are typically found in STEM careers.

## Associations of career interests and activities with STEM education and careers

We tested the associations of career interests and activities with participant's education major (STEM vs. non-STEM) and field of career (STEM vs. non-STEM) using binary logistic regressions. We controlled for gender, age, race, marital status, employment status, income status and education level. We found that Realistic and Investigative types were significantly associated with STEM education and careers. Interestingly, there were mixed findings for the Entrepreneurial types on STEM careers. Further research is needed to understand the role of Entrepreneurial types in STEM careers. We also tested if gender moderated the association between career interests/activities, and type of education and career. Gender was not a significant moderator (results not shown).

**Table 6: Binary logistic regression testing the associations between RIASEC types, and field of education and career.**

| Variable | Education major (STEM/non-STEM) Exp (B) (95% CI) | Career field (STEM/non-STEM) Exp (B) (95% CI) |
|---|---|---|
| Gender (ref: men) | | |
| Women | 0.34 (0.24-0.48) | 0.35 (0.24 – 0.50)* |
| Age | 0.98 (0.97-1.00)* | 0.99 (0.97 – 1.01) |
| Income Level | 1.00 (0.99 – 1.00) | 1.00 (0.99 – 1.00) |
| Ethnicity (ref: Chinese) | | |
| Malay | 0.79 (0.46-1.36) | 0.67 (0.38 – 1.21) |
| Indian | 0.99 (0.55-1.77) | 1.56 (0.88 – 2.85) |
| Other | 0.75 (0.31-1.82) | 0.51 (0.19 – 1.37) |
| Marital status (ref: single/divorced/separated/widowed) | | |
| Married | 1.47 (1.00-2.18) | 1.55 (1.01-2.36)* |
| With a partner | 1.01 (0.56-1.81) | 0.90 (0.78-1.72) |
| Employment status (ref: full-time employment) | | |
| Working part time | 0.55 (0.30-1.030) | 0.27 (0.12-0.58)** |
| Full time student | 1.07 (0.32-3.55) | 0.94 (0.25-3.53) |
| Retired/unemployed/not working | 0.58 (0.34-0.98) | 0.84 (0.48-1.49) |
| Education level (ref: diploma) | | |
| University degree | 0.67 (0.46-0.99)* | 1.01 (0.67-1.53) |
| Above university degree | 0.83 (0.52-1.35) | 1.06 (0.64-1.75) |
| RIASEC career activities (ref: Artistic) | | |
| Realistic | 1.74 (0.88-3.41) | 2.56 (1.22-5.38)* |
| Investigative | 1.92 (0.90-4.10) | 2.33 (1.03-5.31)** |
| Social | 2.48 (1.14-5.41)* | 1.55 (0.66-3.67) |
| Entrepreneurial | 1.55 (0.77-3.10) | 2.77 (1.30-5.91) ** |
| Conventional | 1.08 (0.51 -2.28) | 1.68 (0.75-3.79) |

| Variable | Education major (STEM/non-STEM) Exp (B) (95% CI) | Career field (STEM/non-STEM) Exp (B) (95% CI) |
|---|---|---|
| RIASEC career interests (ref: Artistic) | | |
| Realistic | 1.74 (0.88-3.41) | 2.56 (1.22-5.38)* |
| Investigative | 1.92 (0.90-4.10) | 2.33 (1.03-5.31)** |
| Social | 2.48 (1.14-5.41)* | 1.55 (0.66-3.67) |
| Entrepreneurial | 1.55 (0.77-3.10) | 2.77 (1.30-5.91) ** |
| Conventional | 1.08 (0.51 -2.28) | 1.68 (0.75-3.79) |

Note. *$p$<.01 **$p$<.001

## Gender differences in science and math self-efficacy

In general boys and men have higher self-efficacy than girls and women in domains where they are expected to succeed in (stereotypical male domains such as math, science and technology); whereas there is gender parity in stereotypical female domains such as language arts.[29] Importantly, as self-efficacy is influenced by social feedback and role expectations,[30,31] it may not be an accurate reflection of a person's performance. [32] As such, even though Singaporean girls have generally performed as well as boys in PISA math and science assessments, they consistently report lower math and science self-efficacy than boys.[33] In other words, even though girls perform on par with boys on science and math tests, they do not feel as confident about their science and math skills and abilities as boys do. However, little research has examined if this gender gap in math and science self-efficacy is maintained across the lifespan. Using selected math and science self-efficacy items from PISA 2012 and PISA 2015 respectively,[34] we asked participants how confident they were in solving basic math and science questions. We found that Singaporeans were more confident completing science tasks than they were in completing math tasks and women were significantly less confident in their science and math abilities then men.

**Table 7. Percent of respondents who reported that they feel confident about having to do the following tasks in science by gender.[35]**

| | % of men who were confident | % of women who were confident | Significance |
|---|---|---|---|
| Recognise the science question that underlies a newspaper report on a health issue. | 51[a] | 46[b] | $x^2$ (2,738) = 13.22, $p < 0.01$ |
| Explain why earthquakes occur more frequently in some areas than in others. | 51[a] | 42[b] | $x^2$ (2,739) = 6.71, $p < 0.05$ |
| Describe the role of antibiotics in the treatment of disease. | 45 | 40 | $x^2$ (2,739) = 3.23, $p = 0.20$ |
| Identify the science question associated with the disposal of garbage. | 47[a] | 32[b] | $x^2$ (2,737) = 25.42, $p < 0.01$ |
| Interpret the scientific information provided on the labelling of food items. | 58[a] | 44[b] | $x^2$ (2,738) = 10.10, $p < 0.01$ |

Note. Groups with different superscripts are significantly different from each other ($p < .05$)

**Table 8. Percent of respondents who reported that they feel confident about having to do the following tasks in math by gender.[36]**

| | % of men who were confident | % of women who were confident | Significance |
|---|---|---|---|
| Using a train timetable to work out how long it would take to get from one place to another. | 74[a] | 67[b] | $x^2$ (2,739) = 6.62, $p < 0.05$ |
| Understanding graphs presented in newspapers. | 75[a] | 62[b] | $x^2$ (2,740) = 18.45, $p < 0.01$ |
| Finding the actual distance between two places on a map with a 1:10,000 scale. | 68[a] | 48[b] | $x^2$ (2,739) = 33.43, $p < 0.01$ |

| | % of men who were confident | % of women who were confident | Significance |
|---|---|---|---|
| Solving an equation like 2(x+3) = (x + 3) (x – 3). | 67 | 62 | $x^2$ (2,739) = 8.24, $p < 0.05$ |
| Calculating the petrol consumption rate of a car. | 65[a] | 44[b] | $x^2$ (2,738) = 37.98, $p < 0.01$ |

Note. Groups with different superscripts are significantly different from each other ($p < .05$)

## Perceived norms of belongingness and inclusion in STEM careers.

Research shows that women's intention to pursue a STEM career is influenced by the prevailing cultural stereotypes that males are naturally better in STEM.[37] The more women are aware of this stereotype, the more they feel like they don't belong to STEM and the less confident they feel about the math and science abilities (self-efficacy).[38] Consequently, their sense of belonging in STEM and self-efficacy decreases interest and motivation in pursuing a STEM career.[39,40] For example, women in stereotypically masculine STEM fields such as engineering who experienced a greater sense of belonging were more interested and engaged in these fields.[41,42] The 2020 3M State of the Science survey which reported that among women with a STEM degree who left the STEM career pathway, 36% left due to a lack of diversity/inclusion.[43]

We asked participants to rate the extent to which they agree with three statements on perceived norms of belongingness and inclusion in STEM.[44]

**Table 9. Percent of participants according to category of response to statements that men are more likely to belong in STEM then women.**

| Statement | % of participants who disagree | % of participants who neither disagree nor agree | % of participants who agree |
|---|---|---|---|
| Men are more likely to pursue math and science careers than women. | 13 | 40 | 48 |
| More job opportunities in STEM disciplines are given to men. | 12 | 49 | 39 |
| Women have more difficulty in progressing through their career in STEM than men. | 19 | 49 | 32 |

In general, Singaporeans agreed that men are more likely than women to pursue STEM careers and are fairly neutral on barriers of STEM career entry and career progression.

## Associations of career interests and activities with STEM education and careers

We looked whether perceived norms of belongingness and self-efficacy differed among women and men who remained or left the STEM career pathway. We created a mean score of perceived norms of belongingness by averaging across the three items (*"Men are more likely to pursue math and science careers than women."*; *"More job opportunities in STEM disciplines are given to men."*; *"Women have more difficulty in progressing through their career in STEM than men."*). The Cronbach alpha for the measure was 0.71. Indices of math and science self-efficacy were created by averaging across the items. The Cronbach alpha for the scales are 0.87 and 0.90 respectively. Categorical variables were dummy coded.

We tested the association between gender X education major (STEM vs. non-STEM) X career field (STEM vs. non-STEM) on perceived norms of belongingness and math and science self-efficacy using multiple regression analyses. We controlled for preferred career interests and activities, age group, employment status, income status, education level and marital status. Neither the main effects of gender, education major and career field, nor the interactions were significantly associated with math or science self-efficacy. However, the three way interaction of gender X education major X career field on perceived norms of belongness was significant [t = -2.93, p <.001; Table 10). The simple slopes for non-STEM education/STEM career (t = 3.35, p <.01) and STEM education/non-STEM career (t = 1.92, p <.06) were significant. Women who switch into a STEM career pathway or who left the STEM career pathway were more likely than men to perceive that men have an easier time obtaining a STEM job and progressing in a STEM career than women. There was no gender difference between those who were STEM educated working in a STEM field, or those who were non-STEM educated working in a non-STEM field. There was no change in the results even when we controlled for math and science self-efficacy.

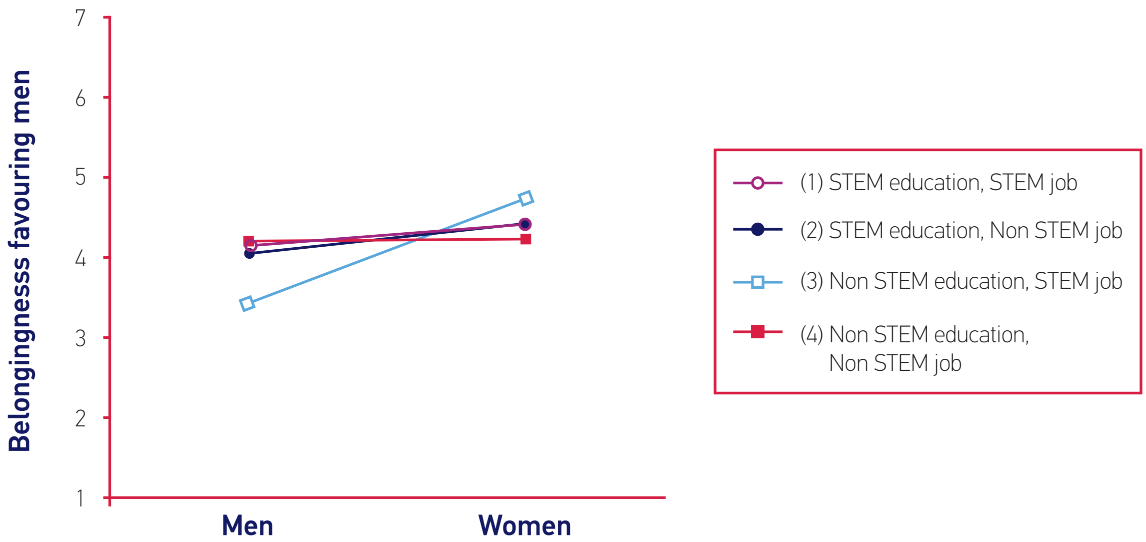
**Table 10. Multiple regression analyses of gender, education major and career field on perceived norms of belongingness among employed participants.**

| Variable | B | SE | β | t |
|---|---|---|---|---|
| Step 1 | | | | |
| Constant | 3.86 | 0.28 | 0.86 | 13.94 |
| Age | 0 | 0 | -0.02 | -0.21 |
| Income level | 0 | 0 | 0 | -0.13 |
| Ethnicity (ref: Chinese) | | | | |
| Malay | 0.01 | 0.12 | 0.001 | 0.06 |
| Indian | -0.20 | 0.14 | -0.01 | -1.42 |
| Other | 0.09 | 0.23 | 0.003 | -0.39 |
| Marital status (ref: single/divorced/separated/widowed) | | | | |
| Married | 0.32 | 0.09 | 0.05 | 3.53** |
| With a partner | 0.16 | 0.15 | 0.01 | 1.11 |
| Education level (ref: diploma) | | | | |
| University degree | 0.11 | 0.09 | 0.02 | 1.17 |
| Above university degree | 0.42 | 0.11 | 0.04 | 3.71** |

| Variable | B | SE | β | t |
|---|---|---|---|---|
| RIASEC career activities (ref: Artistic) | | | | |
| Realistic | -0.24 | 0.17 | -0.03 | -1.45 |
| Investigative | -0.35 | 0.18 | -0.03 | -1.90 |
| Social | -0.15 | 0.20 | -0.01 | -0.75 |
| Entrepreneurial | -0.37 | 0.17 | -0.04 | -2.14* |
| Conventional | -0.23 | 0.18 | -0.02 | -1.23 |
| RIASEC career interests (ref: Artistic) | | | | |
| Realistic | 0.40 | 0.22 | 0.02 | 1.76 |
| Investigative | 0.13 | 0.14 | 0.01 | 0.97 |
| Social | 0.14 | 0.14 | 0.01 | 0.99 |
| Entrepreneurial | 0.08 | 0.14 | 0.01 | 0.54 |
| Conventional | 0.35 | 0.15 | 0.03 | 2.40* |
| Gender (1 = men, 2 = women) | 0.22 | 0.09 | 0.08 | 2.57* |
| Education major (0 = non-STEM, 1 = STEM) | 0.09 | 0.10 | 0.01 | 0.93 |
| Career field (0 = non-STEM, 1 = STEM) | -0.02 | 0.11 | -0.003 | -0.21 |
| Step 2 | | | | |
| Gender X education major | 0.37 | 0.23 | 0.08 | 1.58 |
| Gender X career field | 1.26 | 0.40 | 0.23 | 3.14** |
| Education major X career field | 2.24 | 0.72 | 0.27 | 3.11** |
| Gender X education major X career field | -1.39 | 0.47 | -0.34 | -2.93** |

Note. *$p$<.05, **$p$<.01

**Figure 2. The three way interaction of gender X education major X career field on perceived norms of belongingness among employed participants. Higher scores indicate norms favouring men.**



## Conclusions and recommendations

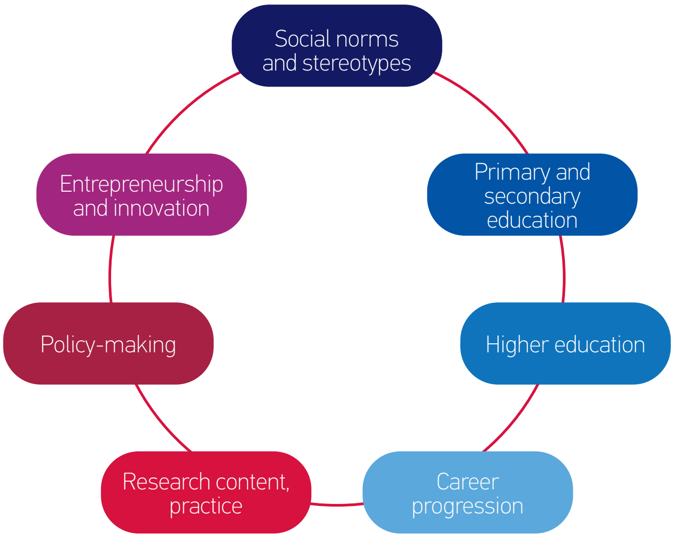
Our survey found that significantly fewer Singapore women with a diploma or degree in STEM are currently working in a STEM field, compared to Singapore men. Interestingly, our results also show that Singapore women express an interest in career activities that are suitable to STEM occupations – that is, activities that are orderly, predictable and systematic in the social or economic domain (Realistic type).

Yet, Singapore women are less confident in their math and science abilities as compared to men. Women are also more likely than men to perceive gender barriers of STEM career entry and career progress. This is consistent with past research that suggest men are more likely than women to justify the gender gap in STEM by blaming women's lack of interest in STEM rather than recognizing systemic biases.[45-46] We also found that the perceived norms of belongingness favouring men were highest among women who entered the STEM career pathway from a non-STEM diploma/degree and those who left the STEM career pathway after their STEM education.

Gender diversity in STEM is crucial to the social fabric and economic health of Singapore. Reducing the gender gap in STEM is consistent with Singapore's foundational principle of meritocracy. Everyone is given an opportunity to succeed only if they are given the opportunities to develop a perception of themselves as equally competent and capable as others. Women are more interested in STEM when they believe they belong in and can succeed in STEM.[47] Simply put, women are not staying away from STEM education and careers because they are choosing not to be like men,[48] rather there are barriers of participation which must be dismantled.

UNESCO states that increasing gender diversity in STEM education and careers requires a change in culture and a reduction in barriers that contribute to women leaving STEM, rather than interventions that focus on encouraging more women to study science and choose a scientific career. The STEM and Gender Advancement (SAGA) project was launched in 2015 by UNESCO to support governments and policymakers in their initiatives to reduce the gender gap in STEM. They identified seven main target areas to reduce the gender gap in STEM education and careers, including changing social norms and stereotypes, establishing gender related research and development programs, and closing the gender gap in remuneration (Figure 3). Employers, research and learning institutes, and the Singapore government need to examine implicit and explicit practices and policies which hinder women from participating in STEM (Table 11).

**Figure 3. The seven target areas for change to achieve gender equality (taken from UNESCO).**



Research has repeatedly shown that people have a strong motive to maintain the status quo and to believe that the world is fair and just.[50] Facing the reality of an unfair world is psychologically uncomfortable as the admission warrants action to address socio-economic inequity. However, the failure to acknowledge that systemic barriers in society have been shown to perpetuate gender biases (e.g., men are more capable than women) even in fields where women are well represented.[51] The gender gap in STEM is a social and economic cost which Singapore cannot afford any longer and immediate action must be taken to change the status quo. Real change requires us to move away from individual-level explanations and examine social-structural factors as target areas of change to close the gender gap in STEM in Singapore.

**Table 11. Objectives and steps to close the gender gap in STEM in seven target areas (taken from UNESCO).**

| Target area | Objectives | Steps to take |
|---|---|---|
| Realistic | Change perception, attitudes, behaviours, social norms and stereotypes towards women in STEM in society | 1.1 Promote awareness of and overcome non-conscious and cultural gender biases widely expressed as gender stereotypes, among scientists, educators, policy-makers, research organizations, the media and the public at large.<br>1.2 Promote visibility of women with STEM qualifications, and in STEM careers, especially in leadership positions in governments, business enterprises, universities and research organizations.<br>1.3 Mainstream gender perspectives in science communication and informal and non-formal STEM education activities, including in science centres and museums. |
| Primary and secondary education | Engage girls and young women in STEM primary and secondary education, as well as in technical and vocational education and training | 2.1 Promote S&E vocations to girls and young women including stimulating interest, fostering in-depth knowledge about S&E career issues, and presenting role models.<br>2.2 Mainstream the gender perspective in educational content (teacher training, curricula, pedagogical methods, and teaching material).<br>2.3 Promote gender-sensitive pedagogical approaches to STEM teaching, including encouraging hands-on training and experiments.<br>2.4 Promote gender balance among STEM teachers.<br>2.5 Promote gender equality in STEM school-to-work transitions. |
| Higher education | Attraction, access to and retention of women in STEM higher education at all levels | 3.1 Promote access of and attract women to STEM higher education (including master's and Ph.D.), including through specific scholarships and awards.<br>3.2 Prevent gender bias in the student admission and financial aid processes.<br>3.3 Promote retention of women in STEM higher education at all levels, including through gender-sensitive mentoring, workshops and networks.<br>3.4 Prevent gender-based discrimination and sexual harassment at all levels, including master's and Ph.D.<br>3.5 Promote gender equality in international mobility of students.<br>3.6 Promote day care/child care facilities for students, particularly at STEM higher education institutions. |
| Career progression | Gender equality in career progression for scientists and engineers (S&E) | 4.1 Ensure gender equality in access to job opportunities, recruitment criteria and processes.<br>4.2 Promote gender equality in access to opportunities in the workplace:<br>• gender equality in remuneration<br>• preventing gender bias in performance evaluation criteria (including productivity measurement) |

| Target area | Objectives | Steps to take |
|---|---|---|
| | | • adequate safety and security of fieldwork.<br>• sexual harassment prevention policies and procedures.<br>4.3 Ensure gender equality in access to opportunities in the workplace:<br>• training and conferences.<br>• research teams, networks (national and international), expert panels and advisory groups.<br>• publications and patent applications, including preventing bias in review.<br>• financial and non-financial incentives.<br>• recognition, rewards and awards.<br>4.4 Promote work-life balance through, among others:<br>• infrastructure for child care.<br>• flexible working hours.<br>• reduction and redistribution of unpaid care and domestic care.<br>• family leave for both parents.<br>• appropriate re-entry mechanisms to the S&E workforce after career break or family leave.<br>4.5 Promote gender equality in international mobility of post-docs and researchers, and facilitate women's return.<br>4.6 Promote gender balance in leadership positions in S&E occupations (including decision making and research).<br>4.7 Promote transformations of STI institutions and organizations (structure, governance, policies, norms and values) aimed at achieving gender equality.<br>4.8 Ensure gender equality in S&E professional certifications, in particular engineering. |
| Research content and practice | Promote the gender dimension in research content, practice and agendas | 5.1 Establish specific gender-oriented R&D programmes, including research on gender in STEM and on the gender dimension of the country's research agenda and portfolio.<br>5.2 Incorporate gender dimensions into the evaluation of R&D projects.<br>5.3 Promote gender-sensitive analysis in research hypotheses and consideration of sex of research subjects.<br>5.4 Promote gender-responsive and gender-sensitive research dissemination and science communication, including through science centres, and museums, science journalism, specific conferences, workshops and publications. |
| Policy-making | Promote gender equality in STEM-related policy-making | 6.1 Ensure gender balance in STEM-related policy design (decision makers, consultative committees, expert groups, etc.):<br>• education policy<br>• higher education policy<br>• STI policy<br>• economic policy<br>• workforce policy<br>• SDGs / international policies.<br>6.2 Ensure gender mainstreaming and prioritization of gender equality in STEM related policy design, monitoring and evaluation:<br>• education policy<br>• higher education policy<br>• STI policy<br>• economic policy<br>• workforce policy<br>• SDGs / international policies |

| | | |
|---|---|---|
| Entrepreneurship and innovation | Promote gender equality in science and technology-based entrepreneurship and innovation activities | 5.1 Promote gender equality in access to seed capital, angel investors, venture capital and similar start-up financing.<br>5.2 Ensure equal access to public support for innovation for women-owned firms.<br>5.3 Ensure visibility of women entrepreneurs as role models.<br>5.4 Ensure women's access to mentorship and participation in the design and implementation of gender-sensitive training in entrepreneurship, innovation management, and intellectual Property Rights.<br>5.5 Promote networks of women entrepreneurs and women's participation in entrepreneur-ship networks.<br>5.6 Promote gendered innovation approaches.<br>5.7 Promote external incentives and recognition for women-led innovation and acceptance of women innovators in society.<br>5.8 Promote gender equality in the access and use of enabling technology, in particular information and communication technology.<br>5.9 Promote a gender balanced workforce and equal opportunities in start-up companies. |

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