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STEM Education for Girls and Women

Breaking Barriers and Exploring Gender Inequality in Asia

Education 2030

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Foreword

The award of the 2020 Noble Prize in chemistry by the Royal Swedish Academy of Sciences to Dr Emmanuel Charpentier and Dr Jennifer A. Doudna for the development of a method for genome editing does not only highlight the potential and promise that girls and women hold in Science, Technology, Engineering and Mathematics (STEM) fields, but also that girls and women can excel to the highest level and achieve prominence in these careers. Sadly though, Dr Charpentier and Dr Doudna are only the sixth and seventh women, out of a total of 185 individuals, to have won the Nobel Prize in chemistry since the annual prize was awarded in 1901.[i] This implies that in the history of the Nobel Prize in chemistry, for every female winner there are 26 male winners. And in the history of all the Nobel Prizes in the sciences, there have been 20 female laureates of the more than 600 prizes awarded in physiology or medicine, chemistry and physics. These ratios reflect the gender disparity and inequality that exists in STEM fields globally.

More specifically, the the World Economic Forum estimates that only 30 per cent of the world's researchers are women, less than a third of female students choose to study higher education courses in the STEM fields and that women working in STEM fields publish less and receive less pay than their male counterparts.[ii] OECD's PISA results showed that in OECD countries, only 14 per cent of girls who were top performers in science or mathematics expected to enter a professional field in science and engineering, compared with 26 per cent of top-performing boys. For example, women account for less than 1 per cent of the Silicon Valley applicant pool for technical jobs in artificial intelligence and data science.[iii] These numbers show that we are a far cry from Sustainable Development Goal (SGD)

i See: https://www.nobelprize.org/prizes/facts/facts-on-the-nobel-prize-in-chemistry/

ii See: https://www.weforum.org/agenda/2020/02/stem-gender-inequality-researchers-bias/

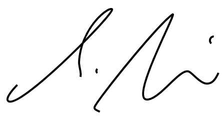
iii See: UNESCO, 2020. Global Education Monitoring Report: Gender Report: A new generation: 25 years of efforts for gender equality in education. Paris: UNESCO

4 which aims to '*ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*' and SDG5 which aims to '*achieve gender equality and empower all women and girls*.'

Just like any other region in the globe, gender disparities in STEM careers are equally observed in the Asia-Pacific region, and it is against this backdrop that this report on '*STEM Education for Girls and Women: Breaking Barriers and Exploring Gender Inequality in Asia*' was written. The report showcases captivating case studies across eight countries in the region (India, Indonesia, Kazakhstan, Lao PDR, Malaysia, Philippines, Singapore and Viet Nam) covering the participation and interest of girls in STEM, STEM careers for girls and women and the experiences of women working in STEM. Although the case studies cannot be considered as a representation of what is happening in the entire Asia-Pacific region, they highlight the barriers and challenges that are likely to discourage girls from pursuing studies, and eventually careers, in STEM fields. The report permits the reader, whether they are a student, parent, teacher, school authority, policymaker, government authority, civil society organization, non-governmental organization, academic or in the private sector, to have a realistic picture of the differences in perception, motivation, and interest in STEM between male and female students.

The report further confronts the reader with some fascinating interventions that have successfully increased access to and participation of girls and women in STEM fields. These promising initiatives highlight how girls and women can be motivated to study and build careers in the STEM fields.

Much work remains to be done to fully achieve gender equality in education and providing equitable means and opportunities is of utmost importance. We cannot let traditional roles and gender stereotypes hinder the progress many countries have already made in providing equitable education. Governments and societies need to lay the groundwork for girls and women to feel welcomed and supported in pursuing any career path. If we are to achieve the Sustainable Development Goals, we must look to leverage the potential for all learners, regardless of gender.



Shigeru Aoyagi
Director
UNESCO Bangkok

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List of Acronyms

AAUW	American Association of University Women
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CIL	Computer and information literacy
COVID-19	Coronavirus disease
CS	Computer Science
DepEd	Department of Education (Philippines)
DFEEST	Department of Further Education, Employment, Science and Technology (Kazakhstan)
EQ	Evaluation Question
GLM	Generalized Linear Model
HE	Higher Education
HEI(s)	Higher Education Institution(s)
IAC	Information Analytic Centre (Kazakhstan)
ICILS	International Computer and Information Literacy Study
ICT	Information and Communication Technology
IEA	International Association for the Evaluation of Educational Achievement
IT	Information Technology
ITU	International Telecommunication Union
IW	Investing in Women
KPI	Key Performance Indicator
MOES	Ministry of Education and Sports (Lao PDR)
MOET	Ministry of Education and Training (Viet Nam)
OECD	Organisation for Economic Co-operation and Development

PBEd	Philippine Business for Education
Lao PDR	Lao People's Democratic Republic
PhD	Doctor of Philosophy
PIAAC	Programme of International Assessment of Adult Competences
PISA	Programme for International Student Assessment
RP	Research Productivity
SDG	Sustainable Development Goal
SEAMEO	Southeast Asian Ministers of Education Organization
SEAQIS	SEAMEO Centre for Quality Improvement of Teachers and Education Personnel in Science
SMEs	Small and Medium-sized Enterprises
SPSS	Statistical Package for Social Sciences
STEM	Science, Technology, Engineering and Mathematics
STEM-G	Science, Technology, Engineering and Mathematics for Girls programme (Singapore)
TALIS	Teaching and Learning International Survey
TIMSS	Trends in International Mathematics and Science Study
UG	Undergraduate
UGC	University Grants Commission (India)
UK	United Kingdom
UKM	Universiti Kebangsaan Malaysia
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
USD	United States Dollars
USM	Universiti Sains Malaysia
VNEN	Vietnam Escuela Nueva
VNIES	Vietnam National Institute of Educational Sciences

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Executive summary

Today, we are seeing scientific innovations advance at an exponential rate. We understand more about our natural world than ever before and have manipulated technology to serve our lives in exciting and meaningful ways. However, for all of these advancements, women make up less than a third of scientific researchers globally (UNESCO, 2019) and a variety of systemic barriers often discourage girls from pursuing science, technology, engineering and mathematics (STEM).

The need to research the status of STEM for girls and women developed from continued concerns that the field is maintaining too slow a progression in terms of Sustainable Development Goal (SDG) 4, to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all; and SDG 5, to achieve gender equality and empower all women and girls. Within STEM professions and education, the unequal participation between genders at the expense of females is of concern given the loss of talent, perspectives, potential advancements and overall strength of the workforce. Furthermore, the low participation and achievement rates of girls and women can negatively impact larger societal progress as STEM innovations have incredible potential to drive sustainable development.

The aim of this publication is to promote the perspectives of STEM practitioners and researchers to gain a wider understanding of the barriers faced by girls and women in this domain. This complements previous UNESCO research on STEM in the Asia-Pacific region by highlighting data and analysis directly from the field and it overall expands the knowledge base on the experiences of girls and women participating in STEM fields in the region.

In line with a global priority to mainstream gender equality across all sectors, UNESCO has undertaken two previous research studies into STEM for girls and women which are pertinent to this publication. *Cracking the Code: Girls' and Women's Education in STEM* is a 2017 global report investigating barriers faced by girls and women. *A Complex Formula. Girls and Women in Science, Technology, Engineering and Mathematics in Asia* is a regional study conducted by UNESCO Bangkok that focused on findings from seven countries in the region. The present publication builds on both of these reports by gathering updated data from eight countries across the Asia-Pacific region and by expanding the data source, inviting external researchers and practitioners to contribute their findings.

In doing so, this research collection is not meant to give an overall view of the status of STEM for girls and women in the Asia-Pacific region, or to compare findings between countries. Instead, it aims to highlight contextual barriers that girls and women face; provide examples of methodological frameworks that can be used to examine the experience of girls and women in STEM; and offer concrete examples of interventions that successfully increased access to, or participation in STEM for girls. In addition, a summary and analysis of key findings and recommendations is made to emphasize any common results that could inspire future research and to strengthen the findings of each individual paper.

Methodology

In 2019, UNESCO Bangkok published a research call, inviting researchers from across the Asia-Pacific to submit either proposals of innovative projects, or interventions that tackle inequality in STEM, or research studies on the same topic. Submitted proposals were score-based on their relevance, methodology, originality and how useful their results were to education stakeholders. Additionally, the final papers were to reflect a balance in location and type of submission (research paper or project report). From these criteria, eight papers were selected to be part of this final publication.

The country settings include India, Indonesia, Kazakhstan, Lao PDR, Malaysia, the Philippines, Singapore and Viet Nam. Each paper has been written independently and has approached the topic from a unique, country-specific perspective. As such, some research papers are initial explorations into the topic, while others build on a collection of research in the country. While there is no common methodology across the different chapters to allow for comparative analysis of each case study, there are common elements between them that provide some cohesion, such as the focus on girls' and women's perceptions, motivations, attitudes and interest in STEM education or careers.

The eight case studies in this publication are organized into three sections: 1) *Encouraging girls' participation and interest in STEM;* 2) *Encouraging STEM careers for girls and women;* and 3) *Experiences of women working in STEM.*

Key findings

The first section, *Encouraging girls' participation and interest in STEM*, explores girls' (and boys') experiences in STEM education and provides an overview of the perceptions, interest, motivation, attitudes and, or overall students' and teacher's views towards STEM through original data.

The first paper, *Reality of STEM education for girls in Viet Nam* reports on data collected through a student survey and interviews with STEM teachers as an initial study to understand STEM education in Viet Nam, with a specific focus on girls' attitudes and confidence in STEM. This research determined that not all teachers understood what STEM education was and that many held a bias against girls when asked about the suitability of STEM careers for their students. Female students perceived themselves as skilled in STEM subjects, although did not want to pursue them professionally, with differences in the preferences, attitudes, confidence and career trends between male and female students.

The second paper, *Perception, motivation and interest of male and female students towards STEM in Indonesia* examines results from a survey measuring perception, motivation and the interest of students towards STEM. This research found differences between male and female students' perception towards science and technology and engineering and their interest in mathematics and technology and engineering, with no significant difference found in their motivations towards the STEM subjects studied.

Girls and women in STEM in Lao PDR measured the perceptions of female STEM professionals and the attitudes of female students towards STEM through a desk study, interviews and a questionnaire. This research found gender imbalances in STEM fields in the form of women sacrificing their careers for their partner's success, or a bias in hiring processes and it emphasized the importance of perception of future earnings in choosing a career. In the questionnaire to school and university students, student preferences for subjects within STEM were explored along with student's attitudes to better inform curriculum, policy and intervention design.

The second section, *Encouraging STEM careers for girls and women*, consists of three project reports which each outline a different intervention programme that aimed to encourage girls to participate, or pursue a career in STEM. Each paper describes the programme, reflects on its success and provides recommendations.

The first project we look at, *Girls2Code: Cultivating interest in programming among young girls in Malaysia by making drawings come to life* was an extra-curricular workshop that aimed to cultivate interest in programming among young girls. This workshop successfully engaged young girls in STEM activities; introduced them to programming concepts; and inspired an interest to learn more about the topic.

STEMpower Our Girls was a year-long project in the Philippines that sought to empower girls to pursue STEM through talks, workshops and an online campaign. This programme had wide-reaching success, engaging over sixty schools and 2.4 million users online. While the initial high rates of interest in STEM by participants meant there were minimal behaviour changes in the students after the conclusion of the programme, there was a significant success in increasing the interest and involvement of parents in STEM as a potential study area and career choice for their children.

The third project, *Evaluation of a science, technology, engineering and mathematics (STEM) for girls (STEM-G) programme in Singapore,* reported on a programme for secondary students that aimed to inspire female students to engage in STEM fields. This school camp was found to have a positive impact on student's learning development, self-concept, attitudes, STEM identity and future career decisions.

The final section, *Experiences of women working in STEM*, includes two papers that present data on the experience of forming a career in STEM. This section outlines barriers faced by women and showcases the voices of professionals and university students through interviews.

Are female academics more research resilient? Evidence from South India's engineering institutions examines the barriers faced by female academics in India and the resilience mechanisms they employ to overcome these barriers. This case study highlighted a variety of issues faced by female researchers, including sociocultural expectations, family and financial issues and institutional or policy factors. It also identified several resilience mechanisms employed to overcome these barriers.

The final case study, *Exploring gender equality in STEM education and careers in Kazakhstan,* reports on the results of a series of interviews and surveys with STEM university students and professionals to explore the factors that impact girls' and women's attraction, participation and retention in STEM education and careers. The results showed gender stereotyping was prevalent in young people as well as adults and suggested the labour market may be more gender biased than the education sector.

Conclusions and recommendations

The sociocultural, psychological and pedagogical barriers faced by many women and girls who participated in these eight research studies reflect obstacles that extend far beyond STEM fields. The cases included herein, although limited in their generalizability, provide valuable insights into the status of gender equality in STEM education and careers and thus into larger challenges to achieve gender equality. In better understanding these barriers and successful interventions or resilience mechanisms used to overcome them, more informed policies and programmes can be created.

A key finding that emerged from the eight cases collectively was a cyclical effect that hindered the participation of females in STEM education and eventually careers. This starts from a young age, with girls receiving messages that STEM subjects are only suitable for boys, thereby discouraging them from choosing STEM courses in school or pursuing advanced studies in STEM. For those who do pursue STEM, there are a series of barriers to success, including discrimination, pressure to marry early, expectations to take full responsibility for household and family duties and 'glass ceilings' that keep females from high leadership positions. All of these factors lead to young girls not seeing examples of successful women in STEM, contributing to the belief that they cannot succeed in the field.

On the basis of individual findings, each paper made recommendations to governments, policy makers, parents, teachers and other education stakeholders. In addition to these, from the overall analysis and conclusions, the following seven overarching recommendations were made:

1. **Strengthen STEM curricula and instructional materials to better promote equal participation in STEM.** Consult gender equality experts in the creation of learning materials to ensure they promote gender equality. Ensure that all students can engage with STEM ideas early and include instruction that connects curricula with real-world problems so students can understand the role of STEM in a broader context.

2. **Strengthen the capacity of teachers and student counsellors to encourage girls to pursue careers in STEM**. Increased awareness of stereotypes and gender disparities in STEM allows educators and career counsellors to understand the barriers faced by their students, ensure equal participation in STEM classes and promote STEM careers to female students.

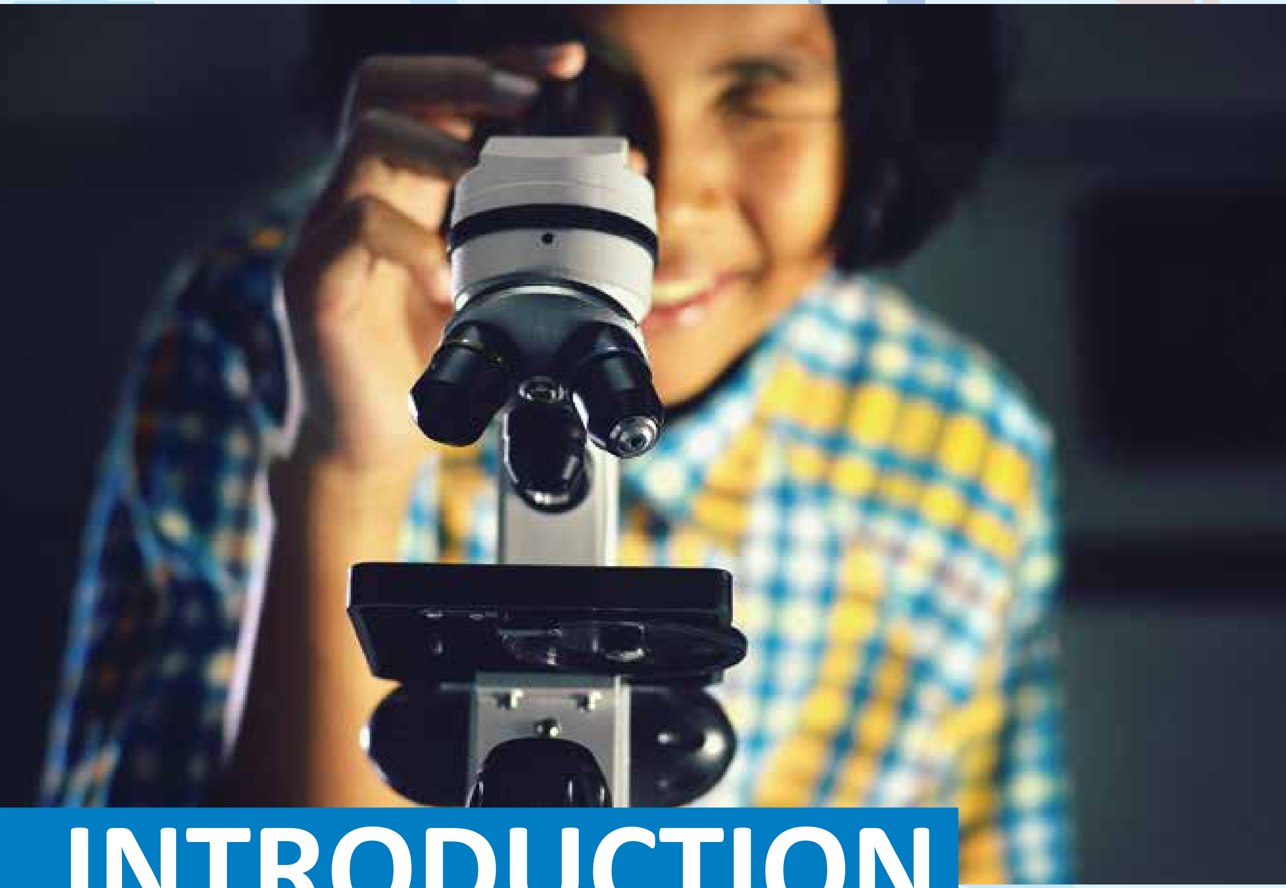
3. **Raise awareness of gender equality in STEM to parents and broader communities.** Include parents in STEM programmes to improve their awareness of STEM careers for their daughters. Work with the larger community to decrease sociocultural factors that impedes girls' progress in STEM.

4. **Promote the stories of successful female STEM professionals**. Encourage successful female role models to participate in STEM classes to subvert negative stereotypes. This can also strengthen the sense of belonging to STEM communities for girls and women.

5. **Encourage STEM participation for girls and women in rural areas**. Include rural and geographically disadvantaged groups specifically in gender equality policies and STEM programmes.

6. **Improve access to STEM facilities for female professionals and students**. This includes investigating and acting on discrepancies in access to STEM laboratories, facilities and resources between male and female students. Examine and act on resource challenges women face in workplaces such as in gathering data or equipment and cultural norms that discourage collaboration between men and women, or policies that make it difficult to balance work and family responsibilities.

7. **Create and enforce policies that promote gender equality in STEM fields.** This approach can include policies that address systematic barriers to participation in STEM and policies in support of STEM education for girls – scholarships, improved STEM facilities, equal access to STEM facilities, or support for initiatives that promote STEM to girls – and gender equality for women, such as flexible work hours, maternity leave and post-maternity leave support, appropriate facilities and targeted programmes to reduce cultural barriers.



INTRODUCTION

1

An overview of girls and women in STEM

In light of current technological advancements across most aspects of daily human activity, STEM fields are considered catalysts for the achievement of the 2030 Agenda for Sustainable Development. Yet, despite being a field strongly associated with advancement, women and girls often lack equal opportunities to succeed in STEM.

As key drivers for innovation, STEM fields flourish with new approaches to tackle present-day challenges to sustainable development, inclusive growth and social well-being. While innovations in STEM have driven advancement towards several sustainable development goals, the field itself lags behind in terms of SDG 4; to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all and SDG 5; to achieve gender equality and empower all women and girls. In STEM fields, girls and women, for a multitude of social, cultural and psychological reasons, engage and participate at a lower rate than boys and men. This means there is an uneven opportunity for individual development and a huge loss of talent that is indispensable to the sustainable development of societies as a whole.

UNESCO has actively emphasized the importance of STEM education for all through the global priority to mainstream gender equality across all sectors. In leading the global Education 2030 agenda, UNESCO is mandated to advance science in the interests of peace, sustainable development and social well-being. Previous UNESCO research into STEM for girls and women includes '*Cracking the*

Code: Girls' and Women's Education in STEM'. This 2017 global report highlights the barriers that impede girls' and women's engagement in and contributions to STEM fields worldwide. This report contributed to gender equality in STEM by advancing knowledge on girls' and women's participation in STEM education through the identification of factors that contribute to female participation and intervention activities that promote female engagement in STEM. Additionally, the pioneering regional report *A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia* examined cases from Cambodia, Indonesia, Malaysia, Mongolia, Nepal, the Republic of Korea and Viet Nam. Similar to the aforementioned publication, this report aims to address the lack of information on girls' and women's participation and gender equality in STEM fields.

This publication builds upon these reports by further examining factors that influence girls' and women's participation in STEM. However, it deviates from previous methodologies by collecting independent research papers from practitioners in the field. This is a bottom-up approach where data and recommendations for advancement come directly from practitioners in the field, thereby ensuring that the analysis is highly context-specific and locally relevant. As such, this publication does not aim to provide an overall view of STEM for girls and women in the Asia-Pacific region, but it promotes the perspectives of practitioners and researchers from the field. This compliments UNESCO's previous research by providing data directly from those involved in the field, with an aim to update and expand our knowledge base on the state of girls' and women's STEM education across the Asia-Pacific. As previous studies have highlighted, much of the disparity arises from social, cultural and psychological barriers that are present in all levels of education and throughout women's career paths. This collection of research will help to identify and isolate these factors in eight specific country contexts.

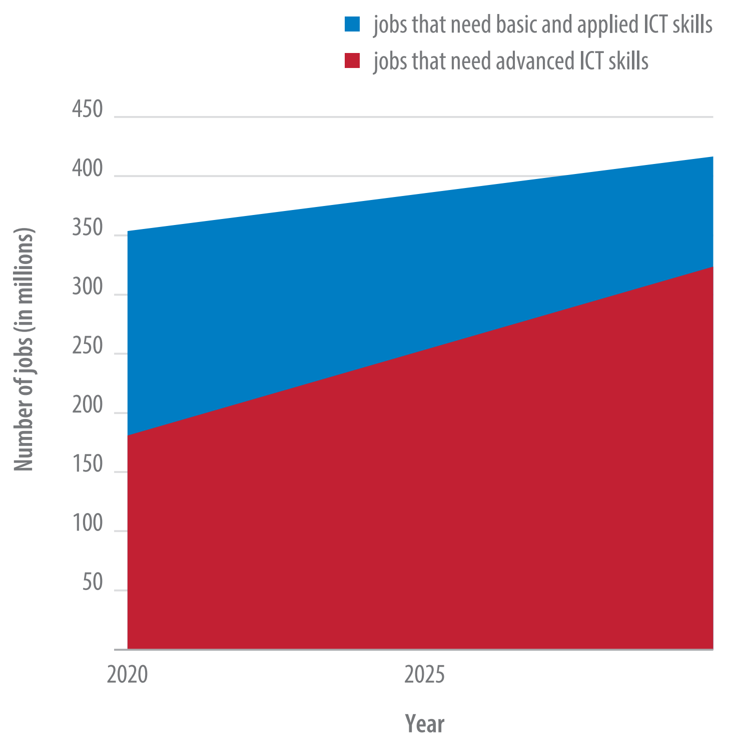
Importantly, there are several different definitions of the acronym STEM and the application of this term changes slightly between papers in this publication, depending on the context. Among the two most common interpretations are: 1) STEM education represents subjects and concepts related to science, technology, engineering and mathematics, either as standalone subjects or interdisciplinary courses. This is a broad interpretation that can apply to many professions or educational programmes; and 2) STEM education refers to an interdisciplinary approach to teaching science, technology, engineering and mathematics that combines two or more of these subjects into one educational programme or project. While both definitions are acceptable, the former definition is used throughout the majority of this publication, including in the executive summary, introduction and conclusion. For clarity, each individual research paper has operationally defined the term.

Status of girls and women in STEM

Research into the status of girls and women in STEM has revealed issues of participation, inclusion and access. While advancements in gender equality have led to economic growth in many contexts, in STEM the potential benefits are even greater given the capacity to develop solutions for current and emerging world problems. Yet, even with these promising gains, in and through education women and girls lack opportunities for advancement, including professional development through work. Particularly for STEM fields, girls and women are often found at a disadvantage for a multitude of social, cultural and psychological reasons.

A report for the UNESCO Institute for Statistics (2019) found women comprised only 29.3 per cent of scientific researchers in the world. Rates are even lower in the Asia-Pacific region where women hold 18.5 per cent of research positions in South and West Asia; 23.9 per cent in East Asia and the Pacific; and 48.2 per cent in Central Asia. This underrepresentation of women in STEM careers has far-reaching implications. On an individual level, up to 80 per cent of jobs in South-East Asia will require basic digital literacy and applied ICT skills by the year 2030 (see Figure 1.1) (The Sasakawa Peace Foundation & Dalberg Global Development Advisors, 2017), a circumstance that will disproportionately affect female students if they lack equal access to technology and ICT learning in school. Within STEM fields, the exclusion of female professionals signifies a loss of ideas, perspectives and talent. Furthermore, on a national and regional scale, gender equality can have strong economic benefits (UNESCO, 2018).

Figure 1.1: The increasing requirement for basic and applied ICT skills in South-East Asian jobs



Source: The Sasakawa Peace Foundation & Dalberg Global Development Advisors, 2017.

Low levels of female participation in STEM fields can be traced back to their school years where a number of influences from society, culture, education and the labour market are at play (UNESCO Bangkok, 2015). A lack of role models and mentoring for female students, social undervaluation of females in STEM careers, stereotyping in teaching materials and instructional approaches and scarcity of different modes of learning can all prevent female students from pursuing STEM careers (UNESCO Bangkok, 2015; UNESCO, 2018).

The extent to which girls and women are interested in and motivated to participate in STEM education and eventually a STEM career is intrinsically linked to their representation in the field. A recent study conducted by YouGov in the Asia-Pacific found 32 per cent of teachers believed girls' low rates of enrolment and participation in STEM were due to a lack of interest (Microsoft, 2019). This is further corroborated by Mastercard's (2017) Girls in STEM research in Asia-Pacific which found that 68 per cent of girls aged twelve to nineteen in Singapore were not interested in STEM while 42 per cent perceived the subjects as difficult. When asked what would motivate them to pursue studies in the field, they cited scholarships, successful women in STEM as role models and opportunities to participate in mentoring programmes.

Many girls aspire to pursue careers in STEM from a young age, but this interest wanes with sociocultural pressures and a lack of support to cultivate and sustain their curiosity. In a survey of more than 2,000 girls in the Asia-Pacific Region, although more than half, aged fifteen to nineteen, considered STEM when they were young, they changed their minds by the time they reached adolescence and only 12 per cent continued their studies in STEM subjects (Mastercard, 2018). The key reasons cited for their decisions to stop pursuing STEM were their learned perceptions of gender bias, subject difficulty and lack of support from parents and teachers (Mastercard, 2018).

This underrepresentation of women and girls in STEM is multifaceted. As such, several key contributing factors will be explored herein, and these are organized into three sections: sociocultural, psychological and pedagogical influences.

Sociocultural factors: Stereotypes, practices and norms

Social norms are one of the many factors that can contribute to upholding practices that deter girls not only from studying science and mathematics but also from pursuing education. Similarly, sociocultural norms play an important role in the degree to which an environment empowers girls and women to pursue studies and careers in STEM.

Participants at the 'Asia-Pacific Economic Cooperation's (APEC) 2016 Women in STEM Forum' agreed that enabling environments were intrinsically tied to attitudes and views about the roles, rights and potential of girls and women. This includes the roles that family, media, schools, communities, workplaces and culture play in shaping girls' and women's goals and perceptions of self (Asia-Pacific Economic Cooperation, 2017). The latest Mastercard STEM research found 46 per cent of girls in India cited parental encouragement as the key reason they chose to pursue a career in STEM (Mastercard, 2018). While 93 per cent of girls surveyed considered STEM-related careers when they were younger, 38 per cent believed they were less likely to pursue STEM in comparison to their male counterparts because of the perceptions that it is male-dominated. The images girls and women see, societal stereotypes and observed behaviours can work either to include or exclude them from the sector. Understanding culture through what Susie Jolly (2002) describes as 'ways of life structured by power and representation' assists in gaining a better understanding of the power dynamics that support the cultural practices affecting girls and women.

Importantly, variance exists between and within countries. To hold onto what New Zealand academic Yvonne Underhill-Sem (2010) coins as a 'template view' of cultures in a region – which in the case of Asia-Pacific is home to 60 per cent of the world's population – and paint the entire region with a broad stroke would detract from the varied efforts of countries to improve the status of girls and women in STEM. For example, in Myanmar, women comprised 60 per cent of graduate tertiary STEM programmes in 2018, while in Brunei Darussalam they made up 54 per cent (UNESCO Institute for Statistics, 2020).

Girls' interest and engagement with the field is heavily influenced by the sociocultural norms upheld by their parents, teachers, and peers. When the pursuit of STEM is viewed as contradicting the perceived role of girls and women as wives, mothers and caretakers of the home, they are discouraged from continuing to engage in these subjects. Schools can play an essential role in mitigating these concerns by facilitating conversations and programmes that cultivate and sustain the participation of girls and women in STEM from primary education into their careers, ensuring that curricula is non-biased and training teachers and school leaders to consciously mainstream gender throughout the learning process. Thousands of women and girls, from primary school to the professional level, participate in programmes to build networks, skills and resiliency to work against the harmful stereotypes and sociocultural influences that have deterred them from pursuing careers in the sector (Mastercard, 2017). These efforts, however, must be strengthened by sound research to better understand and improve the roles of public and private actors to empower girls and women to actively participate in STEM.

Psychological factors: Perception of self, interest and subject difficulty

The attitude a girl has toward STEM education plays a key role in her education choices and thus in gender differences in STEM – even more so than student performance (OECD, 2014). The way girls perceive themselves and their attitudes toward science are two critical factors that determine their level of engagement with the subject, as reported by PISA (2016). Girls elect to opt-out of STEM because they often do not consider professions in this field as suitable for their gender. Two predominant gender stereotypes in STEM which deter girls from participating are: 'boys are better at maths and science than girls' and 'science and engineering careers are masculine domains' (UNESCO, 2017). Even if girls do not hold these views themselves, the knowledge that their peers, parents and teachers perceive them in this way can negatively impact their interest, confidence and performance in these subjects (UNESCO, 2017).

Furthermore, girls' academic self-concept is closely linked to their interest in future courses and career options. In a study of gender stereotypes, gender identity and self-concept in mathematics, Cvencek et al. (2011) tested the extent to which girls and boys associate mathematics with their genders and themselves. The results found that boys associated mathematics with their own gender significantly more than girls. Furthermore, boys were more likely to pick their own gender as 'liking to do mathematics more' than girls, signalling that both boys and girls perceived mathematics to be more strongly associated with boys. In terms of self-concept, boys associated 'me' with 'mathematics' more than girls and identified more strongly with an image of a person of the same gender solving a mathematics problem. These results, although from a different cultural context – from the United States of America – are telling in terms of the potential difference in self-concept between the sexes.

As a student progresses through school, assessments are increasingly used to evaluate their capabilities and performance. While observed gaps between the performance of girls and boys in mathematics and science were often attributed to innate differences in intellectual ability between the sexes, this is not the case (Kane and Mertz, 2012). The *Trends in International Mathematics and Science Study* (TIMSS) 2015 revealed no difference in the performance of girls and boys for nine of the twelve participating countries from the Asia-Pacific region for eighth-grade mathematics (Mullis et al., 2016). However, even though the gender gap is closing for performance – which suggests girls are experiencing less difficulties with these subjects – girls continue to be a minority in the STEM field. These results have spurred research to determine the contributing factors outside of competency which impact girls' engagement, interest and confidence in the sector.

Kane and Mertz (2012) suggest that cultural and social factors affect girls' learning experiences and perception of self in relation to STEM. Here, the lines between sociocultural and psychological factors blur as they are inextricably linked to each other. The harmful stereotypes and messages girls receive which tell them they are not supposed to be good at mathematics and science and that their peers, parents and teachers do not expect them to do well either, results in lower self-concept, disengagement and disinterest. Breda and Napp (2019), however, offer an alternative explanation for the gender gap in STEM. In a review of mathematics and reading scores from 300,000 fifteen-year-old students in sixty-four countries, they found a significant difference in verbal scores between boys and girls. When making decisions about career prospects, girls with high mathematics scores were also likely to demonstrate higher readings scores than their male peers and thus often chose to pursue professions in humanities given their comparative advantage. This advantage in reading, likely influenced by the same cultural factors previously explored in this section, may explain up to 'eighty per cent of the gender gap in intentions to pursue math-studies and career(s)' (Breda and Napp, 2019).

Perceptions of self, interest and difficulty are key factors which influence the extent to which students engage with subjects. When students lack interest, confidence and success in a subject, they are less likely to continue their studies in that area. Negative stereotypes around girls' and women's capabilities in STEM create learning environments that do not encourage success or interest. A study of female students in STEM programmes at the RMIT International University in Viet Nam found that they often experience anxiety when entering the programme due to the perception that IT is traditionally a male choice. However, once they overcame this barrier, they were less likely to drop out of the course and performed better than their male counterparts (Shillabeer and Jackson, 2015).

These psychological factors are strongly connected to the aforementioned sociocultural factors. Stereotypes, perceptions of self, interest and self-concept are often indivisible from sociocultural influence and this is especially true in education given the relationship between education, culture and psychology. As such, pedagogical factors on the status of girls and women in STEM are rooted in both psychological and sociocultural influences.

Pedagogical factors: Teacher-student interactions, access to materials, curriculum and teaching strategies

The settings in which students are taught not only influence how they learn, but also their perception of self and their academic abilities. Psychological research has contributed a wealth of knowledge to classroom dynamics and students' learning, one of the most famous being the Pygmalion effect (Oppong, 2018). Also known as the Rosenthal effect, this theory describes the phenomenon whereby higher expectations lead to an increase in performance. Harvard psychologist Robert Rosenthal developed and proved this theory through his famous experiment in 1964 at Spruce Elementary School in San Francisco (Ellison, 2015). He assigned artificially inflated IQ scores to random students and found they were treated differently by their teachers and had better academic performance. This proved, in the words of Rosenthal: 'If we expect certain behaviours from people, we treat them differently – and that treatment is likely to affect their behaviour… the expectations held in the mind of the teacher – or the parent, or the manager, or the coach – can make an enormous difference' (Oppong, 2018).

When teachers and parents hold negative gender stereotypes of girls and women in science this influences female student's expectations and as a result, negatively impacts their self-perception. A recent study found parental encouragement was a large motivational factor for girls in India who chose to pursue studies and careers in the STEM field where over a third of girls cited lack of parental encouragement as one of the many reasons they made the decision not to continue their studies (Mastercard, 2018).

Storage et al. (2016) further demonstrated the influence that the perception of women has on their inclusion in a given field. In fields in which natural talent was seen as important to success, they found fewer female PhDs and fewer women studying bachelor's degrees. Additionally, the study explored the extent to which the words 'brilliant' and 'genius' were used to describe professors, finding that across eighteen disciplines the terms were used more for male than female professors. However, when examining general positive attributes in the reviews such as 'excellent' and 'amazing' there was no identified gender bias. These results may suggest that women are not perceived as having a natural talent in these fields.

A student's attitude towards a subject is also influenced by interactions with their teachers. A recent study in the UK found that 57 per cent of teachers subconsciously held gender stereotypes around STEM (UNESCO, 2017). These stereotypes influence a teacher's expectations of the type of students who will excel in STEM subjects, making girls less likely to receive encouragement from teachers in comparison to boys. Additionally, classroom observations have shown that girls receive less instructional time, not as much encouragement from teachers and ask fewer questions in comparison to boys. A study of student-teacher interactions in Asia found the majority of teacher interactions were with boys (UNESCO, 2017). This is not an isolated phenomenon, as Sandler et. al (1996) noted that when asked questions, female university students were posed easier questions of a more factual nature, while male students were asked more open-ended questions. This type of behaviour and interaction creates a learning environment that discourages girls' involvement and interest in STEM, resulting in low enrolment numbers.

In addition to unequal interactions with teachers, female students also lack access to resources, a factor closely linked to academic achievement for girls. A TIMSS 2011 study found as the percentage of girls that had access to a laboratory increased, so did their scores in science (UNESCO, 2017). This also applies to the development of ICT skills for girls and women. Limited opportunities and exposure to technology means less time dedicated to practicing relevant skills, which hinders their understanding (The Sasakawa Peace Foundation & Dalberg Global Development Advisors, 2017). Ensuring the equitable distribution of resources for students in the classroom contributes to equal learning opportunities.

In response to these issues, learning institutions have developed gender-responsive pedagogies which work to mainstream gender into lesson planning, teaching, classroom management and performance evaluation (Mlama, et al., 2005). UNESCO's (2019) Gender in Education Network in Asia-Pacific (GENIA) Toolkit on promoting gender equality in education emphasizes the importance of developing curricula and teaching and learning materials from a gender equality perspective. This sends a message to students that diverse groups are valued and mitigates the marginalization of students. STEM textbooks often depict women in subordinate roles to men in science or use language to imply women do not take up leadership roles. A recent UNESCO study of over 100 national curriculum frameworks found seventy-eight used learning materials and textbooks that communicated gender bias (UNESCO, 2017). In order to cultivate and sustain girls' interest and success, textbooks and curricula must dispel gender stereotypes. Furthermore, it has been suggested that a problem-solving approach to STEM instruction, especially when employing real-world problems, could foster the interest of female students (Cooper and Heaverlo, 2013). Solving problems also encourages hands-on work and inquiry-based thinking, allowing girls to demonstrate their competency in subjects. Similarly, collaborative learning has been associated with increased rates of retention in subjects for marginalized students, including girls and women, promoting higher achievement, increased self-esteem and students also demonstrated more enjoyment of subjects (Sandler et al., 1996).

Scope and methodology of the regional research

Given the sociocultural, psychological and pedagogical factors that contribute to ongoing gender disparity in STEM throughout the region, identifying and isolating such factors is an essential step towards achieving equitable, quality education and gender equality in STEM fields. This research aimed to illustrate prevalent barriers faced by girls and women in STEM and present recommendations to address them.

To this aim, in 2019 UNESCO Bangkok put out a call for research, receiving numerous proposals of both research studies on girls' or women's participation in STEM and reports from innovative projects or interventions to tackle gender inequality in STEM fields. The submitted research projects were scored based on set criteria. These standards included:

1. Relevance. Does it examine STEM education for girls/women? Does it address sociocultural or psychological factors?;
2. Methodology. Is the method rigorous and robust? Is the research feasible (if not yet completed)?;
3. Originality. Is it a novel idea? Does it go beyond just analyzing the differences in learning outcomes of gender?;
4. Usability of results. Does it provide policy recommendations for education stakeholders on how to reduce inequality in STEM?

Eight research papers were selected to be included based on this criteria, as well as location and category of submission (research or project report), with the final papers reflecting a regional and categorical balance.

The papers herein explore a variety of themes, each approaching the topic of STEM for girls and women from a unique, country-specific stance. The inclusion of papers from STEM practitioners as well as from formalized research bodies provides an added value to the publication by highlighting varying perspectives on the topic. The country settings include India, Indonesia, Kazakhstan, Lao PDR, Malaysia, the Philippines, Singapore and Viet Nam. Each paper is positioned independently, with some serving as initial, country-specific explorations into the experience of girls or women in STEM and others are built upon larger bodies of research in the context to tackle distinct questions. Each paper individually makes great contributions to the advancement of gender equality in STEM in their respective country and on the whole they advance the Education 2030 agenda in the region by illuminating pressing issues, giving a voice to girls and women and proposing solutions and recommendations to problems faced.

As each report was conducted independently, there is no common structure in the presentation of research in each chapter. This is intentional as each case study was formatted to best present its findings. However, in an effort to create a cohesive publication for the reader, the chapters are grouped under common themes, and organized into the following three sections.

Section I

Encouraging girls' participation and interest in STEM includes research based in Indonesia, Lao PDR and Viet Nam. These papers explore the experiences of studying STEM, providing an overview of the perceptions, interest, motivation, attitudes and/or overall beliefs towards the STEM of students and teachers. They each present original data from their respective countries to illuminate specific aspects of gender inequality while providing recommendations for action to work towards gender equality in STEM.

2. *Reality of STEM education for girls in rural Viet Nam* reports on data collected through a student survey and interviews with STEM teachers.
3. *Perception, motivation and interest of male and female students towards STEM in Indonesia* examines results from a survey measuring perception, motivation and interest of students towards STEM.
4. *Girls and women in STEM in Lao PDR* measured the perception, motivation and interest of female STEM students through a questionnaire.

Section II

Encouraging STEM careers for girls and women includes project-based research from Malaysia, the Philippines and Singapore. These papers each outline a different intervention programme aimed to encourage girls to participate, or pursue a career in STEM. The findings can serve as a great resource for educators, parents or any organization looking to promote STEM participation among girls. Each paper describes the programme, reflects on its success and provides recommendations to other practitioners or policy makers.

5. *Girls2Code: Cultivating interest in programming among young girls in Malaysia by making drawings come to life* was an extra-curricular workshop with the aim to cultivate interest in programming among young girls.
6. *STEMpower Our Girls* was a year-long programme in the Philippines that sought to empower girls to pursue STEM through talks, workshops and an online campaign.
7. *Evaluation of a science, technology, engineering and mathematics for girls (STEM-G) programme in Singapore* reports on a programme for secondary students that aimed to inspire female students to engage in STEM fields.

Section III

Experiences of women working in STEM includes papers from India and Kazakhstan. These two papers explore the experience of forming a career in STEM, outlining some of the specific barriers women face in these contexts and showcasing the voices of professionals and university students through interviews. They provide various recommendations to both improve the status of women working in STEM and to encourage more female students to enter the field.

8. *Are female academics more research resilient? Evidence from South India's engineering institutions* examines the barriers faced by female academics in India and the resilience mechanisms they employ to overcome the barriers.
9. *Exploring gender equality in STEM education and careers in Kazakhstan* reports on the results of a series of interviews and surveys with STEM university students and professionals.

Following these eight chapters are general conclusions and an analysis of the key findings. The framework presented earlier in this chapter of sociocultural, psychological and pedagogical influences is used to analyse any common or divergent findings from the individual reports and guides the establishment of seven overarching recommendations.

Limitations

This methodological framework has several key limitations. As each case study was conducted and written independently there is no common methodology or analytical framework from which comparisons can be based. Additionally, while the inclusion of project-based reports adds a category of research not included in the previous UNESCO publications on the topic, the small sample size of these case studies significantly limits the generalizability of their findings.

Each report provides recommendations for educators, policy makers or researchers to continue advancing the field of STEM for girls and women. Although these recommendations are context-specific, there are challenges and lessons that can be adapted to further gender equality in STEM throughout the region. While each paper stands individually as a 'lens' into the experience of girls and women in STEM in one country, identifying any common challenges or approaches between them allows for lessons learned to be shared and adapted throughout the region for future research, policies and programmes.

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SECTION I

Encouraging girls' participation and interest in STEM

2

Reality of STEM education for girls in Viet Nam

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Context of STEM education for girls in Viet Nam

Over the last decade, there has been a considerable push to integrate STEM into the educational curriculum in many countries around the world. Although a variety of research shows that girls tend to outperform boys in STEM standardized tests, they remain underrepresented in STEM-related careers and in the achievement of STEM degrees (UNESCO Institute for Statistics, 2020). For example, there is evidence that fifteen-year-old Vietnamese girls' PISA 2015 performances are, on average, slightly higher than boys in terms of mathematics and science (OECD, 2016).

Despite a long-term development of STEM education in other countries, in Viet Nam this is still a new field. In Viet Nam, we used the definition of the

National Science Teachers Association (NSTA): 'STEM is a curriculum based on the idea of educating students in four specific disciplines – science, technology, engineering and mathematics – in an interdisciplinary and applied approach.'[1] This integrated approach is how 'STEM' and 'STEM education' are defined throughout this paper. Integrated-based teaching was implemented in Viet Nam many years ago as teachers integrated various topics into a single subject. For example, integrating the contents of population education, environmental education, health protection, or economical education into the subjects of geography, biology, physics, chemistry, mathematics, foreign languages or civic education. In STEM education, rather than teach the four disciplines as separate and discrete subjects, they are integrated into a cohesive learning paradigm based on real-world applications.

In Viet Nam's general education system, STEM education is divided into three levels: teaching STEM-based subjects; organizing STEM experience activities; and organizing scientific and technical research activities. The construction of a STEM lesson also follows a specific process, each learning activity is clearly designed about the purpose, content and learning products that students must complete. Currently, there is no official STEM teaching programme in Viet Nam, although a STEM education programme has been piloted in a number of schools. The Ministry of Education and Training (MOET) has issued draft training materials to develop and implement STEM education topics in secondary schools.

Therefore, this survey was conducted as an initial study to understand STEM education in general and STEM education for girls in some primary and secondary schools in Viet Nam. In particular, it is focused on exploring girls' attitudes towards, and confidence in STEM fields, as well as considering strategies to keep their interest in these areas.

Research design and methodology

this section will describe the overall design and procedures used in conducting the survey, including research purposes, questions, methods, population and sample and instrumentation.

1 See: National Science Teachers Association (NSTA), https://www.nsta.org/nstas-official-positions/stem-education-teaching-and-learning.

Purposes of the research

This research had two main purposes, to examine school leaders and teachers' perceptions of STEM education for girls and teaching and learning practices relating to STEM education for girls in some primary and lower secondary schools in Viet Nam; and to investigate girls' and boys' perceptions, interest, confidence and involvement in STEM subjects in some primary and lower secondary schools in the country.

Research questions

1. How do school leaders and teachers understand STEM education?
2. What are Vietnamese policies on STEM education/for girls specifically? What do school leaders/teachers know about these policies?
3. How has STEM education been integrated into curriculums, textbooks, educational documents and school-based curriculums?
4. What are school leaders and teachers' perspectives on the factors affecting girls' participation in STEM areas?
5. Are there differences in interests, confidence and career orientation towards STEM fields between girls and boys?

Methods and instruments

This study used both qualitative and quantitative methods. For quantitative data, we used three different questionnaires for students (primary and junior secondary school), teachers, and school leaders and administrators. In the questionnaire, various types of questions were used, including: open-ended questions, 'yes' or 'no' questions, multiple choice questions, rating scales and ranking questions. Likert-scale questions were used for items measuring 'importance' or 'agreeance' (for example: 1. 'Strongly disagree'; 2. 'Disagree'; 3 'Neither agree nor disagree'; 4. 'Agree'; and 5.'Strongly agree').

For collecting qualitative data, we use in-depth interviews with three groups: (1) students; (2) teachers; and (3) school leaders. These teachers teach STEM-related subjects in ten schools and were asked about factors influencing the participation of girls in STEM areas and strategies that can engage them.

Survey sample

The respondents to the three respective surveys included thirty administrators, 108 STEM-related teachers and 880 primary and lower secondary students in five provinces. They represent five geographic regions in Viet Nam (including Hoa Binh in the eastern mountain area; Ha Giang in the northern mountain area; Nghe An in the central area; Dak Lak in the Central Highlands; and Tra Vinh in the Mekong Delta). As seen in Table 2.1, the provinces selected are disadvantaged provinces. The selection for the baseline study is expected to provide a basis for the development of the STEM education model in these regions in the future.

Table 2.1: Percentage of low-income families per province in Viet Nam

Province	% of low-income family/ population	Region	Ranking within region
Hòa Bình	14.74%	East mountain area	4/4
Hà Giang	31.7%	North mountain area	1/11
Nghệ An	5.54%	Central area	2/6
Đắk Lắk	12.81%	Central highland area	2/5
Trà Vinh	5.95%	Mekong Delta	7/13

Source: Statistic of Ministry of Labour, War Invalids and Social Affairs, 2018.

The schools surveyed were Viet Nam Escuela Nueva (VNEN) model schools. This innovative education model was developed from Colombia's Escuela Nueva new school model. As opposed to a traditional classroom, in a VNEN school, students are at the centre of the classroom and a strong emphasis is placed on active, collaborative learning and community and parental engagement. These schools are developed to be context-specific, with learning guides and curricula created to be relevant to the children in the area. This is contrasted with traditional schools that follow national textbooks. In terms of STEM learning, in the traditional curriculum only primary science books are written from an integrated perspective while in VNEN schools physics, chemistry and biology have been integrated into a single learning guide in the lower secondary curriculum (Parandekar et al., 2017).

While various types of activities related to STEM education or integrated-based teaching and learning are organized by the school or teachers, this study collected data based on activities such as regular activities, pilot models or competitions annually organized by the MOET.

The survey was conducted in four schools (two primary schools and two junior secondary schools) in each of the five provinces. All students completed the same survey. Thirteen male teachers participated (12.5 per cent, including four primary teachers and nine secondary school teachers) and ninety-one female teachers (87.5 per cent, including fifty-one primary teachers and forty secondary school teachers). From the descriptive data, a large difference in teacher numbers by gender were found in the survey, namely the number of female teachers was higher than that of male teachers.

Findings

How do school leaders and teachers understand STEM education?

There is a lack of awareness of STEM education in Viet Nam. Most teachers in this survey had never heard of or learned about STEM education (53.8 per cent) and those who had were usually secondary school teachers. This may be explained by the fact that STEM education is only included in policy documents for secondary schools, while most primary teachers are not exposed to the concept.

In addition, of those teachers who had knowledge of STEM education, the majority had learned about it through the media (59.7 per cent), while others gained awareness through colleagues (13.4 per cent) or conferences (9 per cent). Interestingly, only 12 teachers' (17.9 per cent) awareness of the term 'STEM education' was through official documents of the MOET, even though it was referred to in the Official Letter No. 4099/BGDDT-GDTrH, dated May 5, 2014 by the minister of the MOET on guiding the implementation of secondary education for the academic year 2014 to 2015. As a result, no participant teachers could identify the name of any official documents referring to STEM education.

In terms of the concept of STEM Education, 38.5 per cent of teachers defined it as 'an interdisciplinary approach in science, technology, engineering and mathematics', while 9.5 per cent of participants considered STEM education as a combination of science, technology, engineering and mathematics, but separately taught. The remainder (14.4 per cent) believed that STEM education was a new educational model that aimed to train theoretical scientists in these four areas.

Although STEM education has only been piloted in a number of schools in major cities, a number of STEM-related optional activities have been annually conducted by MOET. Since the school year of 2016, MOET has piloted STEM education at fourteen lower and upper secondary schools and directed the 2016 to 2017 school year task: 'Continue the spirit of integrated educational programme – STEM in implementing general education of related subjects'. From 02 to 06 August in 2016, the MOET, in collaboration with the British Council and the Newton Foundation, organized a training programme called 'Educational Methods oriented to STEM' for twenty-two leaders and fifty-four teachers of the piloted schools. The course content (bilingual English/Vietnamese) is very concise and practical[2]. MOET organized contests to raise awareness, creativity and the implementation of STEM education at all levels. This approach included a science and technology creation contest for teenagers; a science and technology competition for high school students; application of interdisciplinary knowledge to solve practical problems; an activity called 'Contest – International Exhibition of Science and Technology Creation for Young Scientists'; a national science-technology competition; a fun science application contest 'WEDO'; and a robot contest 'ROBOCON.'

However, because these activities are not compulsory, not every school or teacher is aware of their existence, especially in rural or disadvantaged areas. Among the STEM-related activities referred to in the survey, the activities that most teachers had knowledge of were interdisciplinary integration-based teaching and learning for teachers, followed by scientific research, student competitions that require using interdisciplinary knowledge to solve real life situations and scientific research activities for students. The others included national sciences and technology competitions, and clubs, for example, science and STEM.

What are Vietnamese policies on STEM education/for girls specifically? What do school leaders/teachers know about these policies?

'STEM education' was mentioned in the Official Letter No. 4099/BGDĐT-GDTrH, 5 May, 2014 of MOET's 'Guiding the Implementation of Secondary Education Mission in the school year 2014–2015'. Furthermore, gender equality is mentioned in various documents. The equal rights of women and gender

2 More details on this training model can be accessed at: www.stemvn.com

equality are stipulated by the Viet Nam Constitutions of 1946, 1980, 1992 and 2013; the Education Law; the Civil Code; the Social Insurance Law; the Labour Code; the Marriage and Family Law; the Law on Election of Deputies to the National Assembly; the Law on Election of Deputies to the People's Council; the Residence Law; the Penal Code; the Law on Prevention of Domestic Violence; the Citizenship Law; and the Law on Persons with Disabilities.

The survey results showed teachers did not have sufficient knowledge about legal documents related to gender equality or STEM education (87.5 per cent). Most teachers could not provide any documents mentioning those aspects, including the respondents whose answers were 'yes'. This indicates that there may be a need for teacher training on the topic so educators have a better understanding of both issues of gender equality in education and the legal framework in Viet Nam.

STEM education for girls in curriculums, textbooks and educational documents and the school-based curriculum

More than half of the teachers were unaware of whether STEM education was reflected in the educational curriculum, textbooks or other learning materials. However, 29.8 per cent said they were aware of STEM education in the curriculum; about 26 per cent said they were aware of STEM education in textbooks and other learning materials; and only about 10 per cent said that it was not in any documents.

Most teachers in the survey believed that there was no gender discrimination in policies or curriculum, while more than half (61.7 per cent) said that there was a big gender difference in the content and format of textbooks. When asked, teachers said: 'The image of male and female is not in balance, females do not appear as often as males in the text or in the illustrations.'

Another response was: 'In the textbook, character images are strongly influenced by gender stereotypes, for example scientists or electrical engineers are always male, while nurses or teachers are always female.' The results of the teacher survey have reinforced the view that STEM education is a new concept for the majority of teachers in the surveyed provinces. However, an integrated approach to teaching is not new, as it was implemented in Viet Nam many years ago. Many teachers in the interviews associated the two concepts.

STEM education in the school-based curriculum

STEM education has not been implemented at the surveyed schools with exactly the same meaning yet. However, some schools have implemented interdisciplinary integrated-based teaching and learning. Therefore, another purpose of the survey was to find out if school leaders and teachers had been trained in interdisciplinary integrated-based teaching. The results showed the STEM-related topics with the most training were interdisciplinary themed-based teaching and learning; teaching and assessment of individual subjects, including mathematics, science, engineering and technology; and organizing innovatively experiential activities for secondary school students. It was revealed that STEM education (i.e. teaching and assessment of students in STEM education) and STEM education for girls (i.e. how to encourage the participation of female children in STEM subjects and design STEM activities with the participation of female students) were not included in any training.

The use of computers are also important for the implementation of STEM education. However, among fifteen surveyed schools, only three schools had more than thirty computers; four schools had twenty-one to thirty computers; five schools had eleven to twenty computers; and three schools had less than ten computers. Therefore, the highest computers-per-student ratio was 0:05. It was found that some primary schools in the northern mountainous province of Ha Giang did not have any computers for students' use.

To investigate the types STEM education or integrated-based teaching and learning being organized by the school or teachers, the study collected data on activities such as regular activities, pilot models, or competitions organized by the MOET annually. It was found that most teachers attempted to integrate STEM classroom activities by incorporating content from other subjects or classes into their own subject (60.6 per cent), followed by the implementation of integrated topics (e.g. projects, experiential activities and problem-solving, etc.) related to STEM subjects (39.4 per cent). Another trend observed from the survey results is that teachers who graduated from universities tended organize more STEM-related activities than teachers who did not attend university but who graduated from college or less.

In terms of challenges faced by teachers while applying an interdisciplinary integrated-based teaching and learning approach, the two most common disadvantages are the lack of teaching and learning materials on interdisciplinary integration and limited facilities and teaching and learning equipment for interdisciplinary integration. It is difficult for teachers to apply this approach in practice because they lack the habits and skills necessary for collaborative work in learning projects and of integration-based teaching and learning and their students lack learning habits and skills for interdisciplinary integration-based teaching and learning.

Teachers identified other disadvantages such as the contents of these subjects being highly academic, separated and independent and the lack of time for preparation and implementation of interdisciplinary integration-based teaching and learning. In addition, it seems that senior teachers were more sensitive to these difficulties than newly graduated teachers. This may also be due to the high flexibility and adaptability of young teachers – but further research supporting this finding is necessary.

What are school leaders and teachers' perspectives on the factors affecting girls' participation in STEM areas?

The next section of the research presents the sociocultural factors influencing girls and boys participation in STEM fields. We have designed a five-level Likert question to measure the consent of teachers and administrators for two contents: (1) The view of gender related to STEM fields; (2) Assessing the influence of sociocultural factors related to STEM fields in the Vietnamese context.

Viewpoints on gender issues related to STEM fields

In the questionnaire for teachers and school leaders, we mentioned viewpoints on gender issues related to STEM fields such as: (1) Boys study STEM better than girls because they have a better logical mind; (2) Girls should not study engineering because of their health requirements; (3) Girls' ability to calculate and use computers is not as good as boys; (4) Women are suitable for jobs such as a secretary, diplomat and teacher; (5) Women are not good at technology and practical projects like repairing cars; (6) Women should not choose professions that are supposed to be men's; and (7) I will guide my daughter to study social issues. We found that teachers and school leaders did not have any opinions regarding gender differences between men and women in STEM fields.

Assessing the influence of sociocultural factors related to girls' and boys' participation in STEM fields

All of the teachers and school leaders who participated in interviews agreed with the following social factors related to girls and boys participation in STEM fields:

1. There are fewer female teachers than male teachers in subjects relating to STEM.
2. Teachers have not been trained to solve gender-related issues in STEM subjects.
3. The learning resources and equipment can not be interesting enough to stimulate the interest of female students in STEM subjects.
4. Teaching and learning materials are still influenced by gender stereotypes.
5. Career advice, scholarships/financial support by gender are limited.
6. Sociocultural and educational factors lead to gender discrimination in subject selection.
7. Female students tend to be more worried about mathematics and science than male students.
8. Parents and teachers are less likely to encourage girls to study STEM subjects.
9. The participation of women in the labour market and wages are unequal.
10. Gender stereotypes and norms have made women only focus on some specific STEM occupations.
11. There are less successful female role models in STEM fields, compared to male counterparts.

Encourage girls' participation in STEM

In order to consider the views of teachers and administrators on the need to encourage girls to participate in STEM-related activities/subjects, the study used a 'yes' or 'no' question to measure views on the need to encourage the participation of girls. Most teachers (85.3 per cent) and school leaders (80 per cent) believed that it was necessary to encourage girls to participate in activities related to STEM.

We also use five-level Likert questions: (1. 'Strongly unimportant'; 2. 'Unimportant'; 3. 'Neither important nor unimportant'; 4. 'Important'; 5. 'Strongly Important') to measure the reasons for the importance of encouraging the participation of girls. The study found seven reasons for the importance of encouraging the participation of girls:

1. Narrowing gender gaps in STEM-related careers.
2. Enhancing gender equality.
3. Removing gender stereotypes.
4. Creating diversified opportunities for girls to develop general skills.
5. Improving female students' performances on STEM-related subjects.
6. Helping girls have more opportunities to pursue careers in the future.
7. Increasing the rate of female students choosing STEM-related subjects/areas in higher levels of education.

Are there differences in interests, confidence and career orientation towards STEM fields between girls and boys?

The study used two sets of questionnaires; one for grades four to five and the other for grades six to eight. In this section, the findings will be explained according to five main contents: (1) Subject preferences; (2) Mathematics; (3) Sciences; (4) Engineering and technology; (5) Career trends.

Subject preferences

For subject preferences, we listed twelve subjects for elementary students (mathematics, science, history, geography, Vietnamese language, physical education, music, art, moral education, foreign language, ICT and engineering). We asked students to choose three subjects for each category: (1) Most enjoyed subject; (2) Least enjoyed subject; (3) Highest perceived performance; and (4) Lowest perceived performance. We focused on comparisons between girls and boys in each STEM subject (mathematics, science, ICT and engineering) on the most enjoyed subject and highest perceived performance.

It was found that mathematics was the only subject chosen as one of most enjoyed subjects as well as the best-studied subject by males and females in both primary and secondary schools. At the primary level, boys preferred STEM subjects, including mathematics and sciences, more than girls. At the secondary level, mathematics and biology were STEM subjects both females and males enjoyed the most, while the remaining science subjects, including physics and chemistry, were the lowest perceived performance subjects.

Figure 2.1 and Figure 2.2 show the most enjoyed subjects and highest perceived performance in STEM subjects between male and female elementary students. Students were able to choose more than one item on the survey.

Figure 2.1: Most-enjoyed STEM subject (elementary students)

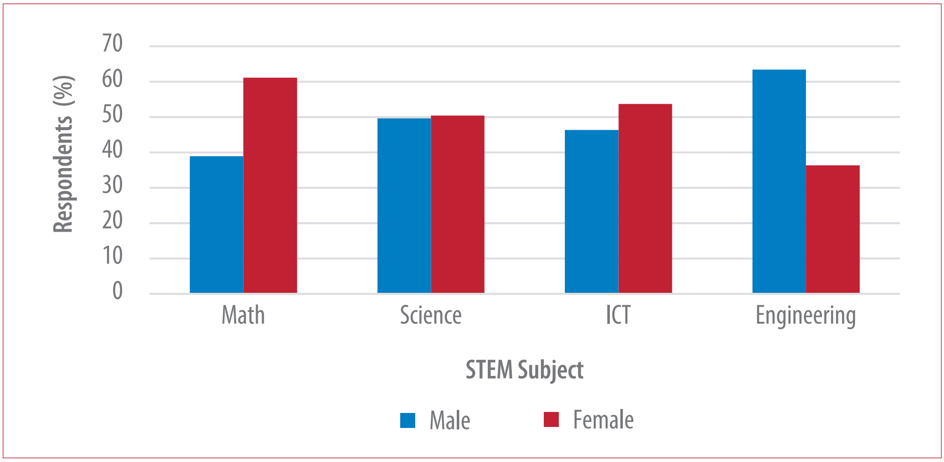
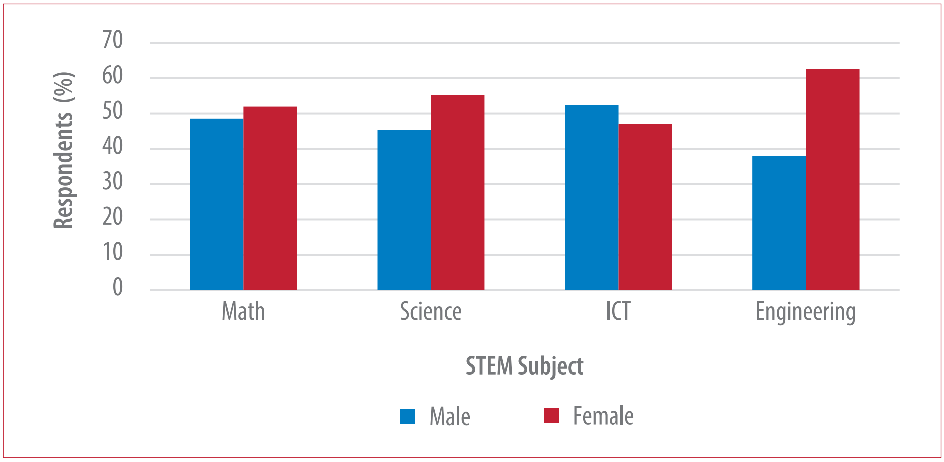


Figure 2.2: Highest perceived performance in STEM subjects (elementary students)



In terms of mathematics and science, female students were seen to enjoy the subjects more and have a higher performance than their male counterparts. For ICT, female students enjoyed the subject more than their male counterparts.

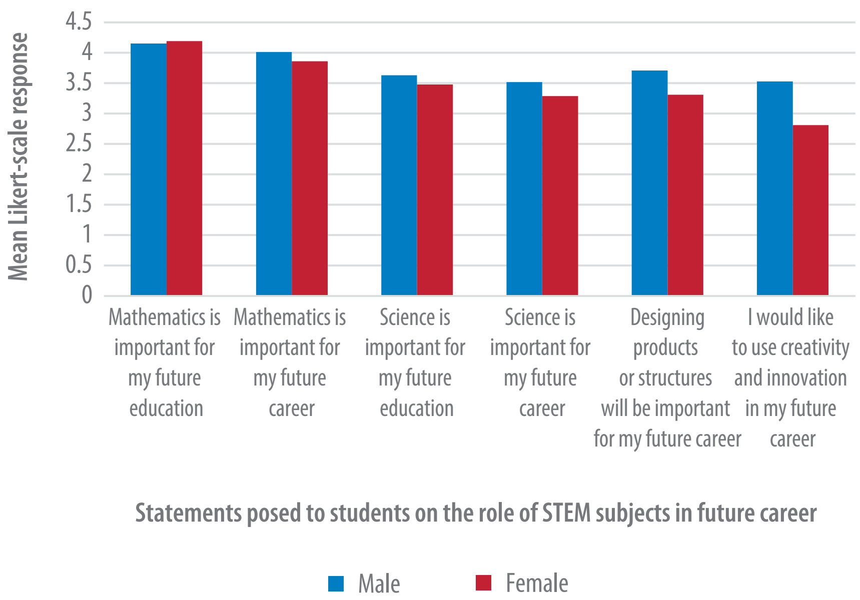
However, male students had a higher performance in this discipline than female students. For engineering, male students were seen to enjoy the subject more than female students. However, a higher percentage of female students compared to male students reported this subject as their highest perceived performance. It is often viewed that male students like technology and engineering more than female students. However, this study's results show this is untrue.

Differences in views and attitudes towards STEM career trends between male and female students

The continuous development of modern science and technology has led to an increased demand for STEM careers. The female labour force has shown that they hold important roles in these fields and in socio-economic development. As such, students need to be equally prepared and equipped to pursue STEM as a career. However, being able to equip all students to pursue STEM, especially female students, requires a change in the education system.

In the present time, most Vietnamese parents orient their children to traditional occupations (e.g. doctors, teachers, etc.) but they have not caught up with the development trend of careers in the STEM field. A survey by the International Labour Organization (ILO, 2016), 'National Programme on Educational Technology and Science, 2018', also showed that more Vietnamese students choose to study economics fields compared to engineering fields. STEM occupations are selected by only 23 per cent of male students and 9 per cent of female students. This is lower than the ASEAN country average, where 28 per cent of male students and 17 per cent of female students select STEM occupations.

Figure 2.3: Views on the role of STEM subjects in their future careers, by gender (elementary school students)



Note: 1 = 'Strongly disagree'; 2 = 'Disagree'; 3 = 'Neither agree nor disagree'; 4 = 'Agree'; 5 = 'Strongly agree'.

A Likert-scale was used to measure primary students' views on the influence of mathematics, sciences, engineering and technology in their future life and career. Figure 2.3 shows that most students agreed that mathematics, sciences, engineering and technology are important for their future and their career.

Students were also asked: 'Which career do you want to pursue?', with an option of twelve careers to choose, including: lawyer, actor, nurse, artist, designer, teacher, athlete, military, economist, engineer, computer sciences and scientist. Looking at Figures 2.4 and 2.5, it can be clearly seen that the percentage of female students who are interested in STEM-related occupations, such as engineering, computer science and science is much lower than male students. On the contrary, the proportion of female students who are interested in non-STEM careers, such as teaching, acting, etc., is much higher than that of males. For example, Figure 2.4 shows the percentage for an interest in engineering occupations at the elementary level is merely 17.6 per cent for female students, while it is 82.4 per cent for males.

Results show a large difference in primary students' views on the role of engineering and technology in their future learning and careers between males and females – but no difference exists between males and females in terms of mathematics and sciences' influence on their future learning and career.

Figure 2.4: Which career do you want to pursue? (elementary students)

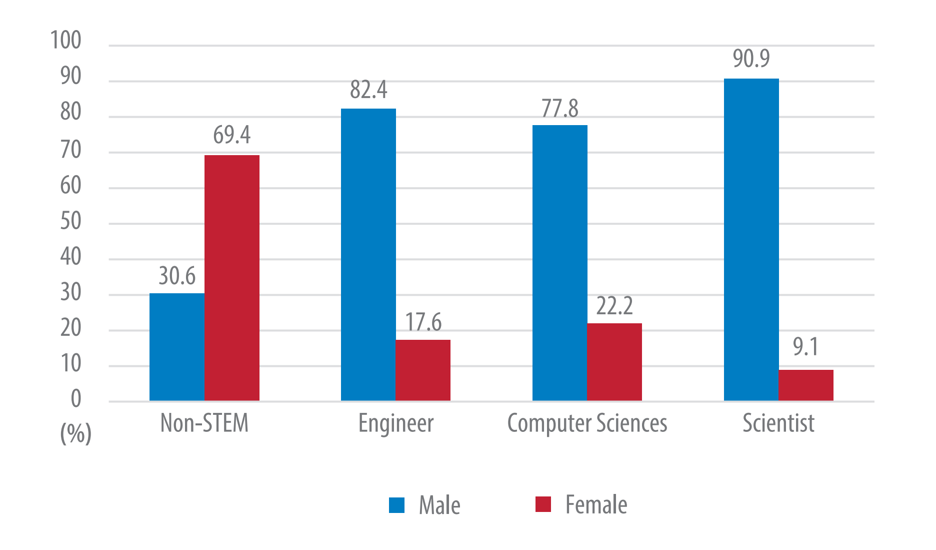
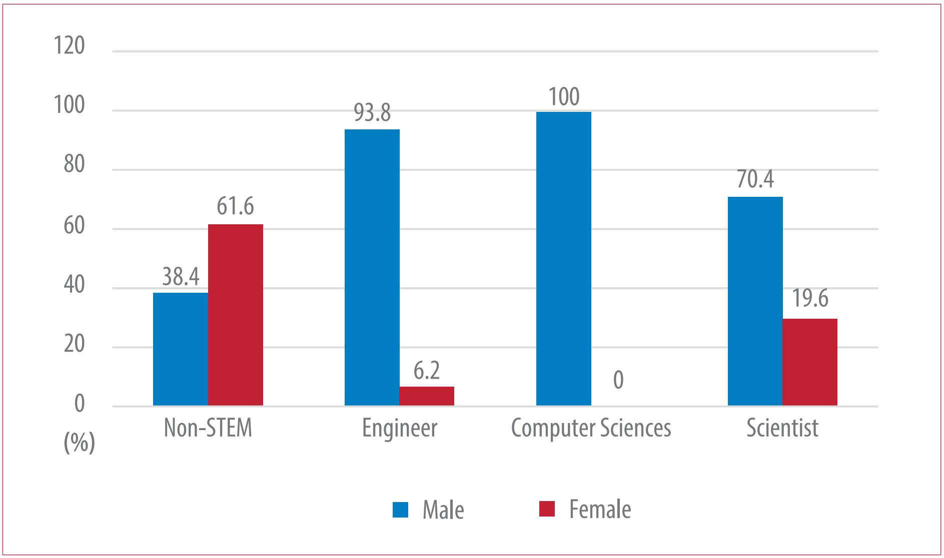


Figure 2.5: Which career do you want to pursue? (secondary students)

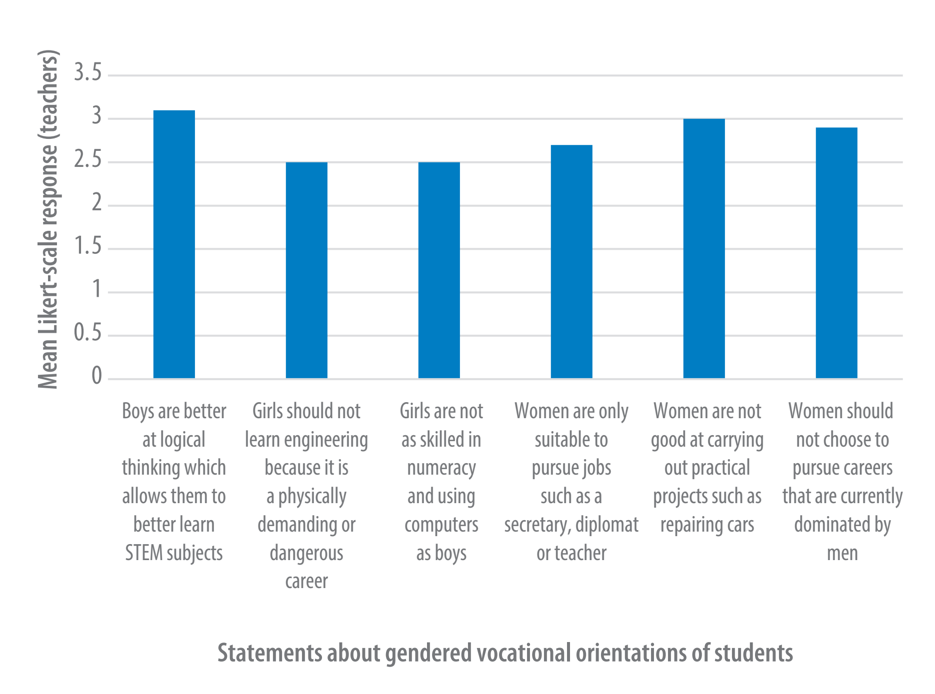


STEM has long been considered a 'field of men' and women are not seen as competent to thrive in this sector. To gauge this popular view, teachers were asked for their opinions on the reasons behind the different vocational orientations of female and male students, through the following statements:

1. Boys are better at logical thinking, which allows them to better learn STEM subjects.
2. Women are not good at carrying out practical projects such as repairing cars.
3. Women should not choose to pursue careers that are currently dominated by men.
4. Women are only suitable to pursue jobs such as a secretary, diplomat or teacher.
5. Girls should not learn engineering because it is a physically demanding or a dangerous career.
6. Girls are not as skilled in numeracy and using computers as boys.

However, Figure 2.6 shows that overall there was no consensus reached on whether any of these factors has any influence on the gender differences in participation or interest in STEM. This provides further evidence that cultural factors and gender inequality in society are the main barriers to girls and women embarking on STEM careers.

Figure 2.6: Teachers' views on gender differences between occupations



Please note: 1 = 'Strongly disagree'; 2 = 'Disagree'; 3 = 'Neither agree nor disagree'; 4 = 'Agree'; 5 = 'Strongly agree'.

Conclusions

Even though girls like STEM subjects and perceived themselves as performing well in mathematics, ICT, engineering and science, they tend not to choose these disciplines for their future educational development and subsequent careers. In Viet Nam there is often still a fixed idea on gender in the recruitment for fields related to STEM and for high-paying jobs and positions. In many cases, the employer specifies gender preference criteria in job advertisements and men are more likely to be preferred for occupations requiring higher technical and professional skills, such as for architecture, engineering and IT positions. This is despite the fact the performance of women is often higher than that of men. Results from both PISA 2015, as well as the 2015 Viet Nam National Examination highlight females posted better results in all subjects than males (OECD, 2016).

In general, the survey results show that most of the surveyed STEM teachers and teachers in the sample did not fully understand the concept of 'STEM education'.

Many teachers and school leaders were confused over the nature of STEM education, thinking it is a group of subjects that are taught independently. If teachers have a better understanding of integrated STEM education practices they can better implement them in class. With more STEM activities and a stronger foundation in STEM topics, students, particularly girls, may be more receptive of STEM careers.

Most of the respondents said that they do not have knowledge on the official documents and policies related to STEM education, despite 'STEM education' being mentioned in Official Letter No. 4099/BGDĐT-GDTrH, 5 May, 2014 of the MOET on 'Guiding the Implementation of Secondary Education Mission in the school year 2014-2015'. However, perhaps more importantly is the finding there was a significant bias from teachers who believed STEM careers are not suitable for girls. This is despite the fact the majority of the teachers were female. This indicates a strong cultural and social bias against women and girls and it has revealed a critical need to include intensive teacher training on STEM education and STEM education for girls.

In the surveyed schools, STEM education was usually carried out by teachers who included contents of other classes into their own subject material. There is almost no cooperation between teachers to undertake interdisciplinary topics. Teachers have not paid much attention to gender equality issues, for example, there are no specific measures to involve girls in STEM-related activities.

Through quantitative analysis, it can be acknowledged that the views of teachers on the factors that affect the vocational orientation of girls in STEM fields included two main reasons: (1) psychological-difficulties of STEM for girls; and (2) the influence of social and cultural factors.

Quantitative analysis reveals statistically significant differences in preferences between male and female students related to ICT, technology and science subjects. Preferences, attitudes, confidence, and career trends between them are most evident in engineering. This is significant in career trends where big differences in career choices were found between boys and girls.

The survey results show that although girls were very fond of mathematics and sciences, they did not want to choose STEM careers. This could be due to a number of reasons and is not necessarily caused by a lack of interest in STEM careers. For example, results of this research showed a significant bias from teachers – so it could be concluded that girls lack support from their teachers or schools. Given that the main barriers identified were social and cultural, it could also be true that there is a lack of support and encouragement from their families and communities as well. Based on the conclusions drawn from the current study, it is necessary to pursue the following course of interventions:

1. Develop a comprehensive, integrated STEM curriculum for Vietnamese general schools, including:
    - Policy-setting on STEM education in general and STEM education for girls in particular, (for example, funding support to facilities and teaching equipment associated with STEM education or policies to support female students after graduation to join STEM careers).
    - Training courses on STEM education, especially teaching strategies that encourage the participation of girls in STEM areas.
    - Development of instructional materials and associated instructional tools.
    - Synchronous development of facilities to ensure the effective implementation of STEM education in schools.
2. Raise awareness of stakeholders such as administrators, teachers, students and parents on gender equality in education in general and STEM education in particular. With better knowledge and awareness, policies are easier to implement.

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3

Perception, motivation and interest of male and female students towards STEM in Indonesia

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Introduction

STEM is a learning approach that integrates science, technology, engineering and mathematics subjects and it focuses on a learning process that solves real life problems. Science can be defined as the study of the natural world that includes observable and measurable phenomena within the universe. It is a tool used by scientists to understand objectively the ever-changing, natural world in which we live. Technology is about human innovation in action and it is everywhere. Technology is used to modify the natural world to meet human needs and wants. It is often used to make our lives better and safer. Engineering is the science, skills and profession of acquiring and applying scientific, economic, social and practical knowledge in order to design, build and maintain structures, machines, devices, systems, materials and processes. Mathematics is the science of patterns and relationships and it provides an exact language for technology, science and engineering.

The existing curriculum in Indonesia does not include engineering and technology subjects. Therefore, science and mathematics can be considered as the main subjects in the implementation of STEM education. In the Indonesian curriculum, STEM is not taught as a certain subject, but it is used as an approach where technology, engineering, and mathematics are incorporated in science learning. This kind of STEM implementation in Indonesia is called 'Integrated STEM Education'. Learning processes in this STEM education incorporate engineering, technology and mathematics and involve authentic problem-solving activities in social, cultural and functional contexts (Robert, 2012).

STEM education has been a SEAQIS concern in developing and improving teachers' competencies since 2015. As one of the centre's efforts in developing STEM education, in 2018, SEAQIS conducted STEM training for lower and higher secondary school teachers representing sixty-seven teachers' working groups from twenty-nine cities in nine Indonesian provinces. Thirty lower secondary schools and ninety higher secondary schools participated in this activity. During the training the participants were divided into three groups, based on the science subjects they taught in schools.

Furthermore, in the same year SEAQIS in collaboration with other SEAMEO centres in Indonesia – namely the Southeast Asian Ministers of Education Organization Centre for Quality Improvement of Teachers and Education Personnel in Mathematics (SEAQIM) and the Directorate of Lower Secondary School, Ministry of Education and Culture of Indonesia – held a STEM training event for teachers from 256 secondary schools in thirty-four provinces in Indonesia. This teacher training programme was intended to improve teachers' competencies in integrating STEM learning in the national curriculum. The centre also promotes STEM activities in schools to improve school community participation in solving local problems, such as creating smart watering systems, palm seed processors to process palm seeds into various types of food and activated charcoal from candlenut skin waste.

Although the STEM industry's future prospects remain promising, there are still challenges in attracting female professional workers to work in the STEM sector, despite the fact that increased participation of women, not only in STEM fields, has a positive impact on the economy as a whole (Duflo, 2012). According to Taylor (2016), this gender disparity in STEM fields is not due to differences in abilities, but differences in women's interest and confidence in the STEM fields.

This is in line with data presented by Google Inc. and Gallup Inc. (2016) that revealed students do not have significant differences in mathematical and scientific abilities, but they do have differences in interests and confidence in the STEM field. For example, only 19 per cent of female students majored in engineering, compared to 81 per cent of male students. (National Science Board, 2018).

A student's involvement in learning, not only STEM, is influenced by perception (Syaripah, 2016), motivation (Hoffman, 2015; Saeed and Zyngier, 2012; Vero 2017), and interest (Abrantes et al., 2006; Triarisanti and Purnawarman, 2019). Additionally, a student's involvement in a group can be associated with a level of collective intelligence (Aschcraft et al., 2016).

A student's attitude toward STEM is an important factor in influencing their motivation to learn STEM subjects and pursue a career in this sector. While there has been considerable research conducted about students' attitudes toward science (Osborne et al., 2003) and mathematics (Elci, 2017), there is less research available about female students' perception, motivation and interest in STEM. Therefore, this research aims to determine Indonesian lower secondary school students' perception, motivation and interest in each STEM education component (science, technology, engineering and mathematics) and to compare male and female results with relation to these three influencers.

Literature review

Students' learning of STEM subjects is intrinsically related to STEM programmes and the schools they attend. While conceptions of what STEM entails varies among researchers, educators and policy makers, there are two commonly accepted approaches to STEM education (Breiner et al., 2012; Sanders, 2009). The first approach, traditional STEM education, views STEM as four separate fields taught as traditional disciplinary courses. The second approach, integrated STEM education, is best elucidated by the following quotation from Sanders in 2019:

'…includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas and/or between a STEM subject and one or more other school subjects.'

Based on other previous research, discrepancy between male and female students in learning STEM might be caused by certain factors such as individual or environmental factors. Individual factors are strongly connected with students' psychology, for instance perception (Syarifah, 2016), motivation (Hoffman, 2015; Saeed and Zyngier, 2012; Vero, 2017) and interest (Abrantes et al., 2006; Triarisanti and Purnawarman, 2019) toward STEM subjects. Environmental factors are related to society and culture, such as STEM subjects being considered a 'masculine' field which results in different peer and teachers' attitudes toward female students in STEM learning activities.

Furthermore, there are multiple factors, either individual, or environmental, resulting in discrepancies between female and male students' learning of STEM disciplines. This research considers the three components of perception, motivation and interest and their influence on male and female students' learning of STEM subjects. These are described in more detail below.

Perception

Perception is an impression of an object that is obtained through sensing, organizing and interpreting the object that is accepted by the individual. Thus, it is a meaningful and integrated activity within the individual (Walgito, 2004). Often, technology and engineering are perceived to be 'male subjects', an assumption that unconsciously affects teachers, parents and people (Madara and Namango, 2016). With a connection to this perception, female students prefer to choose education, psychology and health as their majors in university (Castillo et al., 2014) and males consistently reported slightly more positive perceptions than females (Hoang, 2008; Mutodi et al., 2014).

Positive experiences are necessary for positive perceptions (Asrori, 2009). Robin (2015) declared the factors that influence perception as an individual target or object (stimulus) and situation. These factors need more attention to create more positive student perceptions toward mathematics. Learning activities need to accommodate each student's individual characteristics as they affect their perception. In the learning context, a teacher, as a target, can present clear, interactive and innovative learning materials, which helps students to absorb knowledge. The study environment is also an important factor, as by creating comfortable, pleasant and conducive conditions, students will be in a better position to acquire knowledge and have constructive learning experiences.

Motivation

Motivation is an important factor that drives human behaviour and determines insistence and the energy of humans' behaviour. (Sevinc et al., 2011). Motivational theory includes the influences that increase students' motivation, including the opportunity to try, participate and gain a feeling of achievement. This feeling of gratification will rouse learning motivation (Sukmadinata, 2011).

Interest

Interest is a condition in which a person pays attention to an object accompanied by a feeling of pleasure because it is considered to have benefits (Walgito, 2004). To develop personal interest, learning processes need to pay attention to factors that can increase interest such as making learning processes that allow students to assess their involvement in activities and creating satisfying and exciting experiences (Krapp, 2000, 2002b, in Budiamin, 2009).

Conversely, according to Bernard (Sadirman, 2018), experience and behavioural experience during learning activities encourages students' interest. This is supported by Krapp (2000, 2002b as cited in Budiamin 2009) who stated interest may appear if students consider they have a crucial role in learning activities, referring to rational consideration based on their values and emotional satisfaction. According to Bernard and Krapp, the average level of students' interest may indicate limited factors which have the capability to provoke their learning interest.

These findings form the background of SEAQIS' present study on the differences between female and male students' perception, motivation and interest toward STEM disciplines. Based on the findings of the literature review, the design of integrating STEM learning in Indonesia is through a process that incorporates technology, engineering and mathematics content into science subjects. This implementation takes into account the possible differences between male and females' perception, motivation and interest towards STEM in the learning environment. With a greater understanding of the impact of these three factors, female students can be more effectively supported during their STEM learning and gender inequalities can be better addressed.

Scope and methodology

As stated, the main purpose of this research is to explore the differences between female and male students' perception, motivation and interest in relation to STEM. This study addresses the following questions:

1. What is the difference between female and male students' perception, motivation and interest as a whole toward STEM subjects?
2. What is the difference between female and male students' perception toward STEM subjects?
3. What is the difference between female and male students' motivation toward STEM subjects?
4. What is the difference between female and male students' interest toward STEM subjects?

Instrument development and validation

Referring to the theoretical constructs of perception, motivation and interest as elaborated in the literature review, for this study we defined operationally, a student's perception of STEM as his, or her personal views about STEM on the basis of their involvement in STEM learning activities. We defined operationally, motivation as a student's personal tendency to take any actions or obtain their results immediately in dealing with STEM tasks. Finally, a student's interest about STEM learning was defined, operationally, as his/her expressions of wanting to be part of STEM activities in the future.

This research utilizes a five points Likert scale: ('strongly disagree', 'disagree', 'neutral', 'agree', and 'strongly agree') comprising forty-eight items to measure students' perceptions (thirteen items), motivations (fourteen items) and interest (eleven items) towards STEM components. Some questions include:

Sample questions on 'Perception':

- Technology and engineering: 'I am good when making or fixing things.'
- Mathematics: 'I am the type of student that can follow along during the mathematics course.'

These statements are individual student's personal views on STEM that are subjective. The students who voiced these agreements said technology and engineering are easy subjects which is construed to mean that creating and fixing products is easy. The statement about mathematics is also understood to mean that students find this discipline easy. Both the above statements are positive declarations because they recognize student's personal views that STEM is important, meaningful, fun and easy.

Sample questions on 'Motivation':

- Science: 'Outside of class, I also study and use science at home.'
- Technology and Engineering: 'I hope to continue learning engineering and repair electronic tools in the future.'

These questions contain high motivation indicators, such as spending more time to work alone, independently study outside class time, or employ more determination or passion in learning to achieve better results. Studying harder can be demonstrated by using knowledge gained from learning activities outside the classroom, or by practicing acquired knowledge in daily activities, such as fixing electronic devices.

Sample questions on 'Interest':

- Science: 'I will choose a science major in senior high.'
- Technology and engineering: 'I am curious about how an electronic item or gadget works.'
- Mathematics: 'During high school or college, I will enroll in study programmes that are mathematics-oriented.'

Both these samples illustrate the tendency or desire of the students to continuously be involved in STEM. This reflects a high interest, in which students who agree with this item are those who have a high interest in STEM fields and vice versa.

The survey's content was validated by five experts in related fields and construct validity was confirmed through a trial involving seventy-five respondents of lower secondary students. The Rasch model was employed to assess construct validity and the result showed that each of the survey items met reliability criteria.

Respondents

Three hundred and seventy students (143 males; 227 females) were selected from different cities in Indonesia as respondents of this study. The respondents were junior high school and senior high school students between the ages of thirteen to eighteen. They participated in STEM learning with teachers who had completed SEAQIS STEM training. In the context of this study, there is a possibility the type of STEM learning the students enrolled in was science-dominated. During the development of STEM projects, most of the issues dealt with were related to science. The survey was distributed through a WhatsApp group. The teachers then shared the link to students and asked students to respond to the survey via Google Forms using their own devices. The teachers also provided their responses based on questions on a Google Form. In total, seventy-eight teachers gave their responses.

Data analysis

Data provided by respondents was grouped on responses to STEM subjects and based on the dimensions of motivation, perception and interest. In total, there were nine analysed dimensions with perception, motivation and interest criteria. These are: 1) Students' perception toward science; 2) Technology and engineering; 3) Mathematics; 4) Students' motivation toward Science, 5) Technology and engineering; 6) Mathematics; 7) Students' interest toward science, 8) Technology and engineering, and 9) Mathematics. The data was analysed using a formula established by Syarifuddin (2012) which resulted in a classification of 'very high', 'high', 'moderate', 'low', or 'very low' for each data set. This analysis is detailed in Appendix 3-A on p 49.

Findings

Before discussing gender bias, it is important to find out collective students' perceptions toward STEM, whether positive or negative; students' motivation for STEM learning; and their interest in STEM learning, whether 'high' or 'low'. This study used a GLM statistics analysis tool that provides information about the contribution of independent variables toward the dependent variables as a whole, as well as individually. Therefore, the discussion starts with the contribution of gender toward perception, motivation and interest as a whole, followed by the discussion about the contribution of gender to each dimension toward STEM subjects.

Perception, motivation and interest by gender

The results of this test revealed that gender does contribute to the three dimensions of perception, motivation and interest in STEM subjects. To further determine which dimension and which STEM subject gender contributed significantly to, the follow section focuses on the contribution of gender to perception, motivation and interest toward STEM subjects. A summary table of the findings is included at the end of this section (Table 3.1). Additional information on the statistical analysis that led to these classifications can be found in Appendix 3-B on p. 50.

Perception by gender

As mentioned in the instrument development and validation section, we operationally defined a student's perception of STEM as his or her personal views on STEM on the basis of their involvement in STEM learning activities. Each student has different perceptions toward STEM, since perception is a subjective matter. Students have a positive perception toward STEM if they consider STEM learning is important, useful, joyful, or easy. On the other hand, students have a negative perception toward STEM if they consider STEM learning is unnecessary, boring, or difficult. A very high student perception toward STEM means students have excellent, or have very positive views of STEM. An average perception toward STEM means students have fair or neutral views on STEM and a low perception toward STEM means students have poor or very negative views of STEM. These conditions are also applied to a student's perception toward science when they learn STEM.

Results of the statistical analysis found both male and female students had a high perception towards science. This shows that students have a positive attitude towards science through STEM learning. It also indicates that students have the view that learning science is fun, easy and well-understood. This signifies that STEM learning provides broad knowledge and improves students' abilities in the field of science.

The next aspect is students' perception of technology and engineering. Both male and female students were found to have a high perception towards technology and engineering. This shows that students have the view that technology and engineering subjects can provide knowledge and skills in designing, developing and refining products that are useful and this positive outlook is a basis for obtaining a successful future career in this area.

While the perception for science and technology and engineering were categorized at the same level for both male and female students, the values between male and female students were different. In science, female students had a slightly higher value for perception, while in technology and engineering the finding for male students was greater. As these differences were found to be statistically significant, it is important to remember that although they may be in the same larger category, there is still a subtle difference in how these subjects are perceived by male and female students.

The final aspect of this component is students' perception of mathematics. The value for female students was classified as 'moderate', while the value for male students was classified as 'high'. This shows that female students have a fairly positive perception towards mathematics within STEM learning, although this may also indicate that they find mathematics more difficult to understand in comparison to other STEM subjects that were analysed. Male students are included in the high category, which indicates that male students have a positive perception of mathematics within STEM learning. This may indicate that male students consider mathematics easy to understand. The challenge is in increasing the perception of mathematics for female students because their perception level was still in the moderate category.

Motivation by gender

We operationally defined motivation as an individual student's personal tendency to take any actions or to obtain their results immediately in dealing with STEM tasks. Students are encouraged to make efforts to improve their learning activities in STEM learning. High or low motivation will be reflected in the student's behaviour. A high motivation in STEM learning will be seen from the attitude of these students as they should be more diligent and enthusiastic in learning activities. This section describes students' motivation towards science, technology, engineering and mathematics.

In science, both male and female students' motivation was classified as 'very high'. This shows that both male and female students have a very high motivation for science lessons. This also indicates that they tend to exhibit diligent behaviour in learning and completing tasks, not only at school but also at home independently. This finding also suggests that students also try to overcome any obstacles they face as an effort to understand the content of science lessons. Additionally, the differences between male and female students' motivation values were not significant, indicating that there may be less gender differences in students' motivation towards science.

Male and female students both showed very high motivation towards technology and engineering. This indicates their diligent behaviour in learning and completing assignments. The finding also implies they are highly motivated and have the ability to design a product, fix electronics devices and be creative. As with the results in motivation towards science, there were no significant differences between male and female students in terms of motivation towards technology and engineering.

Finally, regarding mathematics, it was fund that both genders had 'moderate' motivation. This indicated that students exhibited behaviour that is in line with an average standard in learning and completing mathematics assignments. Male and female students' effort to understand this discipline and have competence in it, in preparation for a future career in the mathematics field was not optimal. In line with findings from science and technology and engineering, male and female students did not show significant differences in their motivation towards mathematics.

Interest by gender

We defined operationally an individual student's interest about STEM learning as his or her expression of interest to be part of STEM activities in the future. This section will present the findings of an individual's interest in science, technology, engineering and mathematics.

Female students were found to have a high interest in science, while male students had a moderate interest. This shows that after participating in STEM learning, female students have a high interest in science, which indicates that they have a high desire to choose further education or jobs in STEM fields that require basic scientific knowledge, such as physical and chemical engineering. Whereas, they are not yet fully interested to continue their education or career in STEM fields that require a basic knowledge of science.

In technology and engineering, female students expressed a high interest, while male students showed a low interest. This indicates that female students have a high desire to choose further education or careers in a STEM field that requires basic knowledge of technology and engineering, such as architecture and civil engineering. The mean value of male students' interest was in a moderate category. This indicates that male students have an average interest in technology and engineering and are not yet fully interested enough to continue their education, or have a career in STEM fields that require a basic knowledge of technology and engineering.

Finally, in mathematics both male and female students showed a moderate interest in this subject. This indicates that both genders are not yet fully interested enough to continue their education or career in STEM fields that require basic mathematical knowledge, such as computer science and informatics engineering. Additionally, although both values were categorized as moderate, female students did have a higher interest in mathematics compared to their male counterparts, which indicates that gender differences do prevail in terms of interest in this subject.

Table 3.1: Summary of students' perception, motivation and interest in STEM subjects, by gender

	Subject	Male	Female	Statistical significance
Perception	Science	High	High	Females significantly higher
	Technology and Engineering	High	High	Males significantly higher
	Mathematics	High	Moderate	No significant difference
Motivation	Science	Very High	Very High	No significant difference
	Technology and Engineering	Very High	Very High	No significant difference
	Mathematics	Moderate	Moderate	No significant difference
Interest	Science	Moderate	High	No significant difference
	Technology and Engineering	Low	High	Females significantly higher
	Mathematics	Moderate	Moderate	Females significantly higher

Please note: In some cases male and female students are in different categories but their actual values did not show a statistically significant difference.

Conclusions

Although in many aspects of STEM, male and female students were categorized in the same level for perception, motivation or interest, it was noted that there were significant differences within the categories that indicated gender differences in students' perceptions and interest in STEM learning. The biggest differences were found in the perception of mathematics and the interest in science, technology and engineering.

In general, male students have a higher perception towards STEM learning than their female counterparts, with the exception of science where female students had a higher perception. Despite these differences, neither group of students showed a low perception of STEM learning, suggesting they have a positive attitude toward the subjects.

Regarding the motivation dimension, there were no significant differences between female and male students in any STEM subject. This suggests that both groups of students are equally motivated to study and excel in STEM learning.

There were significant differences between male and female students' interest in technology, engineering and mathematics. Regarding these aspects, female students had a higher interest. On the contrary, there were no significance differences between male and female students' interest in science.

Recommendations

To improve female students' perceptions of mathematics and to reduce gender differences in the perception of science, technology and engineering, it is important to build positive learning experiences in STEM learning. These positive learning experiences should accommodate individual student's characteristics and be clear, interesting, and innovative so students are engaged. Additionally, the teacher should also provide equal opportunities for all, especially female students, to participate in hands-on activities, particularly in engineering and in using technological devices.

To improve students' motivation in mathematics, integrated teaching between science, mathematics and technology needs to be considered, particularly to promote the role of mathematics in these disciplines. Additionally, the STEM curriculum should emphasize the role of mathematics in various careers or study disciplines, as a better understanding of this subject's role in future career or education may help to motivate students.

To improve students' interest in STEM learning, especially male students' interest, topics in STEM learning should be varied and balanced. The variety and balance of topics should give students an equal opportunity to explore comprehensive knowledge and experience during the learning process. Other methods of improving students' interest in STEM should also be investigated in future research and by education practitioners in their classrooms.

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Appendix 3-A

Data analysis process

1. The data was collected from a survey. The data was ordinal data which has a limitation in statistics analysis using GLM Multivariate. Thus, the data was converted into interval data by using the Rasch model with Winsteps v3.73 software.
2. The converted data was then processed to determine the mean value; standard deviation value; and significance value using SPSS v26 software.
3. To determine the level of students' perception, motivation and interest toward STEM subjects, the processed data was analysed using formulation raised by Syarifuddin (2012). Based on Syarifuddin (2012), the data is classified based on each dimension of STEM subjects. The classification process will result in nine data sets and it will be displayed into nine classification tables. The dimensions of STEM subjects are: 1) Students' perception toward science; 2) Technology and engineering; 3) Mathematics; 4) Students' motivation toward science; 5) Technology and engineering; 6) Mathematics; 7) Students' interest toward science; 8) Technology and engineering; and 9) Mathematics.
4. The mean value of each data set of STEM dimensions was then compared with classification table levels to determine the level of students' perception, motivation and interest toward STEM subjects. For example, to determine the level of students' perception toward science, the mean value in the data set of students' perception toward science was compared with the level in the classification table of students' perception toward science to determine if their perception is 'very high', 'high', 'moderate', 'low', or 'very low' levels (see Table 3.2). The result from one data set can not be compared with other data from different STEM dimensions.

The formulas used in the categorization are identified in the table below.

Table 3.2: Formula used to categorize level of perception, motivation and interest in STEM subjects

	Formula	Category
	$+1.5\ \sigma < \mu$	Very High
	$+0.5\ \sigma < \mu \leq +1.5\ \sigma$	High
	$-0.5\ \sigma < \mu \leq +0.5\ \sigma$	Average
	$-1.5\ \sigma < \mu \leq -0.5\ \sigma$	Low
	$\mu < -1.5\ \sigma$	Very Low

Please note: **μ**: Mean; **σ**: Deviation Standard

5. The last step was analysing the significance value to detect the existence of gender bias. Further analysis was conducted to test the significance of gender differences of those three dimensions toward STEM subjects using SPSS v26 by running GLM Multivariate. Pallant (2010) stated the GLM is the regression where the dependent variable is related to the independent variables. In this study, the independent variable is gender and the dependent variables are perceptions, motivation and interest toward STEM subjects**.** This study provides information about the contribution of independent variables toward the dependent variables as a whole, as well as individually.

Appendix 3-B

Analysis results

Perception

Table 3.3: Students' perception of science

Gender	Perceptions	
	Science	
	Mean	Category
Female	0.70	High
Male	0.61	High
Significance	**0.014**	

Table 3.3 shows the statistical data calculation results of students' perception toward science. From the table, it is shown that the mean value of the female students is 0.70 and the mean value of the male students is 0.61. This mean value is in the range of +0.43 and +1.29 and categorized as a 'high' level based on the classification table developed using Syaifuddin's formula. In addition, it is found that the significance value is 0.014 and smaller than 0.05. This means there are differences in the perceptions of male and female students engaged in science.

Table 3.4: Students' perception of technology and engineering

Gender	Perceptions	
	Technology and Engineering	
	Mean	Category
Female	1.12	High
Male	2.00	High
Significance	**0.017**	

In Table 3.4, it is seen that the mean values for male and female students are 1.12 and 2.00 respectively. Based on the classification table, both values are included in the high category because they are in the range of +0.71 to +2.13. The significance value of students' perception of technology and engineering is 0.017. Because the value is less than 0.05, this means there are differences in the perceptions of male and female students engaged in technology and engineering.

Table 3.5: Students' perception of mathematics

Gender	Perceptions	
	Mathematics	
	Mean	Category
Female	-0.06	Moderate
Male	0.09	High
Significance	**0.073**	

Table 3.5 indicates students' perception toward mathematics. Table 3.5 shows that the mean value for female students is -0.06 and for male students it is 0.09. The mean value of female students is categorized as 'moderate' because it is in the range of -0.64 to +0.64. Male students are included in the 'high' category because the mean value is in the range of +0.64 to +1.91. The significance value is 0.073 and it is greater than 0.05.

Motivation

Table 3.6: Students' motivation toward science

Gender	Perceptions	
	Science	
	Mean	Category
Female	2.54	Very High
Male	1.94	Very High
Significance	**0.053**	

Table 3.6 shows the results of data analysis about students' motivation in science. Based on Table 3.6, the mean values of females and males are 2.54 and 1.94 respectively. Both values are categorized as 'very high' because they are greater than +1.85. Furthermore, Table 2.6 also shows a significance value of 0.053. The significance value is greater than 0.05, which indicates that male and female students do not show significant differences in their motivation towards science.

Table 3.7: Students' motivation toward technology and engineering

Gender	Motivation	
	Technology and Engineering	
	Mean	Category
Female	6.41	Very High
Male	5.86	Very High
Significance	**0.085**	

From Table 3.7, it is found that the mean values for females and males students are 6.41 and 5.86 respectively. These values are greater than +4.82 so they are included in the 'very high' category. Table 3.7 also shows a significance value of 0.085 which is greater than 0.05. It indicates that there are no significant differences between male and female students in terms of their motivation towards technology and engineering.

Table 3.8: Students' motivation toward mathematics

Gender	Motivation	
	Mathematics	
	Mean	Category
Female	0.80	Moderate
Male	0.84	Moderate
Significance	**0.422**	

Table 3.8 informs the data processing result of students' motivation towards mathematics. Based on Table 3.8, it is found that the mean values for females and males are 0.80 and 0.84. Both values are in the range of -0.99 to +0.99, which indicate the 'moderate' category. This shows that the motivation of male and female students towards mathematics is 'moderate'. The significance value is 0.442, which is greater than 0.05 and this indicates that both male and female students do not show significant differences in their motivation towards mathematics.

Interest

Table 3.9: Students' interest in science

Gender	Interest	
	Science	
	Mean	Category
Female	1.87	High
Male	1.54	Moderate
Significance	**0.392**	

Based on Table 3.9, it is found that the mean values of female and male students are 1.87 and 1.54 respectively. The mean value for females is in the 'high' category because it is in the range of +1.61 to +4.82. The mean value of male students' interest is in the 'moderate' category because it is in the range of -1.61 to +1.61. This shows that male students have a 'moderate' interest in science. Furthermore, the significance value obtained is 0.392 and this value is greater than 0.05, which indicates that male and female students do not have significant differences in their interest in science.

Table 3.10: Students' interest in technology and engineering

Gender	Interest	
	Technology and Engineering	
	Mean	Category
Female	2.46	High
Male	1.75	Moderate
Significance	**0.014**	

Based on Table 3.10, it is found that the mean values of female and male students are 2.46 and 1.75 respectively. The mean value of the female students' interest is in the 'high' category because it is in the range of +1.79 to +5.37. The mean value of male students' interest is in a 'moderate' category because it is in the range of -1.79 to +1.79. The significance value obtained is 0.014, and this value is smaller than 0.05 which shows that there are significant differences between female and male students' interest towards technology and engineering.

Table 3.11: Students' interest in mathematics

Gender	Interest	
	Mathematics	
	Mean	Category
Female	0.41	Moderate
Male	-0.47	Moderate
Significance	**0.031**	

Based on Table 3.11, the mean values for female students and male students are 0.41 and -0.47 respectively. Both values are in the 'moderate' category because they are in the range of -1.12 to +1.12. This shows that both females and males have a 'moderate' interest in mathematics. The significance value obtained is 0.031 and this value is smaller than 0.05, which shows that male and female students have significant differences in their interest towards mathematics.

4

Girls and women in STEM in Lao PDR

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Introduction

Within the context of the Education for All (EFA) agenda, the importance of education for girls and women has been extensively researched and documented – with strong recognition of education as one of the most effective means of development, not only for girls and women, but also for their communities and wider society. Lao PDR has recognized the need to develop inclusive and accessible education as a key means of graduating from one of the least developed countries (Ministry of Education and Sports, 2015). As former UNESCO Director-General Irina Bokova stated: 'Education for girls and women is a basic right and the best possible investment for human development.' Moreover, SDG 4 and SDG 5 draw attention to inclusiveness, equality in education and lifelong learning opportunities for all, as well as gender equality and the empowerment of all women and girls.

UNESCO recognizes that achieving the 2030 Agenda requires 'the cultivation of transformative, innovative and creative thinking and skills and competent and empowered citizens' (UNESCO, 2017). Better education levels directly contribute to maternal health, reduced child mortality, improved nutrition and an increase in the potential workforce, thereby creating enhanced opportunities for socio-economic growth (Asian Development Bank, 2017). The 'smart economics' of gender equality is well recognized and the inclusion of girls and women in Science, Technology, Engineering and Mathematics (STEM[3]) is therefore a necessary human right, essential to the development of scientific knowledge and ultimately supporting the achievement of the SDGs (UNESCO, 2017).

3 STEM refers to the subjects or fields of study of science, technology, engineering, and mathematics. This generally refers to these subjects individually but can also extend to them being taught in an integrated way. In the context of this study, STEM education refers to educational activities including teaching and learning of science, technology, engineering and mathematics in all grade levels from secondary to tertiary education and STEM careers refer to any career in science, technology, engineering and mathematics.

While current research has reported the participation of girls and women in STEM education from several countries, such as Cambodia, Indonesia, Mongolia, Nepal, the Republic of Korea and Viet Nam, Lao PDR was not originally included in a study published by UNESCO in 2015 on the current status of the participation of girls and women. Also, the Lao government has emphasized that to compete in a global economy, STEM education and careers must be a national priority. However, among the many initiatives led by the Lao PDR government and its development partners, STEM for girls and women has received little focus. Such scarcity results in difficulties for policymakers to find suitable solutions to encourage girls and women to participate in STEM education.

In order to enlighten knowledge and the understanding of the scope of existing barriers to the involvement of women and girls in STEM and potential solutions to support their engagement in key STEM subjects and professions, the Ministry of Education and Sports (MOES) of Lao PDR, via the auspices of the SEAMEO Regional Centre for Community Education Development (SEAMEO CED), proposed a project to conduct a preliminarily study from August to November 2019 to map the current role of girls and women in STEM and document potential strategies to improve their engagement in the future.

Literature review

Prior research on girls and women in STEM education

General studies on the engagement of women and girls in STEM have highlighted issues with socialization and learning (education) processes (Asian Development Bank, 2017). Social and cultural norms have a significant role in the decision making of girls and women in STEM subjects. A study published by UNESCO Bangkok in 2015, entitled *A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia* gave an overview of the current status of the participation of girls and women in the field of STEM. According to the study, although there may be equality in terms of gender at the primary and lower secondary school levels regarding STEM-related subjects, the proportion of female students choosing these disciplines declines at every stage of upper secondary and higher education, which is then reflected in the proportion of women pursuing STEM-related careers.

The UNESCO Bangkok publication also referred to a study conducted in fourteen countries by the Boston Consulting group, which found that on average, female students in upper secondary have a 35 per cent probability of enrolling in STEM; an 18 per cent probability of graduating with a bachelor's degree in a science-related field; an 8 per cent probability of graduating with a master's degree in science; and a 2 per cent probability of completing a doctoral degree in science, compared to 77 per cent 37 per cent; 18 per cent; and 6 per cent respectively for males.

Role of gender differences in STEM higher education and careers

Gender differences in STEM begin in the performance of students, as young as fifteen-years-old, in subjects such as mathematics and science. Girls tend to do relatively better in science as opposed to mathematics and tend to choose science-related fields of study in higher education as opposed to more mathematics-oriented fields – a tendency reflected in the labour market. It could be observed among many countries in the Asia-Pacific region that there are more women in science-based STEM fields compared to mathematics-based STEM fields (UNESCO Bangkok, 2015).

According to the aforementioned literature, the participation of girls and women in STEM at all levels of education is low and the rate of participation decreases as the level of education rises. Similar trends persisted in the choice of careers for women in the labour market; where women achieving higher level managerial and decision-making positions are largely absent. For instance, higher proportions of females are found in pharmacy, medicine and biology, yet remain under-represented in other areas such as computer science, physics and engineering.

Obstacles in STEM education of girls and women in Lao PDR

The preamble of the 1991 Constitution of the Lao People's Democratic Republic recognizes the importance and value of education which is also reiterated by the Education for All National Review 2015: 'Education, cultural and scientific activities are the means to raise the level of knowledge, patriotism, love of the people's democracy, the spirit of solidarity between ethnic groups and the spirit of independence' (Ministry of Education and Sports, 2014). Lao PDR has made impressive progress in terms of closing the overall gender gap in the country by 91 per cent (World Economic Forum, 2018) yet anecdotally there are significant disparities in terms of school dropout rates at the lower secondary level (before students enter into upper secondary education and onto higher education).

Despite meeting the Millennium Development Goals target of universal access to primary education – with a net enrolment in primary education reaching 98.7 per cent (2017) – Lao PDR still has some of the poorest education indicators in terms of secondary gross enrolment and primary survival or completion (Lao Women's Union, 2018). Many students also do not speak the Lao language, which is the official language of instruction. Moreover, many of the existing projects and programmes have been focused on developing school infrastructure and teachers as opposed to programme management (St George, 2015). Likewise, there are progressive dropout rates among girls with the gross enrolment ratio at the primary level at 100.43 per cent declining to 75.23 per cent at lower secondary and 51.13 per cent in upper secondary (UNESCO Institute for Statistics, 2019).

The high repetition and dropout rates in primary grades are strongly influenced by limited access to education opportunities and significant competition with economic opportunities (SEAMEO CED, 2019). As discussed above, this predominantly occurs in rural areas where economic priorities are perceived by students, their families and surrounding communities to conflict with education, especially in marginalized communities where children are obligated to help their parents earn an income. The quality of primary education is another major concern, as well as teachers and principals' limited capacity, a weak pedagogical supporting system, multi-grade teaching and a lack of learning materials (SEAMEO CED, 2019). These constraints shape the future participation of girls and women in STEM education at the higher education level and career path.

Research framework

The research framework of this study is largely adapted from the broader UNESCO study published in *A complex formula*. This approach is deliberately taken in order to ensure that results from the country-based report in Lao PDR could be comparable regionally. The earlier UNESCO study involved an analysis of educational factors including education policies and programmes on girls' education and initiatives promoting girls' learning in mathematics and science; the school environment in regard to teachers' attitudes, analysis of teaching and learning materials and teaching conditions and activities intended to enhance learning in these subjects; career orientation, including the role of teachers and the school; as well as existing career counselling, mentoring and scholarship programmes.

Methodology

This study is divided into two different stages. The first stage is a desk study. This stage sought to review STEM education from a longer-term perspective, integrating all stages of education, from primary to secondary schooling, university and vocational education, to future employment and research within the Lao context. Without an accurate understanding of the overall sector, initiatives to increase women and girls' involvement in STEM ultimately fail as the interventions are either too short-term, poorly coordinated or even contradictory. Stage two was divided into two methods: interviews and a survey that addresses the lack of research on student and teachers' attitudes towards STEM education. As this is a preliminary study, it is important to see a bigger picture of the role of girls and women in STEM education in Lao PDR and subsequently identify research gaps that need to be addressed.

First stage study

The purpose of this stage is to conduct a desk study based on the framework of the broader UNESCO Bangkok study and focus on the following factors within the context of Lao PDR:

1. Psychosocial influences, including student attitudes, self-belief, motivation and aspiration towards mathematics and science subjects.
2. Labour market effects, including the proportion of female professionals in STEM fields, both by occupation as well as by type of employment.
3. National level policy documents.

A literature review was conducted in August 2019 which aimed to provide a summary and an analysis of existing research on the status of girls' and women's access, participation, learning and achievement and progression in STEM. The literature review was carried out independently by a researcher from Universiti Kebangsaan Malaysia (UKM) (the National University of Malaysia) in August 2019 to assess the available evidence on STEM education in Lao PDR.

The desk study results show that currently there is no specific research or data on Lao PDR on the current status of girls and women in STEM fields, except some training programmes related to ICT. For instance, one was provided by the U.S Embassy in 2019 to Lao youth to increase awareness of technical skills. Therefore, the following research recommendations have been made:

1. More research is needed on student and teachers' attitudes and teaching and learning conditions.
2. A greater understanding is needed on how policies related to education, gender and STEM are designed and implemented in Lao PDR.
3. A review of existing funding and investment in infrastructure, equipment and resources is needed.

The development plan of MOES (2015) reports the achievement of its implementation plan from 2011 to 2015 in early childhood care and education, primary and high school education and so on. However, the report on STEM fields is missing. This present study, therefore, concludes that so far there is little published data on the participation of female students in STEM fields at all levels of education, especially lower secondary, higher secondary and higher education and the proportion of females and males who pursued STEM-related careers and professions. Given this limitation, it was decided at this point that a quantitative survey and qualitative interviews were required in order to better understand the performance of female students in mathematics and science and to explore any potential educational, social and demographic characteristics or psychosocial (attitudinal) and labour market factors related to gender and STEM. Therefore, the second stage is focused primarily on the first recommendation – research into student and teachers' attitudes.

Second stage study

Descriptive statistics

According to the results of the first stage study, the second stage study aims to understand student and teachers' attitudes. The selective target samples include students and teachers residing in Vientiane Capital and Champasak province. These areas were selected due to the project's limited time frame and the funding available. Also, within each case study province, a university and series of secondary schools were selected to ensure samples with various demographic characteristics. Table 4.1 shows details of the regions and schools. The samples were recruited in Vientiane Capital and Champasak province as these areas represent both urban and rural areas. Three schools (Sathit Secondary School, Vangtao Secondary School and Kengkhang Primary School) and two universities (National University of Laos and Champasak University) were selected.

Table 4.1: Participating schools

No.	Region	Educational level	Name	Urban	Rural
1.	Vientiane Capital	Secondary school	Sathit	✔	
		University	National University of Laos	✔	
2.	Phonethong District, Champasak Province	Primary school	Kengkhang		✔
		Secondary school	Vangtao		✔
	Champasak Province	University	Champasak University		✔

Overall, 112 female students from schools and universities participated in the survey. The school students came from grades one to twelve, with the majority in grade eleven (20 per cent); grade 10 (15 per cent); and grade 12 (13.3 per cent). The university student participants were from year three (48.1 per cent); year two (28.8 per cent); and year four (23.1 per cent). The age of the school participants ranged from five to fifteen years-old and from eighteen to twenty-two years-old for the university students. Fourteen teachers and lecturers participated in the interviews and these individuals taught at the National University of Laos and Champasak University, in different faculties and departments (see Appendix 4-A, p.77, for more details on the participant's demographics).

Sample and data collection

Interview

To understand the attitudes of teachers towards STEM, the interview method was adopted and key universities in each of the selected provinces were enlisted. These were the National University of Lao and Champasak University. A total of fourteen interviews were held with lecturers and researchers, including more experienced researchers and lecturers, as well as early career researchers. Four open-ended questions were formulated (i.e. gender imbalances; perceptions that woman should not follow certain careers; scholarships and economic needs driving study choices; and private corporations influencing study and career choices) and these were used to interview the participants.

Survey

An online survey (Google Form) in the Lao language was applied to collect data on the attitudes of students towards STEM education. The members of the research team randomly approached each target sample and asked them to participate in an online survey. Tablets and smartphones were used to open the online survey link with the assistance of researchers. There were two different sets of questionnaires; one for university students and the other for those in primary and secondary schools. The university student questionnaire contained seventeen questions, with five questions used to measure students' perceptions and views about areas such as study, grades, the importance of STEM, STEM instructors and parents and family. The school student questionnaire contained more items which were grouped into three sections. The first section asked general questions, such as grade level, name of school, etc. The second section obtained students' perceptions related to mathematics and the third section collected information on their future careers. Both employed a five-point Likert scale ranging from one as 'strongly disagree' to five as 'strongly agree' to measure the perception items and 'yes' and 'no' questions. The questionnaire was widely adapted from the aforementioned 2015 UNESCO study.

Data analysis

The interviews were documented and the main points that are related to the objectives of this research are reported. Collected data from the survey was analysed using different statistical approaches in Statistical Package for Social Sciences (SPSS) for formatting, analysing and presenting the results. Descriptive statistics were calculated in the form of the percentage and mean scores against each Likert-scale category for each question. Also, cross tabulation was performed to identify the depth and breadth of understanding towards respondents.

Findings and discussion of results

Interview results

As a result of the interviews, some key points on STEM education and its influential outcomes in Lao PDR can be summarized as follows:

Sociocultural roles lead to gender imbalance

Gender and access issues appear to occur throughout the education system and a major concern is not only about education pathways but also how to address the lower participation and learning achievement of girls and women in STEM (UNESCO, 2017).

In terms of gender imbalance, caring responsibilities (i.e. childcare or homecare) tend to make women reluctant to pursue a higher education in STEM. According to the interview given by a senior lecturer: 'my partner is also a lecturer in mathematics but from a different faculty. If there are opportunities such as training or other forms of capacity building, I will have to sacrifice for my partner to receive the opportunity first because as a mother and as a woman I want to care for my child.'

Often, women will sacrifice their own career or education advancement so their partners can take advantage of the new opportunities. This could be because there are only funds to financially support one partner, or because there is a need for one partner to take responsibility for childcare or household chores, leaving little time or money for the other partner to advance in their field. More often, it is women who will sacrifice their advancement for their male partners. There have been a number of high-level reports that have noted issues with access to education, especially in rural and, or ethnic communities, in terms of investment and educational services, regional disparities gender stereotypes in secondary and tertiary education, as well as vocational training and adult female literacy (Lao Women's Union, 2018).

Scholarships and economic need driving study choices

As an emerging economy, Lao PDR has previously focused on building its cohort of teachers through specific scholarship programmes that promoted the uptake of teaching in STEM related fields over the last twenty years. In particular, many of the senior lecturers and academics who were interviewed had selected STEM careers based on the availability of scholarships, even where a career in STEM teaching may have been a secondary preference. They also noted that it was unclear what options they had in terms of future study or careers – reflecting the lack of maturity of the STEM sector itself.

Perception that woman should not follow certain careers

In the Lao PDR research, conceptions of STEM from students, their families and communities included peer pressure to study subjects, such as banking or finance, in order to enter into well-paid private sector roles at national corporations in the country, such as BCEL, a large state-owned commercial bank. However, researchers and lecturers were also driven by their passion, hopes and dreams to create changes within Lao society and develop students and human resources in their specific fields. One female hydropower and engineering academic noted she had always been aware of the challenges facing a woman to succeed in the STEM field. However, the view was expressed that there was always a passion for work: '[In my hometown] there was no electricity and this maybe became one good use [of my education] after graduating in this field… I persisted to study this major even if the class had only one woman in the classroom, me.'

Private corporations influencing study and career choices

According to respondents, in Lao PDR, career choices in STEM fields are largely influenced by perceptions of future potential to earn a high income, as well as expectations established by large employers. For example, some participants expressed the view that larger mining companies in Lao PDR tended to employ more men than women, with gender being a criterion for recruiting staff. One interviewee made the following comment based on personal experience: 'after completing my internship at the mining company, if I was a man they would [have] hired me as a permanent staff. The reason that I didn't get hired is because the job description was only suitable for men as they are stronger and they can work more long hours.'

Furthermore, the majority of interviewees reported that where private companies sought specific graduates, they also tended to be biased and demanded graduates in specific fields, such as chemistry, based on the perception that these graduates are 'better'. Engineering graduates have also been seen to be increasingly favoured – especially hydropower and civil engineering which is consistent with the major infrastructure projects implemented in Lao PDR. This alludes to the powerful impact of a surrounding environment on study and career choices – especially within a developing context where career options are limited.

Survey results

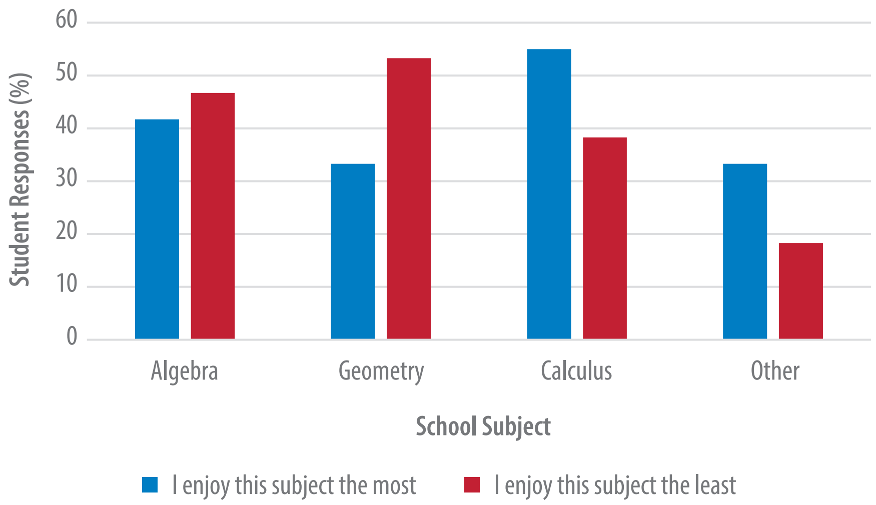
The results of the surveys are reported by question topic to allow for a comparison of the results. Given the similarity of the questions between the school student and university student surveys, the responses are represented in the same graph to emphasize trends in the data. Notes are made where there are differences in the questions asked between the surveys. For questionnaire responses a common scale is used where 1 = 'strongly disagree', 2 = 'disagree', 3 = 'not sure', 4 = 'agree' and 5 = 'strongly agree'.

General questions

Within this section, respondents were asked about the tutoring they received outside of the school environment. Tutoring outside of school hours was considered important in this stage of schooling, as reported by primary and secondary school students. Sixty-five per cent had received tutoring from a private tutor. Mathematics (18.3 per cent) was the subject students received the most tutoring in; followed by chemistry (15 [per cent); biology (11.7 [per cent); and physics (1.7 per cent). The reason students received tutoring was because they wanted to learn school subjects better (45 per cent) and their parents chose it for them (11.7 per cent). This finding indicates students have a desire to improve their school grades and personal achievement.

To understand the students' feelings towards various topics, they were asked to express their feelings for an individual topic by assigning each one as either 'I enjoy this topic the most', or 'I enjoy this topic the least'. In Figure 4.1 it can be seen that over half of the students expressed their feelings for calculus as 'I enjoy this subject the most' (55 per cent) and this was the most enjoyed topic of those provided in this question. On the other hand, the students expressed enjoying geometry the least (53.3 per cent), followed by algebra (46.7 per cent). This finding shows the range of feelings towards STEM topics and how the students express their feelings for them. This is critical to know as it is possible that when the school students do not enjoy a STEM topic (i.e. geometry), they may not to attempt it. This could possibly have an impact on their grades.

Figure 4.1: Students' subject preferences



Attitudes of the students

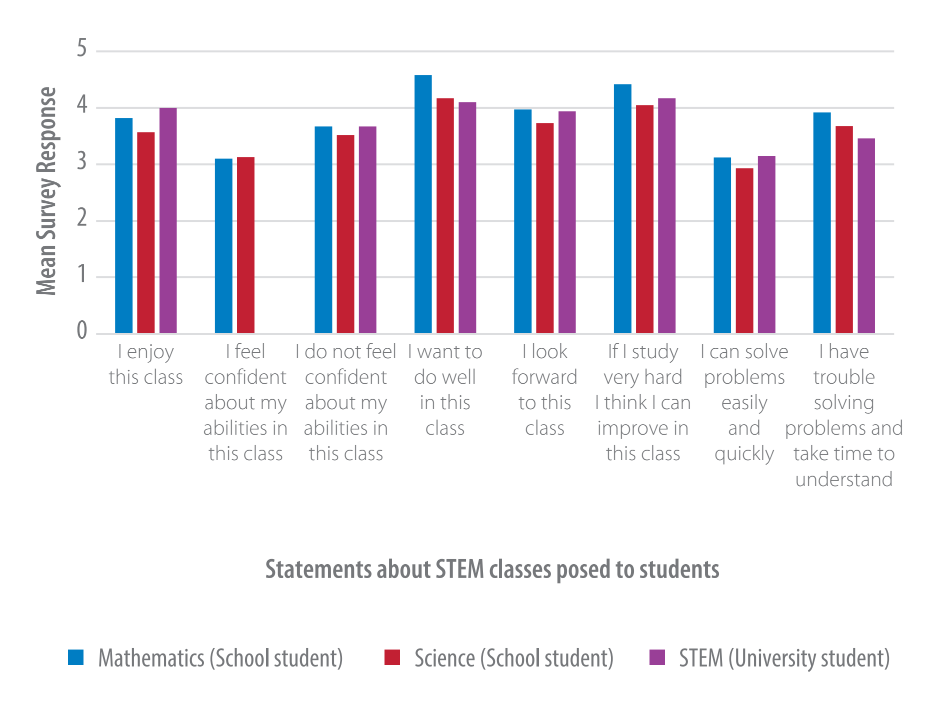
These questions are designed to understand the attitudes of the students toward mathematics, science and STEM classes. A summary of the results is reported in Figure 4.2.

Mathematics Class: The findings showed that 93.4 per cent of the respondents agreed that they wanted to do well in mathematics and 88.3 per cent agreed that if they studied hard they could improve in mathematics. The investigation revealed that 73.3 per cent of the samples agreed that they looked forward to the mathematics class and 61.7 per cent agreed that they enjoyed the mathematics class. Seventy-five per cent agreed that they had trouble solving mathematical problems and took time to understand these; 50 per cent agreed that they did not feel confident about their abilities in mathematics; and 28.3 per cent agreed that they could solve mathematics problems easily and quickly. However, only 25 per cent agreed that they felt confident about their abilities in mathematics.

Science Class: The results showed that 83.3 per cent agreed that they wanted to do well in science and 75 per cent agreed that if they studied very hard they thought they could improve in science. On the other hand, 20 per cent agreed that they could solve science problems easily and quickly. This might indicate that they tended to have trouble solving science problems and took time to understand them.

University students: Analysis results showed that 88.5 per cent of university students agreed that if they studied very hard they thought they could improve and 86.5 per cent agreed that they wanted to do well in their studies and looked forward to class. In addition, 84.6 per cent of the respondents agreed that they enjoyed their studies and only 36.5 per cent of them reported that they agreed they had trouble solving mathematical and other science problems and took time to understand them. The question: 'I feel confident about my abilities in this class', was not posed to university students.

Figure 4.2: Students' attitudes towards STEM subjects/classes



Please note: 1 = 'strongly disagree' and 5 = 'strongly agree'.

In considering the results between mathematics and science classes for school students, students seemed to enjoy mathematics slightly more and have a stronger desire to do well in this subject. However, they had less confidence in mathematics compared to science. In comparing the results between school and university students, it can be suggested there was very little difference in the attitudes of students towards STEM classes as they advanced through their education.

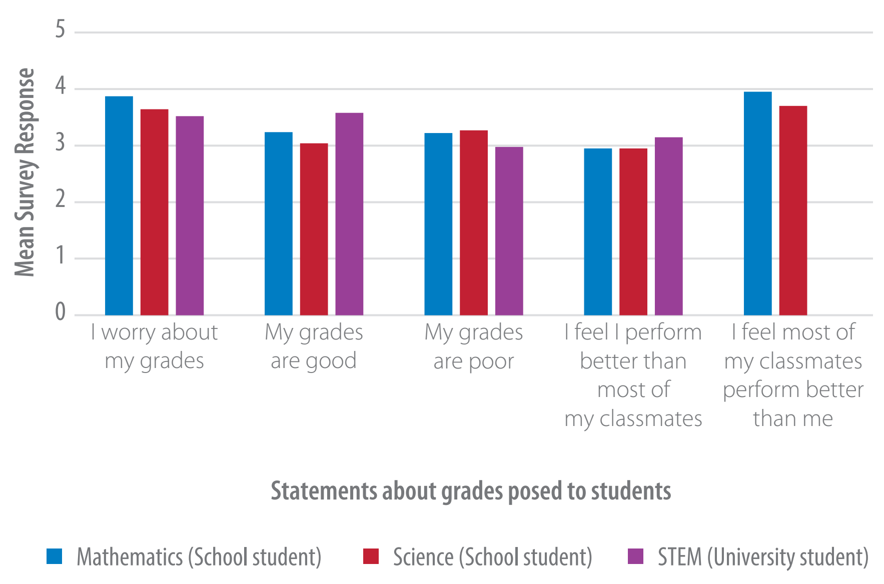
Attitudes of students towards grades

Mathematics class: While students wanted to do well in mathematics, 73.4 per cent agreed that their peers performed better and 66.7 per cent agreed that they worried about their grades. In addition, while 30 per cent agreed that their grades were good, 41.6 per cent agreed that their grades were poor. This may be because competition in the class discourages their self-efficacy in mathematics performance (see Figure 4.3).

Science class: The findings of this section indicated that 58.3 per cent of students agreed that they worried about their science grades and 55 per cent agreed that they felt most of their classmates performed better in science. Furthermore, 40 per cent agreed that their grades in science were poor.

University students: The findings indicated that 63.5 per cent of university student respondents agreed that they worried about their grades. In relation to this, 36.5 per cent of them agreed to the statement that they felt they performed better than their peers. While 34.6 per cent of the participants agreed that their grades were poor and 59.6 per cent agreed that their grades were good. The question: 'I feel most of my classmates perform better than me', was not posed to the university students.

Figure 4.3: Students' attitudes towards performance/grades



Note: 1 = 'strongly disagree' and 5 = 'strongly agree'

In looking at Figure 4.3, it can be seen that there were similar responses to the questions: 'My grades are good' and 'my grades are poor', with students, on average, agreeing with both statements. This could imply that the students are uncertain if the grades they receive are good enough in comparison to their classmates' performance. This could be due to the students tending to be worried about their performance compared to their peers. Increasing students' perception of self-efficacy in mathematics and science classes could be one of the possible ways to solve this problem.

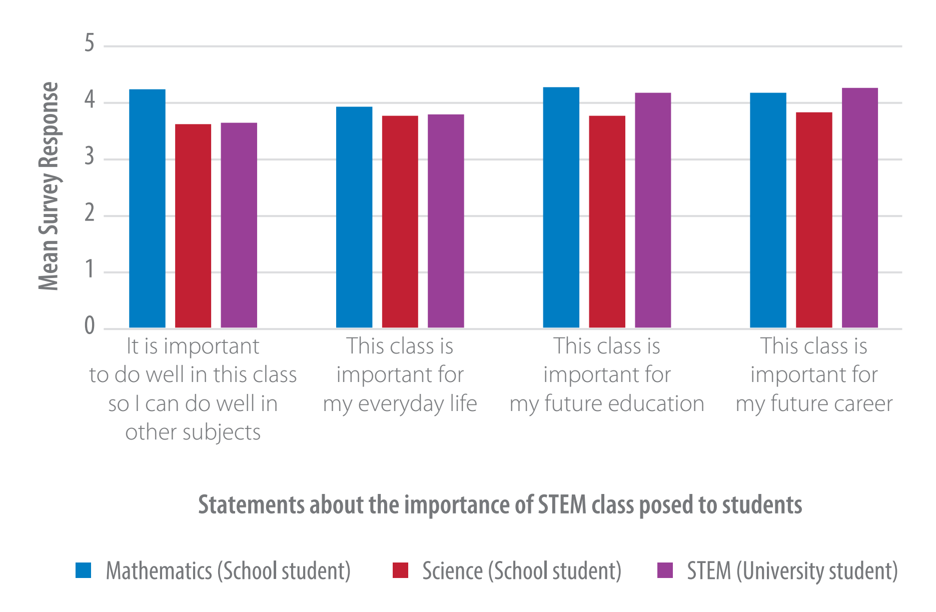
Attitudes of students toward the importance of class

Mathematics class: The findings of this section outline students' attitudes toward the importance of mathematics. Eighty-seven per cent agreed that it is important for them to do well in mathematics so that they can do well in other subjects at school and 85 per cent agreed that mathematics is important for their future career. In addition, mathematics was also seen as important for their future education and daily life (see Figure 4.4).

Science class: The results showed that students seemed to understand the importance of science as they indicated that it was important for their future career, education and everyday life and applying science knowledge in other subjects at school (see Figure 4.4).

University students: The research revealed that 92.3 per cent of university students reported that STEM was important for their future education. This could be the case for those who aimed to pursue a STEM-based education. Additionally, the respondents tended to agree that STEM was important for their future career and everyday life (see Figure 4.4).

Figure 4.4: Students' perceived importance of STEM subject/class



Note: 1 = 'strongly disagree' and 5 = 'strongly agree'

Attitudes of the students toward teacher(s)

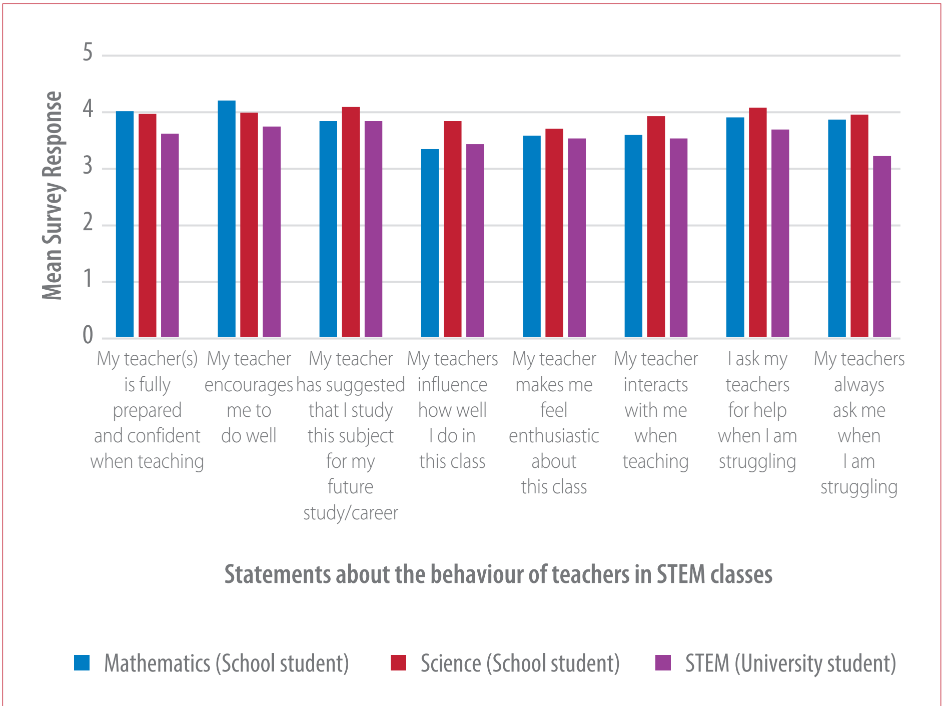
Mathematics class: Figure 4.5 shows that in relation to the mathematics performance of students in primary and secondary schools, students reported that the most important role of a mathematics teacher in their learning of this subject is the encouragement of teachers, followed by the teacher's confidence in mathematics and the individual student's confidence in asking for assistance.

In addition, the teacher asking students if they are struggling and suggesting students study mathematics in the future tended to increase their perception.

Science class: The role of teachers tended to be one of the more influential factors in students learning science. The findings revealed that 86.7 per cent of students agreed that they ask their teachers for help when they are struggling and 85 per cent agreed that a suggestion to pursue science from teachers might influence their future career and education (see Figure 4.5). Overall, the role of teachers in science was likely to impact on achievement outcomes in science classes.

University students: Figure 4.5 shows that university students agreed to the statements: 'my teacher encourages me to do well in class' and 'my teacher has suggested that I study STEM for my future study and career.' Overall, teachers play an important role in influencing students to learn about STEM.

Figure 4.5: Students' perceptions and attitudes toward teacher(s)



Note: 1 = 'strongly disagree' and 5 = 'strongly agree'

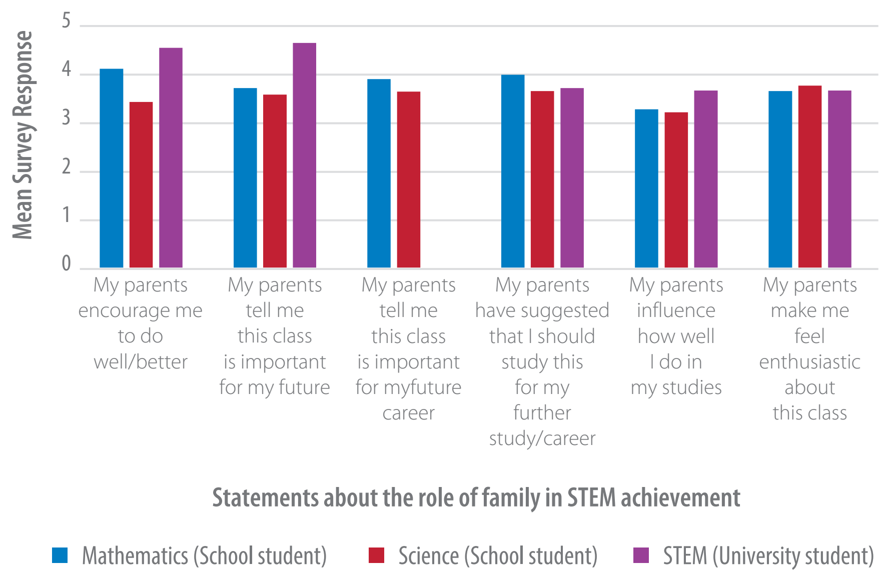
Students' perspectives on family attitudes towards STEM

Mathematics class: This section demonstrates that 83.3 per cent of students agreed that their parents have suggested they study mathematics for their further study and careers and that 81.7 per cent agreed that their parents encouraged them to do well, or better in mathematics. In addition, their parents told them that mathematics was important for their future careers and this made the students enthusiastic about this subject (see Figure 4.6).

Science classes: This section explored the attitudes of students toward parents and family attitudes towards science classes. The results showed that 75 per cent of the students agreed with the statement that their parents made them feel enthusiastic about science subjects and 73.4 per cent agreed that their parents told them that science was important for their future. Overall, parents played an important role in the success of students learning science (see Figure 4.6).

University students: The findings highlight that 94.2 per cent of students agreed that their parents encouraged them to do well and 96.2 per cent of all respondents agreed that their parents told them that study is important for their future. Overall, the results indicate the importance of parents' influence on their offspring's education. The statement 'My parents tell me this class is important for my future career' was not posed to university students.

Figure 4.6: Students' perception on the influence of parents and family

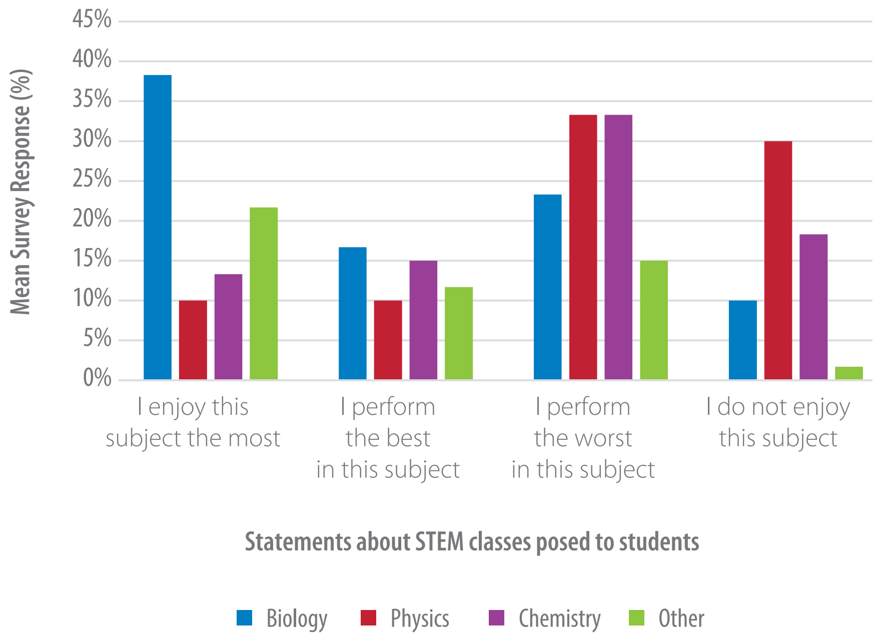


Note: 1 = 'strongly disagree' and 5 = 'strongly agree'

Students tended to agree to all of the statements regarding parental or family involvement in their STEM studies or careers. This could indicate that parents are vocal about their feelings towards STEM and share their opinions often with their children.

This is important to know as it indicates that parents could have a very strong influence on their children's motivation to study STEM or have an interest in the field. Regarding the science class, this section engaged students to share their opinions on how they felt about each topic. As shown in Figure 4.7, apart from biology (55 per cent) students reported that they performed worse in physics and chemistry (33.3 per cent) and did not enjoy them.

Figure 4.7: Student's perception on performance and interest in STEM subjects



Please note: 'Other' refers to any topic indicated by students other than the three given responses.

Conclusions

In the twenty-first century, scientific and technological innovation has become increasingly important as Lao PDR faces the benefits and challenges of pursing its development objectives, while concurrently managing globalization. Therefore, introducing STEM education as an integrated programme in the general reforms of Lao's education system could create new opportunities to develop the interest of all girls and women in STEM education and careers.

This research sets forth to gain a deeper insight into STEM education in Lao PDR and it looks at girls and women as, due to the gender gap in STEM, girls and women are the group that needs to be focused on (UNESCO, 2015). It aims to discover the amount of information available on the topic and get some ideas relating to how girls and women engage in STEM education, what attitudes they have toward mathematics and science and how they could be supported in STEM-related fields. Although this is a preliminary study with a small-scale sample, the report concludes that the key issues arising from the interviews with senior lecturers about gender imbalance, scholarship programmes and support, stereotypes towards women in specific careers and career choices in STEM tend to be the factors affecting the success of women in STEM-related careers. Thus, these issues should be addressed for further development of better outcomes and future guidance. This also requires policymakers to review current policies and key stakeholders to provide support to women with these specific issues.

Encouraging girls and women to engage in STEM-related fields should be based on the understanding of the actual situations and needs of the students. The results show that school students have different preferences among STEM subjects. These results might imply that the students should receive support for what they are interested in learning and enjoy studying. Understanding the preferences of students and the gender differences in these preferences can assist teachers and education professionals in designing an engaging curriculum. Furthermore, these students also reported that they had received tutoring outside of school hours as they wanted to have better educational achievements and it was determined that mathematics was the most studied extracurricular subject.

This might indicate that, of their school subjects, students value a high performance in mathematics and science subjects most at this stage of their learning. Therefore, parents and teachers should encourage students to choose what subject they enjoy and do well in and have tutoring to increase their school performance. Additionally, the high proportion of students that reported receiving extra tutoring outside of school hours can indicate a number of findings, such as pointing to a larger social influence that highly values education, or a concern that students are unable to adequately prepare themselves for further studies or careers. These are issues that could be explored more intensively in future research.

Creating programmes to assist female students in STEM should be based on the level of perceived importance of factors such as subject, class, grades, teacher(s) and parental support. Among these factors, the support of parents and family plays the most critical role and might lead to success in STEM education at the university level. On the other hand, school students strongly identified mathematics, science, grades and teacher encouragement as important. The key findings of the present study and the recommendations made based on the findings are highlighted below to inform policymakers and key stakeholders:

I. Gender imbalances, scholarships, socio-economic difficulties and stereotypes all greatly impact girls' and women's ability to advance and succeed in STEM careers and education.

Interviews with lecturers and researchers teaching at the university level in different departments related to STEM highlighted some important issues; especially, women receive fewer opportunities to continue their higher education due to family commitments. This stops them from chasing their dreams. In addition, the negative perceptions of peers and others toward women in particular fields of study and pursuing professional education tended to influence their decision-making regarding career and education choices. This could be an influence on the outcomes of girls and women in STEM education.

Recommendation 1: Increase the number of scholarships and targeted support for women in STEM. This support needs to expand beyond financial assistance and also include programmes and policies that provide assistance to women who have conflicting family commitments, such as childcare centres, opportunities for flexible study arrangements, or financial grants to secure private childcare during class hours. This approach would create more opportunities for girls and women and encourage them to pursue further studies in STEM fields.

Recommendation 2: The government should promote female role models from STEM fields. Programmes that showcase success stories of girls and women majoring in STEM and, or work in the STEM fields could inspire those who are reluctant, or apprehensive about pursuing a career in the STEM field. This might serve as a social influence that could shape positive perceptions toward STEM and the importance of women in STEM careers and education. This approach could reduce the gender gap in STEM-based career choices and increase the confidence of women in STEM in the long-run.

II. The active encouragement to pursue a STEM education, or a STEM career from parents and teachers is an important, influential factor in the participation of girls and women in STEM.

The results identified several important psychological factors that have an impact on how girls and women make the decision to engage in STEM studies. Significantly, it was revealed that parental and family support has the most important influence on the success of a students' education at the university level (see Figure 4.6). This underscores the benefit students gain from their parents' influence in selecting and studying STEM-related subjects. For school students, a stronger influence was seen in encouragement from their teachers (see Figure 4.5).

Recommendation 3: School leaders and teachers must adapt a holistic approach to STEM education that includes raising parents' awareness of STEM opportunities for their children. Parents should know more about the benefits of STEM education, such as how it could help their children land a successful career in STEM.

Recommendation 4: Increase professional training programmes for STEM teachers that address teaching approaches, methods for coaching students and especially for female students, to pursue STEM careers and how to actively build confidence in young girls that will encourage them pursue to STEM related subjects in the future.

III. Further research on the underlying factors that impact female engagement in STEM in Lao PDR is necessary.

This preliminary study offers a different range of necessary information and granularity of STEM education in Lao PDR, especially for girls and women. Further investigation from the initial findings might provide and increase opportunities within this research stream. However, there remains a need to better understand the mechanisms that underline gender differences in STEM fields since the present study merely concentrates on female samples. The current results inform policymakers and stakeholders about the attitudes of girls and women. However, additional analysis on determinants such as parental encouragement, teacher encouragement, students' perceived importance of subjects and grades would also help policymakers to design a policy which, if any of these determinants are emphasized, would have a large impact on encouraging girls and women to enter STEM fields. Further causal analysis, research modelling validity and evidence of statistical significance are required to support this.

Recommendation 5: Future research should conduct a comparative study that looks at how male and female students and STEM professionals differ in terms of educational impacts, psychological influences and labour market effects. The results could explicate the gap between males and females in STEM work and education and inform policymakers who guide policy design for girls and women in STEM. More studies on student and teacher attitudes and teaching and learning conditions; how policies related to education, gender and STEM are designed and implemented in Lao PDR; and reviews of existing funding and investment in infrastructure, equipment and resources are required. This would support the design of policies and programmes to accommodate girls and women and provide direction to achieve sustainable development and the national goals of Lao PDR.

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Appendix 4-A

Table 4.2: Participant demographics, including grade and schools

School (N=60)			University (N=52)		
School	**N**	**%**	**University**	**N**	**%**
Kengkang	15	25.0	National University of Laos	31	59.6
Vangtao	30	50.0	Champasak University	21	40.4
Sathit	15	25.0			
Grade			**Current year at university**		
Grade 1	1	1.7	Year 1	0	0
Grade 2	1	1.7	Year 2	15	28.8
Grade 3	1	1.7	Year 3	25	48.1
Grade 4	6	10.0	Year 4	12	23.1
Grade 5	7	11.7	Year 5	0	0
Grade 6	4	6.7			
Grade 7	2	3.3			
Grade 8	6	10.0			
Grade 9	3	5.0			
Grade 10	9	15.0			
Grade 11	12	20.0			
Grade 12	8	13.3			
Plan for higher education					
Yes	42	70			
No	6	10			
Maybe	12	20			

Table 4.3: School and department affiliations of interviewees

The National University of Laos	
1.	Faculty of Natural Sciences (Department of Biology)
2.	Faculty of Natural Sciences (Department of Biology)
3.	Faculty of Natural Sciences (Department of Physics)
4.	Faculty of Natural Sciences (Department of Physics)
5.	Faculty of Natural Sciences (Department of Chemistry)
6.	Faculty of Natural Sciences (Department of Mathematics)
7.	Faculty of Natural Sciences (Department of Computer Sciences)
Champasak University	
8.	Faculty of Natural Sciences (Mathematics)
9.	Faculty of Natural Sciences (Chemistry)
10.	Faculty of Engineering (Hydropower)
11.	Faculty of Engineering
12.	Faculty of Education (Physics)
13.	Faculty of Education (Chemistry)
14.	Faculty of Communications (Computer Science)

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SECTION II

Encouraging STEM careers for girls and women

5

Girls2Code: Cultivating interest in programming among young girls in Malaysia by making drawings come to life

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the girls: Lee Ming Li, Ayu Adibah Binti Abdul Halim, Ainatul Wajihah Binti Mazlan, Nursahira Binti Abdul Wahit, Kaushalya A/P Tinakaran, Wan Syazlina Binti Wan Aasim, Chin Kah Hee, Lim Yin Wen, Nur Aina Diyana Binti Roslan, Siti Mastura Binti Mohamed Hussain and Fatin Fatine Binti Mohd Jalani.

Introduction

As computers become more prevalent in our lives, it is important to equip our children, especially young girls, with programming skills to sharpen their logical thinking and to help them make better sense of how technology works. Programming trains us to fundamentally understand computer structures, logic and design, which are the basic building blocks of the technological devices and applications widely used in our everyday lives. Most importantly, the growing demand of information technology (IT) and computer science (CS) professionals in the job market makes exposure to and training in programming for our children from a young age a necessity rather than a luxury (Akbar, 2015).

In Malaysia, although there is no severe imbalance in the gender ratio of computer science students in Malaysian public universities (Ministry of Education Malaysia, 2018; Othman and Latih, 2006; Schlegel et al., 2015), a lower exposure of computer programming among our female students in their primary and secondary education is observed (Lagesen, 2008). Computer science is currently not a mandatory subject in the national primary school curriculum. The majority of girls in schools have never heard of programming or coding (Amir, 2018). Additionally, girls are not geared towards computing due to the negative stereotypes that programming is 'nerdy', technical, boring and a skill that only boys are good at (Amir, 2018; Carter, 2006; Heersink and Moskal, 2010; Schulte and Knobelsdorf, 2007; Sien et al., 2014). Generally, male students tend to start their computer science undergraduate degree with more computer skills compared to girls (Othman and Latih, 2006). Taking these findings into consideration, an earlier exposure to programming is vitally important to better prepare girls for successful future careers in ICT.

In conjunction with the 'International Telecommunication Union's Girls in ICT Day' on 25 April 2019, the School of Computer Sciences, Universiti Sains Malaysia (CS USM), in collaboration with Telebort, launched the 'Girls in ICT Campaign 2019'. The campaign aimed to encourage and empower girls to consider studies and careers in ICT, thus enabling both girls and technology companies to reap the benefits of greater female participation and retention in the ICT sector in

Malaysia. The campaign consisted of a series of workshops conducted for young girls from selected primary schools in Penang, Malaysia. The workshops taught girls to code using the visual programming language *Scratch*, but the approach took an innovative spin by showing the girls how they could use programming to make their drawings come to life and turn still drawings into animations. This report describes the design, execution, outcomes and impact of the campaign.

Project objectives

The objectives of the campaign were: 1) to cultivate an interest in programming among young girls; 2) to break the stereotype that programming is technical, boring and only suitable for boys; and 3) to make female ICT role models more visible to girls. The campaign aimed to make female role models in the ICT field more visible to girls so they can be inspired to consider technology-related professions from a young age.

To achieve the objectives, we designed an 'Animation Using *Scratch*' workshop module that would teach girls to make their drawings come to life. The main goal of the workshops was to expose primary school female students to programming and animation using non-conventional methods and to instil greater interest for them to explore programming tools on their own. The workshops also provided an opportunity for our computer science undergraduate students to volunteer as mentors and serve as role models to the young girls.

Project implementation

A task force from the School of Computer Sciences, Universiti Sains Malaysia (CS USM), a school in a local public university providing computer science education, and Telebort, an education technology start-up, collaborated to carry out the 'Girls in ICT Campaign 2019'. The campaign included two workshops targeting female primary school students aged between ten and eleven years-old. The task force designed and delivered the workshop contents using *Scratch*. This is a drag and drop, visual-based programming language created by MIT Media Lab.[4] It makes simple animations easy to do while exposing students to programming concepts such as sequential processing, loops and decision making.

4 For information about *Scratch*, please access: https://scratch.mit.edu

Workshop 1: Sekolah Jenis Kebangsaan Cina (SJKC) Union, Penang

With the support of the Penang State Education Department, our first 'Animation Using *Scratch*' workshop was hosted at Sekolah Jenis Kebangsaan Cina (SJKC) Union, Penang on 25 April 2019. Participants were recruited from three different schools: SJKC Union; Sekolah Kebangshaan (SK) Methodist Girls; and SJKC Heng Ee.[5] A total of thirty girls between the ages of 10 and 11 participated in the workshop. Table 5.1 shows the breakdown of participants from the three schools. SK Methodist Girls and SJKC Heng Ee were located near the host school so teachers from the respective schools gave the students a ride to and from the workshop.

Table 5.1: Participant breakdown for Girls2Code workshop 1

School	Number of Participants
SJKC Union	24
SK Perempuan Methodist	3
SJKC Heng Ee	3

Unlike many other schools in Penang, SJKC Union, located in the city of Georgetown, is a 'champion school' for technology programmes. The host school had a computer lab with sufficient laptops for all participants. As the laptops were not furnished with an Internet connection, the task force and student mentors arrived at the school an hour before the start of the workshop to install the *Scratch* desktop on each laptop.

We started the workshop by providing an overview of ICT and asked the girls about their ambitions. While aspirations to be doctors, teachers and lawyers remained popular, we did observe a shift in some of the girls aspiring to be 'YouTubers'. Clearly, this group of participants already had some familiarity with technologies such as YouTube. Based on our survey, 62 per cent of the participants had prior experience learning programming. Next, we explained how ICT is becoming more prevalent in our lives regardless of our professions

5 In Malaysia, SK are public primary schools with Bahasa Malaysia-medium of instruction; SJKC are public primary schools with Chinese language of instruction; and SJKT are public primary schools with Tamil language medium of instruction.

and played the ITU's 'Girls in ICT Day 2019' video message.[6] Photos taken during the workshop at the host school are shown in Figure 5.1.

Figure 5.1 Photos from the 'Girls2Code' workshop 1 at SJK (C) Union

Photo credit: Telebort Technologies

Workshop 2: School of Computer Sciences, Universiti Sains Malaysia (CS USM)

For the second workshop held on 8 August 2019, the task force thought it would be a good idea to bring the girls from primary schools close to CS USM to experience learning coding at a university computer laboratory equipped with high-tech computers. One of the challenges in organizing the workshop was to find a primary school computer lab with sufficient computers or laptops for all the participants. Thus, we decided to conduct the second workshop at CS USM. The schools selected by the Penang State Education Department to participate in the second workshop were located in a more suburban neighbourhood some distance away from the city. Twenty-eight primary school students, aged between 10 and 11 years-old, from seven schools; SK Minden Height, SK Sungai Gelugor, SK Bukit Gambir, SK Bukit Gelugor, SJKC Kuang Hwa, Sekolah Jenis Kebangsaan Tamil (SJKT) Subramaniya Barathee and SJKT Jalan Sungai participated in the activity, accompanied by a teacher from each school. Table 5.2 shows the breakdown of participants from the seven schools.

6 To see the ITU's 'Girls in ICT Day 2019' video message, access: https://www.youtube.com/watch?v=_2qNMLLeloo

Table 5.2: Participant breakdown from 'Girls2Code' workshop 2

School	Number of Participants
SK Bukit Gelugor	4
SK Sungai Gelugor	4
SK Bukit Gambir	4
SK Minden Height	4
SJKC Kwang Hwa	4
SJKT Subramaniya Barathee	4
SJKT Jalan Sungai	4

This group of girls had more traditional notions of what they would like to be when they grow up (e.g. professions such as doctor, teacher, lawyer). The few non-conventional ambitions we heard were chef, businesswoman, scientist and fashion designer but none specifically CS or IT centred. None had expressed an interest to become a programmer mainly because they were not aware such careers existed. Unlike the group of participants from workshop 1, this group of girls had less exposure to programming with only 14 per cent having prior programming experience. The lack of computer facilities in the schools could be one reason why these girls had less exposure to programming. Figure 5.2 shows photos taken during workshop 2 at a CS USM computer laboratory.

Figure 5.2: Photos from the 'Girls2Code' workshop 2 at CS USM's computer laboratory

Photo credit: Telebort Technologies

Recruitment of student mentors

To allow participants to interact with more female role models in computer science, we recruited female student mentors from the CS USM's pool of undergraduate students on a voluntary basis. While the opportunity was opened to all female students from the first till the fourth year in our undergraduate programme, we set a greater preference for undergraduate students in their second year and above as they were more likely to have a stronger foundation in computer science. We were also more inclined to recruit student mentors who exhibited enthusiasm and passion to work with young girls. Some of the student mentors had experience working with children under the CSGuru[7] (Computer Science Guru) programme organized by Telebort to provide free coding classes to children.

Student mentors were given a forty-five minute briefing and training on *Scratch* by the task force ahead of the workshop. Ideally, a student mentor would be responsible for taking care of five participants. A total of eight female CS undergraduate students volunteered for workshop 1 and five volunteered for workshop 2. The student mentors played an important role to guide the participants through the learning exercise and made sure none of the participants were left behind. Also, as the student mentors were in their early twenties, it was easier for the participants to connect with and relate to the mentors because of the smaller generation gap. Five student mentors who volunteered for workshop 1 are shown in Figure 5.3.

Figure 5.3: Computer science undergraduate volunteer mentors at workshop 1

Photo credit: Telebort Technologies

7 For more information about CSGuru, please access: https://www.telebort.com/csguru

Workshop design and delivery

Instead of taking the typical pedagogical approach of merely teaching students how programming works in *Scratch*, we used art and animation to help the girls discover the wonders of programming. We planned each workshop to run for two-and-a-half hours. Table 5.3 shows the module breakdown and description of the workshop.

The workshop encompassed three main parts and was led by a facilitator. The three segments were: 1) Drawing activity; 2) Hands-on demonstration of the basics of *Scratch*; and 3) Exploration of *Scratch* through an Animation Challenge.

Table 5.3: Girls2Code workshop module descriptions

Time	Module	Description
15 minutes	Overview	Welcome remark by the Dean, School of Computer Sciences, USM. View ITU's Girls in ICT Day 2019 Video Message.
30 minutes	Drawing Activity[6]	Students are required to draw a simple scene with a house, tree, car and bird which they will later transfer over to Scratch to animate.
45 minutes	Basics of Scratch	Provide an introduction to the students and a hands-on, step-by-step session to convert their drawings into a Scratch animation.
45 minutes	Exploring Scratch through an Animation Challenge	All students will be given forty-five minutes to create a simple cartoon with two characters having a short conversation. Students are given the opportunity to explore and try out various blocks in their new project. This project will be judged and prizes will be given during the closing ceremony.
15 minutes	Closing, plus Prize Giving Ceremony	Top three best cartoons in the Animation Challenge are given prizes. Closing remark by the organizer.
Total: 2.5 hours		

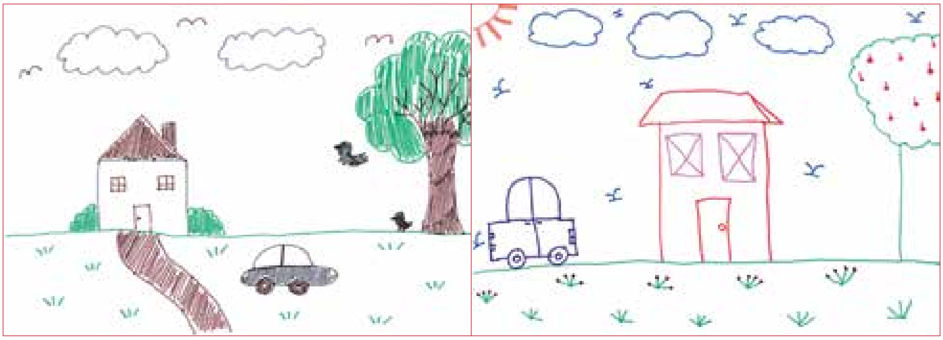
Part 1: Drawing activity

Participants were given thirty minutes to draw a simple scene with a house, tree, car and bird, which they would later transfer over to *Scratch* to animate. Papers and colour pens were provided for this drawing activity. Figures 5.4 and 5.5 illustrate sample drawings from the participants in workshop 1 and workshop 2.

8 The drawing activity was inspired by: https://scratched.gse.harvard.edu/discussions/news-and-announcements/new-resource-teaching-scratch-kids-ages-5-8.html

Figure 5.4: Sample drawings with a house, tree, car and bird from 'Girls2Code' workshop 1

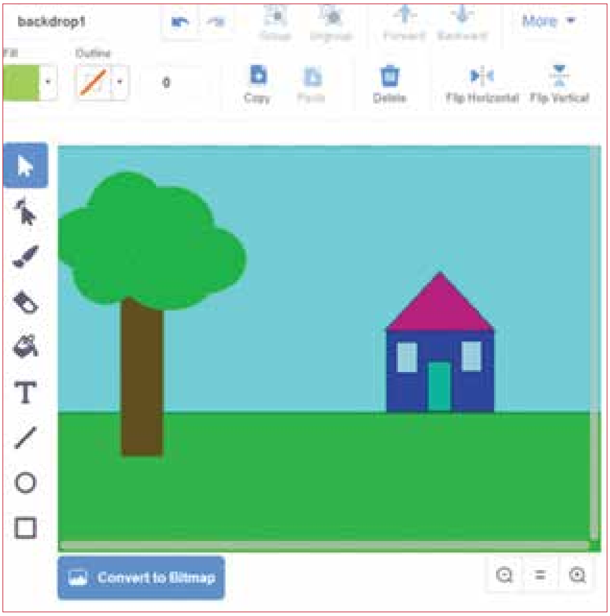
Figure 5.5: Sample drawings with a house, tree, car and bird from 'Girls2Code' workshop 2



Part 2: Basics of Scratch

We provided an introduction of *Scratch* to the participants and a hands-on, step-by-step session to convert their drawings into a *Scratch* animation. First, the facilitator explained what programming was all about in the context of how cartoons and video games were created. Second, we guided the participants to transfer their drawings on paper onto an empty stage in *Scratch*. Using the mouse, participants learnt how to use the drawing tools shown in Figure 5.6 to paint the background (house and tree) and draw a sprite or character (i.e. a car).

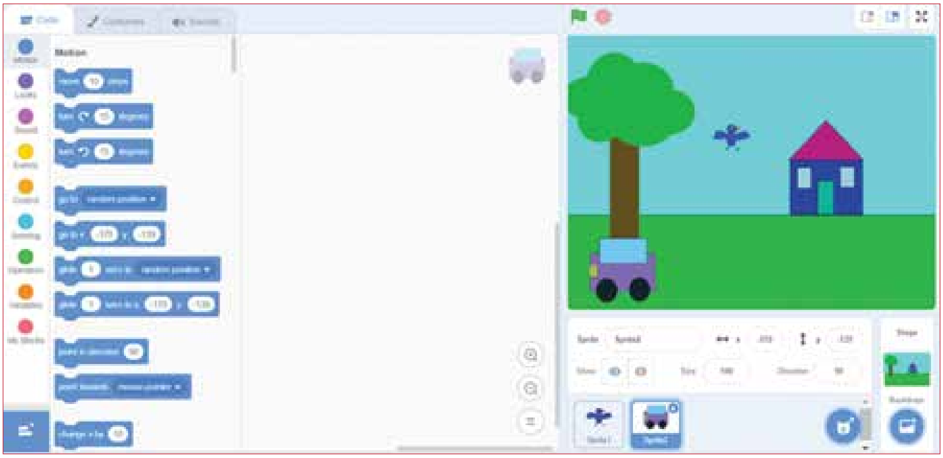
Figure 5.6: Using Scratch drawing tools to paint a background and draw sprites



Scratch also came with a collection of pre-set sprites. As the bird was more challenging for the participants to draw using the mouse, we instructed them to select a pre-set bird sprite. Third, we demonstrated how to animate characters to move and talk by putting together blocks of code as shown in Figure 5.7. The code blocks covered in the module included the following:

1. Move the car sprite 10 steps forward.
2. Make the car sprite bounce off the edges and not in a random direction.
3. Use the control block to repeat an action.
4. Make multiple sprites (both car and bird) move at the same time.
5. Use say and wait blocks to make the sprites talk to each other.

Figure 5.7: Code blocks in Scratch used to animate sprites



Part 3: Exploration of Scratch through an animation challenge

To assess if the participants were able to grasp the basic concepts of programming through animation, all participants were asked to work in pairs and were given forty-five minutes to create a simple cartoon with two characters having a short conversation. Participants were given the opportunity to explore and try out various code blocks in their new project. Each project was evaluated by two judges using the rubric containing seven judging criteria shown in Table 5.4. The judging criteria were the same in workshop 1 and workshop 2 except for one criterion. Due to the time limit, we found that participants struggled to create meaningful conversations between the characters. There was a slightly steeper learning curve in controlling the timing of when the speech bubbles belonging to different characters appear in order to make the conversation coherent. Therefore, we changed the criterion on the conversation topic in workshop 1 to how relevant the story was to the animation title in workshop 2.

Judging was conducted by the task force, student mentors, as well as invited CS lecturers. We did not set a specific theme and purposely kept the challenge open-ended to allow participants to unleash their creativity. After tabulating the scores by all the judges, we awarded the top three winners with prizes generously sponsored by L'Oréal Malaysia at the end of the workshop.

Table 5.4: Rubric and criteria for workshop animation challenge

Category	Below Average (1)	Average (2)	Above Average (3)	Excellent (4)
Character Movement (Random movement? Proper movement? Movement based on story?)				
Sprites (Suitable sprites? Suitable size?)				
Backdrop (Suitable backdrop?)				
Conversation (Smooth conversation? No errors?)				
Animation				
Workshop 1: **Conversation Topic** Workshop 2: **Story** (How close the animation matches the title?)				
Creativity (Award bonus for creativity, otherwise award average)				

Key findings

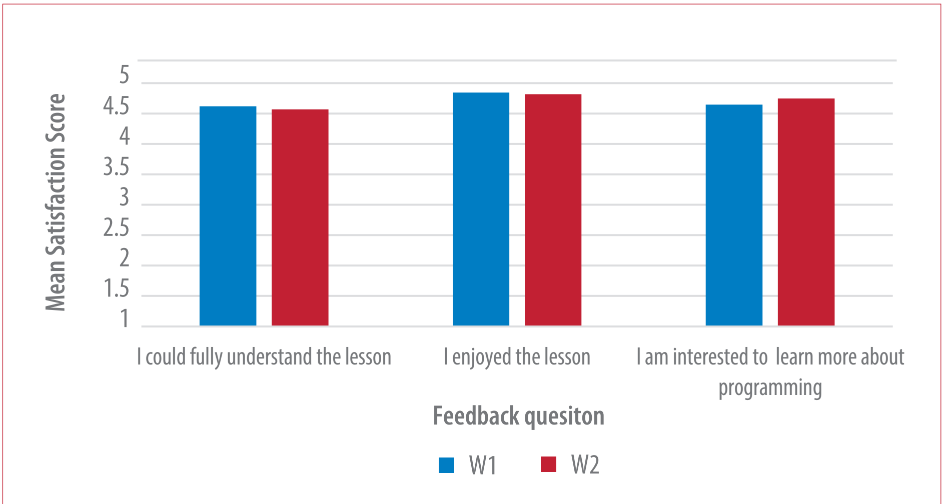
Participant feedback

At the end of the workshop, we provided participants with a feedback form and asked each to rate on a scale of one to five, presented in the form of smiley faces, (one being the 'least satisfied' and five being the 'most satisfied') how they felt about different aspects of the workshop. Overall, the participants found the lesson easy to follow and understand (mean satisfaction rating = 4.6/5.0). Only a few younger girls were not able to understand certain parts of the lesson mainly due to language difficulties and the use of certain technical terms that they were unfamiliar with. The workshop was conducted fully in English by facilitators who were more used to teaching in a university setting. Fortunately, our multi-lingual student mentors and the school teachers present during the workshop were able to translate and explain some instructions in Malay and Chinese. When conducting the workshop, we also realized the importance of using examples that were more relatable to young girls to help them understand the content.

Participants thoroughly enjoyed the lesson and strongly expressed the view that the workshop made them feel happy (mean satisfaction rating = 4.8/5.0). This outcome shows that our approach of combining art and animation with programming appealed to first timers in programming, as well as to those who had some prior experience. Participants showed a high level of excitement, especially when they started to make their sprites move. The girls were able to observe the actions following the sequence of code blocks they put together so they were able to quickly learn how to move the sprites in the desired way without being caught up in the technicalities of programming.

Figure 5.8 shows that the mean satisfaction scores obtained from the two workshops are not significantly different. Therefore, the workshop has been proven to appeal to young girls with different backgrounds and can be replicated for other schools with a trained facilitator who is competent in *Scratch* and ideally one university student mentor assigned to guide five girls. We encouraged the participants to continue exploring *Scratch* by directing them to additional online learning resources they could use for self-learning.

Figure 5.8: Student satisfaction in the Girls2Code workshops



With 96 per cent of the participants expressing a 'high' to 'very high' interest to learn more about programming at the end of the workshop, the objective to cultivate interest in programming among the girls was successfully achieved. The following are selected comments from the participants on what they would like to learn about programming and technology:

- 'I like to learn this programming because this programming makes me happy :)'
- 'I would like to learn to make short cartoon.'
- 'How to build a game with Scratch animation.'
- 'I would like to learn how the computer made the game.'
- 'I would like to learn more animation-like programming. It is very fun.'

Through the workshops, we were also able to break the stereotype that programming is technical and boring. The girls saw programming as a fun activity that can empower them to bring ideas to life. The student mentors who helped solved problems the girls encountered also helped to change the mind-set that programming was too difficult for girls. Some girls even took the initiative to help their struggling peers when an error was encountered. Thus, making the female ICT role models more visible created a positive impact in empowering the girls to be technology creators and problem solvers.

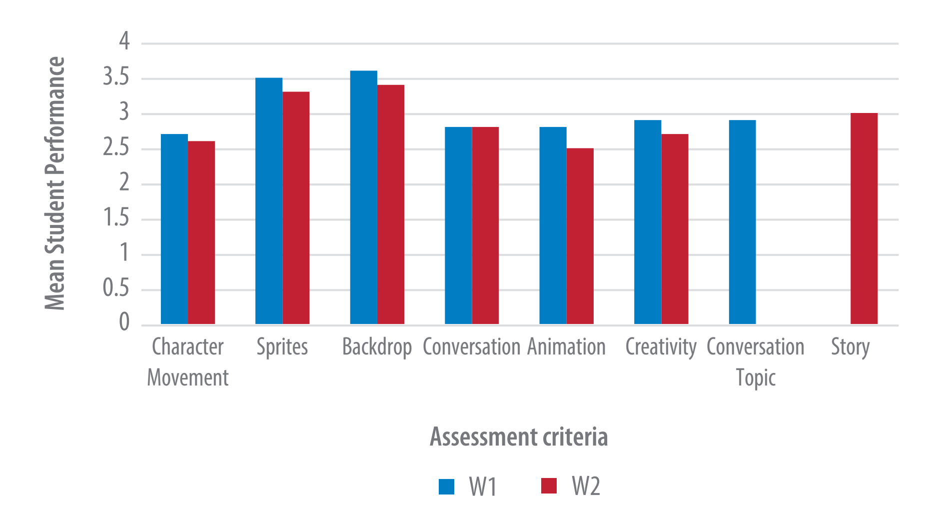
Programming skills assessment

Based on the analysis of the scores given by the judges in the Animation Challenge, we can conclude that overall participant performance on all criteria was at least above average, as shown in Figure 5.9. The participants scored the highest in their ability to select and design suitable backdrop and sprites or characters (i.e. the digital art and design). Participants showed a slightly lower performance in the logic thinking criteria (character movement, conversation and animation).

This standard assessed the ability of the participants to put together a sequence of correct code blocks to ensure the characters move and interact properly and seamlessly tell a story. Almost all participants were able to make the cartoons talk and move but the characters would sometimes behave in an erratic manner or overlap with one another.

Nonetheless, the cartoons produced by the participants were impressive after being given only about an hour to learn the programming basics. The mean performance scores of the participants in workshop 2 is consistent with workshop 1. Assessing the relevance and coherence of the conversation topic proved to be difficult in workshop 1 as the conversations between the characters tended to be short. Thus, it was replaced by another criterion to assess the story being portrayed in the cartoon.

Figure 5.9: Student performance in the Animation Challenge



Note: 1 = 'Below average'; 2 = 'Average'; 3 = 'Above Average'; 4 = 'Excellent'

More importantly, the participants demonstrated creativity in making some mundane scenes they encountered in their everyday lives to come to life digitally. For example, a team created an animated story of how students greeted and interacted with one another at school (Figure 5.10a), while another team depicted what goes on during a basketball game (Figure 5.10b). Some teams took this opportunity to include figments of their imagination into their cartoons, such as animating a space puppy (Figure 5.10c) and an evil witch (Figure 5.10d).

Figure 5.10: Sample cartoons produced by students in the Animation Challenge

5.10 a

5.10 b

5.10 c

5.10 d

Due to the lack of programming exposure in primary and secondary schools, many girls are still trapped in the notion that programming is limited to building robots. The programming skills assessment shows that a non-conventional approach can be as successful in introducing programming concepts to girls, especially using scenarios that are more relatable to them.

Conclusion and recommendations

Although there is no large gender imbalance in the ICT industry within Malaysia, there are less girls than boys interested in and aware of ICT at the lower education levels. Based on the outcomes of the workshop, we conclude that girls' exposure to programming should start at a young age so they can be better equipped with the resources, skills and confidence to join the ICT sector. The conversation about equal representation, equal opportunities and the role of women in STEM should start early to ensure girls are not left behind in preparing themselves for a successful career in STEM-related fields. CS and IT education has not been formally realized in Malaysian classrooms, which represents a missed opportunity for girls to engage with the creation of computer applications and digital media.

We have shown that creative approaches in teaching programming to girls can instil greater interests among girls to explore more about programming and technology. We implemented programming within more artistic expressions, particularly in the context of animation and game, which appealed to young girls between the age of ten and eleven years-old. Our workshops received a very positive response from young girls, from both the city and suburban primary schools.

Our workshops have also helped girls break away from the common stereotype that programming is boring or only cut out for boys. Many of the girls enjoyed the hands-on programming activities and found the experience to be fun. The activities gave the girls a boost of confidence to become technology creators as they got to experience the satisfaction of bringing to life the characters they like. Girls who were first-timers in programming did indicate that they were not fully able to understand the lesson and faced some difficulties in making their characters move as desired.

More analogies and examples that the girls are familiar with can be used in the future to better convey the programming concepts to the girls. Through the workshops, the girls were given the opportunity to interact with computer science female student mentors and lecturers, thus making female role models more visible to the girls. The girls were not hesitant in asking the student mentors questions and were impressed when the student mentors were able to help them solve problems related to their animations.

The keen interest shown by the girls in these workshops is evidence that engaging girls in programming and STEM in general should be brought into their everyday classroom or school curriculum. Although the workshops were conducted on a small scale, we were able to make an impact in cultivating interest in programming among the fifty-eight girls who participated in the campaign. The opportunities presented in the workshops can be brought into all classrooms for all girls to make a greater impact.

On a broader level, engaging girls in programming and technology outside of their regular classrooms can help stimulate greater interest in STEM subjects in the regular classroom setting. These workshops could help girls connect STEM subjects to real world scenarios, which would then give them a greater sense of purpose to join STEM. Learning how to code promotes logical thinking and problem-solving skills, which are inherently useful in STEM. To policymakers, we recommend more effort is focused on designing lesson plans that would appeal differently to girls compared to boys, instead of a 'one-size-fits-all' solution when introducing programming in schools. Research has shown that girls and boys learn programming differently (Stoilescu and Egodawatte, 2010), so it is important to use different, relatable analogies and activities to stimulate interest among girls in programming and STEM subjects. We hope our workshop module has laid a foundation for future CS and IT programmes to build on.

We would also recommend the adoption of non-conventional approaches to make CS and IT education more appealing and interesting to young girls. Research has shown that girls and women are more drawn to the context of computing, as opposed to computing as a pure discipline (Fisher and Margolis, 2002). Our approach of encouraging girls to learn programming through animation is an example of a successful implementation of a non-conventional approach.

Finally, strong support on CS and IT programmes from the government and state-of-the-art computer facilities in schools are required for 'creative coding' programmes (Peppler and Kafai, 2009) to catch on and make an impact on young girls. Ultimately, CS and IT subjects should be absorbed into the formal primary school curriculum in order to not deprive our children of the opportunity to explore and acquire programming skills from a young age. Stronger support by the government, such as funding resources, should be given to initiatives such as Girls in ICT programmes to encourage more community engagement and research efforts to emerge. As such, these initiatives can then be extended to help underprivileged girls in more rural schools.

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6

STEMpower our girls

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Overview of research study

Related studies and research

While the Philippines has closed the gender gap significantly, 2017 findings from the Philippine Statistics Authority show that only 37.5 per cent of the total number of employed people in the country were females. (Philippine Statistics Authority, 2018). From this total, labourers and unskilled workers still comprised the largest occupational category for women, with occupations in leadership positions trailing behind.

In the Philippines, just two in seven engineering students are female, only 41 per cent of students taking IT-related courses are women and women make up only 43 per cent of STEM enrolments – and these are mostly in non-engineering or non-IT fields, according to statistics from the Commission on Higher Education (2018). Only 29.3 per cent of students enrolled in engineering and technology courses during the academic year 2016-2017 were females compared to 70.7 per cent who were males. There were also fewer female students (40.6 per cent) in IT-related courses than male students (59.4 per cent) (Commission on Higher Education, 2018).

According to the Philippine Business for Education's (PBEd) survey of learners from selected national science high schools in the country, girls start to lose interest in STEM subjects as early as the fourth grade (ten years-old). As a result of seeing that STEM-related careers are mostly male-dominated, girls are normalized into thinking that STEM is not for them and that they naturally lack promise in mathematics and science subjects and that only men can do well in these careers. In this context, STEM is defined as the subjects in relation to the fields of science, technology, engineering and mathematics individually, but it can also be seen as an integrated approach in the collective perception of the entire STEM field.

While these subjects are not discussed in detail at a grade school level, this project analyses the motivation of female learners to pursue higher levels of education which are more focused, or specialized on STEM subjects. Such as expressing an interest to pursue college, university undergraduate studies in the standalone fields or courses, or even exploring non-traditional STEM career paths, which means STEM courses traditionally filled with one gender. As women remain underrepresented in fields of STEM, how do we begin to bridge the gender gap and inspire the next generation of female innovators and leaders?

These findings reflect the immense lack of support in sustaining the interest of young girls in STEM through confidence-boosting and encouragement, support from parents and teachers and exposure to role models and engaging STEM content. To address this, our value proposition is to plug the leaky pipeline across all stages, starting with early interventions.

Project objectives and motivations

Marketing and public relations company Evident, together with PBEd, co-designed a twelve-month programme that sought to empower girls for the future. The programme was funded by Investing in Women (IW), an Australian Government initiative that catalyses inclusive economic growth through women's economic empowerment in South-East Asia.

We identified three key stakeholder groups, the female learners as key beneficiaries or participants, and their enablers, parents and teachers. The programme, 'STEMpower Our Girls', aimed to empower girls for the future of work through STEM. Its overarching message communicated the need to be ready for the future through science, technology, engineering, and mathematics – as this will build their foundations and ultimately, boost their confidence. This strategy was supported by tactical approaches that included strategic digital marketing and public relations to generate awareness and engagement.

The programme targeted grade six female learners attending public schools across the country as this level were at a stage of exploration and realization of interests. STEMpower Our Girls believes in change – strong Filipinas in the fields of STEM. Ultimately, the partnership aimed to create an environment in which young girls are inspired and prepared to become involved in STEM.

Methodology

Project conceptualization

Given the lack of female representation in STEM fields, Evident and PBEd wanted to empower girls for the future of work, with the objective of heightening and sustaining the interest of female grade six learners in public schools to pursue a STEM course or career. The shift in the country's educational system to K-12 has enabled students to select and take up specialized subjects before college and this becomes an opportune time for them to immerse and apply themselves into their track of choice.

Key Performance Indicators

The Key Performance Indicators (KPIs) are based on the recommended criteria of IW and the specific KPIs of PBEd and Evident. These KPIs were developed through a series of analysis, verification and audit strategies:

1. **Exposure:** The number of girls reached with messaging and the number of parents and teachers reached with messaging (Total relevant reach and engagement).
2. **Engagement:** The number of students engaged in the activity and girls' social media engagement on this activity (Target number of leads vs. actual leads generation for each class and attendance in the industry talks, career caravans and workshops).
3. **Impact:** Girls reporting a positive career ambition and parents and teachers reporting support for girls' career ambitions (Participant self-report: Interest

in pursuing a STEM career, a desire to enrol in a national science high school after graduation).

Programme phases

Phase 1: Building stakeholder awareness and programme capacity (three months)

This phase of the programme is focused on building stakeholder awareness of the campaign and technical and logistical pre-work before the actual implementation of the programme. Included here is the scoping of implementation partners to support the programme through hosting partnership discussions across the programme's target locations: Manila (Luzon), Cebu City (Visayas) and Cagayan de Oro City (Mindanao). Participant recruitment is also part of this phase where PBEd's expertise in the education sector came into play. PBEd screened potential participants with the help of the regional and division offices of the Department of Education (DepEd) by providing access to regional public school partners to recruit participants for STEMpower's pilot run.

Figure 6.1: STEMpower Our Girls industry talks and career caravans

Photo credit: Tammy David

Next, came the branding and communication strategy. Evident conducted a digital audit and set baseline targets to gauge the online environment before the implementation of STEMpower Our Girls and the agency also designed a digital marketing plan to support online activities. Creative materials were produced during this phase. These included the logo and branding guidelines, art and copy direction and social media guidelines. A public relations plan and a calendar were also produced.

Phase 2: Implementing the Enrichment Programme (twelve months)

The implementation phase included on-the-ground efforts, specifically partnership fora, conducting industry talks, seminar workshops and culminating fora in the three key cities. For communication support, Evident developed monthly digital content across the STEMpower Our Girls' Facebook, Instagram and Twitter accounts. Content themes included gamified and informative assets that appealed to both student and parent audience sets on social media. The digital performance was monitored monthly to ensure regular adjustments and improvement on reach and engagement month-on-month. Evident also increased STEMpower's exposure and visibility to institutional audiences by generating discussions with the media and getting greater coverage of STEM topics in the media through the publication of STEMpower stories.

Phase 3: Measuring and reporting outcomes (14 months)

After implementation, Evident and PBEd processed and evaluated insights and results of the pilot run based on the programme's measurement framework, which will then feed into future plans for the STEMpower programme.

Program implementation

Offline activities

The STEMpower Our Girls programme was implemented through a co-curricular enrichment programme, which involved: 1) Public fora for public schools and DepEd representatives; 2) Industry talks that featured female 'trailblazers' and inspirational role models and career caravans; 3) Tailor-fit workshops for 120 grade six learners and their parents selected across three key cities in the Philippines, Manila (Luzon), Cebu (Visayas) and Cagayan de Oro (Mindanao). This approach enabled us to show learners how to apply their skills and ideas and it highlighted the economic and social benefits of a career in STEM.

Figure 6.2: STEMpower Our Girls workshop series

Photo credit: Hannah Faith P. Saab

The activity was launched by gathering stakeholders in a partnership forum to raise awareness about the programme. PBEd took the lead in mobilizing partners regarding on-the-ground activities, while Evident handled the advocacy communications component through public relations, digital media and content development. With PBEd's expertise in education and a nationwide reach, we were able to build strategic partnerships with schools and organizations to commence a rigorous recruitment, screening and training process. Eventually, the programme identified 120 Filipina sixth graders in Manila, Cebu, and Cagayan de Oro. Each girl was chosen based on academic merit (achievement grades of at least eighty-five in science and mathematics) and a declared interest in STEM. The girls then participated in industry talks and workshops that were designed to raise and sustain their interest in STEM – all part of a concerted effort to encourage them to enrol in a national science high school and pursue a STEM career.

These after-school training programmes were completed specifically through:

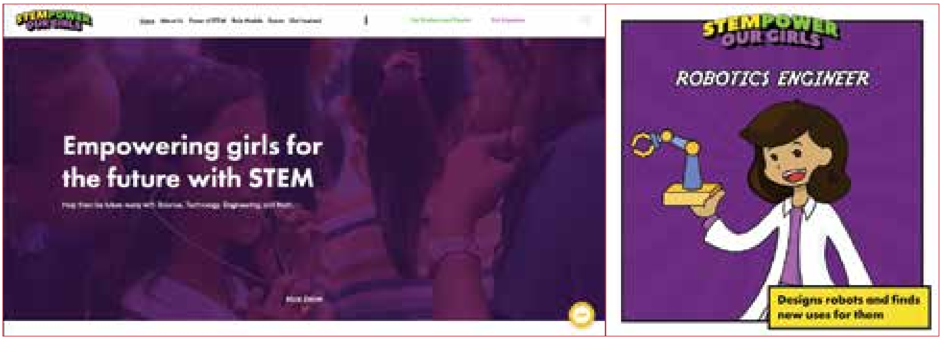
Industry talks and career caravans: Talks were conducted across the aforementioned three cities. These exchanges gave the girls and their parents a deeper understanding of non-traditional STEM topics and careers. Professionals, student role models and organizations from STEM fields were invited to give these talks and answer participants' questions. Booths were set up so both learners and parents could see the practical applications of studying STEM (e.g. Cebu Robotics Society's booth, with sample prototypes and displays).

Workshop series: An experiential scientific literacy programme aimed to: 1) Demonstrate STEM literacies; 2) Relate STEM literacies in different fields; 3) Apply STEM literacies in solving local, real-world problems; and 4) Create a future plan involving STEM opportunities for girls. A workshop series covering three weekends per city was conducted.

Culminating fora: A culminating forum in each city was held in the form of a graduation ceremony or 'moving up day' where learnings were discussed with the learners and their parents. A recap of the participants' STEMpowered journey, as well an award ceremony for learners who completed the programme was conducted.

Online activities

Figure 6.3: STEMpower Our Girls website and social media



On-the-ground activities were complemented by a digital content marketing and public relations campaign that sought to amplify the messages and activities from the ground and build a wider online community that supported girls in STEM – beyond the on-ground efforts. This included communication strategy development, content deployment and monthly analytics and insights reporting. We utilized Facebook, Instagram, and Twitter as the main social media channels and developed a website for students, parents and educators. This communication strategy amplified on-the-ground efforts by PBEd in Metro Manila, Cebu and Cagayan de Oro. Evident supported this with a content strategy that makes STEM real, accessible and aspirational. The agency also used this approach to amplify what was happening on the ground to a broader set of audiences, specifically through the following:

1. **Gamified visuals:** This is a fun and interactive quiz-type content that encouraged the students to engage. It also served as an after-school learning medium.
2. **STEMpowered girls and women stories/testimonials:** Other than proving that STEM learning can be fun, we developed real, aspirational content by sharing stories of Filipina role models and their journey to a STEM course or career.
3. **STEM careers:** We generated awareness about unconventional STEM career options. By mainstreaming these careers, we aimed to pique the interest of students who were unaware that certain every day, or unconventional careers or jobs involved STEM. This type of content engaged the adult audience set on social media as enablers to advocate for STEM courses and learning among the younger age group.
4. **Online resources:** We shared online resources which expounded on STEM topics, as well as learning activities and projects that parents and their daughters can undertake at home.
5. **Pre- and post- event content and documentation:** This approach was used to create awareness among our online audiences of current efforts being done to empower students to take the STEM track.
6. **Website:** We also developed a website with information about the campaign and profiles of the STEMpowered girls and women, both offline and online and various resources and activities for students, parents and educators.
7. **Digital analytics and monitoring:** We targeted specific areas (Metro Manila, Cebu and Cagayan de Oro) for content boosting. We continuously monitored and gathered insights from our audiences' online behaviour to optimize our content and initiatives.

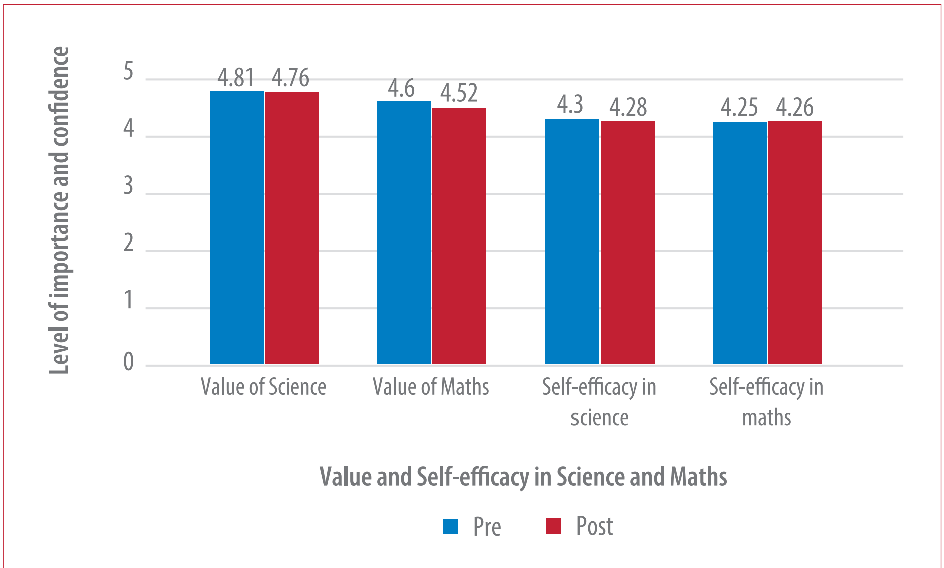
This was coupled with a public relations campaign that supported the offline efforts of STEMpower Our Girls to generate interest within the media community for more science-oriented stories and to generate potential partnerships, such as private companies and other independent organizations.

Key findings

For on-the-ground activities, the activities reached over sixty schools, with 348 student applications and 120 STEMpowered girls that participated from Manila, Cebu, and Cagayan de Oro.[9] We also reached over 119 partners, including school representatives, district office representatives and corporate companies.

One of our major findings during the first phase of the campaign was the resulting minimal spike in behaviour change among the girls. This can be attributed to the existing high level of interest in STEM of the phase one participants (see Figure 6.4). The implementers decided to involve girls who already had a certain level of interest in STEM-related courses. This was a limitation of the programme primarily due to the timeline and runway of the project.

Figure 6.4: Changes in girls' STEM attitudes and aptitudes



Secondly, the researchers discovered the overall attitude of parents regarding awareness, involvement and interest in STEM significantly increased (see Figures 6.5 and 6.6). This means more parents grew to favour STEM for their children. This can be identified by the observed increase in childrens' grades, especially in mathematics and science, plus an expression of desire from the children to specialize in STEM careers – a trend that was not noticeable prior to their engagement with STEMpower.

9 Testimonials from 'STEMpowered Girls' can be accessed at: www.facebook.com/stempowerourgirls/videos

Figure 6.5: Parental attitudes towards daughters' engagement in STEM

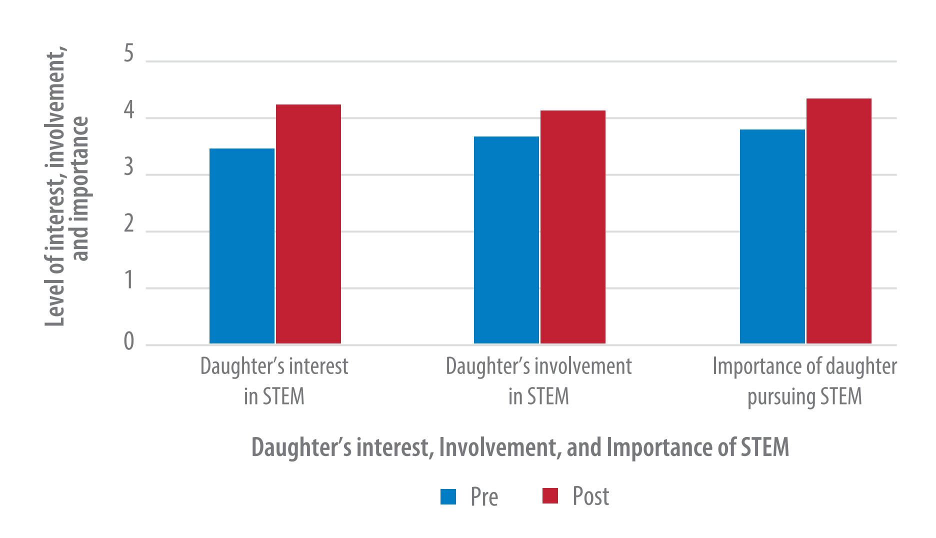
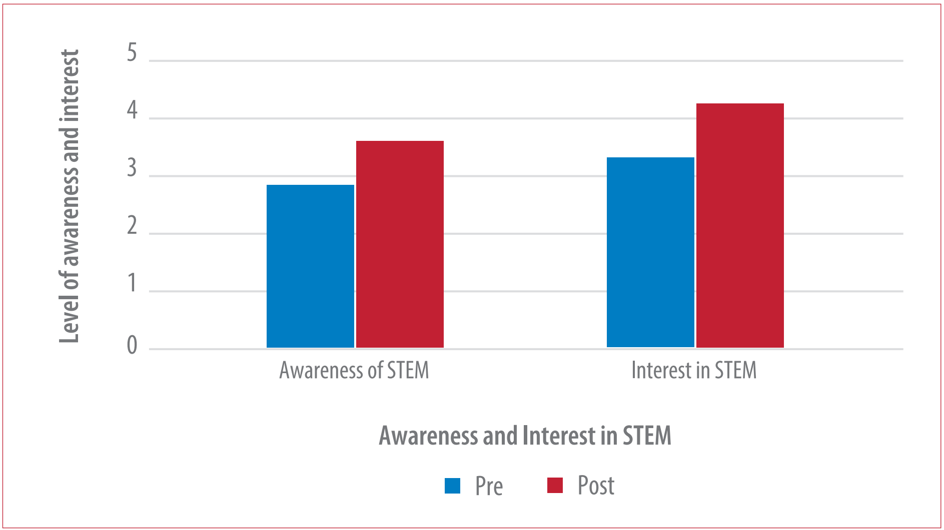


Figure 6.6: Parents' attitudes towards STEM



As for the digital strategy, total reach towards the end of the campaign was 2.4 million users, with engagement from our target audience set in social media. The results show a slow and steady penetration of a much wider audience who expressed an interest in STEM online. We received over 152,262 engagements, with an average engagement rate of 7 per cent – 673 per cent higher than the original target. The implementers also classified the types of content that works best with different audiences: 1) The younger audience set (children) engaged more with gamified content; while 2) The older audience set (parents) engaged more with practical content tackling topics such as careers and quotographics, or social media static images containing inspirational stories and testimonials from STEMpowered women and girls.

Our public relations campaign generated over twenty features in local, national print and broadcast media. Even personal blogs gained coverage. This PR campaign identified the need for more representation of STEM topics in both the media and public domain. This view was validated by the favourable interest of journalists who wrote the feature stories and their evident positive attitude towards covering future STEM topics.

Through lessons learned from the programme's implementation, interviews and Focus Group Discussions (FGDs) with target stakeholders, a pattern emerged on how teachers play an important role in a girl's choice of STEM tracks. While parents may be the major decision makers regarding the tracks (STEM or otherwise), their children absorb the greatest influence from their teachers and communicate this influence to their fellow student and their parents. This is evidenced by the following trends: 1) Parents rely on teachers to be the primary source of education and career advice for their children and more notably, the source of information on what their children need to learn in school, specifically with regard to STEM; and 2) Students listen and obey to what their teachers say or tell them to do and share their experiences with their parents.

Learnings, conclusions and recommendations

Since phase one of the programme was completed, the implementers have been making efforts to sustain the STEMpower Our Girls project and also prepare for the next phase of the campaign.

Implementers observed the important influence educators and teachers have on decisions made by learners and parents regarding STEM. Some of the learners and parents said some teachers told them which decision to make. The level of trust they put in these educators was immense and so deep that they can serve as opinion leaders for children and their parents. The implementers plan to include and engage the teachers more as we plan for phase two of the programme.

There is also a need to have more female representation in the fields of engineering and mathematics. Moving forward, the programme aims to expand by developing strategies to engage a broader set of participants and engage in new partnerships with corporate and private schools.

Overall, the findings and overall reception of the programme revealed that there is high interest in STEM among girls at this crucial phase of their educational journey and it is important to sustain and heighten this interest. The long-term objective for STEMpower Our Girls is for it to be adopted and institutionalized by the Department of Education. We are gearing up for a second phase to focus on partnerships and improved digital content as we look to change behaviour – not just with young girls and their enablers, but also with a wider partner network. Greater involvement with a larger association will enable more parties to get involved and look at its impact on a societal and economic level, particularly on the future of work.

Next steps

For phase two of the STEMpower campaign, the team will focus on engaging the enablers of phase one of the campaign; the parents and teachers. We will move forward through an institutional approach and engage these audiences so they can generate dialogue to learners regarding non-traditional career paths.

The campaign's main objectives include: 1) heightening the interest and knowledge of parents and career and guidance counsellors on non-traditional career paths; and 2) building the capacity of these enablers to engage in discussions about non-traditional career paths with learners.

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7

Evaluation of a science, technology, engineering and mathematics for girls (STEM-G) programme in Singapore

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Introduction

The underrepresentation of women in Science, Technology, Engineering and Mathematics (STEM)[10] fields is a persistent problem that plagues many nations across the world. According to the U.S. Department of Commerce, Economics and Statistics Administration (Beeden et al., 2009), women held less than 25 per cent of STEM jobs and disproportionately fewer women have earned STEM undergraduate degrees, especially in engineering. In the U.K. (Kirkup et al., 2010), women represented less than 12.3 per cent of the workforce in all science, engineering and technology occupations. Only one-in-five countries in the world had achieved gender equality in research careers (UNESCO, 2012).

A 2017 UNESCO report, *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)* has also underscored the persistence and pervasiveness of the equality gap between the two genders. For example, it was reported that girls drop out of STEM subjects at a faster rate than boys as they move up the education grade levels. Girls also form the minority group in STEM advanced courses and this trend persists all the way to higher education. However, data on STEM education achievements are mixed, suggesting that contextual factors and student demographics affect the measured outcomes.

Women and girls in STEM in Singapore

Singapore is well-known for its excellent student academic achievements in international mathematics and science benchmark tests such as Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). In TIMSS 2015, Singapore was the only participating country where grade eight girls outperformed boys (TIMSS, 2015). Nonetheless, the percentage of female graduates from STEM programmes in tertiary education was 22.55 per cent in 2017.

This was much lower in comparison to male graduates from STEM programmes in tertiary education who made up 48.92 per cent in 2017 (UNESCO, 2019).

10 In this chapter, STEM is broadly referred to as the disciplinary fields of work in science, technology, engineering and, or mathematics. These fields of work may be mono-, inter-, multi-, of trans-disciplinary. The integration may happen within the disciplines (i.e. vertical integration) or between two or more disciplines (i.e. horizontal integration) (Tan, Teo, Choy and Ong, 2019).

This suggests that high academic achievements do not necessarily translate into longer-term interest or actual pursuance of STEM higher education and, or STEM careers (e.g. pharmacy, forensic science, mechanical engineering, or computer science). The lower representation of women in STEM also implies the lack of women's perspectives and voices being incorporated into the creation of STEM innovations that are more responsive to women's needs.

Recently, there have been calls for more women in STEM. The Minister for Culture, Community and Youth, Grace Fu, spoke at the annual conference of the People's Action Party, Women's Wing, on the need for more women to pursue STEM careers as Singapore moves towards becoming a 'Smart Nation'. She highlighted the underrepresentation of women in technology and engineering courses. Specifically, the proportion of women enrolled in information and technology courses in universities dropped from 39 per cent in 2007 to 36 per cent in 2016. The proportion of females enrolled in engineering courses increased only slightly from 28 per cent in 2007 to 30 per cent in 2016 (Tay, 2018).

A recent study by Mastercard (2019) revealed more about the current status of girls and women in STEM in Singapore. The study noted that enthusiasm for STEM starts early among fifteen to nineteen year-old teenagers and seven-in-ten teenage girls intend to pursue STEM in higher education. However, 41 per cent of the teenage girls expressed the view that girls are less likely to pursue STEM-related jobs because of a strong male presence. The majority of female 'first-jobbers' were in STEM fields, but their job satisfaction remains low. Although 66 per cent of these were likely to remain in STEM throughout their careers, 44 per cent echoed the same sentiments of the teenage girls that women are generally less interested in STEM than men.

A STEM for girls programme in Singapore

There are multiple advocacy efforts to promote STEM to women or girls with the goal to interest them in STEM. Such efforts are premised on the belief that STEM is an engine, conduit and platform to expose diverse worldviews and ways of thinking and acting that contribute positively to the current state of affairs for individuals and groups. This is precisely the thinking that helms the efforts of Singapore social enterprises such as Phi Life and School of Concept that have conducted informal STEM education for children and youths, including girls. Besides these ground-up efforts, there are additional large-scale events that address the interests and needs of girls in schools through STEM.

This paper reports on the evaluation findings of the 'STEM for Girls' (STEM-G) programme that was run by a large, non-profit and intergovernmental organization based in Singapore[11] with a mandate to improve gender equity. STEM-G was a programme comprising fun and innovative day camps, field trips and mentorship that aimed to attract more women and girls into STEM. Since the launch of STEM-G in 1999, over one million students from thirty countries have benefited from it. STEM-G was first launched in Singapore in 2014 and it was targeted to reach 3,000 students (grades four to fifteen) annually. STEM-G was implemented in several all-girls secondary schools in Singapore to spark and sustain participants' interest in STEM.

This paper reports on the results of an evaluation study of STEM-G implemented in one Singapore secondary school for girls, with the goal to examine its impact on them. Specifically, pre- and post-survey instruments were administered to track changes in the following: (1) Views about participating in a STEM camp; (2) Self-concept as a STEM learner; (3) Attitudes toward STEM; (4) STEM identity; and (5) STEM career choice.

Significance of this study

A recent review by Tang Wee Teo and Leck Wee Yeo (2017) on gender studies in science and science education in Singapore revealed a paucity of studies as only thirty-nine empirical journal articles were found. Hence, this paper contributes to international STEM education literature that has limited information about STEM for girls in Asia, especially Singapore. Based on the findings, recommendations have been offered to the STEM-G programme implementers and STEM teachers to improve the STEM-G curriculum in subsequent years. School leaders adapted the survey instrument to evaluate their whole school STEM programme the following year.

Evaluation questions

The evaluation questions (EQ) addressed in this paper are:

11 The organization wishes to remain anonymous.

1. **How did STEM-G impact girls':** 1) Views about participating in STEM; 2) Self-concept when participating in STEM; 3) Attitudes towards STEM; 4) STEM identities; and 5) STEM career decisions?
2. **To what extent did STEM-G change girls':** 1) Views about participating in STEM; 2) Self-concept when participating in STEM; 3) Attitudes towards STEM; 4) STEM identities; and 5) STEM career decisions?

The five constructs studied encompass their perception of STEM-G; self-perceived ability to perform in STEM-G; personal attitudes toward STEM-G; self-perception in the broader context of STEM; and projected views in STEM career decisions. In the education and programme evaluation literature, these constructs have been widely examined as desired outcomes of an intervention as correlations to current and projected interest in a disciplinary domain have been established. For example, Cheung (2018) found that the strongest factors affecting students' individual interest in school science was science self-concept, followed by individual interest in science and situational influences in science lessons. In addressing EQ1, each of the five constructs were unpacked and a few key areas of concerns identified so that specific strategies, or recommendations could be made to address the issues. EQ2 focused on measuring the change (if any) that occurred as a result of the STEM-G.

Research methodology

Data collection

STEM-G was a half-day school camp. Each camp comprised one warm-up activity and four STEM activities lasting approximately three hours. While lesson videos and pre- and post-surveys were used to collect the student data, only survey data were reported in this paper. Before the implementation of the programme, the students completed a pre-programme survey consisting of ten items per construct. At the end of the programme, a post-programme survey was administered within a week after the end of the programme. The data were analysed using Rasch analysis (Wright, 1993, 1996; Wright and Linacre, 1994; Wright and Masters, 1982; Wright and Stone, 1979) and paired T-tests. Details on the methodology and analysis (Rasch Wright maps and T-tests) can be found in Appendix 7-A, 7-B and 7-C on p. 126-131.

Although the STEM activities were different for the three groups of students (grades seven, nine and ten), the overarching goal of STEM-G was to use activity-based STEM activities to promote more experiential and interactive learning. Hence, the lessons typically began with an instructor giving students some background information about the activity and getting them to work in groups to solve a problem, or carry out a task by applying what they had learned and from their prior knowledge.

Sampling of participants

A total of 254 students from an all-girls school in Singapore participated in the study. Only secondary one (grade seven equivalent; aged thirteen), secondary three (grade nine equivalent; aged fifteen) and secondary four (grade ten equivalent; aged sixteen) students participated in STEM-G. All students were recruited to participate in the study on a voluntary basis. Students who participated in the study submitted the student assent form and parent consent form prior to the data collection. Table 7.1 below shows the sample size and respective grade levels of the participants who completed the survey.

Table 7.1: Description of participant sample for STEM-G

Grade Level	Sample size for pre-programme survey	Sample size for post-programme survey
Secondary 1 (Grade 7; aged 13)	60	63
Secondary 3 (Grade 9; aged 15)	81	79
Secondary 4 (Grade 10; aged 16)	121	112

Limitations

There are a few limitations to this study. First, this survey was validated for STEM-G and with students from one school. To achieve even better validation results, the instrument could be administered to more participants across different schools participating in STEM-G. In this way, this instrument may be utilized by STEM-G organizers and schools to measure the impact of STEM-G in the future. Second, the post-survey was administered immediately after the STEM-G curriculum was completed. The novelty effect from attending lessons without examinations and with instructors that the students had not met before may have resulted in the positive responses across all five constructs. However, since STEM-G was only one of the activities in the school's overall STEM programme, it was necessary to implement the survey immediately after the completion of STEM-G to ensure that the responses did not incorporate the students' views about other STEM activities.

Findings and discussion

EQ1: How does STEM-G impact the girls' views about participating in STEM, self-concept, attitudes towards STEM, STEM identities and STEM career decisions?

1. Students' views about participating in STEM-G

The findings show that the students generally had positive views toward participating in STEM-G.

Table 7.2: Summary of students' views about STEM-G

Items Easier to Agree With	Items Harder to Agree With
• I have learned interesting things during STEM-G. • I did not have problems understanding what was taught in STEM-G. • I like having more STEM-G activies in school. • I like participating in STEM-G. • I like solving problems presented to us at STEM-G. • Participation in STEM-G has been good for my overall learning development.	• I think the activities in STEM-G were challenging. • Participation in STEM-G has improved my confidence in pursuing a career in STEM. • Participation in STEM-G has increased my interest in pursuing a STEM-related career. • I would like to participate in future STEM-G activities.

The statement students found relatively hardest to agree with was: '*I think the activities in STEM-G were challenging.*' This was coherent with the finding that most of them found it relatively easy to agree with '*I did not have problems understanding what was taught in STEM-G.*' This suggests a need for STEM-G organizers to work with school teachers to determine girls' interests and competency levels. With this knowledge, they would be more equipped to design more challenging activities that were also empowering.

Although more than 90 per cent (N=254) of the students found that participating in STEM-G was good for their overall learning development, a lower proportion of them felt that participating in STEM-G had improved their confidence in pursuing a career in STEM, or increased their interest in pursuing a STEM-related career. This could be due to the lack of discussion about STEM-related careers during STEM-G, even though some of the instructors (volunteers) were professionals from the STEM-related industry. Perhaps the STEM industry professionals could have spent more time during the programme to talk about the applications of what the students learnt in STEM-G in the actual STEM workplace, or in producing STEM outputs. They could have offered concrete advice on pathways to some STEM careers. After all, most students have little, if any, contact with real STEM professionals in their everyday interaction with adults.

However, it is important to note that STEM professionals speaking with students may not necessarily lead to expected outcomes, such as dispelling stereotypical views about scientists, mathematicians, or engineers. In a study by Buck, Leslie-Pelecky, and Kirby (2002), they brought female scientists into the elementary classrooms with the goal to promote a change in children's stereotypical images of scientists. However, they found that the children held on to these stereotypical ideas. The children also thought that female scientists looked like their teachers and reached the conclusion that they were teachers. Perhaps a longer-term engagement; an actual visit to scientist's workplace and seeing them in action may help the children to construct stronger images of STEM professionals.

2. Students' *s*elf-*c*oncept *w*hen participating in STEM-G

The students generally had a positive self-concept when participating in STEM-G (see Table 7.3). The students seemed to express a strong self-concept when thinking about their own learning during STEM-G. They found it relatively easy to agree that they had developed a good understanding of STEM during STEM-G. Similar to what was reported earlier under the construct 'Students Views About Participating in STEM-G', the students expressed having little difficulty learning STEM; that they could learn new STEM ideas quickly; and were able to do well during STEM-G activities. Less than 20 per cent of the students expressed concerns about not being good enough in STEM during STEM-G and thought that they were not as good in STEM subjects in comparison to other subjects.

Over 50 per cent of the students reportedly felt that they were generally strong in their STEM content knowledge, but less than 50 per cent of them felt that they could solve complex STEM problems easily. This finding illuminates the gap between the knowledge and skill-based competencies and hence, the need to focus more on the latter in the STEM-G curriculum.

Table 7.3: Summary of students' responses of their self-concept during STEM-G

Items Easier to Agree With	Items Harder to Agree With
• I have developed a good understanding of STEM during STEM-G. • Learning STEM is not too difficult for me. • I can learn new STEM ideas quickly. • I am able to do well in the STEM activities during STEM-G. • I am not concerned that I am not good enough in STEM during STEM-G. • I am better at STEM subjects compared to other subjects.	• I am better than most students in STEM-G. • My STEM skills are generally better compared to my classmates. • I can solve complex STEM problems easily. • I am generally strong in my STEM content knowledge.

However, it was interesting to note that the two statements: 'I am better than most students in STEM-G' and 'My STEM skills are generally better compared to my classmates' were the two hardest items for students to agree with. Relativism was applied to the notion of self-concept when responding to these items and the students thought less of their own competencies in relation to others.

Many previous studies have reported on how boys tend to have a stronger self-concept than girls. For example, Dahlbom et al. (2011) found that boys were overconfident but girls were under confident about their mathematics performance. In a study by Gillibrand et al. (1999) in mixed secondary schools in England, they found that girls who elected to study physics in an all-girls class gained confidence in the subject and achieved better scores than the girls in the co-ed classrooms. The findings from the evaluation study reported here underscore the need to move beyond the comparison of boys and girls, and to examine more closely how girls perceive their own STEM competencies within an all-girls STEM context. This might allude to some deeper, intrinsic, issues that girls confront as they participate in STEM. It is thus, important for STEM-G developers to think of ways to work on the confidence levels of the girls in developmental ways as they enact the curriculum. The girls' self-confidence should be addressed in absolute and relative terms.

3. Students' attitudes toward STEM

The students generally had positive attitudes toward STEM (see Table 7.4). The item that students found relatively easiest to agree with was: 'STEM is important for the society.' Students also found it relatively easy to agree that STEM improves the quality of living. However, the item that students found relatively hardest to agree with was: 'Anything we need to know can be found through STEM.' This means that while they felt that everyone should learn about STEM, they did not think that STEM offered the answers to every problem or question. It is thus necessary for STEM-G to make explicit connections between what is introduced during the lessons to what is 'out there' in everyday life so that students can see the pervasiveness of STEM.

The students were cognizant that there would be huge opportunities for future research in STEM and had positive feelings toward STEM. However, they did not see how gaining knowledge about STEM had improved their ability to apply what they learnt in school. This suggests the need for STEM-G to help students make connections between the STEM-G curriculum and school curriculum. In bridging the formal and informal, students can make better connections between the two and better appreciate the value of what they learn in STEM-G.

The students found it relatively harder to agree with the view that the value of STEM lied in solving practical problems and improving their ability to see things from a wider perspective. This suggests that the STEM-G curriculum should attempt to make more connections to real-life problems. It should also offer more opportunities for the students to understand the personal gains they may have from learning STEM. Through STEM-G, students should also learn about the macro (e.g. institutional, social and economic) gains that they can gain from developing problem-solving competencies from multiple viewpoints. Pedagogies that provide students opportunities to express and construct multiple perspectives, as opposed to accepting only one school of thought, have been noted as important for a gender-balanced classroom (Maher, 1985).

Table 7.4: Summary of students' attitudes towards STEM-G

Items Easier to Agree With	Items Harder to Agree With
• STEM is important for the society. • STEM improves the quality of living. • There would be huge opportunities for future research in STEM. • I have positive feelings toward STEM. • Everyone should learn about STEM.	• Anything we need to know can be found through STEM. • Gaining knowledge about STEM has improved my ability to apply what I have learnt in school. • The value of STEM lies in its usefulness in solving practical problems. • Gaining knowledge about STEM has improved my ability to look at problems from a wider perspective.

Notably, one statement: 'STEM is too difficult that only highly trained professionals can understand it' was not included in the analysis of the responses for the construct measuring students' attitudes toward STEM. This could be because it was the only negatively phrased item in the construct. In the future, this may be revised to be phrased in a positive manner, or a few more negatively phrased statements may be included in this construct. This construct will then be re-validated.

4. Students' STEM identities

The students generally saw themselves as a member of the STEM community (see Table 7.5). Two statements that were the relatively easiest for students to agree with were: 'I see myself as a STEM learner' and 'It is important to me to be good in STEM.' It was also relatively easy for students to agree that they could describe themselves as STEM learners and saw STEM as part of their identity. Participating in STEM-G was beneficial in making them feel they were a part of the STEM community. Over 60 per cent of the students generally agreed that being a STEM student was an important part of their self-image and they saw themselves as a budding STEM professional and associated STEM to their own image. The findings suggest that students harboured STEM identities as part of their overall identity as a learner.

However, two statements: 'Being a STEM student has a lot to do with how I feel about myself' and: 'I have a strong sense of belonging to the STEM community,' were relatively harder for students to agree with. This suggests a lack of strong connections between their STEM identity and overall self-identity. It could also be that when students positioned themselves in the larger STEM community, they may not have known who the STEM individuals in the STEM fields were and what they did as STEM professionals. Hence, the students were not able to develop a strong sense of belonging to the broader STEM community of professionals. Again, this could be related to the earlier point raised under the first construct 'Students' Views About Participating in STEM-G' on the lack of explicit discussion about who who real STEM professionals are and what kind of work they are involved in.

Table 7.5: Summary of students' responses to their STEM identity

Items Easier to Agree With	Items Harder to Agree With
• I see myself as a STEM learner. • It is important for me to be good in STEM. • I can describe myself as a STEM learner. • I see how STEM is part of my identity. • Participation in STEM-G makes me feel part of the STEM community.	• Being a STEM learner has a lot to do with how I feel about myself. • I have a strong sense of belonging to the STEM community. • Being a STEM student is an important part of my self-image. • I see myself as a budding STEM professional. • Being a STEM student reflects who I currently am.

The lack of identification with the larger STEM community is important to girls who want to pursue STEM higher education and or careers. One benefit to this is the anticipation of the gender inequalities that they are likely to confront when they enter these STEM spaces and learn about ways to deal with these experiences so that they do not receive a rude shock. For example, Frederick et al. (2019) found that Hispanic women college students in a STEM programme downplayed gender disparities and few had anticipated gender inequalities as a result of the structural disparities. Thus, understanding various STEM contexts that form the larger STEM community would be beneficial to girls and women in navigating their learning and working experiences in STEM.

5. Students' STEM career decisions

Students showed positive views or inclinations toward pursuing STEM careers (see Table 7.6). Generally, the statements students found relatively easy to agree with were:

- I understand why anyone would want a job in STEM;
- I would enjoy a career in STEM;

- I would like to have a career in STEM;
- When I leave school, I would like to work with people who make discoveries in STEM.

This set of findings reflects students positive inclinations toward pursuing STEM careers. Over 50 per cent of the students thought that having knowledge about STEM would improve their competitiveness in the workplace.

However, it is interesting to note that while the students thought having a STEM degree would allow them to obtain a well-paid job, they did not think that STEM careers are more prestigious than other careers. Furthermore, while they may enjoy and like a STEM career, it may not be something that they would really want or find easy to work in. This suggests that promises on good remuneration from STEM careers are not sufficient in enticing the students to take up STEM jobs.

Many of the students also reportedly disagreed with the statement: 'My family has encouraged me to take up a career in STEM.' This suggests the absence or deficiency of cultural capital (resources provided by families) needed to motivate or inspire them to pursue a STEM career. Yet, many studies (see, e.g. Ing, 2013; Moakler Jr. and Kim, 2014; Rozak et al., 2017) have reported on the importance of parents in influencing STEM achievements and careers. To cite an example, Moakler Jr. and Kim (2014) found that students with parents in STEM occupations were more likely to choose STEM majors in college. This is where formal and informal STEM curriculum, such as STEM-G, can play an important role as a social-leveller, especially for students who lack the cultural capital in STEM.

Table 7.6: Summary of student responses to their STEM career-decisions

Items Easier to Agree With	Items Harder to Agree With
• I understand why anyone would want a job in STEM. • I would enjoy a career in STEM. • A degree in STEM would allow me to obtain a well-paying job. • I would like to have a career in STEM. • When I leave school, I would like to work with people who make discoveries in STEM. • Having knowledge about STEM will improve my competitiveness in the workplace.	• STEM careers are more prestigious than other careers. • It would be easy for me to work in STEM-related jobs. • Getting a job in STEM is what I really want. • My family has encouraged me to take up a career in STEM.

EQ2: To what extent has STEM-G changed girls' views about participating in STEM; attitudes towards STEM; self-concept; STEM identities; and STEM career decisions?

In order to study the impact of STEM-G on students and changes in students' responses in the survey administered before and after, STEM-G was analysed. While the previous section offered an overview of the students' responses after attending STEM-G and a more detailed analysis within each construct, this section provides comparisons for before and after participation in STEM-G for each grade level. Table 7.7 below summarizes the changes in the five constructs for each grade level. Specifically, it shows the change in statistical significance (see Appendix 7-C on p. 130 for more details on the statistical analysis).

Table 7.7: Changes in the five constructs before and after STEM-G

Group	Participation	Self-concept	Attitudes	STEM Identities	Career decisions
Grade 7	o	↑	↑	↑	↑
Grade 9	↓	↑	o	o	o
Grade 10	↑	↑	↑	↑	↑

Please note. o: 'no significant difference'; ↓: 'significant decrease'; ↑: 'significant increase'.

The impact of STEM-G on these three groups of students was different. For the grade seven students, their self-concept about STEM, attitudes toward STEM, STEM identities and STEM career decisions had improved and the changes were significant. For grade nine students, only their self-concept had improved and the change was significant. Their views about participating in STEM-G decreased and the change was significant. For the grade ten students, STEM-G had a positive impact on all five constructs and the changes were significant. This implies that the STEM-G curriculum for the grade ten students resulted in the most gains for students. The STEM-G curriculum for the grade nine students may need to be adjusted for subsequent implementation to students of a similar profile

Conclusion

Generally, STEM-G had a positive impact on girls' views about participating in STEM, self-concept, attitudes towards STEM, STEM identities and STEM career decisions. Nonetheless, some aspects of each construct that required more attention were identified. This included enhancing the contextual knowledge of STEM-G organizers; strengthening the role of families; harnessing the experiences of STEM-G professionals; broadening students' views about STEM careers; having students engage in authentic STEM learning; and strengthening students' self-confidence and STEM identity.

Based on these findings and existing literature, some specific recommendations were made to address these areas (see below). The paired T-tests results showed improvements in all five constructs for grade ten students. For grade nine students, only improvements in self-concept were found. For the grade seven students, improvements in their attitudes toward STEM, self-concept, STEM identities and STEM career decisions were found. The only construct that showed significant decrease was in grade nine students' views about participating in STEM-G.

Recommendations

Based on the findings, several recommendations were provided to STEM-G organizers and STEM teachers in schools with the goal to improve the implementation of STEM-G in subsequent years. The recommendations are:

1. STEM teachers and STEM-G organizers can work more closely to help the latter understand the ability of the students and pitch the difficulty of the activities closer to the individual student's ability levels.
2. Encourage more family support in advocating for STEM higher education or careers in STEM.
3. STEM-G volunteers who are STEM professionals could share personal narratives and experiences to help students understand the work that they do, why they chose STEM, etc. This approach may facilitate the dissemination of sound advice to students in anticipation of potential issues, plus strategies to manage these issues.
4. STEM teachers and STEM-G organizers can help students to understand the personal benefits one can derive from participating in STEM so they will be more willing to invest time and effort in STEM learning. The reason for taking up STEM jobs should not be limited to economic gains.
5. Enhance students' perceptions about the prestige of STEM careers by having more authentic engagements with STEM professionals whose work makes important contributions to the growth and development of the country.

6. The STEM-G curriculum can afford more opportunities for students to engage in discussions from multiple viewpoints.
7. Support students in developing strong and healthy self-concepts in STEM learning, whether they position themselves as an individual learner, or as a member of a larger community.
8. Develop students' core STEM identity and help them see that they are, or can be a member of the larger STEM community.

Based upon the above recommendations, six critical features of a successful STEM programme for girls were identified:

1. **Empower individuals:** Challenge the girls and provide opportunities that give feelings of success for future confidence building.
2. **Underscore the importance of STEM:** Emphasize the pervasiveness of STEM in life and the usefulness of STEM knowledge.
3. **Address diversity:** Offer a range of curricular structures that provide individual and group experiences for students to develop self-confidence compared with others.
4. **Promote membership in the STEM community:** Create opportunities for students to understand how one fits in the larger community or space of STEM.
5. **Enhance perceptions of STEM careers:** Help students to understand the nature and importance of STEM careers and the prestige of STEM employment.
6. **Engage multiple perspectives:** Provide more opportunities for students to engage in discussions from multiple perspectives (systems thinking) as a way of engaging in STEM.

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Appendix 7-A. Methods

To investigate the change in the five constructs before and after participating in STEM-G, a paired T-test was performed.

To answer the first evaluation question, Rasch analysis was utilized in the post-programme survey collected from all three groups of students. Item separation reliabilities and person separation reliabilities were also achieved for the constructs, hence, the survey was validated for use. Validity is established as the item fit statistics were within the mean square value of 2.0

and less (AERA, n.d.). Based on the infit and outfit mean square values (MNSQ), only one statement: *'STEM is too difficult that only highly trained professionals can understand it'* in the construct 'Attitudes toward STEM' was found to be improper, that is, not functioning well in determining students' attitudes toward STEM. The responses to this statement were removed and the Rasch analysis was repeated and no items were found to be improper. To answer the second evaluation question, a paired T-test was performed on the data collected from the pre- and post-survey within each grade level to monitor the change.

Appendix 7-B. Rasch Wright Maps

Figure 7.1: Wright map of the construct measuring students' views about participation in STEM-G

Please note.: The asterisk "*" indicates the item that has been inverted from negative to positive.

Figure 7.2: Wright map for the construct measuring students' self-concept when participating in STEM-G

Please note: The asterisk "*" indicates the item that has been inverted from negative to positive

Figure 7.3: Wright map for the construct measuring students' attitudes toward STEM

Figure 7.4: Wright map for the construct measuring students' STEM identities

Please note: The asterisk "*" indicates the item that has been inverted from negative to positive.

Figure 7.5: Wright map for the construct measuring students' STEM career decisions

Please note: The asterisk "*" indicates the item that has been inverted from negative to positive.

Appendix 7-C

Tables 7.8-7.12 below summarize the results from comparing the pre- and post-surveys for the five constructs for each grade level. A negative T1-T2 measure means that the average score has increased after attending STEM-G and *vice versa*. The differences that are significant are highlighted in underlined text.

Table 7.8: Changes in students' views about participation in STEM before and after STEM-G

Grade Level	T1-T2 measures	Significance (2-tailed)
Grade 7	-1.991	0.052
Grade 9	2.351 ↓	0.022
Grade 10	-4.324 ↑	0.000

Please note: T1 = pre-programme; T2 = post-programme.

Table 7.9: Changes in students' self-concept towards STEM before and after STEM-G

Grade Level	T1-T2 measures	Significance (2-tailed)
Grade 7	-6.946 ↑	0.000
Grade 9	-2.765 ↑	0.007
Grade 10	-6.681 ↑	0.000

Please note: T1 = pre-programme; T2 = post-programme.

Table 7.10: Changes in students' attitudes towards STEM before and after STEM-G

Grade Level	T1-T2 measures	Significance (2-tailed)
Grade 7	-4.653 ↑	0.000
Grade 9	-0.436	0.664
Grade 10	-4.405 ↑	0.000

Please note: T1 = pre-programme; T2 = post-programme.

Table 7.11: Changes in students' STEM identities before and after STEM-G

Grade Level	T1-T2 measures	Significance (2-tailed)
Grade 7	-3.881 ↑	0.000
Grade 9	-0.550	0.584
Grade 10	-2.797 ↑	0.006

Please note. T1 = pre-programme; T2 = post-programme.

Table 7.12 Changes in students' STEM career decisions before and after STEM-G

Grade Level	T1-T2 measures	Significance (2-tailed)
Grade 7	-4.763 ↑	0.000
Grade 9	1.412	0.163
Grade 10	-3.647 ↑	0.006

Please note. T1 = pre-programme; T2 = post-programme.

In summary, a significant increase in all five constructs was observed for the grade ten students. With the exception of views about participation in STEM, the remaining four constructs were observed to increase significantly for the grade seven students. For the grade nine students, only their views of self-concept improved significantly. Only one construct, views of participation in STEM, had decreased and this was for the secondary three level students.

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SECTION III

Experiences of women working in STEM

8

Are female academics more research resilient? Evidence from South India's engineering institutions

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Introduction

This study explores the various factors that influence female academics to be able to conduct research and publish in a developing country scenario, specifically India. This ongoing study focuses on Sustainable Development Goal (SDG) 4: Quality Education, SDG5: Gender Equality and SDG8: Decent Work and Economic Development by looking at South India's engineering academics, with the main purpose of identifying and exploring various factors influencing their employment and Research Productivity (RP).

The study uses a qualitative approach to understand the perceptions of the academics regarding the various hurdles faced by female academics in their research and the mechanisms they use to overcome them. Interviews were conducted with both male and female academics. Content analysis was used for data analysis. This research builds upon the quantitative results from a previous study on this topic by Bakthavatchaalam (2018), who identified that, as in many developing countries, Indian female academics face a considerable number of disadvantages, such as economic pressures, family duties, not being able to access adequate resources and interestingly, social and cultural factors vis-a-vis their male peers. Even with these disadvantages, the study revealed, rather surprisingly, that female academics had similar levels of research productivity with their counterpart male academics. This research examines how female academics are managing to achieve this level of productivity.

Literature review

Conducting research, advancing knowledge and publishing the results are at the heart of any higher education institution (HEI). Academic papers have become an important indicator of academics' productivity within HEIs. Publications are seen as an essential element in measuring and influencing academics' carrier progression, a department's performance, individual academic distinction and institutional excellence, as well as an indicator for acquiring grants and securing funding (Carayol and Matt, 2006; Fox, 2005; Nygaard, 2015). Since academics are the fundamental building blocks on which institutional research is based (Enders, 2007), institutions need to identify the factors that influence academics' research; to invest in the factors that increase it; and to eliminate any impeding factors.

Research Productivity (RP) is a quantifiable measure of conducting and publishing research (Abramo and D'Angelo, 2014; Altbach, 2015). RP is an accumulation of different activities, including publishing papers at the national and international levels, producing books, chapters and monographs, securing grants, supervising research students, serving as a peer reviewer, being an editorial board member, giving lectures as a guest speaker, contributing to national and international level committees, and filing patents (Horodnic and Zait, 2015; Wootton, 2013).

RP is an effect with various and complex determinants (Ramesh Babu and Singh, 1998). Academics' motivation to conduct research and publish results is influenced by a complex array of factors, including their demographics, such as age, sex, marital status, qualifications and the composition of academic staff in their department (Aksnes, 2012; Adams and Clemmons, 2009; Ebadi and Schiffauerova, 2016; Oshagbemi, 2000). There are also personal and professional factors, such as motivation and self-efficacy, time allocated for different duties, pay scales, institutional position and promotion opportunities (Callaghan, 2015; Horodnic and Zait, 2015; Tien and Blackburn, 1996). Governing bodies, national and international educational policies and how they evolve (Amaral et al., 2009; Diogo, 2015; Frolich and Caspersen, 2017; Vlasceanu and Hancean, 2015), along with the Changing Academic Environment (CAE) (Arimoto et al., 2013; Bakthavatchaalam et al., 2019; Machado-Taylor et al., 2017; Rani, 2010) may all have an influence.

When focusing on genders' RP, several studies have pointed to the lower RP of female academics compared with their male counterparts and have explored the causes and consequences of this difference. Lariviere et al. (2013), in their bibliometric study, comment that men having a higher RP is a worldwide phenomenon and they add that women have a lower first authorship. Aksnes et al. (2011) and Prpic (2002) report that for all age groups, male academics have a higher research output. However, in a later study, Rorstad and Aksnes (2015) suggest that men publish more only until fifty-five to fifty-nine years of age, after which women overtake them. Even though male academics are reported to have higher RP, female peers are reported to have a higher job satisfaction (Katoch, 2012; Smeby and Try, 2005).

Astegiano et al. (2019) point out the prevalence of male-oriented research environments, especially in STEM fields of study, generating a range of socio-psychological hurdles for female academics. This creates an environment where female academics have to outperform men so that their research potential or contribution is noticed. Similarly, Ozkanlı et al. (2009) and Harley (2003) point out that the higher education (HE) system and its structure favour norms that disadvantage women in being recruited, for instance, for top institutional posts and the allocation of various resources. The sociocultural system also impedes female academics by assuming their pivotal centrality within the family and domestic setting, thus undervaluing their role in a scientific and public setting. Usually, the lower level of female academics' RP is ascribed to them having to balance parenting and work roles. However, Aiston and Jung (2015) comment that it is not just family-related factors that decrease female academics' RP but, importantly, it is the systemic and structural discriminatory practices within academia that disadvantage them.

Reduced mobility for data collection, networking and other research tasks (Abramo et al., 2013), academic gatekeepers and paper reviewers undervaluing women's scientific contributions are all factors reported to be disadvantaging females (Knobloch-Westerwick et al., 2013). Parenting and having young children are reported by Hunter and Leahey (2010) and Richards (2006) as predominant factors that limit female academics' RP and their academic career advancement.

Men are widely reported as being better at using their networks for their research compared to women who find it more difficult to engage in networking. Networks range from professional and business groups, alumni associations and just simply talking with their seniors, which could enhance job opportunities and the ability to access resources and increase their social capital (Klasen and Pieters, 2012; Paksi and Tardos, 2018; Sarkar et al., 2019). This absence of networking also affects female academics' collaboration patterns. This can be seen in Huang (2019) and Lee and Bozeman (2005) who revealed the lack of international collaboration and publications of female academics. Cultural prejudices associated with collaborating with academics of the opposite sex are also seen to negatively impact female academics in some countries, whereas this situation is seen to have less influence on male academics (Abramo et al., 2013).

Along with the cited difficulties, Fox (2005) maintains that there is a presupposition of how RP and being an active researcher varies between genders. The perception is that an active and productive academic is either a married man or a woman with no husband or children. There also appears to be a lack of understanding of the gender differences and shortage of policies and practices for building equity (Acker, 2006).

Especially in STEM, the underrepresentation of female academics is seen to be an important reason for their lower RP (Aguinis et al., 2018). It is common across most nations to have gender inequality in STEM, with the number of males being significantly higher than that of females, with India being no exception. Even though there has been an effort to increase female representation in STEM, this has been slow, especially in fields where there is a high gender bias (Aguinis et al., 2018; Astegiano et al., 2019).

Other reasons cited for the disadvantages female academics face include females being drafted for more teaching-oriented duties (Bosanquet, 2017; Suitor et al., 2001); the absence of day-care and child-care facilities in institutions; and a denial of the existence of gender-related issues in institutions (Gupta, 2017). Also, women are culturally considered for more pastoral 'academic mommies' roles (Ropers-Huilman, 2002). Inequality in the allocation of time and resources (Xie and Shauman, 2004) are proven factors that have limited women's research participation and consequently their RP. However, a recent study by Bakthavatchaalam (2018) found no difference between the time spent for teaching, research and administrative duties between male and female academics.

Overall, despite women's high level of educational attainment, the general social structure and assumptions of gender roles continue to flow into academia. Gender equality in STEM is a hotly debated topic and an essential element in achieving the SDGs (UNESCO, 2017). STEM education, especially engineering, is expected to play a major role in the achievement of the SDGs. While it is encouraging to see an increasing number of women choosing STEM-related subjects, Holman et al.(2018) and West et al. (2013), based on their analysis of eight million papers, comment that even though the gender gap seems to be closing and that there is a projected increase in the number of female STEM learners, gender parity will not be achieved in specialist science, physics and mathematics subjects within this century. This is rather alarming, especially in regard to achieving SDG5.

Looking at the first authorship of papers in India, Thelwall et al. (2019) concluded, in that year, that there were 50 per cent more male first authors than females in scientific publications. It was also noted that male academics preferred to conduct research in 'things-oriented' fields, whereas female academics chose to conduct research in 'human-oriented' fields.

It is critical to identify, understand and analyse the various difficulties faced by female academics in STEM disciplines in order to overcome them. UNESCO (2017) highlighted a range of barriers to women pursuing STEM, such as biological factors, neuroscience and brain structures. However, this research focuses on the influence of social, economic, cultural, institutional and family-oriented factors. It is essential that policies not only address these issues but also recognize the historical bias that has caused this gender imbalance in STEM in the first place. Furthermore, rather than having generic gender policies, these should be designed for distinct academic disciplines.

With respect to female academics' resilience, Richman et al. (2011) advocate that in mathematics-intensive fields they are becoming more successful at coping effectively, even though they are a minority in traditional male-dominated fields.

The authors further postulate that helpful female role models, family support and social support outside of work enable women to build resilience. Even more interesting was the finding that women in engineering fields are less sensitive to experiencing a 'social identity threat' than female academics from other gender-balanced fields. How this work reflects the scenario in South India is open to question.

Bakthavatchaalam (2018), in his research on the RP of south Indian engineering academics, identifies and quantifies that, irrespective of marital status and age, there was no significant statistical difference in RP between male and female academics. This is a surprising result that challenges established literature. This paper builds upon the work of Bakthavatchaalam (2018) and explores how, despite the various barriers female academics face, they are capable of overcoming them and succeeding in being equally productive as men.

Need for the research

Recent publications, including Sarkar et al. (2019), Deshpande (2019) and IMF (2015), are generic in addressing female participation across professions, as well as in low-skilled and low-paid jobs. Whereas this research looks into the academic participation of women, particularly in STEM professions. This is the first of this kind of research to be conducted in South India and it attempts to better understand female academics' resilience. The findings should be of use in other developing countries where female academics might face similar issues. It should also help to address the challenges of productive job creation and the goal of achieving gender equality and decent work for all.

This research is important and timely, particularly considering the rapid expansion of the Indian Higher Education (HE) system. Currently, there are 37.4 million enrolled students, 48.6 per cent of whom are female. In terms of the HEIs (Higher Education Institutions), in 2018–19, a total of 993 universities, 39,931 colleges and 10,725 stand-alone institutions were operational in India (AISHE, 2019). The rapid increase in the HE system is evident from the fact that over the last eighteen years, the number of HEIs increased by 230 per cent, the number of students by 311 per cent and the number of academics by 269 per cent (UGC-Report, 2018). Of these academics, 42 per cent are female, emphasising the importance of this research. Also, as Aguinis et al. (2018) stated, this female focus is a new area of research in India. Also, as we attempt to achieve SDGs 4, 5 and 8, it is essential that we explore and understand the various issues faced by female academics in engineering, along with their resilience mechanisms. So, building on the literature and the need for this research, this paper seeks to answer the following questions:

1. What are the various factors that uniquely influence female academics' research productivity?
2. How do sociocultural factors in India affect different genders' RP?
3. How are female academics able to overcome the barriers to RP stemming from social and cultural factors in South India?

Methodology

This study uses a qualitative approach, given that its main purpose is to identify and understand the impact of cultural and social factors on the RP of male and female academics in South India. Qualitative methods are more suited to grasp and interpret the meanings of the results for the chosen research questions (Denzin and Lincoln, 2011; Merriam and Tisdell, 2009; Willig, 2001). This is a privileged way of collecting data about an individual's personal history, perceptions, feelings, perspectives and social worlds (Galletta, 2013; Hennink et al., 2010).

Sample and data collection method

In-depth interviews were used to collect data. Twenty interviews were conducted with ten male and ten female engineering academics. Five interviewees of each gender had more than ten years' research experience and the other five were in the early stages of their career and conducting their PhD studies. An equal number of male and female interviewees was sought to provide a balance in the data. Similarly, their experience was deemed an important element, as the reasons why a person is conducting research during and after their PhD are different, as more experienced academics will be older and more likely to have a settled family life. During the eighteenth interview, the researchers concluded that no new categories, themes, or explanations had emerged from the data; thus, the theoretical and empirical saturations were achieved (Auerbach and Silverstein, 2003; Mark, 2010) and the remaining two interviews served as confirmation of the saturation.

Data analysis

Content analysis was used to analyse the qualitative data collected. This approach, as Krippendorff (2018) stated, enables the compression of a large number of words and text into fewer content categories based on explicit rules of coding (Bardin, 1977). The interview was the unit of analysis, following the suggestion of Graneheim and Lundman (2004), and the data was coded by paragraph and sentence, as proposed by Strauss and Corbin (1998). Also, quantitative results from Bakthavatchaalam (2018), upon which this research is built, was used to quantify academic RP and help to understand the 'why' and 'how' cultural factors influence RP.

Findings and discussion

As explained in the methodology section, a set of categories, coded *a priori*, were built based on a critical review of literature carried out on the impact of cultural and social factors on genders' RP. However, the categorization initially created was not intended to be closed; data analysis allowed for the establishment of emerging categories, i.e. categories that, according to their relevance to the study, have been incorporated throughout data analysis. This analysis resulted in the identification of the broad themes and categories depicted in Table 8.1.

Table 8.1: Themes and categories based on literature review

Themes	Categories
Issues faced by women	Sociocultural expectations
	Family oriented issues
	Financial issues
	Professional and institutional factors
	Specific policies to help female academics
	Career progression
Resilience mechanisms	Family support
	Focus and concentration/dedication to work
	Male peer support
	Changing social system
	Increasing education for women
	Types of research chosen by women

Thus, the findings and discussion section is divided into two parts. The first part discusses the barriers faced by female academics in being able to conduct research. The second part looks at the various resilience mechanisms that female academics employ to overcome these disadvantages and to be as research productive as their male peers.

Issues faced by women

One of the purposes of this study is to explore the various problems and research barriers female academics face that affect their RP. Several interesting factors emerged from the narratives and these are discussed below.

Sociocultural expectations

This category includes social and cultural norms and roles, as well as the expectations of society towards a woman. It also addresses the academics' perception of this topic. The analysis revealed a range of everyday real-world difficulties that were perceived as limiting female academics. In terms of the practical difficulties, almost all the interviewed academics commented about the ability of female academics to go out for data collection and to participate in conferences, networking events, or training sessions. As an experienced female[12] stated: 'Going to industries for data collection, the practicalities are less for female academics.' However, two academics commented that female academics have no barriers compared to their male peers.

Mobility (i.e. the ability to move from one city to another) was reported to be limited for female academics compared to males. An experienced male academic observed that, 'if they [male academics] get an opportunity in a different city or location, it is easier for them to move than it is for a female academic.'

The issue of female academics having a difficulty in travelling to locations to develop their research is commented on by Abramo et al. (2013), who stated that female academics' reduced mobility has a significant negative impact on their research. Mobility issues also result in a comparative lack of research networks and this is disadvantageous to female academics. This lack of physical movement and lack of interaction with men outside their family circles further

12 As indicated in the Informed consent form handed to respondents before the interview, all excerpts from narratives are anonymised. Thus, quotes are identified as 'new male academic', 'experienced male academic', 'new female academic' and 'experienced female academic'.

restricts women's networking opportunities and their access to informal knowledge and the social capital that their counterparts enjoy. This hampers them not only in their research, but also promotion prospects, availing funds, pay and tenure (Paksi and Tardos, 2018).

Other practical issues that were pointed out include a female academic's general reliance on her husband or a male colleague's help in purchasing new equipment, instruments and contact with different companies for tenders and research resources. A male academic stated: 'For male academics this is easy. They would just get on their motorcycle, make a few contacts and acquire the resources and instruments quicker than a female. She will have to think a few times before being able to go and make contacts.' Another academic added that only in the last twenty years or so, that women have started to come out and be professionally active and that it is still difficult for them, but as time progresses, they will find it easier.

From a sociocultural perspective, in Indian society, there is an expectation that women play a more active role in family life; participating in the care of elders and child-rearing, among other tasks, which is seen to limit their RP (Abramo et al., 2013; Elsevier, 2017; Kyvik and Teigen, 1996). Almost half of the academics pointed out that even though society is changing, it is still male-dominated and women tend to take on a more caring role and that it will take time for women to make the transition from a caring to a competitive mind-set.

The issue with transportation plays a major role in creating a barrier for female academics. An experienced male academic stated, 'Men can travel further and they can also come home late in the evening if they want to spend more time at the laboratory or library to conduct research. On the contrary, female academics mostly depend on the college or institutional transportation, so even if they wish to spend more time at the research institution, it is very difficult for them.'

Another cultural aspect that emerged from the interviews was that woman's employment – or the income from their employment – was only seen as an additional resource to the family and not a primary income source, which usually comes from a man's employment. An experienced male academic pointed out that: 'In India, [the] male is still perceived as the breadwinner of the family. If the female is unemployed, it is ok, but it is seen as a social stigma if the man is unemployed.'

In terms of cultural and social expectations, in line with Gupta (2014), women were seen to prefer having a lower educational attainment and salary compared to their husbands. The interviews pointed out that they still see themselves as secondary to their husbands. A good example of this is reflected by a new female academic, who commented, 'when I am with my husband and someone praises me, it feels like they say that, in a way, I am better than my husband. It makes me shy and uncomfortable. I am not sure why I feel like this, perhaps it is culturally ingrained. It is not just me, most women think the same.'

Surprisingly, three experienced male, two experienced female and one new male academic thought that there was no distinction between male and female academics in terms of cultural barriers to conducting research. They commented that, from an institutional point of view, since both genders are being paid the same, the work, quality and quantity of teaching and research would be the same and that no adjustments are required. What really surprised the authors was that these comments came from experienced academics in charge of forming and revising institutional policies.

> *'I do not think there are any social barriers for female academics.'*
>
> *– Comment from an experienced male academic*

In terms of social norms, four academics commented that the family's religious and cultural background might also be a factor that disadvantages female academics in their opportunities to conduct research.

> *'If the family follows Islam, usually, in South India, the woman gets married at an earlier age, before taking advantage of educational and work opportunities.'*
>
> *– Comment from an experienced male academic*

However, Sahu et al. (2017) pointed out that females face similar barriers for HE attainment despite their religious backgrounds.

The cultural upbringing of girls was also reported to create a sense of limiting their freedom. As stated by an experienced male academic, 'the main reason for women to be psychologically disadvantaged is based on how we have brought them up right from childhood.'

This was further expanded by another experienced male academic, who observed,

> Usually, girls are being cautioned a lot due to their gender. Parents say 'do not go alone, let me take you to college/school', 'are you on the bus?', 'are you safe?', etc. So, right from a young age, we have created in female[s] a sense of dependency. Suddenly, if you ask them to do it all on their own while they are conducting research, it clearly becomes very difficult for them. It is parents who have ingrained this dependency in them.

The commentator further added that this was a way of protecting their female children, a way of loving them, but, reflecting on it, they were able to see how this in a way has disadvantaged women and their research.

Family-oriented issues

Indian female academics prioritising their home, family and children more than their professional life and how it takes up considerable research time was a common theme in the interviews.

> *'Research requires a lot of sacrifices. It demands time. Since female academics do most of the care, child-rearing and house chores, this negatively influences their research.'*
>
> *– Comment from an experienced male academic*
>
> *'It is more difficult for a female academic to work on research after coming home than it is for a male.'*
>
> *– Comment from an experienced female academic*
>
> *'Culturally speaking, holding the family together is more important for Indian women, so whenever they feel that research constrains their family life, research becomes secondary.'*
>
> *– Comment from an experienced male academic*

In cultural terms, even though the Indian scenario is changing, society is still largely male-dominated. Regarding this, an experienced female academic commented, 'even if a woman is highly educated and working as an academic, men in the family point them out to their gender and use it as a kind of a controlling mechanism.'

This has a negative impact on their identity as academics and even as women. Few of the respondents accepted that it took longer for female academics to conduct strict time-bound research with tight deadlines due to family duties, which is considerably more in comparison with males.

The data showed some of the ways marriage influences female academics and their research, such as getting accustomed to a new family environment, new family roles and responsibilities, pregnancy, child-rearing and new house chores.

> *'We got married when she just started her PhD and we had a child soon after. It has been three years and my wife is yet to get back to her research or academic practice. She has serious doubts if she will be able to.'*
>
> *– Comment from a new male academic*

The requirement for research was cited as causing additional stress for female academics in addition to that associated with their academic, teaching and family lives. It could be seen that it was clearly difficult for females to balance both spheres of their life.

Overall, the data revealed female academics have to take on more family responsibilities, which impacts on their research time. When research and academic life starts to consume family time, women were reported to face active and passive sanctions, either from their husband or from their in-laws. This again psychologically disadvantaged them. The data showed that there is still a conservative *ethos* in which the man is supposed to have a higher educational qualification and earning than the woman. Ego within the family was reported when the female did better than their husbands either in research, earning a higher salary, or education, etc.

> *'How many husbands do not have ego problems if their wife is more educated than them?'*
>
> *– Comment from an experienced male academic*

Financial issues

An economic model emerged from analysing the interviews. If the family is financially well off and if the husband earns a good wage, then a passive discouragement for the female to conduct research was reported. An experienced male academic said, 'my wife and I are both academics, sometimes I tell her, "what I earn is enough, there is no need for you to work and bring money." Thinking of it now, even though I am an academic, I feel like I stopped my wife from being an active researcher.'

The interaction between a family's economic situation and the support a female academic received was commented upon by at least six academics of both genders and experience. However, it was also seen that, if the academic was from a middle-class family or financially not so well off, then there was an expectation that the female works and contributes to the household income. In such cases, females received more support from their husbands and the family to finish their PhD, to publish, get a promotion, have a pay raise, etc. These results are in line with the works of Sarkar et al. (2019) and Sorsa (2015), who comment on the relationship between household income and female participation in the workforce.

It was seen that the family also encouraged female academics to finish their PhD quickly as they have to pay the tuition fee every semester, adding to the family's financial commitments towards the PhD. So, this further increases the pressure for the female to finish the PhD research sooner. It is interesting to observe how economic motivation plays a role in a family's support towards the female family member's research. It also raises the question that if once the family's economic requirements are satisfied, would they still support the female family member's research endeavours?

Professional and institutional factors

The respondents reported that female academics face various barriers at the institutional level, in their work environment and the way they are perceived by their male colleagues. Seven respondents commented that they have seen instances of passive harassment towards females in institutions. This can either be from a lead researcher, a male colleague, a senior academic peer, or their research supervisors. Passive harassment included 'flirting, drooling and calling them often to talk'.

> *'These are discomforting. Especially in India, you don't want to be direct with people, making it difficult for female academics to confront them [male academics]. There are policies available in the institutions to address active harassment, but passive ones need to be explored carefully.'*
>
> *– Comment from an experienced female academic*

Two of the female academics commented that to avoid such circumstances, female academics prefer to have another female as their lead researcher or research supervisor. While some male academics disagreed, female academics said that it is difficult for them to be noticed and acknowledged by the management, even if they produce the same amount of research and work as their male colleagues. They felt that the institutions valued male more than female academics, thus demotivating them and negatively affecting their RP.

Almost all the academics remarked that many South Indian engineering institutions have poor research facilities. These are mostly teaching-oriented HEIs, but, currently, there is a growing demand in these institutions for their academics to conduct research and publish increase institutional rankings.

> *'They [HEIs] have little to no laboratory or library facilities. Research is being conducted here because there is a requirement.'*
>
> *– Comment from an experienced male academic*

This seems to be an important factor influencing academics' choice of conducting research. How much and in what way this influences academics' motivation to conduct research should be explored carefully. Along with teaching and research, academics are also loaded with a range of administrative tasks, which is increasingly demanding of their time. Seven respondents mentioned that academics are tasked with recruiting (if needed, by knocking on potential students' doors) a certain number of students every year and also to find them jobs. This is more difficult for female academics, especially with their limited contacts and network. In line with Aiston and Jung (2015), it is not just the sociocultural and family-related factors that hinder females' research, but also the systemic and structural discriminatory practices within academia. Furthermore, studies by Ozkanlı et al. (2009) and Harley (2003), among others, point out how the HE system and structure favour masculine norms, which naturally increases female academics' difficulties.

Even within the same institution, academics' RP was noticed to differ with respect to engineering disciplines. Female academics predominantly chose to conduct research in IT, computing and electrical engineering which required less physical and field work. In these scientific departments, female academics are likely to have higher RP than in disciplines that traditionally require a more physical approach. Also, these fields do not demand expensive hardware and laboratory equipment, making it easier for the academics and the institutions to invest in them. These results are in line with the findings attained by Bakthavatchaalam (2018), which show that computing and IT-related departments were the most research productive, with mechanical-related departments having the lowest RP. This is also confirmed by Klasen and Pieters (2012) who concluded that the choice of subjects within engineering is influenced by gender.

Specific policies to help female academics

Most of the academics knew about some of the national schemes that encourage female academics to carry out research, which includes the flagship 'Women Scientist Scheme'[13]. However, at the institutional level, none of the respondents were aware of any policies that specifically prioritize and support female academics and their research.

> *'There is nothing that takes into consideration the barriers we face and the policies are gender-neutral.'*
>
> *– Comment from a new female academic*

Such a gender-neutral approach results in the institutions imposing the same teaching and research loads on male and female academics. It is important that further research and consultations are made to assess the effectiveness of such gender-neutral policies. With reference to maternity leave, interviewees commented that, even though the government allocates one year of maternity leave for female academics, the institutions do not strictly follow it, a situation that is corroborated by Gupta (2017). This is particularly so in the newly founded institutions, which cannot afford to have a temporary staff member until the female academic returns from the maternity leave. Thus, usually, female academics are requested to resign their post and if there are any suitable positions available after they finish their maternity leave, the institution would consider employing them. The following statements reflect this reality:

> *'There is no job security based on maternity. It's like an unwritten rule.'*
>
> *– Comment from a new female academic*

13 This programme was launched by the Department of Science and Technology (DST) in 2002/2003. This initiative aims to support women scientists and technologists conducting research in science and engineering.

'Even if maternity leave is provided, it is unpaid.'

– Comment from a new female academic

This job insecurity due to pregnancy was further mentioned by a new female academic, 'if I have to quit my job because of pregnancy, then it is difficult for me to get back to the flow of conducting research. This job insecurity and the thought that I might not be able to continue research puts me off.' In addition, Gupta (2017) reported that female academics who make use of flexi-time given to them by their organization (if any), this is seen unfavourably by the hierarchy and male peers and they are unfairly perceived as not being dedicated to their work. When pressed to provide a reason for the absence of the maternity leave, flexi-time, etc., six academics commented that there has been a fall in the number of students choosing to study engineering, with many institutions having half or even lower student enrolments (AnnaUniv, 2020). This has resulted in the newly founded institutions, which predominantly depend on the students' tuition fee to run, to work in 'survival mode'. Consequently, it is hard for these institutions to provide the 'luxury' of maternity leave to their female staff.

The respondents also commented that female academics should make full use of the various government schemes that help them and that they were not doing so. This may indicate that female academics are either constrained by the *status quo,* or that they feel that they still do not have enough power in a male-dominated society to claim or fight for their rights. The interviewees further stated that if the female academics' range of disadvantages were minimised or, ideally, eliminated and their opportunities for research increased, then their RP would be higher than that of their male counterparts. More than half of the respondents commented that there should be proper support mechanisms put in place by the HEIs for female academics, especially for those with children.

Career progression

Female academics reported that they were dissatisfied with their career progression opportunities compared with male academics. Even when a female produces the same quantity of research, they felt that the management preferred to promote male academics and for them to progress quicker through the ranks.

Female academics commented that forming institutional policies that give them the same opportunities to conduct research as men, as is the current practice, are actually not sufficient, as they face a considerable number of other barriers compared to men.

> *'There is no difference in the promotion policy for male and female academics, meaning females will have to produce the same number of publications as males, but unfortunately I told you already the various difficulties they face.'*
>
> *– Comment from an experienced female academic*

> *'Women are passionate about research as well, but if the opportunities for that person to express their potential are limited, then it is difficult.'*
>
> *– Comment from an experienced male academic*

This suggests that female academics have to overcome more barriers to get a promotion. There were suggestions from academics that, rather than having a gender-equal promotion policy, positive discrimination for female academics would create more equality. An experienced female academic said, 'even if females are research productive and do their job well, the maximum they can progress is to be the head of the department or the dean. Most of the time, males occupy senior roles. This glass ceiling demotivates females as they know that, no matter how much and how good research they conduct, they will not be able to progress to the top management level.'

Female academics also indicated that they feel there is a considerable amount of 'underground politics' within the institution, which prioritise male academics in progressing quicker.

> *'A lot happens behind the scene.'*
>
> *– Comment from a new female academic*

These results are in line with the ones by Aguinis et al. (2018), who point out that female academics, compared to their male counterparts, would have to accrue higher social and scientific capital and resources to achieve the same level of RP and consequently, promotion. These sections have discussed the various barriers faced by the female academics. In order to understand the impact of these barriers on their RP, the respondents were asked to comment on their perception of the RP of genders. This is seen in the next section.

Research productivity of genders

Three academics, two experienced female academics and one experienced male academic, pointed out that female academics' RP is the same as male academics' RP, with one experienced female academic pointing out that females might have higher RP than men. Otherwise, the remainder of the sixteen respondents asserted that male academics produce more research papers and publications and overall have a higher RP than their female peers. Most of the respondents commented that female academics have considerably greater disadvantages compared to their male colleagues when it comes to research. Respondents who commented that female academics have equal or higher research outputs claimed that gender differences make little sense when it comes to research and that a person's RP is based solely on the individual interests and motivation.

> *'It is the person's commitment, nothing else matters.'*
>
> *– Comment from an experienced female academic*

In his research, Bakthavatchaalam (2018) quantified the RP of genders and surprisingly found no statistical difference in the RP, including the number of publications, conferences, etc., of male and female academics in South India. Furthermore, the results obtained from other cultural backgrounds such as Vuong et al., (2017), Bland et al., (2005) and Gonzalez-Brambila and Veloso (2007) also found no difference in the RP. However, other literature (Aguinis et al., 2018; Lariviere et al., 2013; Lee and Bozeman, 2005) identifies the differences in the RP of genders.

Comparing the results of the current research that shows a range of barriers facing female academics with that of the results by Bakthavatchaalam (2018), who identified that females managed to produce the same research as their male counterparts, is surprising. It clearly shows research resilience in the female academics. The next section will explore the various resilience mechanisms that female academics use and the various changes that are happening within society that help female academics conduct research and be productive.

Resilience mechanisms

Family support

Most of the respondents mentioned the importance of family support for female academics wanting to conduct research. Two subcategories of family support emerged from the data: family support before and after marriage.

Family support before marriage

Before marriage, most respondents reported that female academics' parents predominantly took care of family responsibilities, ensuring their daughters have sufficient time to focus on their research. As a respondent said:

> *'In Indian culture, children mostly stay with their families until marriage, with the mother doing the house chores, with the female academic helping in one or two activities.'*
>
> *– Comment from a new male academic*

Over the last decade, parents have started to encourage their daughters to get a master's and/or a PhD, which often means that they are ready to postpone their daughter's wedding if required. Parents also accompany their daughters to different cities, to participate in conferences and to collect data. This parental support not only helps females logistically and physically, but it also is seen to be a major psychological encouragement. As a new female academic said, 'fifteen to twenty years ago, parents would start searching for a groom when their daughter is still studying her UG, or just after, but now they encourage their daughter to study further if she desires.'

One interesting observation was that parents tend to celebrate their daughters' 'academic success' in order to increase her marriage prospects. Furthermore, it was seen that women, in general, had more time and fewer responsibilities before marriage compared to after marriage, with 'marriage' being a defining change in their life.

Support after marriage

Most of the respondents mentioned that, after marriage, the spouse's support is crucial for females to conduct research and to be successful academically. One new male academic respondent stated: 'Husbands play a major role in females conducting research. If there is no support from the spouse, it will be very difficult.'

Husbands were seen to support their wives in a variety of ways. Acknowledging that female academics might lack contacts, husbands use their network to assist their wives. They assist them in data collection, travel with them to different places for participation in conferences and support them by sharing household chores.

Along with the husband's support, support from the husband's family, such as the in-laws, was also reported to be important. A new male academic said, 'without the support of in-laws in a joint family, it is very difficult in the Indian scenario for a female to be able to balance both personal and professional life.'

However, on the positive side, a new female academic said, 'a joint family is advantageous because the female will have some reassurance that her children would be looked after by the family members while she is conducting research, whereas in a nuclear family, she will have to [do] most of the work.'

Some respondents mentioned that there has been a change in the family structure, from joint to nuclear families and commented that this new family structure has both advantages and disadvantages for female academics. It is advantageous, as, with fewer family members to attend to, female academics can dedicate more time and effort to research. One experienced male academic said, 'being in a nuclear family shields the couple from the various 'gossips' and the societal and cultural expectations that would be placed on them if they were living in a joint family, thus increasing females' freedom to conduct research.'

Gupta (2014) comments that with the decreasing number of joint families, young couples can have more egalitarian attitudes with women finding it easier to come out of their homes and be employed and be more independent. Such social changes would enhance women's opportunities to conduct research.

Respondents also mentioned that some husbands shared aspects of their wives' research, including data collection, analysis and writing up reports. As one new male academic stated: 'If the husband and wife are working in the same (academic/research) field, then sometimes it is indistinguishable whose research that is.'

It was observed that even though husbands understood their wives' academic ambitions and supported them in any way they could, they still expected them to prioritize the family needs. As one young female academic said, 'if her professional and research life starts eating into the family life, then the support the family offers her starts to erode.'

Interestingly, the link between the overall financial condition of the family and support for the female's research was revealed by the data. It was reported that the husband's support is lower in a financially affluent family compared to the situation when there is a financial requirement for the wife to contribute to the household income. Even though there is an increasing support before and after marriage, there are arguments (Bakthavatchaalam, 2018), that the support before marriage is mostly to increase their marriage prospects to a well-off educated person and that the support after marriage is to increase the financial status of the family. Even if this is so, the output of this increasing support has positively influenced female academics' RP. Overall, these societal changes have positively influenced female academics in their RP and as a spill over, their confidence in research.

Focus and concentration/dedication to work

Another resilience mechanism that emerged from data was female academics' ability to focus and work without getting distracted compared to their male counterparts. Irrespective of the gender and experience, this was reported at least ten times by the respondents. An experienced male academic said that, 'women procrastinate less, at least in their research work, are more organized and plan ahead, giving them an edge.'

The focus of female academics and the quality of their research were mentioned by an experienced female, who said, 'in terms of the duration of conducting a PhD, even if a male and a female academic start their research at the same time, females finish it quicker and also with higher quality.'

In addition to the focus of females towards their research, males' easy-going nature was pointed as a contributing factor. For instance, a new male academic said that, 'men get easily distracted and make jolly, just keep postponing their research on a regular basis, compared with women.' Another new male academic said, 'when a male academic sits to do research, he thinks, "let me go have a cup of tea or let me call my friend, etc.", whereas a female tries to finish as much as she can without getting distracted. This might work to their advantage.'

Six academics, two experienced males and females and one new male and female, commented that female academics were very good in data analysis and writing up, compared with their male peers. Male academics were reported to be good in networking and collecting data, especially if it is physical or field work. An experienced male academic said, 'if you give them [females] the data, they can sit and finish it, even if it takes a long time, unlike men. To share a personal incident, my wife, who is also an academic, spent almost four hours last night working through her data, whereas if it were me, after 10 pm I would say "well, let us see tomorrow" [laughs].'

Looking at these findings, the authors do question if there has actually been any change in the traditional gender roles in the target society. Comparing this situation to prehistoric times, when men went hunting and women predominantly stayed at home and cooked, the current situation looks analogous, in that male academics go hunting for data and do the physical work, whereas female academics analyse and write up the research. It could be interesting to explore the changing gender roles, not only within academia but also at a societal level. Further research will have to be carried out to look into male and female academics' self-efficacy and focus, as it is unclear what factors enable female academics to focus better than their male counterparts and the reasons why male academics are easily distracted.

What really surprised the authors was that even though half of the respondents commented that women are more focused and are good with data analysis and writing up, they also commented that despite the above skills, women still have a lower RP than men. This is contradictory.

Male peer support

Most female respondents commented that other male academics, peers help them in conducting research, for instance, to travel to buy some equipment, to visit a laboratory, etc. An experienced male academic said: 'Male academics are aware that females have certain disadvantages, so they try to help them in their research and some administrative tasks.'

In addition, a new female academic stated: 'It is not possible for me or other female academics to do all the work by ourselves, so usually I offer ideas to my students and colleagues and ask for help. I cannot take the full credit for the work, but it is a mutually beneficial work for us all.'

This academic further indicated that not only male peers of the same rank, but also senior male academics, assist them. However, at least two academics mentioned that male academics tend to support their female peers only after they had achieved their own targets and that helping female colleagues might not be their priority. Overall, the results show that female academics' RP was positively influenced by their male colleagues' support. At the same time, it further deepens a sense of dependency on their male counterparts. One of the interesting results that emerged from the data was the increasing trend of academics to get married within academia, as remarked by at least four respondents. This perhaps gives both partners a better understanding of what the other person is going through and the various avenues in which they can produce synergies together to benefit each other. As one of the experienced male academics said, 'don't be surprised if you go to any institution and you find at least three or four couples.'

There are also instances in which the husband adds his wife's name as *gratis* in his papers, especially if they are both working in the same domain. As an experienced male academic stated: 'If my wife is not actively participating in any of the research that I conduct, I have her name as a co-author, just for her career growth.'

Overall, the increasing understanding and assistance provided by male colleagues has a positive influence on a female's RP.

A changing social system

The data revealed a variety of changes that are happening in the social and cultural system in South India that enable and support female academics in their RP. The changing social system was divided into the following subcategories: (1) Changing gender roles; (2) Increase in the age of marriage; (3) Increase in the confidence of women; and (4) An increase in education for women. The changes are not just within academia; rather, these are wider social changes, whose impact overflows into academia.

Increasing education for women

Seven respondents reported that parents wanted their female children to be highly educated and employed before getting married. This shift in the parents' perception of their daughters' role in society enables women to build resilience. It also enables them to be financially independent of their husbands and their husbands' family. Parents see education and employment as 'insurance' for their daughters in case something goes wrong with the marriage. Regarding the increase in female education, a new male academic said:

> Twenty years ago, if you look at the wedding invitation cards, mostly, they would only show the groom's educational attainment and workplace. The bride's won't be as she might not have a degree or employment. However, in the current invitations, you have the educational attainment and workplace of both the bride and the groom. This not only shows an increase in women's education, but also how proud their families are to exhibit their daughter, daughter-in-law's education and employment. This shows a huge change.

Looking at this particular development, the authors are encouraged to expect this upward trend to continue. When more women are highly educated and enter the professional world, they not only gain more exposure and confidence, but also create a positive impact on society, serve as role models and inspire young girls and other women. Furthermore, comparing the findings of this study with the results of a study on female engineers in India from fifteen years ago (Patel and Parmentier, 2005) that concluded that increasing education and technological changes did not equate to a redefining of the gender roles, we believe that this redefinition is now well underway.

An experienced female academic said, 'parents see their daughters being employed as a positive social status, whereas, before, this was widely not the case. This increased education and opportunity give[s] them confidence both personally and professionally.' Two more academics indicated that, even though there may be no economic requirement for the daughter to work, the families still support and encourage their daughter to work before and even after marriage, depicting a changing mind-set.

On the whole, results show how society has increasingly started to value females and their education. All these shifts are seen to be positively influencing female academics' resilience. As a new male academic stated: 'Fifteen years ago, parents educated their male child [more] because there was an inherent expectation that their male child would take care of them during old age, but now they think that their daughters are the ones who will take care of them. So, they are more interested in making sure that their daughter is equally educated as their male child or even better educated.'

Changing gender roles

The data suggested that the strict gender roles that were prevalent a couple of decades ago in India are now getting more blurred. One of the major reasons for this was reported to be an increasing professional understanding of the married couple in terms of each other's employment requirements and how it affects their family life. Earlier, mostly the husbands were involved in paid employment and females predominantly did the household chores, whereas today, when the wives also work, the husbands usually try to share a few household chores. The change in this regard can be explicitly seen from the statement of an experienced male academic, who said, 'my mother will be unhappy if she sees me doing house chores. In her generation, it was predominantly female's work, but now, we [him and his wife] take it as a shared responsibility. This sharing in a way might enhance female academics' RP.'

Historically, the in-laws have had a huge influence on the decisions of the family, including their daughter in law's employment or the restriction of it. Yet, the data show that there has been a change in the perception of the in-laws regarding the gender roles of their son and his wife. A new female academic said, 'years ago, daughters-in-law working was not seen in a positive light. However, now this has changed considerably. To say that their daughter-in-law is working, for instance, as an academic is seen as a positive status symbol and they are very happy to showcase this.'

This change in perception is not just reflective of their daughter-in-law's employment, but also an acknowledgement of the changing gender roles within the family. In addition, it is about the more flexible nature of gender roles and its celebration or, at least, its acceptance. The results suggest that there is a shift in the societal attitude regarding gender norms. For instance, most of the respondents commented that, unlike twenty years ago, when gender roles were comparatively strict, currently there is an ease of it within the family. Men are happy to share house chores with their wives and they are taking on considerably more family responsibilities. The social and cultural transformation that is taking place was either seen by some as progressive but by others as culturally detrimental. However, everyone acknowledged the changing social system and the reduction of the once strict gender roles.

Increase in the age of marriage

In Indian society, the age for marriage is, traditionally, different for men and women. It is well accepted that a man gets married in his late twenties, whereas, for women, this age is considered too late. This may still be a hindrance for women who wish to progress academically. As an experienced male academic said, 'if a female gets married just after her master's, she would be around 23, 24, which is seen as the normal age for getting married. But if she chooses to do her PhD just after the master's, by the time when she finishes it and publishes a couple of papers, she will be around 29 years old and that is considered to be old.'

However, this is starting to change and the families are now happy and willing to postpone their daughter's marriage in favour of her education and employment. Four of the interviewed academics said that there is a steady increase in the age of females getting married in South India, at least for those who are working in HE. This has increased the opportunities for women to study and work before marriage. One experienced male academic acknowledged these changes and the resulting advantages for female academics by stating, 'the parents advocate that, even if it takes a couple of years for their daughters to finish their master's or their research work on their PhD, then let it be so and after that, they can get married. This is an important social change that has happened in the last decade or so.'

However, a couple of academics, experienced male and female, were quite conservative and sceptical about women getting married in their late twenties, whereas for men, it was still felt to be a reasonable age for marriage. This suggests that even now, few of the older academics are still under the influence of the traditional way of envisaging the gender roles. Yet, there is a definite change. This shift in the sociocultural system is bringing benefits for women in their academic progression and RP, as they are now increasingly having the opportunity to invest in their education before marriage.

Increase in the confidence of women

The data pointed out that one of the reasons for female academics' research resilience is the increased confidence of women, due to changes in the sociocultural system in the last twenty to thirty years. However, at least five of the academics pointed out that even though there is an increase in women's empowerment, there are still boundaries.

> *'The range of freedom has increased considerably, but they [women] still operate within the current social norms.'*
>
> *– Comment from a new male academic*

An experienced female academic said, 'ten years ago, I would be expected to be at home at around six pm or so, but now I can come home at around 8 or 9 pm. There has been an increase in freedom. However, the expectation is that I will be home at that time and not be working or conducting research until 10 or 11 pm. Our society has not probably evolved to that level.'

The data also pointed out that, since women are, today, better educated, they are more demanding of their rights compared to a decade ago. A new female academic said, 'well, I am well educated, I am earning money, and if my opinions are not respected, then I am not very happy and I will express my dissatisfaction. This was not the case for the previous generation.'

The increase in women's confidence was explicitly visible when a new female academic stated: 'Twenty years ago, if a lady went to talk with a male colleague, people would look at it strangely, but now it is considered a common thing. Earlier, my husband would not really like me going and talking with other male academics, but not nowadays, especially if it is for professional, academic purposes.'

This has opened up new avenues for female academics to discuss their research with male peers and to expand their network. One experienced male academic pointed out the increase in female academics' confidence and the social view of it with the following comment, 'they [female academics] are more confident now. Just look at the movies that come out, a lot of them speak of women empowerment.'

Within STEM, it seems that female academics are learning to deal with adversity, in sociocultural, institutional and scientific terms. The work of Richman et al. (2011) stresses that women are becoming more successful and are striving effectively in STEM-related disciplines, despite still being a minority. Whether these changes will be sufficient to bring about SDG 5 in HE research is questionable.

Type of research chosen by female academics

Gender differences were noticed in the type of research female academics chose to conduct. Five of the respondents mentioned that female academics choose disciplines that require less travel and are more institutional-based. The data showed that females chose to conduct research in areas that required less fieldwork compared with men. This reduced some of the disadvantages seen in the previous section. A new female academic commented, 'if they [female] choose research which does not demand a lot of fieldwork, then it is easy.

For example, a topic that is more computer-based and also being closer to home and being able to work from home.'

Furthermore, to overcome some of the mobility barriers faced by female academics, it was reported that they seek the assistance of their students and fellow male peers, either for long-distance travel or to a particular place where they might not feel comfortable or safe. An experienced female academic stated that this approach was a 'smart' way of overcoming the travel barrier.

Similarly, an experienced male academic said, 'if the research is about bringing out a new product or a process or implementation, then it is difficult for them [female academics] compared with males.'

In summary, the choice of the type of research that female academics conduct is seen to be conditioned by the hurdles they have to face in a still traditional, yet changing society. The next section brings together the issues faced and the approaches female academics used to overcome barriers and restrictions.

Relationship between the barriers and the resilience mechanisms

Even though the results show decreasing social and cultural impediments for females, they still operate in a patriarchal society in which females face considerable control (Batra and Reio, 2016; Bhattacharyya, 2014). Data showed evidence of family members using gender as a controlling mechanism, even if the female is highly educated. Such patriarchal thoughts have had a spill-over effect in organizational policies as well.

Shukla (2015) found in her work that even though the younger generation were less traditional and more supportive of women's employment, men still expected women to shoulder child-care and household responsibilities, which they considered women's primary role and not their professional and research development. Conducting research demands a considerable amount of personal time, but sociocultural expectations increase the chores females have to perform after coming home, thus further hampering their work-life balance and their RP.

Shukla (2015) also points out that gender roles in India are undergoing a considerable transformation, albeit slowly. This includes an increased professional understanding; husbands getting more involved with domestic chores; helping their wives with their research by using their networks; and also assisting with data collection, thereby allowing their spouses to focus on their research more intensively. In the institutional environment, male colleagues who are ready and willing to help their female colleagues with their research also help the females' RP potential. It should be noted that the word 'help' – not 'collaborate, or share' – is used profusely by both male and female respondents when referring to the professional relationship between the genders. The same word, help, was used in a family scenario as well. By giving or not giving help, it could be argued that men, either a family member or a male peer, still have an important influence on the potential success, or lack of success of female colleagues and spouses.

Mobility constraints affecting female academics was cited as one issue that limited their opportunity to conduct research and further their professional development. One solution to this could be online-networking, especially with increased use of the Internet, which, in theory, should enhance female academics' networking opportunities. Exploring this idea, Paige Miller and Shrum (2012) state that female academics' networks still tend to be localized and not broad. By embracing the opportunities online networking offers, female academics could offset some of the disadvantages, as commented by three of the female respondents, who mentioned their growing online network and the research openings it has provided them.

Looking at the respondents' narratives, it can be commented that, given that female academics have considerable travel constraints when collecting data, they have little choice but to become experts in writing literature reviews, analysing data, etc. Furthermore, female academics have to make greater efforts to start and be resilient to continue their academic career. This might be one of the reasons for them to be very focused and dedicated, as they have little room to make mistakes. Institutional closures during COVID-19 resulted in a drastic increase of online education and research in academia, making it common place. This situation has increased not only online teaching and learning, but also online research and networking between academics. It remains to be seen how this has influenced academics' RP and if there are any gender differences in RP during the lockdown.

However, from the interviews, it was noticed that currently there is increasing support from female academics' families both before and after marriage, which enables them to overcome the mobility barrier to a certain extent. While having a male family member willing to accompany them will potentially provide them with new research and networking opportunities, it still raises the question of overdependence on the other gender. This needs further consideration in the promotion of SDG5, gender equality.

Mitra and Pooja (2007) point out the importance of a change in the social and cultural norms, along with female education, to create gender equality. The vicissitudes in the last thirteen years after their article was published reflect the required changes in people's attitude starting to take place, which is encouraging. Rather than considering that the increase in females' RP as largely due to the male family member's help, these findings represent a wider change. They embody a changing society, its norms and a changing cultural perspective. They are seen as a reflection that society as a whole has started to acknowledge the potential of female academics and women in general, increasing their opportunities to succeed. It should be acknowledged that there are abundant problems surrounding this transition, but what really interests the researchers is to see this transition happening, slowly but steadily. This is an encouraging step towards achieving gender equality. Overall, these societal changes have positively influenced female academics in their RP and especially their research resilience.

Currently, there is an increasing awareness among parents about the importance and advantages of females pursuing HE, including the financial and social independence it offers their daughters. The families postponing their daughters' wedding for them to pursue research programmes such as a PhD stands out as a prime example. For instance, Das and Das (2018) comment on how increasing educational opportunities has impacted positively on a woman's age of marriage and their consequent social wellbeing. These are important social changes positively impacting female employment, research and vice versa. As UNESCO research (2017) stated, these women in turn serve as role models for younger women to pursue their educational and research goals.

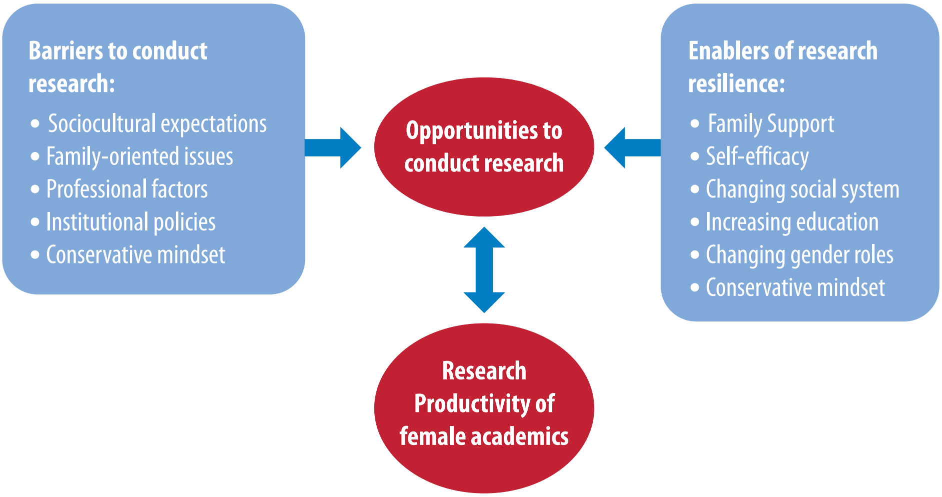
Even after marriage, there is increasing support from husbands to their wives to pursue research and increasingly, also from their in-laws. Even though it was reported that this support is mostly for economic reasons, i.e. to increase the family's income, this trend has enabled greater research opportunities for wives, with a related increase in their confidence, employment opportunities and financial independence. Data shows academic managers and those at the policymaking levels in HEIs are happy with the promotion of gender-neutral policies for research and promotion opportunities. Although this seems a positive development, it actually disadvantages female academics as they have to overcome comparatively more barriers than men to have the same RP.

The institutional practices, though said to be gender-neutral, in reality, these do not result in gender equality. Employment practices, such as females losing their post due to pregnancy and child-rearing demands, need to change, as they create job insecurity and result in women leaving research and academia. Regarding promotion, even with the 'gender-neutral' policies the institutions propose, females presume there is a 'glass ceiling' and that it is easier for their male counterparts to achieve professional advancement. Institutional policies making promotion and pay rise decisions more open could address this issue. It is essential for institutions to break down the barriers women face, which are usually accepted as the norm (Batra and Reio, 2016). This can be done by first acknowledging the existence of the sociocultural barriers female academics face, exploring the barriers and finally, forming policies and practices to eliminate them. To promote active research collaboration between the genders, it is essential for the institutions to form and actively follow the practices related to the 'passive harassment' that was reported. This is especially important in engineering and other STEM related institutions where females are in the minority.

Focusing on engineering education and research, traditional engineering disciplines such as civil, mechanical and manufacturing engineering are still dominated by men. Whereas the emergence of disciplines such as electronic and communications engineering, computing and ICT, which require less physical work, has motivated more females in these disciplines. For instance, Gupta (2014) stated that in India, a 'woman-friendly' image of ICT and computing engineering fields is developing. Moreover, the current increased opportunities to study engineering and job prospects in this field have encouraged greater female participation. Even in the disciplines that demand a lot of fieldwork, travel and laboratory equipment, such as civil and mechanical engineering, currently there is an impetus towards inter-disciplinary research, programming, design, simulation and online testing etc., which can be done with a computer and from home. This could, in the future, make these scientific fields more female-friendly and increase female participation and research in these areas. This is an encouraging possibility. These changes could factor in to fix the 'leaky pipeline' as highlighted by Huyer (2015), where even though the enrolment in science and engineering is high for females in UG, when it comes to PhD level and choosing a research career, there is a huge drop in female numbers compared to men.

It is essential that institutions promote the evolution of engineering as a female-friendly area for study and research and form policies that support this transition, both for aspiring female students and female academics. The results from this research allowed the development of a model that brings together the essence of the various factors identified (Figure 8.1). The model depicts a number of hurdles Indian female academics in STEM have to overcome, namely through a set of resilience mechanisms that they have developed and which are also the results of the changing Indian sociocultural system.

Figure 8.1: Model of Indian female academics' research productivity in STEM



Source: developed by authors

Conclusion and recommendations

Academics are the heart and soul around which research and HEIs are built (Enders, 2007). Unfortunately, many female academics are held back by a range of factors, including social norms and expectations derived from gender discrimination and bias. There is a considerable body of evidence that suggests female academics inspire more female students to enter STEM education (UNESCO, 2017) and currently there are an increasing number of female engineering academics who may positively influence more females to choose an engineering course and successfully forge a career in this discipline. Overall, this paper shows a considerable resolve in female academics in wanting to match or even better their male counterparts in research, despite the hurdles they face. The research is based on a sample of twenty academics, which the authors believe should be increased in future research to better understand the mechanisms used to achieve this resolve.

Some of the contributions of this paper are that it has identified the various issues faced by female academics and that, despite these disadvantages, they manage to produce the same research as their male counterparts. Research has also identified some of the mechanisms they use to overcome their disadvantages and importantly, how the evolving cultural and social factors aid in the process. The authors acknowledge that this research has just scratched the surface and that further investigation could unearth a range of hidden factors.

The studies suggest that when HEIs, policymakers and governing-bodies form their research policies, they should consider gender differences and cultural factors. Proper provisions should be put in place to support female academics in their research activities. Also, interventions through targeted public policies could potentially reduce the influence of cultural factors impacting on females' RP. This would seek to bring about and foster equitable conditions and opportunities for male and female academics and would empower them to conduct quality research. The identified mechanisms which female academics appear to employ can be more widely adopted, not only in Indian academia but as a reference in the wider labour market in other developing countries and similar cultural systems.

Such policies should enhance gender equity (SDG5) in the workplace, especially in terms of research and also reduce inequality in research opportunities (SDG10). This approach would have a huge and favourable impact on the quality of the research produced and ultimately, influence the quality of wider education (SDG4). The lessons from this research could be applied to institutions specializing in disciplines other than engineering and also, with an understanding of local data, to institutions in other parts of the country. The results of this research can be used as a basis for further investigation; for institutions to develop their research policies; and to help their academics conduct and produce high-quality research and publications.

Limitations of the research and future work

Just like any other qualitative study, generalizability is a major limitation of this study. This research was conducted in Coimbatore's (a city in the South Indian state of Tamil Nadu) engineering institutions, which might reflect the situation in South India, but generalizing it to the whole country or Asia should be done carefully, as the socio-economic and cultural milieu are different. A nationwide or a South-East Asia wide study could be conducted in the future that could compare the different geographic regions and female academics' RP and their resilience. To make inferences from the small sample of engineering academics, to academics in disciplines such as humanities, science, medicine, etc., might potentially be limited and must be done with caution. One commonality between the target academics and academics from different disciplines would be that they would have all largely come through the same education system and will currently be operating in a similar cultural environment.

The lack of empirical research in this subject area in India limits the potential to compare the results with that of other studies. As interest in this field increases, there will be more opportunities to further investigate this. In this research, the RP measured is based only on the number of different publications and future studies might consider both the quantity and quality of publications, including the citation index, the impact factor, etc. A longitudinal study could be conducted to assess how, over time, the changing academic environment and the sociocultural system influence the opportunities for female academics to conduct research and consequently, their RP.

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9

Exploring gender equality in STEM education and careers in Kazakhstan

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Introduction

The advancements in science, technology and innovation, which constantly make various aspects of our lives better and more efficient, play a pivotal role in achieving the United Nations 17 SDGs through contributing to food security, healthcare and addressing limited freshwater resources and climate change (UNESCO, 2017). Therefore, the role of STEM fields cannot be overestimated in the achievement of SDGs. STEM is an abbreviation that combines science, technology, engineering and mathematics and it is used to define fields and occupations associated with these subjects (Beede et al., 2011).

Many of the future jobs in Kazakhstan and in the world will be associated with STEM. Therefore, Kazakhstan is putting great effort into developing STEM education at all levels. At the school level, within a renewed curriculum, Kazakhstan is actively promoting a STEM approach, in which science, technology, engineering and mathematics concepts are taught and learned in tandem in order to solve real life problems (Tsupros, as cited in Nogaibayeva and Zhumazhanova, 2016). Other initiatives include organizing and participating in national and international STEM competitions and Olympiads and phased transition to teaching some STEM subjects in English in the scope of trilingual education reform (Nogaibayeva and Zhumazhanova, 2016). At the higher education level, the largest proportion of state grants are allocated to STEM majors and are increasing each year (Mukhametkaliev, 2018). However, due to the relative novelty of STEM in the country, a more comprehensive approach that emphasizes an inter-disciplinary approach to STEM is still necessary.

Along with devoting attention to STEM, it is also extremely important that everyone is given equal opportunities to develop and contribute to society and the economy regardless of their demographic characteristics (Dasgupta and Stout, 2014). Undoubtedly, active and full participation of women will lead to economic growth in any country. According to McKinsey's assessment, countries in the Asia Pacific region could increase their GDP by USD$4.5 trillion by 2025 by accelerating gender equality (Woetzel et al., 2018). So far, STEM fields worldwide 'continues to face significant challenges in attracting, advancing and retaining women' (ADB, 2018; Male Champions of Change, 2019). Allowing and facilitating the participation of girls and women in this field is vital from human rights, scientific and development perspectives (UNESCO, 2017, p.15). The participation of women in STEM makes the workforce more diverse, which in turn contributes to creativity, productivity, innovation and success (Blackburn, 2017). Statistically, in the context of Kazakhstan, women are underrepresented in key leadership positions and industries that are conventionally considered as masculine-styled (Stat.gov, 2019). This indicates a need to explore the factors that underpin these gender inequalities in order to better address them in the future.

To our knowledge, no studies have focused on gender equality in STEM in Kazakhstan. This research study aims to contribute to filling this gap, particularly shedding light on factors that facilitate and hinder girls and women's attraction, participation and retention in STEM education and careers. By exploring the experiences and views of university students and mid-career professionals this research could potentially help stakeholders take informed measures to strengthen the role of females in STEM. Since Kazakhstan, as a UN member state, is committed to achieving the SDGs and SDG 4 and 5 specifically, this research will also contribute to identifying further policy options that could address gender equality issues in STEM fields.

Literature review

State of gender policy and practice in Kazakhstan

Since independence, Kazakhstan has been positioning itself as a gender-equality orientated sovereign state by adopting numerous policy documents that promote gender equality. These policy documents include the Concept of Gender Policy (2003); the Concept of Family and Gender Policy of the Republic of Kazakhstan until 2030 (2016); and the ratification of a few international treaties, including the Beijing Declaration and Platform for Action (ratified in 1995); the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW joined 1998); the Convention on the Political Rights of Women; the Convention on the Nationality of Married Women (ratified in 2000); the Millennium Development Goals; and the recently adopted SDGs, which includes gender equality under Goal 5 (ADB, 2018). As a result, we can say that the situation is progressively improving. The share of women is rising in the sectors that initially were totally male dominated (Kazinform, 2018). In politics women make up 22 per cent of members of Parliament and about 33 to 57 per cent of political parties. In the civil service, the share of women reached 55 per cent. Women also run over 500,000 small and medium-sized enterprises (SMEs).

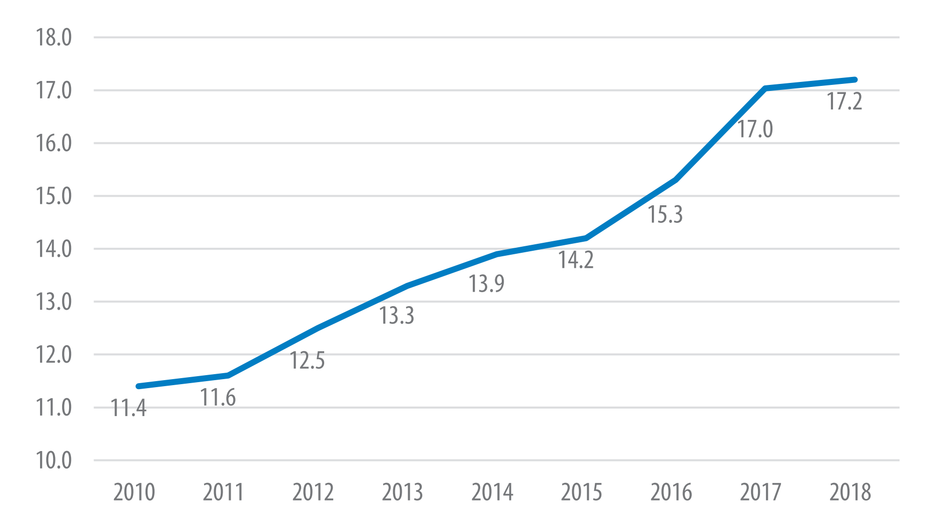
Nevertheless, gender imbalances and inequalities persist regarding pay, career opportunities and advancement and stereotypes (UN Women, n.d & OECD, 2017). According to the latest available statistics, women earn on average 67.8 per cent of what men earn (Stat.gov, 2019), which is lower than the indicator of the USA (80 per cent) (World Economic Forum, 2018). A recent study (Kireyeva and Satybaldin, 2019) on the gender pay gap in Kazakhstan showed a positive trend; the gap is getting narrower. However, the situation remains stable in the industrial sector and in managerial positions with several reasons contributing to this imbalance. In 2017, 11.8 per cent of women and 7.7 per cent of men worked part-time in Kazakhstan. In urban areas the share of women (8.2 per cent) working part-time was twice as much as men (4.1 per cent) (Ministry of National Economics of the Republic of Kazakhstan, Statistics Committee, 2017) while in rural areas the gap was closer; 17 per cent and 12.3 per cent respectively. This may imply that women take part-time jobs to take better care of the family. Working part-time serves as one factor why women earn less than men.

Secondly, even though women are well represented in the labour market, they tend to work in low-paid fields, for example, education and usually take lower positions on the career ladder. They make up a low percentage of higher salaried fields such as STEM. Women still face the 'glass ceiling' and experience the 'sticky floor' when it comes to career advancement and taking leadership roles (Kuzhabekova et al., 2018). For example, only 27.1 per cent of the House of Representatives and 6.48 per cent of the Senate (OECD, 2017) are women. Although half (55 per cent) of all judges are women, their share shrinks to 36.4 per cent in the Supreme Court. Even in the education sector, which is considered a feminized domain, while women make up the majority of teaching positions, they are a minority among school principals in half of the forty-eight participating countries, including Kazakhstan, in the OECD's latest TALIS study (OECD, 2019).

Another main factor that holds women back from thriving professionally is difficulty in returning to the workplace while taking care of children. Women are traditionally expected to be the main caregivers to children (Kuzhabekova et al., 2018) and therefore can be reluctant to rely on preschool organizations. Despite the proportion of children under three-years-old in preschool organizations, kindergartens and mini centres having increased substantially in the last decade, this share still remains low at around 30 per cent.

In addition, lower aspiration for leadership positions and barriers in forms of societal expectations can hinder career advancement for women (Kuzhabekova et al., 2018). As of 2018, women run only about one third (27.9 per cent) of all enterprises in Kazakhstan. As a rule, they lead SMEs rather than large enterprises. However, every year the share of women leading large businesses is gradually increasing (Figure 9.1).

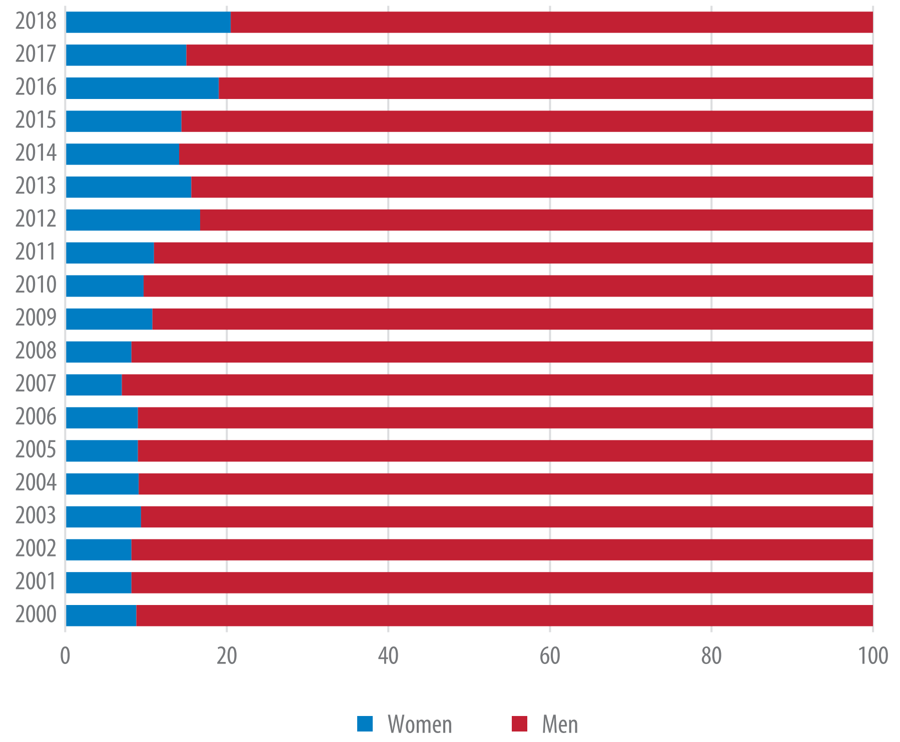
Figure 9.1: Percentage of large enterprises run by women in Kazakhstan (2010–2018)



Please note: Data source, stat.gov, 2019

As for academia, despite the feminization of the teaching profession at all levels of education, the share of male faculty members with the highest academic degree, Doctor of Science, exceeds the share of females who have achieved this qualification (IAC, 2018). Moreover, male faculty members are more involved in scientific research than females (IAC, 2018) and are also in the majority among key leadership positions in higher education institutions (HEIs) (see Figure 9.2). However, over a period of eighteen years there has been a slight growth in the number of female leaders in HEIs.

Figure 9.2: Proportion of women and men in senior positions at HEIs by percentage (2000 to 2018)



Please note. Data source, stat.gov, 2019

Leadership skills are not determined by gender or ethnicity (J. L. Lewis, 2014), but poor representation of women in leadership roles leads to a scarcity of female role models and a greater tendency to perceive leadership positions as primarily masculine. As a result, women can be viewed as less competent for leadership positions (Kuzhabekova et al., 2018). Overall, while it may seem that opportunities and conditions for women are gradually improving and their participation beyond the family level has been changing (Pascal and Manning, 2000), they are still more likely to be considered as having more responsibilities in the family and as a result enjoy less benefits and do not fulfil their potential.

State of gender equality in STEM education and careers in Kazakhstan

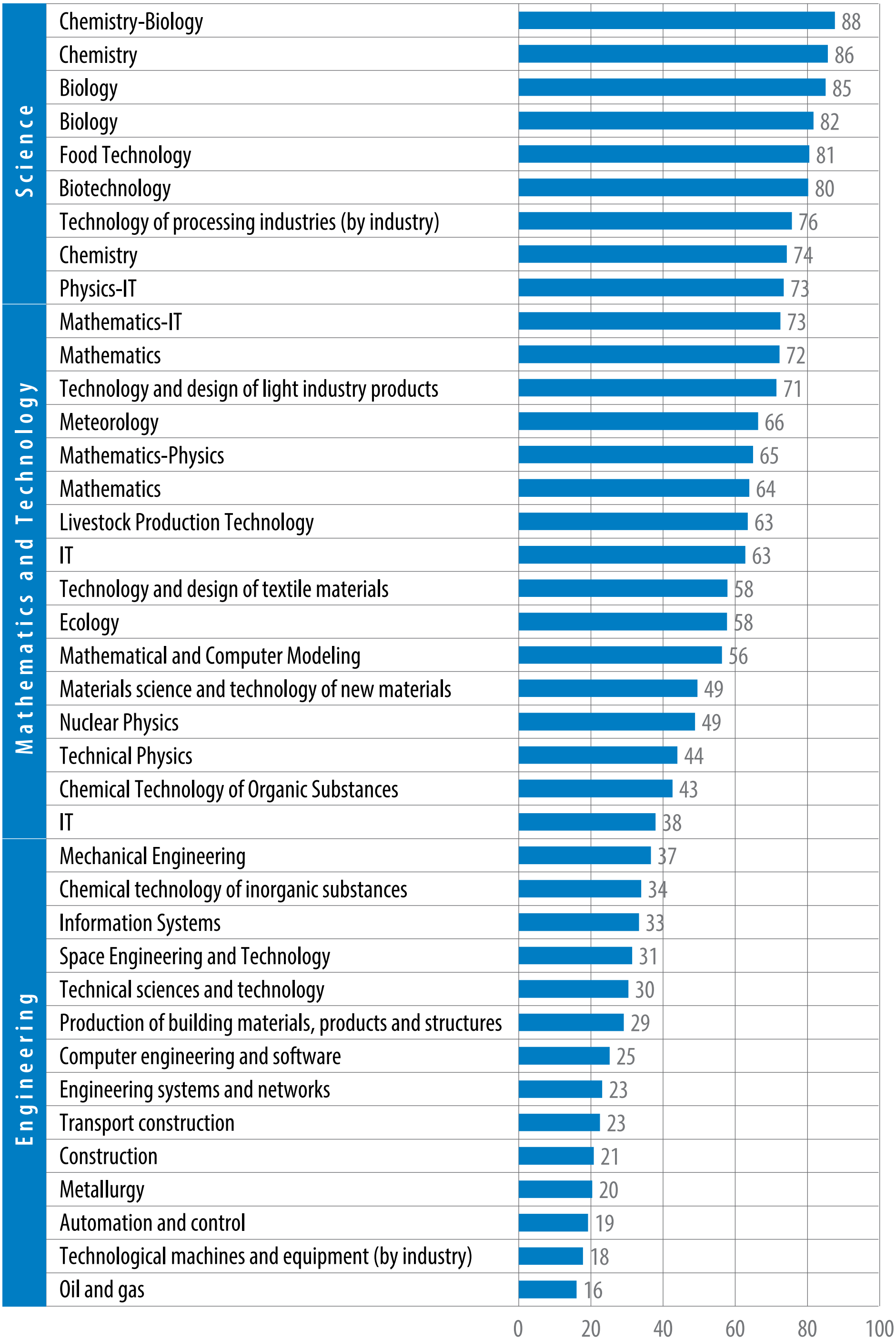
International large-scale assessments, such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), can shed light on the state of STEM education and its quality at a school level internationally. In the latest PISA studies in 2015 and 2018, generally girls continued to significantly outperform boys in reading and performed them roughly equally in science, while boys mostly outperformed girls in mathematics (OECD, 2019a; OECD, 2020). These results confirm that a gender imbalance in STEM fields cannot be confirmed by certain sexes having greater or lesser abilities. On the contrary, success in learning depends on the neuroplasticity of the brain i.e. 'the capacity to expand and form new connections…' and 'is influenced by experience and improved through targeted interventions' (UNESCO, 2017, p.11). In Kazakhstan, girls outperformed boys in reading and scored equally in mathematics (OECD, 2019b).

It is disturbing that the gap in average points is significantly wider among students of rural and urban parts of Kazakhstan. Rural students are on average nineteen points (or one-and-a-half years) behind urban students in science and twenty-five points in mathematics. Significant differences exist among students based on their socio-economic status. Moreover, regional differences exist; some regions are constantly at the top of the scale while some are at the bottom. This regional gap also manifests itself in nationwide competitions where students from big cities usually show greater advancement (Yerkebulan, 2019).

Students from economically disadvantaged homes gained forty-one points less than students from advantaged families in PISA-2015. The same tendency has been traced in TIMSS-2015. There was a difference of up to thirty-seven points between urban and rural school students and up to a sixty-five point difference among student groups depending on their socio-economic status. These results suggest that boys and girls from rural areas and from economically disadvantaged homes need more support. The other large-scale assessments, such as the Programme of International Assessment of Adult Competences (PIAAC) and the Information and Computer Literacy Study (ICILS) 2018, the results of which were released in November 2019, also give valuable evidence on gender-related differences of skills and competences in STEM subjects. In the International Association for the Evaluation of Educational Achievement's (IEA) ICILS, on average, girls in the eighth grade in Kazakhstan performed better than boys in computer and information literacy (CIL), with 505 and 488 points respectively. However, boys outperformed girls in computational thinking (CT) with 498 to 502 respectively. While CIL measures basic skills needed for working in ICT, CT tests require more analytical, problem solving and advanced mathematics skills to perform more complex tasks using computers (IEA, 2019). This data might suggest that by the eighth grade girls already have a disadvantage in the ICT field compared to boys. Later in adulthood, according to the latest OECD's PIAAC results, which tests sixteen to sixty-five year-old adults' skills, there were no significant differences in the numeracy scores of women and men in Kazakhstan. However, in reading literacy tests, women in Kazakhstan show a result two points higher than men (250 compared to 248).

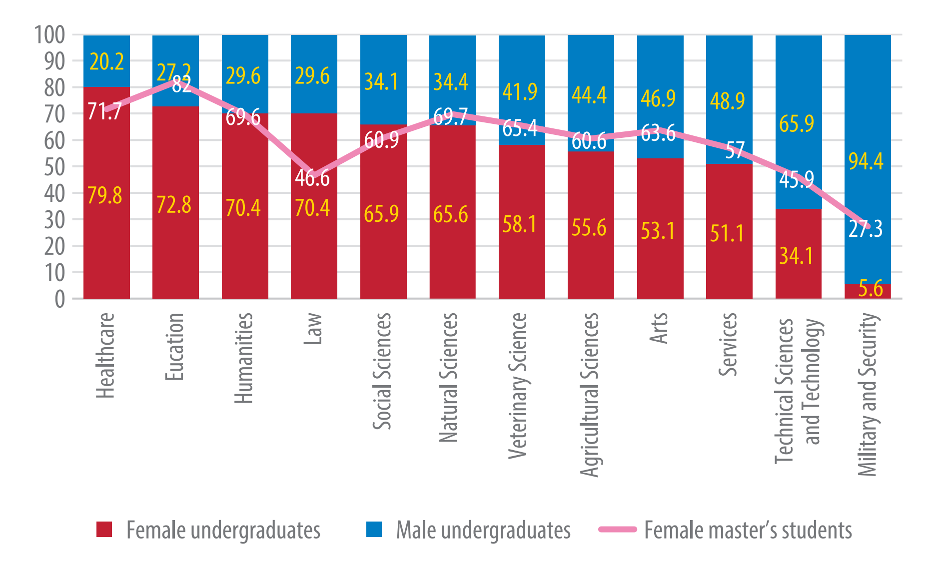
Other than skills and competencies, researchers also note that boys demonstrate stronger confidence and interest in professions associated with ICT and engineering, while girls show strong confidence in healthcare. In addition, according to the PISA 2018 results, fifteen-year-old girls are more motivated to master a task than boys, but boys have stronger attitudes towards competition and are less afraid of failure than girls (OECD, 2020). Girls more often tend to pursue higher education compared to boys. In 2018, 67 per cent of female perspective students and 55 per cent of male students enrolled in HEIs in Kazakhstan (Stat.gov, 2019). As for their majors in 2017 at the undergraduate level, the top three fields female students enrolled in were healthcare, education and humanities, while the top three subjects for male students were military and security, services and technical sciences and technology (Stat.gov, 2019).

Figure 9.3: Percentage of female students in HEIs by major (2017)



Please note: Data source, stat.gov, 2019

Figure 9.4: Student enrolment by gender in 2016–2017 (percentage)



Please note: Data source, stat.gov, 2019

Among STEM majors, female students greatly outnumber male students in science, and slightly outnumber males in mathematics related majors, while male students greatly outnumber females in technology and engineering related majors (Stat.gov, 2019).

Getting a master's degree is more common for women than men. In almost all fields, the share of female master's students outnumbers that of male master's students. It is interesting to note that even in male dominated majors at the undergraduate level, female students often outnumber male students at the graduate level. This data suggests that women are more likely to continue their studies than males, pointing to their studiousness. Moreover, according to the data, female students have higher expectations and demonstrate, on average, a better performance than male students.

With regard to the overall proportion of scientists in STEM fields in Kazakhstan, equal representation of females can be observed compared to other countries, ranging from the lowest of 48.3 per cent in 2004 and highest of 53.3 per cent in 2016 (Stat.gov, 2019). More than half of the scientists in Kazakhstan (52.8 per cent) in 2018 were women. However, according to Kazakh scientist Damel Mektepbayeva, when it comes to career or academic advancement, the issue of gender inequality rises. Women are underrepresented among key leadership positions in STEM fields such as heads of research departments and chairs of committees (Yerkebulan, 2019). Women tend to take the lowest positions with the least impact power on STEM fields. As a young scientist in Kazakhstan, Dana Akylbekova said, 'women have to always choose between career and family. Being a scientist means mobility. We need to work in different laboratories in different parts of the world in order to broaden our expertise and establish partnership. Without support of a partner or family, a woman has to sacrifice her scientific career' (Baitelova, 2018).

Moreover, underfunding seems to be the most burning issue affecting science in Kazakhstan. Low salaries and insufficient funding, that is considerably captivated by the bureaucratic schemes, are amongst them (Baitelova, 2018). All in all, being limited in terms of gender research, we can still state there is no formal gender discrimination against girls and women in Kazakhstan in education, nor in the workplace, but there are gender inequalities. Both boys and girls are represented in STEM education, but generally girls prevail in science related majors and boys in technology. However, their success is influenced by their place of schooling, rural or urban, region and socio-economic status. When growing up, women are more hindered by barriers of traditional sociocultural expectations. This results in gender inequalities in career opportunities and the advancement of women.

Promising initiatives for gender equality in STEM in Kazakhstan

In correspondence with the global interest in STEM and initiatives to deal with gender inequalities, several projects were initiated in Kazakhstan. To our knowledge these projects include:

- The **Technovation Challenge.** This was launched in Kazakhstan in 2016 to tackle gender stereotypes in STEM. According to founder Diana Tsoi: 'Technovation is aimed at equipping girls between ten and eighteen years with the skills in technology and entrepreneurship so that girls from their early age could learn that they can solve problems with the help of technologies.' (Yerkebulan, 2019).
- The **Scinet.kz** platform. This was launched by emerging scientists in Kazakhstan to build a network of scientists. It is a place where young boys and girls in the country get to explore science and determine what it is like to be a scientist. About twenty members of the platform act

as mentors to the younger generation who plan to pursue a career in science in Kazakhstan and beyond (Baitelova, 2018).

- **GenderBot** is a telegram-bot that aims to raise awareness in the field of gender equality, as well as the rights and opportunities of women. The Bot provides a dictionary with gender-related terms and key gender statistics related to Kazakhstan (UNDP, 2019).

Although such projects are in place, a more systematic and holistic approach and vision of STEM seems to be lacking. As a result, it becomes difficult to monitor, evaluate and develop gender equality in STEM. Moreover, the current situation does not fully allow progress tracking or dealing with challenges, since these initiatives are stand-alone and scattered across different levels of education. As a result, they may be not successive of each other and may not fully support the continued development of men and women throughout their lives.

Issues causing gender inequality in STEM

Factors that contribute to girls' and women's underrepresentation in STEM fields are common in many parts of the world. Most of them are associated with gender stereotyping about STEM majors and a lack of female role models. In addition, viewing children and family care as a women's utmost responsibility and the unavailability of family-friendly conditions in workplaces impede women's ability to be successful in STEM careers (Beede et al., 2011). Gender stereotyping has been deeply rooted in the minds of some people for a long time. Therefore, this is probably the most time-consuming task that countries should tackle on their way to eliminating gender discrimination and inequalities (Ivie and Guo, 2006). A gender stereotype is by definition 'harmful when it limits women's and men's capacity to develop their personal abilities, pursue their professional careers and make choices about their lives and life plans' (Equality Challenge Unit & Opening Educational Practices, 2017).

Gender stereotyping has a negative impact on women from an early age (UNESCO, 2017). It has an adverse effect in that it can make girls less interested in STEM subjects and also complicate the situation for those who are interested in them. Research in England into fifteen to sixteen year-old's attitudes towards STEM subjects found female students considered STEM fields as potentially more profitable and they also outperformed boys in these subjects. However, they were less likely to rank STEM-related subjects first among the subjects they enjoyed the most. They were also less confident about their abilities in

STEM and slightly less likely to choose a STEM-related profession (Department for Education, 2019). Another research study discovered negative stereotypes about girls' poorer abilities can lower their performance and aspirations for STEM careers over time (AAUW, 2010).

One of the main groups that propagate damaging stereotypical views about females' involvement with STEM subjects and careers can be parents. Parents may expect their sons to choose STEM majors and their daughters to choose non-STEM subjects. Parents may also think 'boys are more interested and capable in STEM subjects and that STEM subjects are more difficult and less important for girls than boys' (Sarkar et al., 2019).

Gender stereotypes and biases that start at the school level seem to continue their negative effect in later studies. Female students' interest in STEM moves away from 'prime STEM subjects' to 'allied STEM subjects' such as Healthcare (Department of Further Education, Employment, Science and Technology [DFEEST], 2012). At the university level in many STEM related departments, females are the minority among students and faculty members. Moreover, females enrolled in STEM majors seem to experience 'decreasing levels of confidence as they progress to advanced courses in mathematics and science' (Leslie et al., 1998, as cited in Edzie, 2014). A study conducted in Australia revealed that despite the reality that females may make up the majority of students compared to male students who will move from enrolment to graduation in STEM majors, the transition to the work place is not that smooth (Department of Further Education, Employment, Science and Technology [DFEEST], 2012). In the labour market, the share of women is smaller than that of men. This may indicate that women encounter barriers in the university-work continuum. As other literature shows, these barriers are related to family-work balance.

Worldwide, women are less represented in the labour market than men. Women who work in STEM related workplaces can be judged to be less competent than men and if they are proven to be successful and competent, they become less likable (AAUW, 2010). They are even less represented in key leadership positions. A lack of females in such positions in STEM fields can also inhibit the process of equalizing the share of women and men since more women leaders could motivate and support female participation (Sarkar et al., 2019). This lack of female co-workers in the workplace environment can make it less user-friendly to the needs of women. For example, measures such as allocating parking spots nearer to the exit area for pregnant women would never cross men's minds (Yerkebulan, 2019).

Overall, as a result, longstanding female underrepresentation in STEM fields exacerbates already existing gender stereotypes. Specifically, 'it can activate negative stereotypes about women's abilities and bring about underperformance among women who have identified those domains as important to them' (Cheryan et al., 2011). So if this critical issue remains unsolved, it turns into a vicious circle; stereotypes disable women's full representation, while underrepresentation strengthens the stereotypes.

The literature reviewed here suggests that the main barriers that hamper girls' and women's participation in STEM comes from longstanding gender stereotypes and biases. They cause underrepresentation, a lack of confidence, a lack of interest among girls in STEM education and later in their career. Though the number of gender studies and expert discussions are growing worldwide, there is still a lot that needs to be done (Brookings, 2019). The latter especially applies to the Kazakhstani context, where such studies seem to be scarce. Therefore, this research aims to fill the knowledge gap in the gender equality state in STEM fields in Kazakhstan. Since the research was concerned with getting an in-depth exploration of gender equality in STEM education and careers by investigating the views and experiences of students and mid-career professionals in STEM subjects, the study addressed the following research questions:

1. What motivates girls and women to choose STEM?
2. How do girls and women perceive STEM related majors?
3. What benefits and challenges do women see in the STEM field?
4. What barriers do women face on their way to a STEM education and career?

Research methodology

This research aims to explore factors that facilitate and hinder girls' and women's attraction, participation and retention in STEM education and careers. The study draws on the primary data collected through interviewing female students and mid-career professionals and surveying female and male students of STEM majors in Kazakhstan. A mixed methods research design was employed for this study. Qualitative evidence was gathered through focus group interviews and quantitative evidence was gathered through an online survey. Quantitative data gave a general sense of the state and attitude towards gender equality in STEM fields, while qualitative data provided a more in-depth exploration of this issue.

The participants were recruited through a purposeful sampling strategy for the quantitative data and through convenient (snowball) sampling for qualitative data. For the online survey, a sample of 600 university STEM majors was utilized. To get a holistic view of the issue, both female and male students responded to the online survey questions. This also enabled us to see the differences and similarities between the perceptions of males and females. The response rate to the online survey was 33 per cent (N=200). The sample was diversified with respect to the geographical region of the country (central, north, south, east, and west). One university from each part of the country was selected except for the central region where two universities participated. Overall, student respondents represented six universities.

A link to the online survey was created in Google forms and spread throughout the selected universities with the help of gatekeepers, who were mostly lecturers or students. It contained closed-ended, open-ended, multiple choice and Likert scale questions. For the qualitative part, two focus group interviews with six female university students and six female mid-career professionals in STEM fields were conducted in Nur-Sultan. There were more representatives of computer science and IT students and professionals.

Table 9.1: Participant profiles: Mid-career professionals

	Position	Sector	Age	Marital Status	Children
1	Data Manager	Information Technology	28	Single	0
2	Chief analyst	Statistics	35	Married	2
3	Business analyst	Information Technology	26	Single	0
4	Business analyst	Information Technology	27	Single	0
5	Chemistry teacher (secondary school)	Education	31	Married	1
6	Chemistry teacher (secondary school)	Education	39	Married	2

Table 9.2: Participant profiles: University students

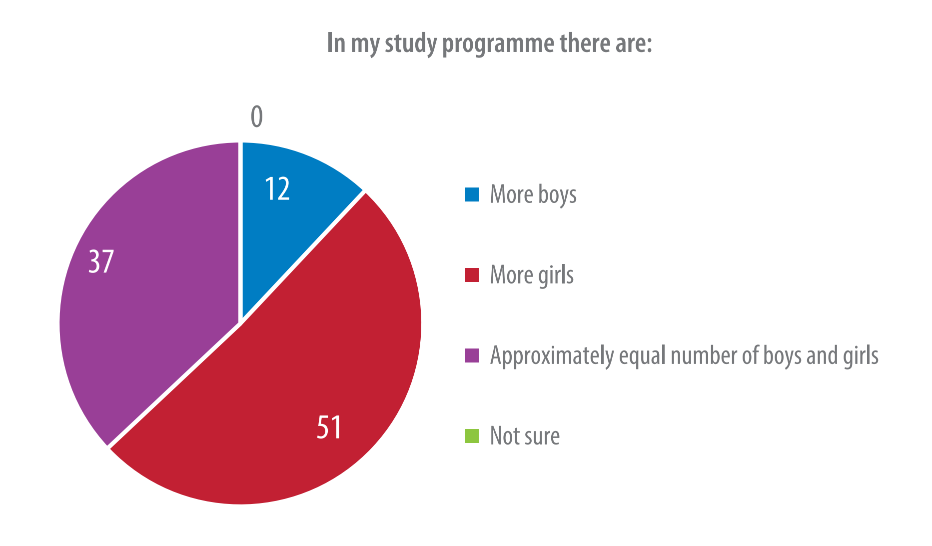
	Major	Year of study	Degree of study
1	Computer Science	1	Doctoral student
2	Information Technology	2	Master's student
3	Computing machinery	3	Bachelor's student
4	Biology	2	Bachelor's student
5	Radio engineering electronics and telecommunications	4	Bachelor's student
6	Radio engineering electronics and telecommunications	4	Bachelor's student

The qualitative data was coded thematically according to the research questions. The confidentiality and anonymity of participants was guaranteed since no personal identifiable information was collected through the online survey. Due to the small research nature of the study, the scope (only university students and mid-career professionals) and sample of the qualitative data (only in one city of Kazakhstan) there may be obvious limitations. Therefore, a representative sample for the qualitative part would have yielded much richer data. In addition, the sample population only included people already in STEM fields, while a larger sample with prospective students in the field and, or individuals who had left the field would provide a better picture of the overall situation. Nevertheless, these findings offer valuable insights to better understand the state of gender equality in STEM fields in Kazakhstan and particularly what attracts females to STEM and what their learning experiences and barriers are. The survey and the interviews were conducted in the Russian language. For the analysis the results were translated from Russian to English.

Findings

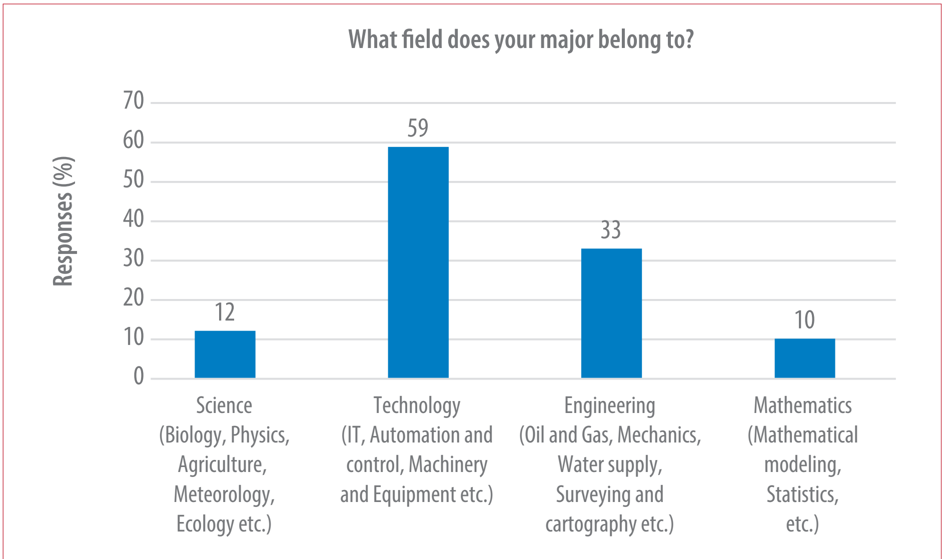
Descriptive statistics of the survey were provided by Google forms automatically. The demographic data of the participants was as follows: 56 per cent of survey respondents were male and 44 per cent were female students; 63 per cent of students' study was at the bachelor's level; 29 per cent was at the master's level and 8 per pent were PhD students. The majority of the respondents indicated that in their study programmes, the proportion of male students was slightly more than females (Figure 9.5).

Figure 9.5: Students' perceived proportion of female and male students in a study programme (percentage)



Most of the participants who answered the survey questions were students of majors associated with technology (59 per cent), engineering (33 per cent) and the rest science (12 per cent) and mathematics (10 per cent) (see Figure 9.6).

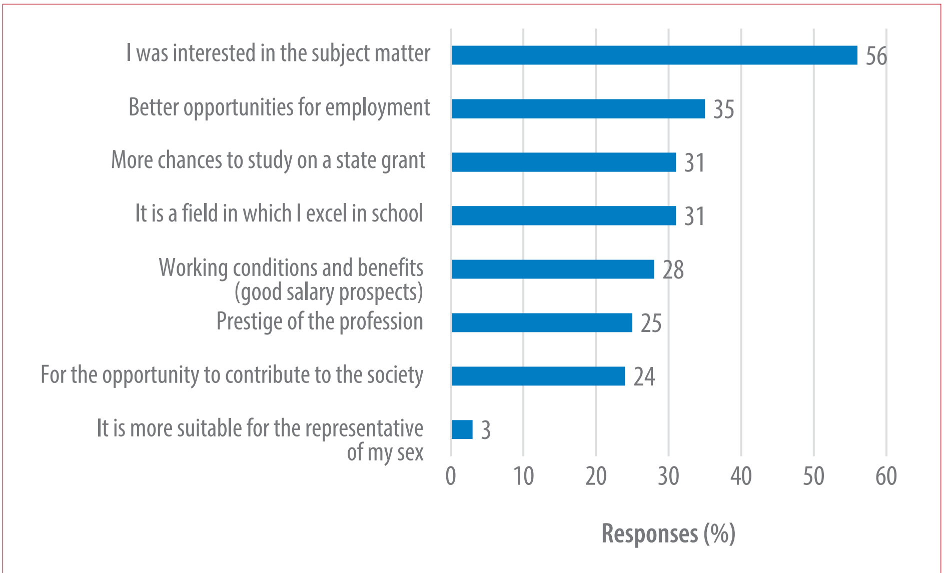
Figure 9.6: Participants' fields of study



What motivates girls and women to choose STEM?

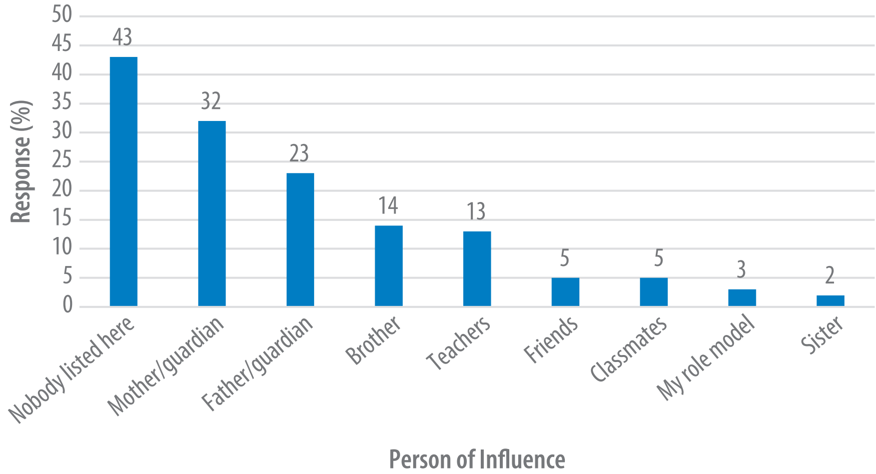
Over half of the respondents (56 per cent) said that they chose the major because they were more interested in it. Other popular responses were 'better opportunities for employment' (35 per cent); 'more chances to study on a state grant' (31 per cent); and 'it is a field I excel in school' (31 per cent) (see Figure 9.7). It is interesting to note that the answer 'It is more suitable for the representatives of my gender', was chosen by male students involved in technology fields where more males were involved in this study discipline.

Figure 9.7: Students' reported reasons for choosing STEM majors



As for the person who influenced their choice to study STEM, the majority (43 per cent) of the respondents chose 'nobody listed here'. Next, most of them noted that their parents played an important role when choosing their majors. Eight respondents in the open box wrote that it was solely their choice. It could be implied that some of the 43 per cent of the respondents also chose the major without any influence from other people.

Figure 9.8: Student's reported 'person of influence' on choosing a STEM major



For as many as 80 per cent of the respondents, their major was their first career choice, meaning that the major was their top priority. In the context of Kazakhstan, when passing the National Unified Test (UNT), school graduates can choose four different but related majors. Among interviewees, the majority of both current students and mid-career professionals named more opportunities to 'win' a state grant and their own interest as main reasons for choosing STEM related majors.

> *'To be honest ICT was not my first choice of career when I was just thinking about my future perspectives. Previously I was thinking of applying for something related to international relations, something that would require speaking because that was what I was good at, but then when we had this very important discussion with my parents, we came up to the idea that information systems is actually more recognized in a society and it's a highly paid job and this was the primary reason for me to choose the IT. Yeah! My parents inspired me.'*
>
> *– Comment from a survey interviewee*

As for the actual person who influenced their decision, the majority of the interviewees said their parents or their mother. One individual, a graduate of a physics/mathematics school, was motivated by his classmates and said, 'in my case I think it is because of [a] scholarship. And in this time IT was developing in our country, there were a lot of scholarships, so I chose to study in IT.'

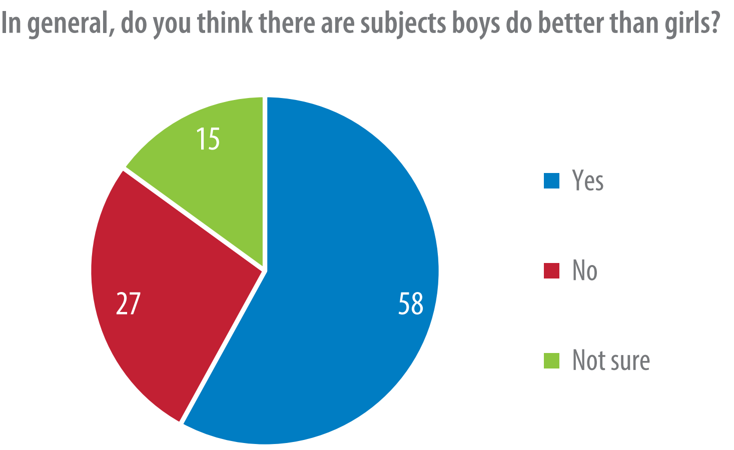
IT students all agreed that upon graduation, they could find a job in almost any sector since IT specialists are needed everywhere.

These results indicate girls' motivations to choose STEM related majors can be intrinsic and extrinsic. When choosing these majors, young people considered such factors as their own interest in the subject area, ease of entry and the perceived lucrative nature of a STEM career. Parents seem to be the most influential people for a girl's motivation to choose their future job. Although the greater availability of state scholarship provisions surely attracts more candidates to the STEM major, including girls, the ease of entry is not always considered as an advantage since it can also attract less motivated and less strong candidates to the field.

How do girls and women perceive STEM related majors?

To find out whether there is any gender stereotyping in STEM related subjects in Kazakhstan, participants were asked to reflect on their perception that girls and boys have certain subject areas in which they are strong and can excel. To the question: 'Do you think there are subjects that boys do better than girls?' slightly over half of the survey respondents (58 per cent) said 'yes', 27 per cent of them said 'no' and 15 per cent were unsure. To the reverse question: 'Do you think there are subjects that girls do better than boys?' Again, slightly more than half (59 per cent) agreed; 28 per cent disagreed and the rest were uncertain. These results suggest that half of the young people believe that better performance and achievement in certain subjects is gender-dependent.

Figure 9.9: Student perspectives on the relationship between gender and achievement (percentage)



In the subsequent question, the participants who said 'yes', got to indicate the subjects from the list. According to the results, boys did better in physics, robotics, ICT and mathematics, while girls excelled in design, languages, biology and literature.

Unlike survey participants, the interview respondents, who were all females, believed that inclination and achievement in certain subjects solely depends on an individual's personal ability and personality, not gender, meaning that everyone could succeed in STEM-related jobs in the future, except some 'masculine jobs', which require physical strength, such as a firefighter.

> *'I cannot say that there's the gender question here. It mostly depends on behaviour or the environment he, or she is growing and on how you have been taught at school.'*
>
> *– Comment from a survey respondent*

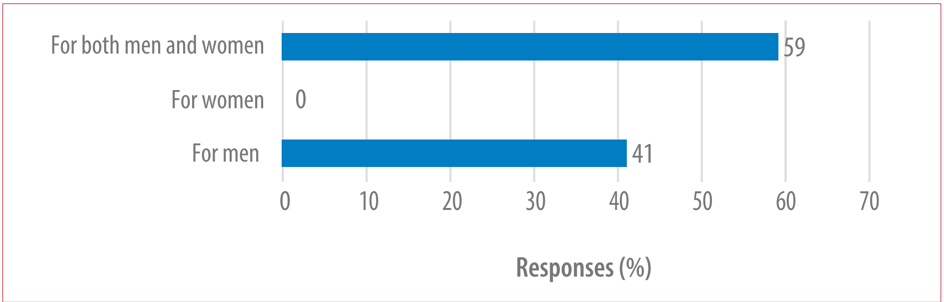
> *'I would say that a fireman is a masculine profession but not STEM subjects.'*
>
> *– Comment from a survey respondent*

The interview participants were also asked to describe their field of study and work using three words. Most of the respondents described STEM fields as difficult compared to other spheres such as humanities and social sciences. All respondents stated that IT, in particular, requires more hard work, persistence and commitment. As one of the respondents said:

> Nothing can be harder than IT and it's like you can always learn something new in two years but you can't really learn IT in such a short period of time only if you choose one specific subject area like for example maybe programming in ***Python***. You can do it in a short period of time, but you cannot really become very competent. So, it takes more time and commitment than any other discipline, but it is worth it.

Other respondents added that their major is the major of the future and it is rapidly growing and developing. Both survey and interview respondents answered the question 'whether their major was more suitable for men or for women, or for both men and women'. While interview respondents, who were all females, responded that their major was equally suitable for both sexes. Survey responses yielded different results.

Figure 9.10: Perception of suitability of STEM Majors, by gender (percentage)



Almost half, 41 per cent, of the respondents thought that their major was more suitable for men, while 59 per cent thought it was suitable for both men and women. Looking closer at the data, among those who noted their major as more suitable for men, 39 per cent were women, and 61 per cent were men. It was significant that none of the interview respondents could name any Kazakhstani female role models in the field.

> *'I think most of the people know as successful, mostly are males, like Mark Zuckerberg, Steve Jobs, but I sometimes hear about females and I always get surprised.'*
>
> *– Comment from an interview respondent*

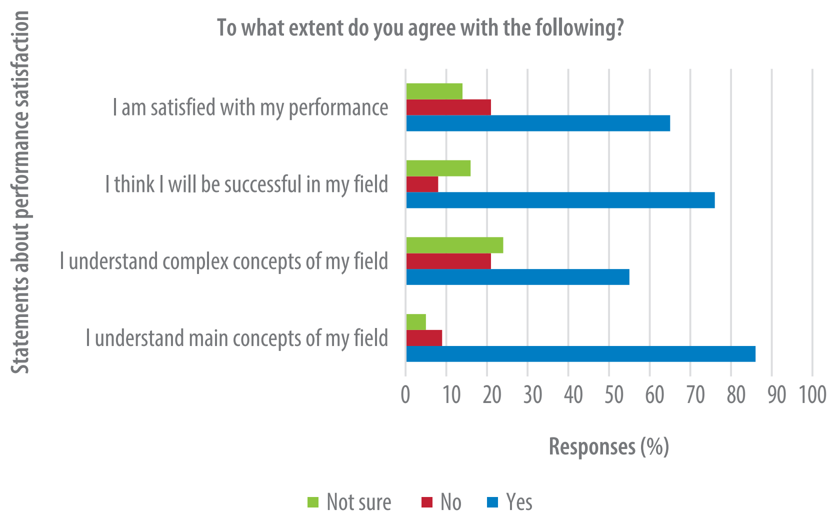
Some interviewees said the lack of female role models is because women have family responsibilities.

> *'I don't know anyone famous females here. I think it's because of when the woman get[s] married she just gives up science and doing [a] career because it's hard to do the family, take care of your husband and your kids and do the career also in parallel. So in this case, especially in our country, most of the woman I think they choose to stay at home and in most case just leave their work.'*
>
> *– Comment from an interview respondent*

Another respondent said, 'maybe because if you look at the males they get recognized after forty. But at this time, most of the females already have a family and they don't have time or [the] motivation to go further so they just stop in their thirties when they're like [a] vice-director or something else and instead of going up, I think they mostly go down in their career.'

Regarding the question: 'Are there any role models in your field among representatives of your gender', 50 per cent of the survey respondents said yes, 19 per cent said no and 31 per cent were not sure. Most of the respondents were satisfied with their performance and thought they could be successful in the future. Half of the respondents, who were equally male and female students, noted that they did not understand complex concepts in their field.

Figure 9.11: Satisfaction with performance in the STEM field (percentage)



What benefits and challenges do women see in STEM fields?

All participants said they found their major and profession beneficial. Most of the interviewed participants cited economic, social and individual benefits. They also stressed the importance and relevance of their field. IT specialists mentioned their work requires a constant improvement of knowledge and skills and that they are the first people to know the latest innovations. Another respondent said their field is in high demand and they would never be jobless.

> *'I think one of the advantages of doing IT in your bachelor's is that it can always be an asset for your next studies even if you decide to continue or to choose a different major. Whatever job you decide to do in future, computer and programming skills are always an asset.'*
>
> *– Comment from an interviewee*

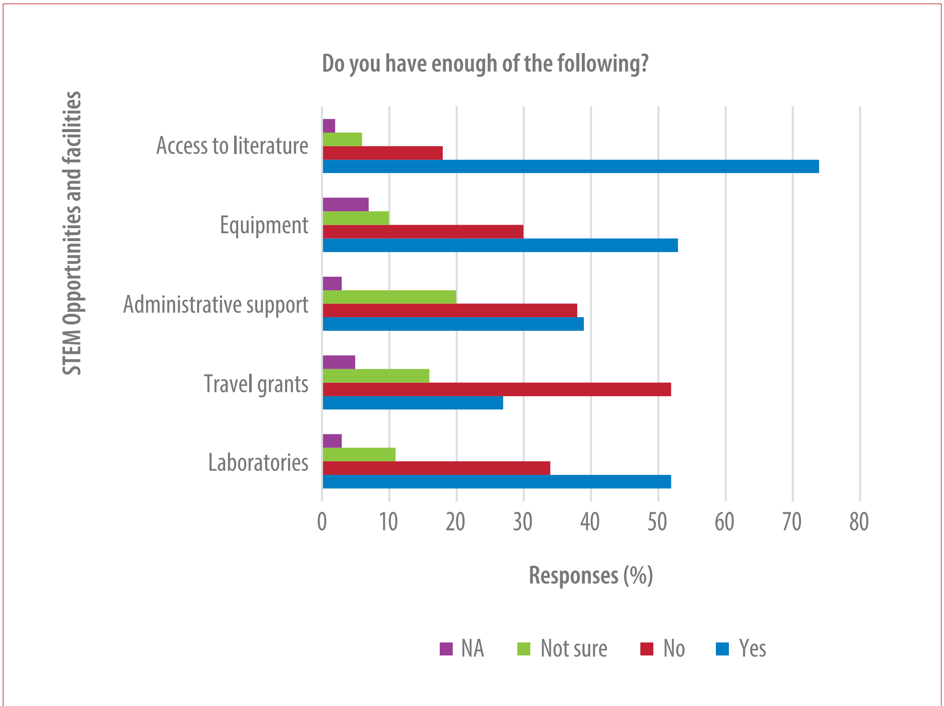
As for the challenges, all students mentioned the complexity and difficulty of their major, while women working in programming said it is difficult to succeed in their field.

'It's actually much harder than succeeding in any other job. You really need [to] sacrifice and you need to decide to do the job without doing anything else.'

– Comment from a female interviewee

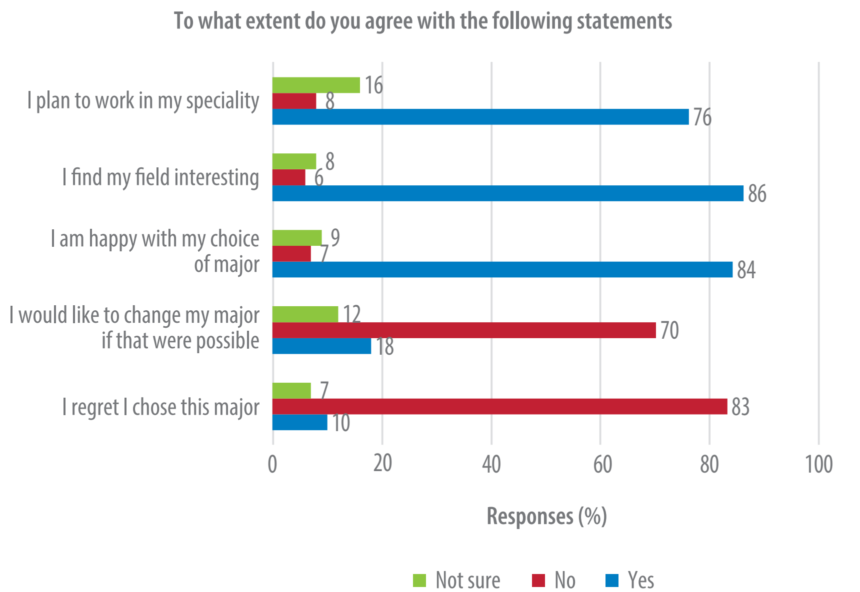
Survey respondents were asked if they had enough opportunity to participate and develop while studying. The majority of the respondents (74 per cent) said they had access to literature and half of the student body (53 per cent) said they had enough equipment and laboratories. Students seemed to have less access to travel grants and not everyone had administrative support.

Figure 9.12: Access to opportunities and facilities for STEM students (percentage)



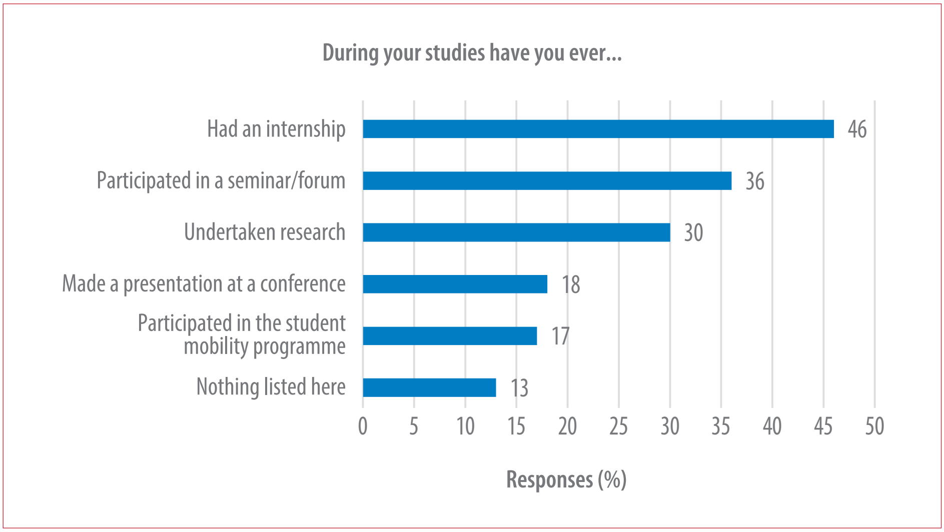
The majority of the respondents said they were happy with the choice of their major and found their field interesting. However, 18 per cent of the students said they would like to change their major if it were possible.

Figure 9.13: STEM students' satisfaction with their choice of major (percentage)



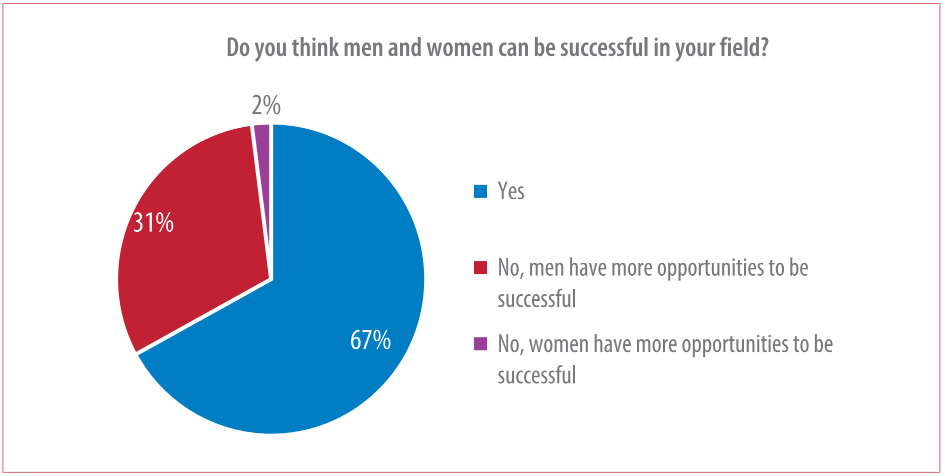
Research revealed that 46 per cent of students involved in STEM fields undertook an internship and 36 per cent were found to have participated in seminars and forums. The break-down of students in STEM who participated in differing extra-curricular activities is detailed in Figure 9.14.

Figure 9.14: STEM student participation in extra-curricular activities (percentage)



The majority of the students said they believe both men and women can be successful in their respective field. However, among the group of students who said males have more opportunities to be successful than females, more males than females made this comment. This suggests that in a more male-dominated study environment, an assumption that this field is more suitable for men can be developed.

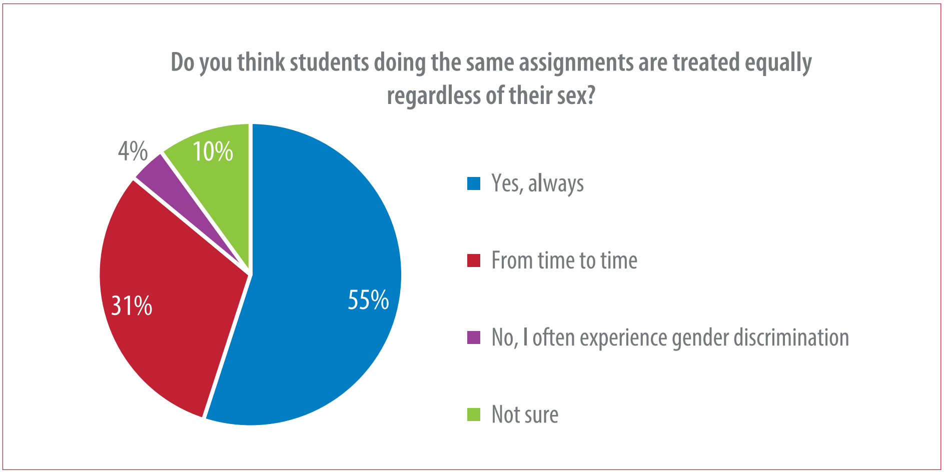
Figure 9.15: Students' perception on the relationship between gender and success in STEM fields (percentage)



What barriers do women face on their way to undertaking a STEM education and careers?

Previous international research indicated that female students enrolled in STEM-related majors face gender discrimination and develop uncertainty about their abilities and confidence. The survey asked students if they thought they are fairly assessed. Half of the participants (55 per cent) said students are always treated equally and 31 per cent said they are treated equally from time to time. One in ten students said they had experienced gender discrimination. Both male and female students reported gender discrimination.

Figure 9.16: Students' perception on gender discrimination in assessments (percentage)



Literature also suggests that women face barriers when entering the labour market such as the need to balance family and work obligations and they also suffer gender discrimination. One interviewee, working in the IT sector summarized this as:

> When we talk about the gender imbalance and inequality, we really need to split these two stages of entering the STEM education and entering the STEM job because these are two different cases. Entering the STEM education is regulated by the government standards and when the selection process happens it only assesses the results of an individual [based on the standardized UNT results] but when a person enters the job and he, or she gets interviewed. Most of the people have some expectations. They want a programmer to be a male. With two CVs with equal skills and equal profiles they would definitely go for a male. I'm 100 per cent sure.

Another respondent said, 'programming like STEM is becoming very diverse nowadays. And the more it gets developed the more tasks it requires, so it requires both technical and soft skills, so you really need to be good at both if you want to be in a leading position. I think that females have the equal chance now and it's no longer just [a] masculine job.'

The most surprising aspect of the data is that when students are the minority in the group, they are likely to be treated more favourably. In the open question of the survey, several male respondents noted that they were constantly facing gender discrimination in terms of assessment. As one of the male respondents said, 'there is no gender equality in our university. Girls get 100 points just because there are two of them while us [male students] fifteen.'

So, in male-dominated groups, which is usually common in some STEM majors, female students may be treated with favour. The opposite tendency might be observed in female-dominated classrooms where male students are in the minority. This question requires further investigation. Participants of the interview discussed gender stereotypes in their universities and workplaces. The majority of focus group participants stated that they have never faced any gender discrimination. However, some of them shared the view that they had witnessed gender discrimination during job seeking and some female students noted that their learning environments are very competitive.

> *'I remember that in our department most of the lecturers were women and young girls and our dean always complained about hiring women, especially young women. He said girls would get married and then get pregnant and we would need to search for the other employees.'*
>
> *– Comment from a female interviewee*

Another student recalled a single incidence of gender discrimination at their university, 'just one elderly professor would complain about more girls enrolling nowadays to [the] computing machinery major. Others were completely fine with it.'

A female student studying in computer science noted that there is always tension in terms of competition with male students in the group:

> In my case it's competition with males because there are a lot of males. So, you need to be competitive, you need to show that you also can figure out and solve the math problems etc. [The] same situation was in school and now at university. You need to show that you are in a same level as boys and in most of [the] time you do not compete with girls, most [of the] time you compete with boys.

It was revealed that some girls face family and peer group pressure to abandon their studies, at a higher educational level and get married and start a family.

> *'I think in our country it depends on our mentality. When girls study at bachelor's degree it's okay to study but when you get older and are single, parents tell you to get married. They say "why you are studying so hard? You just need to get married." Relatives, friends, parents say "what are you doing? Get married." In this case, also you see that the parents most of [the] time don't allow the girls to further their career, [or] do science because of these cultural issues. The most important thing is just to get married and have kids [and a] family. I think because of this in our country, women don't go that high because family care takes a lot of time. While being a programmer takes a lot of time too, working late and at the weekends.'*
>
> *– Comment from a female interviewee*

Judging from the next comment, left by another male participant of the survey, the leading role of women in the workplace might not be welcoming:

> In Kazakhstan, everything is fine with gender equality in education. I believe that God created men better for one and women for another. But overall, they complement each other. I am against the dominant role of women in the family or at work, but also against violence and suppression, the woman is a good mother and assistant. There must be natural harmony.

These findings, overall, give evidence of the existence of gender stereotyping in society. This negatively affects women's personal, educational and professional skills and hampers aspirations. Such stereotypes hinder the promotion and progression of women in the workplaces to higher and leading positions. As a result, women are underrepresented in major key decision-making roles. This in turn also curtails the number of female role models who would inspire younger generations to enter STEM fields.

Conclusion

The purpose of this study was to explore gender equality in STEM fields in Kazakhstan. This paper has shown that universal gender equality issues in STEM fields and gender stereotyping in particular, apply to the Kazakhstani context. The research revealed that gender stereotyping starts in the early years. Half of the young people in STEM fields think better performance and achievement in STEM subjects are predetermined by gender. More specifically, they ascribe STEM related subjects, except life sciences, to boys and subjects related to humanity fields to girls. Therefore, it is not surprising that almost half of the respondents said their major is more suitable for men. Female students in STEM majors expressed the view they are always compared to males and have to compete against them. These findings indicate the existence of an unequally welcoming study environment for all people, regardless of gender.

As for perception, female students described their field as more difficult than other fields. They also used the following words and phrases to describe STEM related disciplines: 'important', 'interesting', 'beneficial', 'lucrative', 'time consuming', 'commitment requiring', 'rapidly growing' and 'developing'. Females usually expressed the view that they did not regret their career choices. They stated that STEM disciplines are not easy, but at the same time, said studying STEM subjects provides very worthwhile experiences.

The most surprising aspect that emerged from the data is that in groups, where a student's gender is a minority in the group, they are likely to be treated more favourably in terms of grading, which is the case for female STEM majors. More research is needed to explore this issue. The findings also suggest the labour market is more gender-biased than the education sector. Women face more of these gender barriers when first entering the STEM labour market and placement in the work environment itself. These barriers, coupled with conventional expectations for women to be the first person responsible for the family and children, do not fully allow career advancement and leadership for females. This will result in, as reported by the interviewees, a lack of female role models in STEM and therefore, future role models to encourage more girls to enter STEM learning and STEM related careers. The growing number of females in previously male-dominated fields indicates a positive change. Nevertheless, girls and women are still decisively affected by gender stereotypes.

Recommendations

At the school level

As indicated in this report, much emphasis is being put on STEM subjects. However, it is challenging for schools and teachers since there is limited capacity and a lack of a holistic policy and provision in STEM education. Creating more welcoming and supportive learning environments in this field might help eliminate gender stereotypes. This also brings another issue – insufficient attention to develop transversal or key competencies of the twenty-first century. This approach would help learners be more resilient to different barriers and gender stereotypes. For transformation to happen, the education curriculum should mainstream these skills for sustainable development.

Another point of interest should be mainstreaming gender equality principles in the education content overall. This aspect is usually left unattended in the education system. The education content should be revised through gender 'lenses' in order to abolish gender stereotypes in STEM fields. For example, the exercises or examples in school subjects and textbooks should consider representation of both male and female professionals. There should also be programmes, either as part of the formal curriculum, or as extra-curricular activities, that focus on applying knowledge and skills gained from STEM subjects in schools, specifically targeted for girls. Such programmes would not only help develop practical skills and use project-based learning to apply STEM subject knowledge, but they would also generate interest in STEM fields. These programmes could also integrate the development of soft skills and be oriented to solve different societal challenges through problem- and project-based learning. Such programmes may also serve as part of career counselling in schools and increase interest and the confidence of girls in STEM. Female counsellors and instructors are crucial in such programmes in order for girls to be willing to be involved in them.

The role of school psychologists and career advisors cannot be overestimated. They should be well informed and free from existing gender stereotypes when it comes to guiding girls and boys in making career choices. Career counselling programmes should engage female role models that have been successful in STEM fields. Preventive measures should be in place to ensure girls are given fair and equal opportunities that would enable them to grow up into strong individuals and professionals. Continued efforts are also needed to reduce the achievement gap in STEM subjects associated with students' backgrounds. This should focus on factors such as living in urban, compared to rural areas, regional differences, socio-economic status etc.

At the university level

Greater efforts are needed to ensure a friendlier environment for female students in STEM majors. A reasonable approach to tackle this issue could be conducting mentoring programmes, talks, and meetings with prominent female scientists and entrepreneurs. Their assistance and success stories could leverage the study environment. Student associations and groups on campus for those pursuing STEM careers might also help build peer learning and support.

Workplaces

Women in workplaces need tailored support to help them balance life, family and work. While there is an ongoing need to alter attitudes about a women's role in society and the family in general, workplaces could play a greater role as support spaces that provide women with child-friendly (flexible) hours, appropriate facilities and post-maternity leave support programmes to enhance and improve women's knowledge, their ability to perform tasks, with improved support systems to facilitate these objectives. With this approach in mind, creating and being part of special communities or associations of women in STEM would help women to share their experiences and boost their confidence. All of these activities should be showcased in social media platforms to increase awareness and implementation. Overall, the challenge now is to raise awareness of existing gender stereotypes in Kazakhstan and the long-term effect on girls and women, society and the economy in a broad sense and the negative consequences if this issue remains unsolved, or is ignored.

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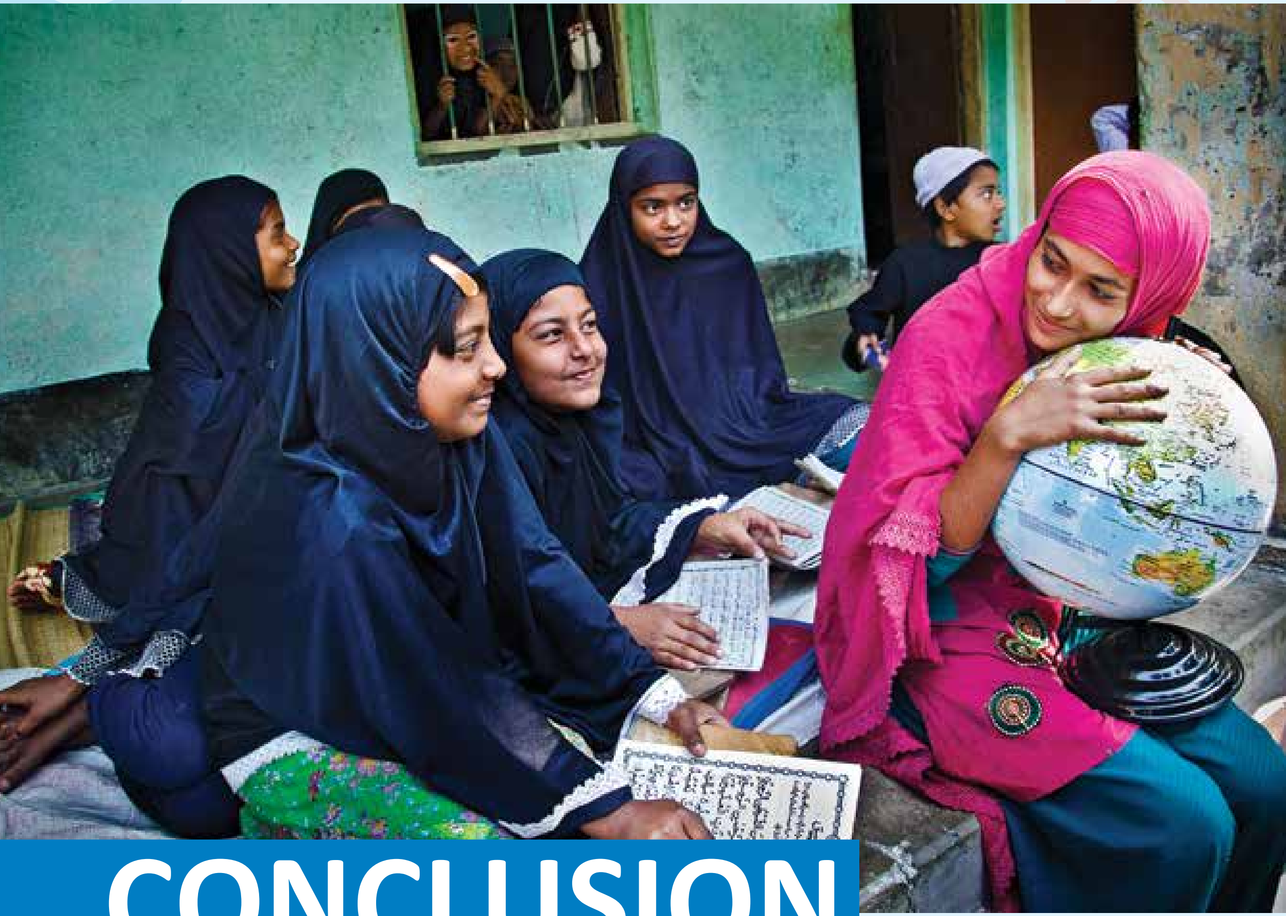

CONCLUSION

10

Lessons learned and way forward: Overcoming sociocultural, psychosocial and pedagogical barriers

The participation of girls and women in STEM fields is much more than a discussion of involvement in specific careers or fields of study. For many, participation in STEM comes after surmounting a series of systemic, social and cultural barriers, each of which reflect obstacles that affect girls and women in multiple aspects of their lives. For example, in many cultural contexts women are expected to take primary responsibility for raising children and domestic duties, leaving them with little time or resources to pursue STEM careers. This reflects larger social structures that limit the opportunities of girls and women in pursuits inside and outside of STEM fields. As such, in investigating the experiences of girls and women in STEM across eight countries in the Asia-Pacific, this research collection has also identified larger challenges to achieving gender equality.

These eight case studies further the achievement of SDG 4 and SDG 5 through a focus on data collected and presented by field practitioners, as well as researchers. The cases included in this report give context-specific analysis of different aspects of gender disparities in the respective countries. Although there are limits to the generalizability of results both in the country settings and regionally, valuable and unique insights can be taken from the conclusions. Through a better understanding of the experiences of girls and women in STEM, especially when considering accounts from practitioners working in the field, informed policies and interventions can be created.

Despite limits in generalizability, there is value in comparing findings between case studies to strengthen recommendations made by authors; identify areas for future research; and suggest approaches to increasing the participation of girls and women in STEM. As such, in the cases described throughout this research, various common themes were identified. In regard to girls studying STEM in school, while there were differences in subject preferences compared to boys, with girls generally preferring ICT, technology and science subjects, overall female students enjoyed STEM subjects and had no better or worse skills compared to their male counterparts. As such, any observed gender differences in STEM participation cannot be attributed simply to lower interest, but instead this indicates sociocultural and psychological factors that impact girls' interest and participation in STEM studies and professional fields. Additionally, the location could have an influence on academic success; researchers from Kazakhstan, Lao PDR and Viet Nam found that students in rural areas had lower achievement scores, higher dropout rates and generally less access to educational opportunities.

Overall, a cyclical effect can be seen in the factors identified in these case studies and this affects the participation of girls and women in STEM. From a young age, girls are often discouraged from pursing STEM careers through messages from family, school, or the media that negatively reinforce the misplaced notion that STEM subjects are more appropriate for boys. This leads to fewer girls choosing STEM courses in school and fewer women pursuing advanced studies in STEM. For those that do pursue advanced STEM studies, there may be additional barriers to success, such as discrimination in school, or pressure to marry earlier and start a family. These challenges spill over to professional fields where women continue to face obstacles to their success. As they progress through their career, women who overcome these barriers experience 'glass ceilings' or 'sticky floors' that prevent them from achieving high leadership positions. This creates a scenario in which young schoolgirls do not see many examples of successful women in STEM. Consequently, they acquire the misplaced belief that this field is not meant for them, fuelling a disadvantageous and negative cycle.

There are many contributing sociocultural, psychological and pedagogical influences on girls' and women's participation in STEM. In identifying and understanding these influences, we can begin to break them down to interrupt the harmful cycle and create targeted, effective programmes and policies that address and overcome barriers to participation. With this aim, an overview of the key factors that contribute to gender disparities in STEM from the eight research papers follows. These are arranged in sociocultural, psychological and pedagogical factors.

Key findings

Sociocultural factors, stereotypes, practices and norms

Overall, there were several overarching sociocultural factors that influenced the experiences of girls and women in the STEM field. In multiple cases, researchers found that STEM careers were perceived as inappropriate for women. This was the basis of the 'Girls2Code' programme in Malaysia where researchers ran a workshop with female students to break prevalent stereotypes that STEM and ICT is for boys. In Kazakhstan, there was a strongly perceived relationship between STEM fields and gender, as young people expressed the view that achievement in STEM was predetermined by gender, associating STEM subjects with boys more so than girls. These sociocultural factors can influence girls' career paths, as was seen in both Indonesia and Viet Nam where they were shown to have a high interest in STEM subjects, yet did not want to work in the STEM field. This was also supported by findings in Lao PDR where negative perceptions of females in STEM fields influenced career and education choices.

Further to the gendered perceptions of STEM fields, parental influence was also seen as a strong factor in a student's pursuance of STEM-related disciplines. Researchers from Lao PDR found the support of parents and family played a critical role in the success of STEM students at the university level. This is similar to observations in India where family support, both before and after marriage, influenced the success and participation of female academics in STEM. However, it was determined that parents do not always have the experience or knowledge to encourage their children to pursue STEM, as was the case for participants of STEM-G in Singapore. Working with parents using a holistic model to encourage the participation of girls in STEM can help mitigate some of these factors as the STEMpower Our Girls programme in the Philippines revealed.

The visibility of female role models in STEM as a positive influence on a girl's interest and confidence in STEM was noted by six of the eight case studies. For example, in 'Girls2Code' in Malaysia, the visibility of female ICT role models empowered more girls to be creators and problem solvers. On the whole, female role models who have achieved success in STEM fields can be a positive influence on girls or women who are considering pursuing a career in the STEM field. This can be successfully achieved through making role models available through in-person or virtual visits to STEM classes and workshops. Another approach is to make them visible through social media campaigns. Alternatively, they could be discussed in a class room setting. In addition to role models, teachers and school counsellors were also found to have a profound influence on girls' collective interest in pursuing a STEM career. As such, teachers, school counsellors and leaders all need training on guiding females towards STEM careers without any prejudice.

As women progress to work in STEM fields, they continue to face barriers to participation and success, potentially even more so during their education, as was found in Kazakhstan. Some barriers come from larger sociocultural structures, such as the expectation that women take on the majority of family and domestic responsibilities, leaving them with less time to focus on their work or studies. Another issue is a lack of mobility that makes it difficult for women to travel for research purposes, to conferences and seminars, to purchase equipment, or to collect data. Half of the case studies noted the need for specific support mechanisms in STEM workplaces, such as maternity leave or policy-level support. Notably, some found unreliable support structures in place. For example, in the case of maternity leave, researchers in India found that despite maternity leave being allocated by the government, this policy was not always respected by some workplaces. As such, it is important to remember that the presence of a support mechanism does not on its own indicate an inclusive workplace or academic environment.

Notably, despite experiencing various sociocultural barriers, in India female academics were found to have the same research productivity as their male colleagues, indicating that they employ what the researchers referred to as 'resilience mechanisms' to overcome these barriers. The specific mechanisms female STEM professionals use to counter the barriers they face were not deeply examined by other papers in this report. This is an important area of research to explore when considering further approaches to supporting women in STEM.

Psychological factors: Perception of self, interest and subject difficulty

Several studies in this research have established that, despite there being no differences in the abilities of girls and boys to learn STEM subjects, there exists a perception that their ability to achieve progress in these fields is predetermined by gender. Although this stereotype is incorrect, it is important to explore what affect it has on girls and how these and other psychological factors impact their study and career choices.

One important psychological factor is confidence, specifically, how confident girls feel in pursing or studying STEM, as well as their confidence in their own abilities. Whether in reference to pursing STEM, competence in STEM or otherwise, confidence was mentioned or discussed in all eight case studies. Researchers in Kazakhstan and Viet Nam found girl's confidence differed between STEM topics, although in Lao PDR there was no difference found in confidence levels between mathematics and science classes. In Singapore, students thought less of their own competencies in relation to their peers and it was suggested that there could be a difference in how girls perceive their abilities within all-girl STEM contexts. This suggests that although great success was shown in the STEM workshops, the results may have differed if the workshops included male and female students, or the confidence girls felt post-workshop may not carry into mixed-gendered contexts.

Several ideas were proposed to increase girl's confidence in their participation in STEM, including introducing role models, or starting STEM studies at a younger age. However, confidence can also be strongly influenced by larger social systems, as was noted by researchers in India where participants connected women's confidence in pursuing STEM careers with larger changing social systems. Additionally, finding larger STEM communities can connect girls and women within social systems. As well as increasing their confidence, these communities can help girls navigate STEM careers and prepare them for the various context-specific sociocultural barriers they may face.

In addition to confidence, the attitude toward STEM is also important as it raises the question of how students perceive and feel about STEM classes and careers. In Lao PDR, it was found that, in general, female students had positive attitudes towards STEM classes in the sense that they enjoyed the classes and looked forward to them, while the same positive attitude was found among STEM-G participants in Singapore. These attitudes were found by some researchers to be slightly different between girls and boys, such as in Viet Nam, although it was noted that this difference was not caused by biology, but instead by socialization, such as in Lao PDR. Attitudes towards STEM were found to be influenced by parents and teachers and were improved in some cases through STEM workshops.

Pedagogical factors

There are many levels of influence on a STEM classroom, including government education policies, curriculum, teachers and pedagogical approaches. How a STEM class is taught can have a ripple effect on the confidence of students and their attitudes towards the subject. A supportive, encouraging teacher has the potential to circumvent some of the sociocultural barriers that girls and women face when entering STEM fields.

Having a clear STEM curriculum that has been developed through gender mainstreaming equips schools and educators to provide an equal STEM education for both girls and boys. For example, in Viet Nam it was found that there was a lack of STEM orientation in the curriculum and that existing textbooks depicted gender stereotypes about females in STEM, such as making examples of male engineers or scientists. Results from Kazakhstan went further to suggest that including key competencies for the twenty-first century in curricula would help learners become more resilient in the face of sociocultural and psychological barriers.

Teachers themselves play an integral role in building a positive experience for girls studying STEM, as well as encouraging them to pursue careers in this field. This was especially true for secondary students in Lao PDR and for students in the Philippines where it was found that teachers were integral sources of guidance for students when choosing study paths. Unfortunately, teachers are not always armed with the necessary tools needed to accomplish this, as results from Viet Nam found that not all teachers understood integrated STEM education, nor had they paid much attention to gender equality issues, although they did disagree with gender discrimination in the classroom.

Although, as previously mentioned, there are no gender differences in the ability to understand STEM concepts. However, a few studies suggested inherent differences in the way female and male STEM professionals and students work. Findings from 'Girls2Code' in Malaysia suggested that male and female students may learn differently, or be attracted to different examples or activities than their male counterparts, while interview results from India suggested that female academics may have a heightened ability to focus on their work. These potential differences are important to keep in mind when designing workshops or classroom activities in order to keep all students engaged and interested and when creating policies to support women in STEM workplaces.

In discussing specific teaching approaches, findings from STEM-G in Singapore suggested that curricula should focus on skills-based competencies. The Girls2Code workshops showed that creative approaches, such as art and animation, were successful in making programming more appealing to beginners and using examples that are relatable to young girls was especially important. All three of the workshop programmes found that an extra-curricular, or a co-curricular approach, were successful in making STEM more appealing and interesting to girls, while 'Girls2Code' also showed that it acted as an effective 'social leveller' in that it benefitted students who did not have a parent working in STEM and with a knowledge of the field.

Recommendations

Strengthen STEM curricula and instructional materials to better promote equal participation in STEM. It is recommended gender equality experts are enlisted to create instructional materials, textbooks and other learning materials so gender equality principles are reinforced and negative stereotypes diminished. Include STEM subjects much earlier in the school curriculum to ensure all students can engage with STEM ideas and include hands-on approaches to teaching STEM that connect curricula with real-world problems so students can understand the role of STEM in a broader context.

Strengthen the capacity of teachers and student counsellors to encourage girls to pursue careers in STEM. Increased awareness of stereotypes and gender disparities in STEM allows educators and career counsellors to understand the barriers faced by their students, ensure equal participation in STEM classes and promote STEM careers to female students.

Raise awareness of gender equality in STEM to parents and broader communities. Teachers and school leaders need to include parents in STEM programmes for girls to improve parents' awareness of and support for STEM careers for their daughters. Additionally, working within larger communities to promote gender equality in STEM can decrease stereotypes and other sociocultural factors that make it difficult for girls to pursue STEM.

Promote stories of successful female STEM professionals. Encourage successful role models to participate in STEM classes and programmes to connect with girls and boys in order to subvert negative stereotypes. This can also strengthen the sense of belonging to STEM communities for girls and women, allowing them to build networks of support and encouragement.

Encourage STEM participation for girls and women in rural areas. Girls and women in rural areas are often disproportionally affected by sociocultural factors that discourage equal participation in STEM. Including rural and geographically disadvantaged groups specifically in gender equality policies and STEM programmes will help to ensure that they are not left behind.

Improve access to STEM facilities for female professionals and students. This includes investigating and acting on any discrepancies in access to STEM laboratories, facilities and resources between male and female students, or between all-girls and all-boys schools. Additionally, examine and act on any challenges women face in accessing STEM resources in the workplace. This can include barriers to gathering data or equipment, cultural norms that discourage collaboration between men and women in the work environment, or policies that make it difficult to balance work and family responsibilities.

Create and enforce policies that promote gender equality in STEM fields. These can include policies that address systematic barriers to participation in STEM and those in support of STEM education for girls, such as increased scholarships, improved STEM facilities, equal access to STEM facilities, or support for initiatives that promote STEM to girls. Additionally, policies that promote gender equality for women in STEM can include policies that mandate supportive workplaces for women, such as flexible working hours, maternity leave and post-maternity leave support programmes and appropriate facilities, as well as interventions through targeted public policies that reduce the influence of cultural factors that are barriers to women's success in STEM.

Education Sector

United Nations
Educational, Scientific and
Cultural Organization

STEM Education for Girls and Women

Breaking Barriers and Exploring Gender Inequality in Asia

Science, Technology, Engineering and Mathematics (STEM) fields are considered catalysts for the achievement of the 2030 Agenda for Sustainable Development. Yet, particularly for STEM fields, girls and women, for a multitude of social, cultural and psychological reasons, engage and participate at a lower rate than boys and men. This research collection aims to highlight the contextual barriers that girls and women face in STEM education and careers and offer concrete examples of interventions that successfully encourage participation of girls and women in STEM. These eight case studies from across Asia explore both the barriers and the achievements in SDG 4 and SDG 5, and give context-specific analysis of different aspects of gender disparities in the respective countries.

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4 QUALITY EDUCATION

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