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To STEM or Not To STEM? Factors Influencing Adolescent Girls' Choice of STEM Subjects

Final Report

Submitted by
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TWF FOREWORD

"Expanding and developing the STEM workforce is a critical issue for government, industry leaders and educators. Despite the tremendous gains that girls and women have made in education and the workforce during the past 50 years, progress has been uneven, and certain scientific and engineering disciplines remain overwhelmingly male."

- Why So Few? Women in Science, Technology, Engineering and Mathematics

At The Women's Foundation, our key goals are challenging gender stereotypes, helping women and girls from low income and poor families to be more economically self-reliant and increasing the number of women leaders. It should be no surprise then that we are so concerned about increasing the number of girls in Hong Kong studying for, and moving into, STEM careers which is where the brightest job prospects will be found in the future.

Hong Kong has a bold vision to be at the forefront of technology and innovation. When you consider our world-class universities with their strong R&D capabilities, the significant investment the Government has already committed to this area, our successful entrepreneurs and our proximity to, and connections with, Mainland China, many of us believe this should be achievable but we need the talent of both

FEWER HONG KONG SCHOOL PUPILS OPT FOR SCIENCE SUBJECTS, ENDANGERING GOVERNMENT BID TO BOOST TECHNOLOGY SECTOR

The Head of the Academy of Sciences of Hong Kong and the former President of the University of Hong Kong, Tsui Lap-chee, said more must be done to allow students to pursue science-related courses or they risk falling behind against international competition. Core subjects of the senior secondary school curriculum (DSE) should be trimmed and basic and advanced level courses offered to provide space for students interested in advanced mathematics and science subjects.

- SCMP, January 5, 2017

TWF'S VIEW

If this is true of Hong Kong students in general, the fall-out is even greater for girls than for boys.

women and men in order for Hong Kong to be a global centre for technological innovation and to be able to compete domestically and globally.

At the same time, we believe it is important that women have a meaningful role in the definition and development of emerging fields that will drive the industries of tomorrow and shape all of our futures — areas like artificial intelligence and machine learning, augmented and virtual reality, big data, fintech and blockchain systems.

The career opportunities in the STEM sector are so broad and so exciting, it is concerning to think that significant numbers of Hong Kong girls are closing themselves off to careers in this area, as evidenced by the marked gender skew in STEM-related DSE subject choices and university degree enrollments. A lot of good work has been done in recent times to encourage Hong Kong students to embrace STEM subjects. These include last year's Education Bureau's public consultation on the promotion of STEM education in Hong Kong which, while being gender-blind, nonetheless generated some good recommendations (see side-bar) for the positive promotion of STEM education in primary and secondary schools. Also of note are initiatives by organisations like Accenture, Barclays, Bloomberg, Capital Group, Cisco, CLP, Credit Suisse, Goldman Sachs, Google, HKT, Microsoft, MTRC, Telstra and Thomson Reuters – many of whom are supporting TWF's Girls Go Tech and other STEM-related programmes. A growing number of companies are also working in partnership with the Government and our

EDUCATION BUREAU

Strategies for Promoting STEM Education

DECEMBER 2016

1) Renew the curricula of STEM Key Learning Areas

2) Enrich learning activities for students

3) Provide learning and teaching resources

4) Enhance professional development of schools and teachers

5) Strengthen partnerships with community key stakeholders

6) Conduct review and disseminate good practices universities to bridge the gap between educational priorities and industry needs.

However, as the report attached to this foreword shows, the challenge of attracting girls in Hong Kong into STEM continues. In order to gain a greater understanding of the attitudes of girls and in particular junior secondary school girls towards STEM, TWF commissioned Dr Dannii Yeung and Dr Mario Liong to produce a report examining Hong Kong female students' inclination not to select STEM subjects. As mentioned above, this gender skew clearly manifests itself in boys' and girls' choices of DSE subjects. In 2015, physics and ICT featured in boys' top 10 subject choices with 26.5% of boys taking physics versus 10.2% of girls and nearly three times as many boys taking ICT as girls. For girls, physics was a distant tenth most popular subject and ICT did not feature in their top 10 subjects. These early subject choices are important because they are pivotal to whether girls go onto STEM-related university disciplines and the jobs of tomorrow.

For their report, Dr Yeung and Dr Liong elicited the views of almost 1,000 female secondary school students and teachers from five girls-only and eight co-ed schools in Hong Kong. Thanks to their excellent work, we know that girls' attitudes towards STEM vary significantly depending on whether or not they have had early positive experiences with STEM, whether they are at a girls-only or co-ed school, whether they have received positive encouragement from their parents and teachers and whether they subscribe to the gender stereotype that STEM subjects are more suited to boys.

STEM THE DECLINE IN OUR SCIENCE EDUCATION

In past PISA tests, Hong Kong came in second in science, maths and reading but last year we dropped to ninth place in science, behind Vietnam and Macau.... [If critics of] the Diploma of Secondary Education which was introduced in 2012 to replace the Certificate of Education Examination are right, the DSE curriculum not only fails to attract more students to STEM, it may actually discourage them... If so, solutions go far beyond the one-off subsidy of HK$200,000 subsidy to each public secondary school to promote STEM in Chief Executive Leung Chun-ying's latest policy address.

- SCMP, January 24, 2017

TWF'S VIEW

We assume an overhaul of the DSE is some time away but much more can be done now to encourage more girls to choose STEM subjects.

BARRIERS TO GIRLS PURSUING STEM SUBJECTS

1	Girls do not come by their perceptions of what they are good at, their interests and their career decisions innately or in a vacuum. These are shaped by society and their school and family environments - all this significantly influences their "choices" to pursue STEM subjects and careers.
2	While mathematics is a compulsory DSE core subject, physics, chemistry, biology, design & applied technology and ICT are offered as voluntary electives rather than mandatory subjects. If girls choose to drop physics, chemistry and technology subjects for their DSEs, this lack of formal education in the core sciences impacts girls' interest in, and opportunities to pursue, STEM choices at university especially given boys have more informal opportunities to be exposed to these areas.
3	Many girls say they find STEM subjects boring because of the perception that these topics involve dry concepts, mechanical exercises and an emphasis on individual performance. The large number of girls pursuing biology (9,991 or 27.7% of girls versus 6,936 or 18% of boys in 2015) with biology being the fifth most popular DSE subject for girls vs the eighth most popular for boys) reflects the fact that girls see biology as an easier course of study than chemistry and physics and more interesting/less dry.
4	Girls at girls-only schools see more value in pursuing STEM subjects and feel more confident in their abilities and supported in their choices. Girls at co-ed schools are concerned about the learning environment and worry about being the only girl or one of very few girls in STEM classrooms.
5	Teachers at girls-only schools are more committed to increasing girls' confidence and abilities in STEM.
6	Positive early physical or emotional experiences with STEM make a huge difference. Girls who have performed well and/or had positive past experiences with science and technology are more confident in their ability to succeed in, and are more motivated to pursue, STEM subjects.

7	Negative stereotypes continue to persist that STEM subjects are more suitable for boys. Many girls limit themselves because of their own gender biases. Girls express less confidence and rate their ability in STEM lower than boys. At the same time, many girls feel constrained and discouraged by negative stereotypes on the part of their parents teachers and close friends.
8	Parents often lack information on STEM career options yet they are the main influencers when it comes to advising their daughters on educational subjects and career paths.
9	The media and popular culture contain and promote stereotypes about STEM fields being a male domain.

When you consider these barriers to girls' participation in STEM, it is clear that there is no single easy answer to increasing girls' participation and how to achieve change. Clearly, what is needed is a multi-faceted approach involving multiple stakeholders, from policy-makers to educators to the business sector. These findings suggest that in order to increase the number of girls opting for STEM subjects, the considerations below are relevant and important.

RECOMMENDATIONS

1	Changing curriculum and pedagogy to emphasise creativity and collaborative project-based learning opportunities would attract more girls to STEM particularly physics and computing courses.
2	We need to identify what is special about the environment in girls-only schools and to try and re-create the same nurturing culture for girls across the entire education system.
3	Investment is required in more support and training - including gender-sensitivity training - for teachers whose skills, abilities and encouragement are crucial in inspiring passion and enthusiasm for the sciences in their students.

4	We need to find ways to inspire and develop girls' interest to select physics and ICT as DSE subjects. This will give them a stronger platform from which to pursue STEM subjects at university and STEM related career pathways later on.
5	It is critically important that we counter negative stereotypes that STEM is more suitable for boys by demonstrating that girls are just as capable as boys. We can do this by promoting female role models and publicising success stories.
6	Since one of the strongest direct predictors of girls' interest in STEM is the extent to which they see value and relevance in the pursuit of STEM subjects, showing girls the positive societal contribution they can make is vital for increasing their levels of interest.
7	Encouragement goes a long way toward mitigating differences in levels of self-confidence and perceived ability. Encouragement to persist from parents, teachers and other influencers is a driving factor behind a girl's likelihood to choose a STEM major or career – this is promising news for interventions aimed at increasing girls' and women's participation since encouragement is a relatively simple strategy that most institutions and people can readily implement.
8	Girls and their parents have limited perceptions of the latest and emerging career possibilities particularly in computing and technology. Parents have an important role to play in influencing girls in their selection of subjects but may not be aware of the variety of jobs available in STEM fields particularly if they are less educated and work in blue collar jobs. We need to make sure families from all walks of life have easily accessible information on the choices and career paths available to girls when it comes to STEM.
9	Experience boosts girls' attitudes towards and confidence in STEM. It is never too early to start fostering girls' interest and curiosity in, and getting girls exposed to, and positively engaged with, STEM which suggests that this needs to be a priority for kindergartens and primary schools.

WHAT YOU CAN DO

WHAT CAN PARENTS AND FAMILIES DO?

- Help your daughter know that effort and appropriate experiences, rather than natural ability, are mainly responsible for STEM success.
- Provide girls with early technology and STEM experiences and familial encouragement to pursue these interests.
- Talk about how STEM subjects are important and relevant to school, work and everyday life.
- Discuss media representation and unconscious biases with your girls. Debunk narrow and limiting stereotypes by discussing how women in STEM are just like other women in other professions and sectors.
- Educate yourselves on new and emerging career pathways in STEM.

WHAT CAN SCHOOLS AND TEACHERS DO?

- Offer Kindergarten through Secondary STEM programmes (whether as core or extra-curricular programmes) and encourage girls to apply.
- If you are a teacher or educator, avoid perpetuating biases such as confusing prior experience with innate ability, treating STEM as a masculine field or equating students' confidence with future success.
- Adopt more of a problem-based teaching and learning approach and include more collaborative team projects related to STEM.
- Leverage industry support to stay abreast of new and emerging career pathways in STEM and the preparation required to enter those careers.
- Leverage industry support to find mentors for girls interested in STEM.

WHAT CAN THE GOVERNMENT, LEGISLATORS AND EDUCATIONAL POLICYMAKERS DO?

- Press for the continuous review of, and improvements to, STEM education in Hong Kong and investment in teacher training and related resources.
- Ensure government departments apply a gender lens to new policies and programmes to promote STEM education and career pathways, recognising that girls don't start from the same level of the playing field as boys.
- Provide resources and training including gender-sensitivity training to schools and teachers so that they can implement initiatives to address the current gender imbalance in STEM.
- Encourage initiatives to inspire and develop girls' interest to select physics and ICT as DSE subjects. Publicise girls' academic accomplishments in STEM-related subjects especially physics and ICT
- Ensure STEM learning materials include female role models and avoid gender stereotypes.

WHAT CAN BUSINESSES DO?

- Promote the importance of, and excitement around, careers in STEM for women and girls. Through careers fairs and career talks at schools, help families and girls understand the ways that STEM can be used in a variety of fields to solve important problems and highlight that these jobs are well-paying and likely to be plentiful.
- Promote female role models within the business and make them available as inspirational speakers for girls and their parents.
- Partner with NGOs and education providers to fund/enhance their STEM programmes to ensure they reach girls from under-privileged families.

WHAT CAN THE MEDIA DO?

- Spotlight more female STEM role models and promote the exciting careers and lifestyles offered by the STEM sectors.

We are very grateful to Dr Yeung and Dr Liong for their excellent work. We would also like to thank Goldman Sachs for their support for this study through ***Goldman Sachs Gives***.

In closing, we know that words alone cannot drive the change we need. Our greatest hope is that this research and our recommendations will serve as a catalyst for systemic change by spurring multi-sector initiatives that will allow the full participation of girls in STEM in Hong Kong.

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STANDARD ABBREVIATIONS

EVM - Expectancy Value Model

HKDSE - Hong Kong Diploma of Secondary Education Examination

ICT – Information and Communications Technology

SD - Standard Deviation

STEM - Science, Technology, Engineering and Mathematics

EXECUTIVE SUMMARY

The present study adopted the Expectancy Value Model (EVM) developed by Eccles (2011) to examine Hong Kong female students' inclination to select STEM subjects. The study hypothesized that individual factors including subjective task values, self-efficacy, expectations for success, cultural norms, previous academic and affective experiences, attitudes of parents, teachers and close friends towards girls' pursuit of STEM subjects and the extent to which their school environment supports girls and STEM would impact girls' intention to study biology, chemistry/physics and ICT. In addition, the study investigated whether gender stereotypical beliefs among teachers, parents and girls themselves would influence girls' intention of pursuing STEM subjects.

A total of 836 Form 3 female students and 146 STEM and class teachers from 13 schools voluntarily participated in the study through self-administered questionnaires. Of the 13 schools, five were girls-only schools and eight were co-educational (co-ed) schools for boys and girls. Seven schools were Band 1, five were Band 2 and one was Band 3. Among them, five schools were located in Kowloon and the remaining eight were located in New Territories. Results showed that compared to female students at co-educational schools, students at girls-only schools perceive knowledge of biology, chemistry/physics and ICT to be useful; they believe they can manage and succeed in the study of these subjects and they perceive greater support from their parents and close friends to pursue STEM subjects. These factors, in turn, contribute to a stronger intention on the part of girls to study biology, chemistry/physics and ICT. In general, parents who have been educated to a higher level and work in white-collar jobs tend to be more supportive of their daughters studying biology, chemistry/physics and ICT. In addition, teachers at girls-only schools are more likely to pay attention to girls' interest and capability in science and technology than teachers at co-ed schools.

Concerning the impact of gender stereotypical beliefs, students with more entrenched gender stereotypical beliefs are less likely to perceive learning biology, chemistry/physics and ICT as valuable and enjoyable or to think that they can manage and succeed in these subjects and subsequently are less inclined to study these subjects in the future. In addition, when students have performed well in the past and had affective reactions to biology, chemistry/physics and ICT, they are more likely to report higher levels of subjective task values and self-efficacy which subsequently increase their intention to study these subjects.

Although the study found only imperceptible differences between teachers in girls-only schools and in co-ed schools in terms of conforming to gender stereotypes around science and technology and the perception of girls being less able than boys in STEM, teachers at girls-only schools scored themselves higher in terms of paying attention to female students' interest and capability in science and technology and putting more effort in their teaching to increase female students' interest and capability to study STEM subjects than their counterparts in co-ed schools. We believe this is one of the key reasons for the greater intention to study STEM subjects among students at girls-only schools than those in co-ed schools. In addition, girls also perceive their parents, teachers and close friends as having stereotypical beliefs toward girls' study of science and technology subjects with more girls reporting a lack of encouragement and support from their fathers, teachers and close friends versus neutral or supportive attitudes on the part of these important influencers.

INTRODUCTION

In Hong Kong, as in elsewhere, science and technology are driving innovation across industries which will bring new jobs and improved societal benefits for our citizens. We can see the increasing importance of STEM in the Hong Kong economy over the past decade. Total exports of high-tech products in Hong Kong increased from HK$409 billion in 2002 to HK$1,624 billion in 2012, with an annual average growth rate of 15%, much faster than the growth rate of 8% for total merchandise exports (Census and Statistics Department, 2013). Among these hi-tech products, 58% of the total export value came from information and communication technology products in 2015 (Census and Statistics Department, 2016a). The amount of funds invested in research and development (of which 94% was in the field of natural sciences, engineering and technology) increased from HK$13,945 million in 2011 to HK$16,727 million in 2014 (Census and Statistics Department, 2015). The demand for talent with STEM-related skills has been increasing too. In 2002, only 61,356 people worked in the information technology field (Census and Statistics Department, 2002). This figure had increased to 129,500 by 2014, accounting for 3.5% of the total labour force (Census and Statistics Department, 2016a). There has also been a steady rise in the number of students studying science, engineering and technology at university level. For example, 26,525 students studied STEM subjects at local universities in 2006/2007, 33,559 in 2013/2014 and 35,403 in 2015/2016 (Census and Statistics Department, 2016b).

However, gender imbalance remains a serious issue in the STEM workforce. For example, in information and communications, men outnumber women consistently by 2:1 (35,400 vs. 74,000 in 2008 and 40,200 vs. 90,700 in 2015) (Census and Statistics Department, 2016b).

Although international studies increasingly show girls catching up with boys in terms of performance in STEM subjects (Campbell & Clewell, 1999; Kerr & Kurpius, 2004), and despite girls and boys achieving a comparable overall performance in the OECD's 2013 Programme for International Student Assessment (PISA), research shows that girls are less confident in their ability in solving science and mathematics problems (Stout, Dasgupta, Hunsinger, & McManus, 2010) and report high levels of anxiety toward mathematics (Johns, Schmader, & Martens, 2005). It suggests that gender variations in performance in science and mathematics do not stem from innate differences in aptitude but are due to students' own attitude toward these subjects or expectations from parents and teachers (Hill, Corbett, & Rose, 2010).

PISA 2006 examined gender differences in attitude toward science across countries and regions (OECD, 2007). Hong Kong was one of the regions where female students held less positive attitudes toward science than their male counterparts (OECD, 2007). An analysis of the 2015 Hong Kong Diploma of Secondary Education Examination (HKDSE) shows that the number of female students who took science (especially physics and chemistry) and technology subjects (e.g., information and communication technology) was far below the number of male students. For example, 26.5% of male students (10,119 male students out of a total of 38,183 male candidates) took physics versus 10.2% of female students (3,659 female students out of a total of 35,948 female candidates), and nearly three times as many males students took ICT compared versus female students (5,089 male students versus 1,698 female students). While the number of girls completing science and technology courses at the high school level lags behind boys, at university, the picture is even starker with female undergraduates significantly under-represented in STEM disciplines. Female students made up 38.8% of the total student population pursuing science disciplines and 30.5% pursuing engineering and technology disciplines in local universities in 2015/2016 (Census and Statistics, 2016b). These seemingly high numbers mask the fact that female undergraduates predominate in biology, psychology and life sciences but are significantly outnumbered when it comes to physics, engineering and technology. In STEM-related fields, men persistently outnumber women over the years.

Despite these gender imbalances in STEM learning and careers in Hong Kong, the Education Bureau did not explicitly address the issue of gender in their public consultation and ensuing recommendations and strategies for promoting STEM in Hong Kong schools (Curriculum Development Council, 2015) although the Bureau has endorsed and is supporting various initiatives focusing on girls including The Women's Foundation's Girls Go Tech Programme which provides Form 3-4 secondary school girls from under-privileged backgrounds with free coding and digital literacy workshops, extra-curricular activities, opportunities for company visits, and access to role models and mentors.

The present study examines the factors influencing Hong Kong female students' intention to pursue STEM subjects as part of their senior secondary education. We focused on three STEM subjects - namely life sciences (e.g., biology), physical science (e.g., chemistry, physics) and technology [e.g., information and communication technology (ICT)). Mathematics and engineering were excluded from the exercise because mathematics is one of the four core subjects in the DSE examination whereas engineering is not offered as a secondary subject by mainstream schools in Hong Kong. We differentiated between biology and physics / chemistry because girls are studying biology in much larger numbers than physics or chemistry and their reasons for choosing to study biology are in general different from why they are or are not selecting physics and chemistry (Buckner & Botcherby, 2012; Lyons, 2006). In addition, female students tend to have lower self-efficacy or a lesser belief in their capabilities to achieve goals and outcomes in physics than in biology (Zhu, 2007).

The Expectancy Value Model (EVM; Eccles, 2011) is one of the most dominant theories for studying educational and occupational choices because of its multiple components of motivational factors and linkages to social and cultural factors. This model has been widely applied to investigate educational and occupational choices of primary and secondary school students, e.g., aspirations for physical and IT-related sciences among American and Finnish high school students (Chow, Eccles, & Salmela-Aro, 2012), educational choice of science subjects of Norwegian secondary students (Boe, 2012), and educational expectations and occupational aspirations of Finnish adolescents for languages, maths and science, social sciences, and practical and art subjects (Viljaranta, Nurmi, Aunola, & Salmela-Aro, 2009). Eccles' expectancy value theory provides one of the most comprehensive theoretical frameworks for studying the psychological and contextual factors underlying both individual and gender differences in maths and science academic motivation, performance and career choice (Eccles, 1994, 2005; Wigfield & Eccles, 2000).

Drawing on work associated with identity formation, achievement theory, and attribution theory, expectancy-value theorists posit that the STEM pathway is composed of a series of choices and achievements that commence in childhood and adolescence. Achievement-related behaviors such as educational and career choice are most directly related to expectations for success and the value attached to the various options perceived as available. These domain-specific competence and task-related beliefs are influenced by cultural norms, behavior genetic, social experiences, aptitudes, and the affective reactions of previous experiences as individuals move through adulthood (Eccles, 1994; Eccles, Wigfield, & Schiefele, 1997). In other words, individual characteristics and experiences associated with STEM-related activities shape the development of self-efficacy, interests, task values, and long-term life goals, which in turn, influence educational and career choices in STEM and non-STEM fields (Eccles et al., 1993; Jacobs et al., 2005). Therefore, it is likely that male and female differences in STEM field selection are associated with gendered differences in these motivational beliefs (e.g., self-efficacy, interests, and task value).

Using the Expectancy Value Model as a guiding framework, this study aimed to investigate the effect on girls' motivation to pursue biology, chemistry/physics and technology subjects of five key determinants of educational choices: (1) subjective task values, (2) self-efficacy, (3) expectations for success, (4) cultural norms and (5) previous academic and affective experiences. In addition, it also assessed the effect of teachers' gender-related beliefs and teaching methods on girls' selection or non-selection of STEM subjects.

The present study consisted of two assessments: 1) Student Assessments which examined the effects of the five major EVM components among Form 3 female students at both co-educational and girls–only schools; and 2) Teacher Assessments which measured STEM and Form 3 class teachers' attitudes toward girls' pursuit of science and technology to explore the effect of the school environment on students' intention to study STEM subjects.

Five hypotheses were tested in this project:

H1: Intention to study biology, chemistry/physics and ICT would be predicted by higher subjective task values, self-efficacy and expected success in these subjects.

H2: Intention to study biology, chemistry/physics and ICT would be predicted by positive perception of their father's, mother's, teachers' and close friends' attitudes toward girls' study of STEM subjects.

H3: Girls' stereotypical beliefs related to STEM subjects would be negatively correlated with subjective task values, self-efficacy and expected success in biology, chemistry/physics and ICT.

H4: Previous experiences in STEM subjects would indirectly affect one's intention to study biology, chemistry/physics and ICT via self-efficacy and subjective task values.

H5: Intention to study biology, chemistry/physics and ICT would be higher among students with more supportive school environments.

METHOD

PARTICIPANTS AND PROCESS

One hundred and thirty schools were invited to join this project via letters or phone calls. Thirteen secondary schools agreed to take part in this project, with 5 girls' schools and 8 co-educational (co-ed) schools. Participation was totally voluntarily and parental or principal consent was sought before students participated in this research. A total of 836 Form 3 female students completed the student questionnaires in class or at home. Among the student sample, 286 participants came from co-ed schools with a mean age of 14.66 years (SD = .89) and 550 participants were from girls' schools with a mean age of 14.47 years (SD = .65).

STEM and class teachers from these 13 schools were also invited to participate in the study. Questionnaires were distributed to the target teachers and participation in the study was again totally voluntary. Among the 149 teachers who returned the questionnaires, 3 of them were not STEM or Form 3 class teachers, therefore they were excluded from the final sample of teacher assessments (N = 146). 88 of them were STEM teachers (60.3%) and 58 were class teachers (39.7%). Table 1 summarizes the numbers of student and teacher participants by type of school.

Across the 13 schools, a total of 1,392 student questionnaires and 305 teacher questionnaires were distributed. The response rates for student and teacher participants are 60.1% and 48.9% respectively.

Table 1. Numbers of student and teacher participants by type of school

	Co-educational Schools	Girls' schools	Total
Students	286	550	836
Teachers	90 (51 STEM teachers & 39 Class teachers)	56 (37 STEM teachers & 19 Class teachers)	146

MEASURES USED IN THE STUDENT ASSESSMENT

With reference to past research (Eccles & Wigfield, 2002; Eccles et al., 1998), the following constructs were measured for each subject (biology, chemistry/physics and ICT):

- Subjective task values were assessed by four components: importance of doing well in the subject, subjective interest in the subject, utility value of the subject, and relative cost of engaging in the subject (Chow, Eccles & Salmela-Aro, 2012).
- Self-efficacy, also referred to as personal efficacy, meaning the extent or strength of one's belief in one's own ability to complete tasks and reach goals (PISA 2012 assessment: OECD, 2013).
- Expected success reflects one's expectations of future success in the subject domain (Hood, Creed, & Neumann 2012).
- Cultural norms were measured by different components namely, perceived father's, mother's, teachers' and close friends' attitudes toward the subject (Giles & Larmour, 2000; Leaper, Farkas & Brown, 2012); gender role stereotypes (Tantekin, 2002) and gender stereotypes toward girls' study of the subject (Stout, Dasgupta, Hunsinger, & McManus, 2010).
- Previous experiences in learning the subject including past performance and affective reactions (SATS-36, Schau, 2003) were also assessed. A sample item of affective reactions to biology is "I get frustrated going over biology tests in class."

MEASURES USED IN THE TEACHER ASSESSMENTS

Both STEM and class teachers were asked to respond to the following measurements:

- Gender stereotypes in STEM measure teachers' attitudes toward girls' study of science and technology (Stout et al., 2010). For example, "When I think of people who are very good at science, I think of … (1 = mostly men to 11 = mostly women)."
- Gender role stereotypes (Tantekin, 2002) measure teachers' general beliefs about gender roles. For example, "Women are naturally sensitive (1 = strongly agree to 7 = strongly disagree).
- Attention to female students' interest and capability in science and technology, which was created with reference to Labudde, Herzog, Neuenschwander, Violi, & Gerber (2000).
- STEM teachers were also asked to describe their teaching methods (Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000; Lumpe, Haney, & Czerniak, 2000).
    - Self-concepts of girls' study of STEM subjects were created with reference to Labudde, et al. (2000). Teachers were asked to share their impressions and attribution of girls' good performance in STEM. An example is, "I think girls' good performance in science/technology is due to their diligence and discipline."
    - Content of STEM instruction was created with reference to Labudde et al. (2000). Teachers were asked to reflect on whether their STEM teaching consisted of interaction and feedback, whether they paid attention to different experiences of girls and boys, and whether they supported cooperative learning. An example is "I associate science/technology knowledge with people and everyday life."
    - Environment and methods of teaching and learning were adopted from Lumpe, Haney, and Czerniak (2000). Teachers were asked to rate how important each environmental factor (e.g., parental involvement, involvement of science experts like university faculty and industry experts, and planning time) is in influencing STEM teaching and learning in their schools.

With the exception of gender stereotypical beliefs about science and technology, all the constructs in both student and teacher assessments were measured by a 7-point Likert scale, with higher scores representing higher levels of the construct. Gender stereotypical beliefs were assessed by an 11-point Likert scale, with higher scores representing more favorable attitudes toward girls' study of science and technology.

RESULTS

STUDENT ASSESSMENT

Form 3 female students' intention to study and attitudes toward biology, chemistry/physics and information and communication technology (ICT) was measured in the student questionnaire. Table 2 summarizes the mean score, standard deviation (SD) of each construct by type of school.

A. DIFFERENCES BETWEEN STUDENTS OF CO-ED AND GIRLS' SCHOOLS:

Compared with female students of co-ed schools, students at girls-only schools:

- showed greater intention, subjective task values and perceived success in studying biology, chemistry/physics and ICT
- indicated higher levels of self-efficacy in chemistry/physics and ICT
- held fewer stereotypical beliefs toward chemistry/physics and ICT
- perceived their mothers and close friends had more positive attitudes toward girls' study of biology, chemistry/physics and ICT
- perceived more favourable perception and affective reactions on the part of their fathers toward girls' study of biology, chemistry/physics and ICT, and
- had more positive past experiences in the three subjects

These findings suggest that compared to girls at co-ed schools, girls at girls-only schools have more positive attitudes toward, and a greater intention to study, biology, chemistry/physics and ICT subjects.

B. COMPARISON AMONG THE THREE SUBJECTS:

Results of within-subject analyses showed that

- Female students had the highest intention to study biology, followed by chemistry/physics and ICT.
- The levels of subjective task values, self-efficacy and expected success associated with biology were also higher than for chemistry/physics and ICT.

These findings suggest that girls in general hold more positive attitudes toward the study of biology than for chemistry/physics and ICT.

As revealed in the in-depth interviews, there were different reasons for female students to choose biology over other science and technology subjects. A female student who was interested in studying biology in senior form shared that her father encouraged her to study to be a doctor:

> My dad told me to choose biology…because he said he hoped I could be a doctor in the future. He said I had to study biology at high school to be a doctor. (係我爹地有同我講過話揀生物…因為佢好似係希望我將來做醫生。佢話做醫生就一定要係中學讀左呢一科先，所以希望我讀呢一科。)
>
> (School B, student 3)

Some girls preferred biology to chemistry/physics because they liked animals:

> I prefer biology because I can learn about many many different kinds of animals. They have different structures. Through them, I can see every organism has different physiological structures. I think it's very interesting. I don't like physics because there are a lot of things to recite and remember. (我揀 Biology，因為我可以接觸到好多好多唔同種類嘅動物，佢地唔同嘅構造。我覺得睇住每一樣生物唔同嘅構造好得意。如果係物理，我有少少唔鍾意，因為好多野背同記。)
>
> (School B, student 4)

> I am interested in human organs and I am interested in organisms or animals. (How about chemistry?) Chemistry? I got very bad grades in Chemistry. I don't

understand what the teacher is saying. Although I got a pass grade, I was among the bottom. (我反而對人類器官方面有興趣。或者對生物，或者動物果啲有興趣。(咁 Chemistry 咧？)Chemistry, 我考得好差，同埋我聽唔明老師講野。係啊，雖然合格，但係真係比較低分嗰批。)

(School B, student 5)

Some girls actually liked biology, physics and chemistry. They found biology interesting because of the possibility of doing animal dissection:

I think there is a lot to remember in biology. It's time-consuming. But I am interested in dissection because it's fun. (Bio 我覺得要背好多野，要花時間。對解剖都幾有興趣，因為好好玩。)

(School B, student 6)

Although in general, female students preferred biology to chemistry and physics, some girls liked chemistry or physics more than biology. Fear of blood was one of the reasons given for avoiding biology:

I read more about physics when I was small. So why I didn't choose chemistry and biology? I actually got good grades in physics, chemistry and biology. But we could only look at the model of molecules when we learnt chemistry and it's meaningless. For biology, I don't like blood or anything relating to organisms. So that leaves physics. Light rays are ok. (因為我細個嗰陣睇嘅野多啲關於 Physics；點解唔揀 Chem 同 Bio？其實 Phy Chem Bio 我喺學校嘅成績都係中上，但係上 Chem 堂就係望住嗰啲 molecules 嘅模型，無乜用。Biology 我就唔係好鍾意見血，或者生物嘅東西我就唔係好感興趣。咁就剩返 Physics，light ray 嗰啲就 ok。)

(School B, student 10)

Table 2. Descriptive statistics of the student assessment by type of school.

	Co-educational Schools			Girls' Schools			Total		
	Biology subject	Chemistry / Physics subject	ICT subject	Biology subject	Chemistry / Physics subject	ICT subject	Biology subject	Chemistry / Physics subject	ICT subject
Intention to study	3.71 (1.91)	3.24 (1.94)	2.53 (1.60)	4.01 [a] (1.90)	3.86 [b] (2.02)	2.91 [c] (1.68)	3.91 (1.91)	3.64 (2.01)	2.78 (1.66)
Subjective task values	4.29 (1.18)	3.92 (1.16)	3.74 (1.05)	4.44 [a] (1.01)	4.25 [b] (1.12)	4.06 [c] (1.05)	4.39 (1.07)	4.14 (1.15)	3.95 (1.06)
Self-efficacy	4.21 (1.44)	3.77 (1.53)	3.50 (1.37)	4.37 (1.31)	4.14 [b] (1.45)	3.78 [c] (1.33)	4.31 (1.36)	4.02 (1.49)	3.69 (1.35)
Perceived success	4.76 (1.49)	4.41 (1.57)	3.91 (1.39)	5.14 [a] (1.28)	4.90 [b] (1.41)	4.32 [c] (1.36)	5.01 (1.37)	4.73 (1.48)	4.18 (1.38)
Gender stereotypes [1]	4.02 (2.71)	3.03 (2.15)	2.75 (1.94)	3.99 (2.18)	3.53 [b] (2.01)	3.25 [c] (1.86)	4.00 (2.37)	3.36 (2.07)	3.07 (1.90)
Father perception	3.71 (1.50)	3.73 (1.54)	3.40 (1.46)	3.94 [a] (1.42)	3.95 (1.47)	3.58 (1.36)	3.87 (1.45)	3.88 (1.50)	3.52 (1.39)

Mother perception	3.65 (1.52)	3.51 (1.49)	3.10 (1.34)	4.10 [a] (1.43)	4.00 [b] (1.45)	3.46 [c] (1.34)	3.95 (1.48)	3.84 (1.48)	3.34 (1.35)
Close friend perception	3.83 (1.40)	3.75 (1.44)	3.34 (1.33)	4.17 [a] (1.24)	4.11 [b] (1.32)	3.65 [c] (1.23)	4.05 (1.31)	3.99 (1.37)	3.54 (1.27)
Teacher perception	4.10 (1.30)	4.05 (1.38)	3.70 (1.34)	4.14 (1.17)	4.18 (1.24)	3.84 (1.19)	4.13 (1.22)	4.14 (1.29)	3.79 (1.24)
Past performance	3.96 (1.60)	3.70 (1.65)	3.52 (1.61)	4.25 [a] (1.42)	4.06 [b] (1.53)	3.75 [c] (1.48)	4.15 (1.49)	3.94 (1.58)	3.67 (1.53)
Affective reactions	4.52 (1.17)	4.13 (1.26)	3.96 (1.16)	4.65 (1.10)	4.40 [b] (1.23)	4.21 [c] (1.15)	4.60 (1.12)	4.31 (1.25)	4.13 (1.16)

Note. [1] Scores of gender stereotypes range from 1 to 11. Higher scores of gender stereotypes represent more favourable attitudes toward girls' study of the subject. [a] denotes the biology-related scores of students of girls' schools are significantly higher than that of students of co-ed schools. [b] denotes the chemistry/physics-related scores of students of girls' schools are significantly higher than that of students of co-ed schools. [c] denotes the ICT-related scores of students of girls' schools are significantly higher than that of students of co-ed schools.

C. Effects of Demographic Background on Major Variables:

Table 3. Parents' education and occupation

	Father (%)	Mother (%)
Education Level:		
Primary or no formal education	9.7	11.4
Secondary education	60.1	60.3
Higher diploma or non-degree	7.2	8.8
Bachelor's degree	16.4	13.6
Master degree or above	6.6	5.8
Occupation:		
Managerial	20.2	11.5
Professionals	13.1	11.8
Clerical	7.8	16.4
Service & Sales Work	9.6	14.3
Technicians & Operational	30.4	1.6
Unskillful Work	10.0	4.6
Housework	1.5	36.2
Unemployed	2.6	1.8
Others	4.8	1.8

Students were asked to report the education levels and occupations of their parents (Table 3). In the current sample, about 60% of the participants reported their fathers and mothers attained secondary education, and 16.4% and 13.6% respectively had bachelor's degree. The majority of fathers worked as technicians and operational workers (30.4%) or managerial employees (20.2%) whereas most of the mothers took care of housework (36.2%) or worked as clerical employees (16.4%).

Table 4. Influence of Father's Education on the Student's Attitudes toward and Intention to Study STEM Subjects

	Father's Education						
	1. Primary or below	2. Secondary	3. Higher diploma	4. Bachelor	5. Master or above	F	Differences
Intention to study biology	4.18 (2.02)	3.76 (1.88)	4.10 (1.70)	4.36 (1.77)	3.87 (2.12)	2.90*	2 < 4
Intention to study chemistry/physics	3.68 (1.94)	3.56 (2.00)	4.05 (1.94)	4.07 (2.02)	3.94 (2.19)	2.23	
Intention to study ICT	2.29 (1.51)	2.81 (1.65)	2.85 (1.63)	3.00 (1.58)	2.84 (1.94)	2.27	
Subjective task values of biology	4.49 (1.05)	4.32 (1.37)	4.52 (.99)	4.52 (.98)	4.46 (1.41)	1.30	
Subjective task values of chemistry/physics	4.10 (1.23)	4.07 (1.11)	4.34 (1.04)	4.33 (1.17)	4.39 (1.45)	1.23	
Subjective task values of ICT	3.84 (1.15)	3.96 (1.01)	4.03 (.91)	4.04 (1.13)	3.93 (1.38)	.47	
Self-efficacy in biology	4.44 (1.43)	4.24 (1.35)	4.50 (1.28)	4.55 (1.22)	4.29 (1.48)	1.76	
Self-efficacy in chemistry/physics	3.89 (1.69)	3.97 (1.47)	4.34 (1.32)	4.28 (1.45)	4.25 (1.53)	1.80	
Self-efficacy in ICT	3.33 (1.27)	3.69 (1.33)	3.88 (1.16)	3.93 (1.42)	3.81 (1.58)	2.57*	1 < 4
Perceived success in biology	5.06 (1.47)	4.94 (1.35)	5.15 (1.29)	5.26 (1.26)	4.95 (1.49)	1.54	
Perceived success in chemistry/physics	4.56 (1.62)	4.68 (1.49)	5.08 (1.26)	4.98 (1.44)	4.89 (1.54)	2.05	
Perceived success in ICT	3.82 (1.26)	4.16 (1.37)	4.33 (1.24)	4.46 (1.40)	4.26 (1.56)	2.69*	1 < 4
Father's perception toward biology	3.44 (1.66)	3.68 (1.35)	4.21 (1.43)	4.34 (1.38)	4.66 (1.42)	11.56*	1, 2 < 3, 4, 5

Father's perception toward chemistry/physics	3.35 (1.62)	3.70 (1.40)	4.19 (1.27)	4.33 (1.49)	4.86 (1.52)	12.99*	1 < 3, 4, 5; 2 < 4, 5
Father's perception toward ICT	2.79 (1.41)	3.50 (1.31)	3.65 (1.17)	3.86 (1.45)	3.89 (1.54)	7.78*	1 < all

Note. * denotes there are significant differences between education levels.

Table 4 presents the mean and SD of each variable by father's education level. Overall, girls' self-efficacy and perceived success in biology, chemistry/physics and ICT were higher in families with fathers having a bachelor's degree than those with just primary education or below. Students also perceived their fathers as having more positive attitudes toward biology, chemistry/physics and ICT if their fathers had attained higher education levels.

Table 5. Influence of Mother's Education on the Student's Attitudes toward and Intention to Study STEM Subjects

	Mother's Education						
	1. Primary or below	2. Secondary	3. Higher diploma	4. Bachelor	5. Master or above	F	Differences
Intention to study biology	3.86 (1.81)	3.73 (1.90)	3.96 (1.89)	4.60 (1.81)	4.25 (1.89)	5.00*	2 < 4
Intention to study chemistry/physics	3.18 (1.86)	3.53 (2.00)	3.97 (2.02)	4.55 (2.00)	3.59 (2.18)	7.41*	2 < 4
Intention to study ICT	2.21 (1.37)	2.84 (1.65)	3.00 (1.75)	3.01 (1.66)	2.53 (1.96)	3.89*	1 < 2, 3, 4
Subjective task values of biology	4.35 (1.02)	4.30 (1.08)	4.34 (1.02)	4.72 (1.07)	4.77 (1.07)	4.85	2 < 4
Subjective task values of chemistry/physics	3.97 (1.11)	4.02 (1.15)	4.30 (1.02)	4.59 (1.21)	4.43 (1.28)	6.73*	1, 2 < 4
Subjective task values of ICT	3.70 (.98)	3.93 (1.04)	4.15 (1.13)	4.07 (1.13)	4.10 (1.21)	2.38	
Self-efficacy in biology	4.08 (1.35)	4.22 (1.34)	4.33 (1.45)	4.74 (1.24)	4.69 (1..32)	4.81*	1, 2 < 4
Self-efficacy in chemistry/physics	3.66 (1.54)	3.91 (1.48)	4.19 (1.45)	4.56 (1.46)	4.32 (1.49)	6.13*	1, 2 < 4
Self-efficacy in ICT	3.20 (1.09)	3.68 (1.35)	3.98 (1.34)	3.93 (1.35)	3.82 (1.59)	4.74*	1 < 2, 3, 4
Perceived success in biology	4.82 (1.30)	4.91 (1.40)	4.97 (1.42)	5.41 (1.20)	5.49 (1.16)	4.79*	1, 2 < 4
Perceived success in chemistry/physics	4.35 (1.48)	4.61 (1.51)	4.93 (1.39)	5.28 (1.42)	5.17 (1.38)	7.15*	1 < 4, 5; 2 < 4
Perceived success in ICT	3.65 (1.11)	4.14 (1.40)	4.49 (1.42)	4.50 (1.32)	4.35 (1.50)	5.96*	1 < 2, 3, 4
Mother's perception toward biology	3.49 (1.65)	3.67 (1.43)	4.43 (1.43)	4.46 (1.35)	4.68 (1.19)	11.73*	1, 2 < 3, 4, 5

Mother's perception toward chemistry/physics	3.39 (1.65)	3.67 (1.43)	4.30 (1.49)	4.42 (1.31)	4.34 (1.35)	10.51*	1, 2 < 3, 4, 5
Mother's perception toward ICT	2.71 (1.38)	3.28 (1.31)	3.87 (1.51)	3.66 (1.16)	3.49 (1.35)	8.97*	1 < all; 2 < 3

Note. * denotes there are significant differences between education levels.

Table 5 summarizes the mean and SD of each variable by father's education level. Students' attitudes toward STEM, intention to study the three subjects, and perceived maternal attitudes varied significantly by their mother's education. Overall, students with mothers having only primary and/or secondary school education had less positive subjective task values, self-efficacy, perceived success in, and intention to study STEM subjects than students with mothers with higher education levels. Mothers who had been educated to the higher diploma level and above were perceived as more supportive toward their daughters' study of the three subjects.

Table 6. Influence of Father's Occupation on the Student's Attitudes toward and Intention to Study STEM Subjects

	Father's Occupation			
	White Collar (1)	Blue Collar (2)	F	Differences
Intention to study biology	4.03 (1.96)	3.90 (1.85)	.76	
Intention to study chemistry/physics	3.79 (2.05)	3.72 (1.99)	.16	
Intention to study ICT	2.78 (1.73)	2.83 (1.64)	.11	
Subjective task values of biology	4.38 (1.16)	4.44 (1.00)	.47	
Subjective task values of chemistry/physics	4.20 (1.20)	4.16 (1.13)	.16	
Subjective task values of ICT	3.95 (1.42)	3.98 (1.07)	.16	
Self-efficacy in biology	4.33 (1.41)	4.41 (1.26)	.60	
Self-efficacy in chemistry/physics	4.15 (1.46)	4.06 (1.49)	.67	
Self-efficacy in ICT	3.72 (1.39)	3.76 (1.36)	.12	
Perceived success in biology	5.07 (1.36)	5.05 (1.34)	.03	
Perceived success in chemistry/physics	4.85 (1.44)	4.77 (1.49)	.52	
Perceived success in ICT	4.21 (1.39)	4.21 (1.41)	.00	
Father's perception toward biology	4.18 (1.40)	3.72 (1.43)	16.43*	1 > 2

Father's perception toward chemistry/physics	4.20 (1.47)	3.75 (1.47)	14.05*	1 > 2
Father's perception toward ICT	3.68 (1.38)	3.50 (1.41)	2.78	

Note. [1] White-collar includes managerial, professional and clerical employees. [2] Blue-collar includes service and sales work, technicians and operational workers and unskilled work. * denotes there are significant differences between occupations.

Table 6 summarizes the mean and SD of each variable by father's occupation. Overall, students whose fathers working in white-collar jobs were more likely to perceive their fathers as being supportive of their study of biology, chemistry/physics and ICT than those whose fathers were working in blue-collar jobs.

Table 7. Influence of Mother's Occupation on the Student's Attitudes toward and Intention to Study STEM Subjects

	Mother's Occupation				
	White Collar (1)	Blue Collar (2)	Housework (3)	F	Differences
Intention to study biology	4.06 (1.84)	3.85 (1.73)	3.79 (2.03)	1.63	
Intention to study chemistry/physics	3.84 (2.00)	3.40 (1.87)	3.63 (2.11)	2.47	
Intention to study ICT	2.78 (1.65)	2.85 (1.60)	2.69 (1.68)	.47	
Subjective task values of biology	4.45 (1.11)	4.32 (.99)	4.38 (1.06)	.75	
Subjective task values of chemistry/physics	4.27 (1.20)	3.95 (1.11)	4.13 (1.14)	4.09*	2 < 1
Subjective task values of ICT	3.96 (1.11)	3.92 (1.06)	3.95 (1.02)	.07	
Self-efficacy in biology	4.41 (1.35)	4.19 (1.30)	4.30 (1.40)	1.46	
Self-efficacy in chemistry/physics	4.20 (1.49)	3.81 (1.42)	3.96 (1.54)	3.84*	2 < 1
Self-efficacy in ICT	3.70 (1.41)	3.51 (1.30)	3.76 (1.31)	1.77	
Perceived success in biology	5.12 (1.38)	4.91 (1.25)	4.97 (1.40)	1.51	
Perceived success in chemistry/physics	4.93 (1.45)	4.56 (1.38)	4.64 (1.57)	4.15*	2 < 1
Perceived success in ICT	4.22 (1.42)	4.07 (1.28)	4.17 (1.42)	.59	
Mother's perception toward biology	4.22 (1.38)	3.60 (1.51)	3.84 (1.48)	9.83*	2, 3 < 1
Mother's perception toward chemistry/physics	4.09 (1.45)	3.52 (1.47)	3.77 (1.50)	7.73*	2, 3 < 1
Mother's perception toward ICT	3.56 (1.33)	3.11 (1.45)	3.21 (1.29)	7.39*	2, 3 < 1

Note. [1] White-collar includes managerial, professional and clerical employees. [2] Blue-collar includes service and sales work, technicians and operational workers and unskilled work. [3] Housework includes mothers without a full time job taking care of household chores. * denotes there are significant differences between occupations.

Table 7 presents the mean and SD of each variable by the mother's occupation. Overall, students whose mothers were working in white-collar jobs were more likely to perceive their mothers as supportive to their study of biology, chemistry/physics and ICT than those whose mothers were working in blue-collar jobs or taking care of household chores. Subjective task values, self-efficacy and perceived success in chemistry/physics were higher among students whose mothers were working in white-collar jobs than students whose mothers were working in blue-collar jobs.

In-depth interviews with students from all-girls' schools indicated that fathers and mothers exert significant influence over their daughters' interest in science and ICT learning. Parents who were not familiar with ICT did not encourage their daughters to learn ICT whereas parents who understood the importance of ICT urged their daughters to pursue ICT learning:

> [Do your parents encourage you to learn ICT or coding?] Not really. It's because …the way my family thinks is that you should just pick what you feel most comfortable doing… my dad doesn't know very much about computing. ([你爹地媽咪會唔會鼓勵你去學多啲電腦科？或者 coding 嘅野？]都未必，因為我屋企嘅做法係，你自己想做咩，就向住目標去做…某程度上我爸爸唔係好識電腦…我媽媽就係內地返工，所以好多時都唔喺屋企。)
>
> (School B, student 4)

> I think the biggest influence on me is my mom. My mom is working in the financial industry. She often tells me…because of computers and advanced technology, everything in the financial services business like complex calculations or how the stock exchange works is much easier and more efficient. She often uses this example to encourage me, "Honey, no matter what you do in the future, you must learn computing - it will be useful to you for your whole life. Even now I am old, I must learn computing. This is the most important skill for the future. So I encourage you to learn IT. When you go to college, you must at least minor in IT. This is a very important skill." (我覺得應該係我媽媽影響大D，因為我媽媽係做金融業，佢同我講…自從有左電腦呢啲比較高科技嘅野，無論你係金融業做咩，例如計數或者買賣股票，都方便左好多。佢就拎呢個例子成日鼓勵我話，無論第時出黎做咩野都好，學好電腦，一定係一世

都有用。佢話自己而家年紀大啦，但係我就一定要學電腦，呢個係未來嘅世界最緊要嘅資源，所以好鼓勵我去學 IT。仲話上到大學，都要副修 IT，因為真係一個好緊要嘅資源。)

(School A, student 5)

D. PREDICTORS OF INTENTION TO STUDY BIOLOGY, CHEMISTRY/PHYSICS OR ICT

To test the first two hypotheses, regression analyses were conducted to determine which factors would be more predictive of students' intention to study biology, chemistry/physics and ICT subjects. The predictors consisted of each student's personal characteristics (age, type of school, banding of school and self-reported academic performance); subjective task values, self-efficacy, and perceived success in studying the subject; and her father's, mother's, close friends' and teachers' perceived attitudes toward girls' study of the subject. Table 8 summarizes the results of regression analyses on intention to study the three subjects.

Results showed that:

- Intention to study biology, chemistry/physics and ICT was positively correlated to the student's subjective task values, self-efficacy and perceived success in studying the subject.
- Intention to study biology, chemistry/physics and ICT was positively correlated to self-perceived close friends' attitudes toward the subject.
- Overall, the mother's perceived attitudes toward biology, chemistry/physics and ICT significantly influenced intention to study these subjects.
- Overall, the father's perceived attitude toward biology, chemistry/physics and ICT affected the intention to study these subjects.
- Entrenched gender stereotypes on the part of the girl or her parents or peers also significantly influenced intention to study STEM.

It is interesting to note the effect of type of school attended by the respondents. In particular, the type of school was found to have a significant effect on intention to study chemistry/physics and ICT before controlling for subjective task values, self-efficacy and expected success. However, the type of school was no longer found to be significant after accounting for the influences of other factors in the model, suggesting that individual attributes are more critical in predicting students' decision of educational choice.

Qualitative data also revealed similar findings. Female students who were interested in STEM reported higher subjective task values, self-efficacy and perceived success from studying the subjects.

For example, student 5 from school B enjoyed learning science and ICT and had a high subjective task value in science and ICT:

> I am very interested in science. I find it very interesting…I think that science, similar to ICT, is a form of power, knowledge to change people's life. It changes the world and the way people look at the world. This is what brings ICT and science together and makes it so interesting. There are a lot of unknowns in science, for example, the origin of human beings. There are a lot of things to be answered. This unknown knowledge fascinates me the most. (我自己對科學好有興趣、覺得好得意。…其實佢同 ICT 有少少類同嘅地方，都係想用一種力量、一種知識去改變人類嘅生活，即係去改變世界；同埋想去改變人類一直以黎對呢個世界嘅睇法，所以我覺得 ICT 同科學之間的共通點，亦係最得意嘅野，就係佢有好多未知嘅變數可以發生，例如科學仲有好多野未解答到，又例如人類起源係邊度，其實仲有好多野有待解答。我覺得最得意嘅就係呢啲人類仲未研究到嘅知識。)

At the same time, her previous learning experience gave her a high self-efficacy and expected success in learning science:

> I love Integrated Science (IS). I find it easy to grasp at the secondary school level because I studied in an English primary school and they taught us science starting from primary three. I have glanced through the IS textbook this year and those were the things I learnt in the first term of primary six. So I find it an easy subject for me and I enjoy studying it. (我覺得 IS 都幾得意，而且上到中學我覺得係比較容易掌握，因為我係讀英文小學，三年級開始已經學科學，而且我都睇過今年嘅 IS 書，其實係我小學六年班上學期教嘅野，而家係下學期先至有。所以我就覺得 IS 對我黎講算係比較容易掌握嘅一科，我覺得讀得幾開心啦。)

Table 8. Regression analyses on intention to study biology, chemistry/physics and ICT.

		Intention to Study Biology			Intention to Study Chemistry/Physics			Intention to Study ICT		
		B	SE	ΔR²	B	SE	ΔR²	B	SE	ΔR²
Block 1				.06*			.11*			.01
	Age	-.13	.10		-.01	.10		.06	.09	
	Type of school	.41	.21		.47*	.22		.39*	.19	
	Banding of school	.18	.22		-.20	.23		.12	.20	
	Academic performance	.49*	.08		.74*	.09		-.03	.08	
Block 2				.49*			.54*			.46*
	Subjective task values	.55*	.09		.65*	.08		.48*	.07	
	Self-efficacy	.26*	.08		.38*	.07		.37*	.06	
	Perceived success	.43*	.07		.27*	.06		.16*	.06	
Block 3				.06*			.04*			.06*
	Father perception	.01	.05		.01	.05		.21*	.05	
	Mother perception	.27*	.05		.24*	.05		.06	.06	
	Close friends' perception	.17*	.05		.10*	.05		.15*	.05	
	Teacher perception	.01	.05		.06	.05		-.02	.05	
	Gender stereotypes	.01	.02		.02	.02		.05*	.03	

Note. B denotes unstandardized coefficient. SE denotes standard error. Δ R^2 denotes R square change. Type of school was coded as 1 = co-ed schools and 2 = girls' schools. Higher scores of gender stereotypes represent more favourable attitudes toward girls' study of the subject. * denotes the factor could significantly predict the intention to study the subject.

E. Relationship between gender role stereotypes and major factors related to STEM:

To test Hypothesis 3 about the relationships between gender role stereotypes and other factors related to the study of STEM, correlation analyses were performed. Results showed that:

- If the student held more stereotypical beliefs about gender roles, she tended to have significantly lower subjective task values (biology: r = -.15; chemistry/physics: r = -.17; ICT: r = -.21), self-efficacy (biology: r = -.11; chemistry/physics: r = -.15; ICT: r = -.14), and expected success in the three subjects (biology: r = -.15; chemistry/physics: r = -.17; ICT: r = -.16).
- If the student held more stereotypical beliefs about gender roles, she had significantly lower intention to study chemistry/physics (r = -.10) and ICT (r = -.08) and marginally lower intention to study biology (r = -.07, p = .058) than her peers with less stereotypical beliefs.
    - The above-mentioned negative relationships between gender role stereotypes and major constructs of the EVM are observed in students at both girls' and co-ed schools but the strength of the negative association was stronger in co-ed schools than in girls' schools.

These findings largely support the prediction in H3 that gender role stereotypes are negatively correlated with subjective task values, self-efficacy, expected success in and intention to study STEM.

Some girls we interviewed demonstrated gender stereotypical beliefs that women and girls do not belong in the STEM fields, especially engineering, and therefore were not motivated in pursuing further study in these areas:

> (Student 4, school A)
> (Are you interested in science? Do you want to work in science?) Yes…I'd like to be a doctor…It is also related to science. If there is a possibility [for me to study medicine], then I may be a doctor. But for sure girls can't be engineers.((對 Science 有冇覺得可以

做到任何野？ 或者你想唔想向 Sciences 個邊發展？)都會想。…醫生啦…都係 Sciences 個邊，不過女仔唔會做工程師。)

F. Effect of previous learning experiences on intention to study STEM:

To test H4 about the indirect effect of previous learning experiences (past performance and affective reactions) on the intention to study the three STEM subjects, mediation analyses were conducted. Figure 1 illustrates the proposed indirect effect of previous learning experiences on intention via subjective task values and self-efficacy. Consistent with our predictions, when the student had better past performance in and affective reactions to biology, chemistry/physics and ICT, they were more likely to report higher levels of subjective task values and self-efficacy, which subsequently increased their intention to study these three subjects. The same pattern of indirect effect of previous learning experiences on intention to study STEM is observed in students at both girls' and co-ed schools.

Interviews with students replicated the above findings. Students who had good grades in STEM subjects tended to like studying the subjects they were good at:

> My maths results are below average. I got low grades. It's because I don't like maths…My foundation in maths is not good. Also, maths is taught in English so it is even more boring. (我數學都唔過 Average，係好低分。…因為唔鍾意計數。…本身數學底子唔好，仲要用英文教，而家就更加無興趣。)
>
> (School B, student 6)

> (What do you like about Integrated Science?) Experiments…Using the microscope to make things larger…Looking at the structure of an onion. [She got a very good score in Integrated Science: 44 out of 50.] For maths, I like it but it is too difficult…I don't like maths…too difficult…I just got a pass grade. ((你鍾意做啲咩 IS 野？) 鍾意實驗之類。…

用顯微鏡放大啲野…睇洋蔥結構。我 IS 成績係 44/50...數學，係鍾意嘅但佢難囉。…抗拒數學 …太難 …啱啱好合格左右啦 。)

(Student 2, school C)

Figure 1. The relationship among previous experiences, subjective task values, self-efficacy and intention to study biology.

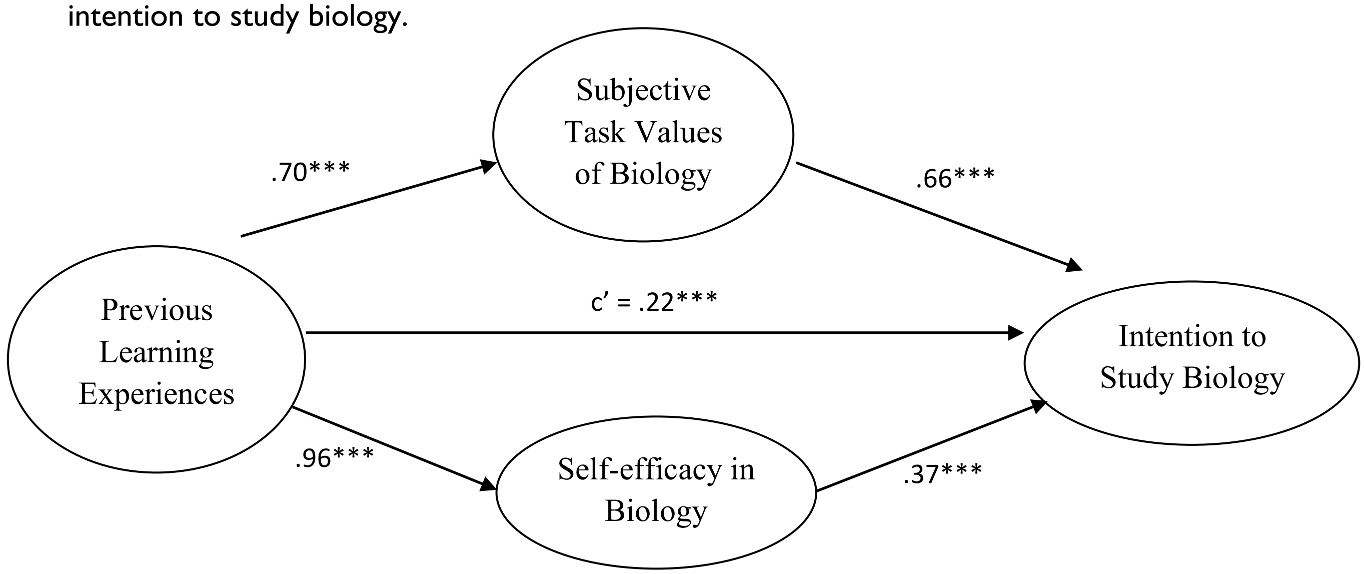


Figure 2. The relationship among previous experiences, subjective task values, self-efficacy and intention to study chemistry and physics.

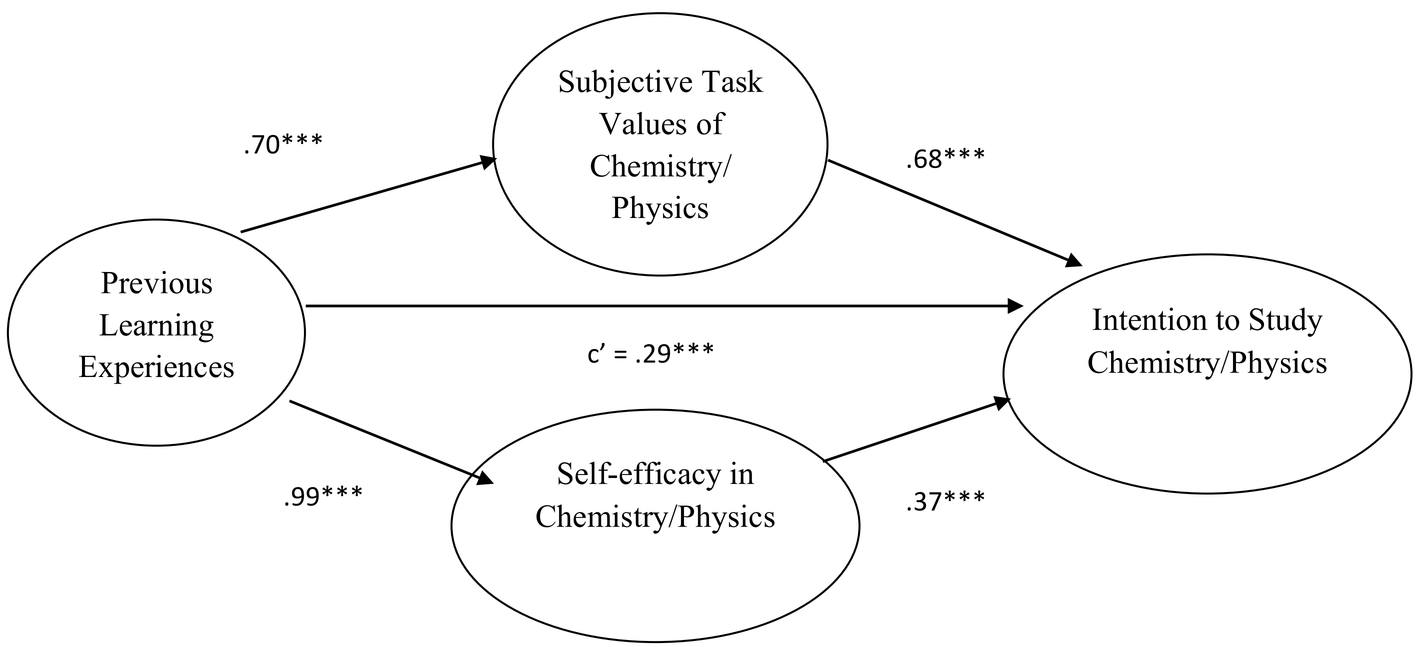
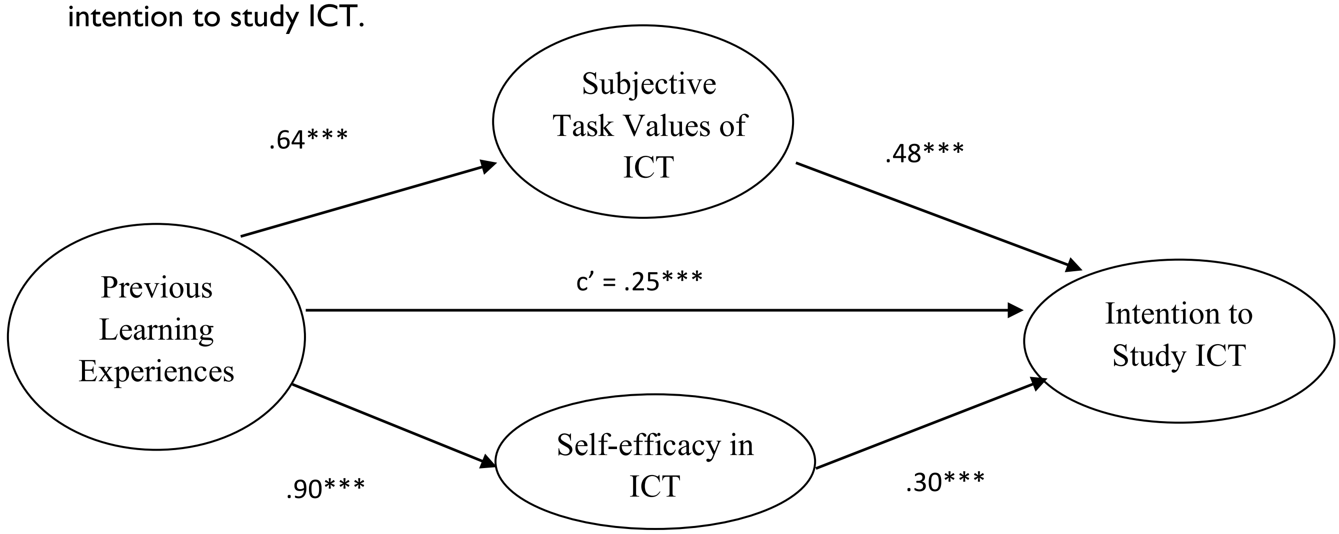


Figure 3. The relationship among previous experiences, subjective task values, self-efficacy and intention to study ICT.



TEACHER ASSESSMENT

Table 9. Background characteristics of teacher participants

	Percent
Age	
21-30 years	22.5
31-40 years	33.1
41-50 years	30.3
51-60 years	14.1
Gender of participants	
Female	54.2
Male	45.8
Education	
Secondary education	4.1
Diploma or non-degree	1.4
Bachelor's degree	42.8
Master's degree or above	51.7
Years of teaching	
1-5 years	19.9
6-10 years	27.6
11-15 years	13.5
16-20 years	19.1
21 years and above	19.9
Subjects taught	
STEM teachers (n = 86)	
Female teachers	47.7
Male teachers	52.3

Class teachers (n = 58)	
Female teachers	63.8
Male teachers	36.2
Type of school	
Girls' schools (n = 55)	
% of female teacher participants	67.3
% of male teacher participants	32.7
Co-educational schools (n = 89)	
% of female teacher participants	46.1
% of male teacher participants	53.9

Teachers' responses did not vary much by their demographic characteristics except that female teachers paid more attention to students' interest in science (M = 4.27, SD = .89) and technology (M = 4.16, SD = .72) than male teachers (M = 3.80, SD = 1.12 and M = 3.81, SD = 1.11, respectively).

Both STEM and class teachers were asked to report their gender stereotypes about science and technology and attention to female students' interest and capability in science and technology. STEM teachers were also asked to rate their self-perception of girls' ability in STEM and whether the content of their STEM instruction – namely whether their STEM teaching emphasised interaction and feedback, whether they paid attention to different experiences of girls and boys, and whether they supported cooperative learning. Table 10 summarizes the mean score and SD of these constructs by type of school. In particular,

- Significant group differences were shown in relation to female students' interest and capability in science {t(144) = 3.18, p = .002} and technology {t(143) = 3.48, p = .001}, with teachers at girls' schools paying greater attention to this than teachers at co-ed schools.

- Teachers at girls' schools scored higher in content of STEM instruction than teachers at co-ed schools {$t(86) = 3.59$, $p = .001$}, revealing that teachers at girls' schools put more efforts in their teaching to increase female students' interest and capability to study STEM subjects.
- No difference was found in the extent of gender stereotypes about science and technology, gender role stereotypes and self-perception of girls' ability in STEM between teachers at girls' schools and teachers at co-ed schools.
- The learning environment and method of learning were only assessed for STEM teachers at co-ed schools. The mean score of this construct was 4.54 ($SD = .72$), implying that teachers at co-ed schools showed a moderate level of creating a gender-egalitarian learning environment in their classes.

Table 10. Descriptive statistics of the teacher assessment by type of school.

	Co-ed Schools	Girls' Schools	Total
Gender stereotypes in science [1]	4.11 (1.22)	4.07 (1.18)	4.10 (1.20)
Gender stereotypes in technology [1]	3.86 (1.15)	3.89 (1.23)	3.87 (1.18)
Gender role stereotypes	3.57 (.48)	3.44 (.46)	3.52 (.48)
Attention to students' interest and capability in science	3.86 (.94)	4.39 [a] (1.07)	4.06 (1.02)
Attention to students' interest and capability in technology	3.80 (.96)	4.33 [a] (.95)	4.00 (.93)
Self-concept of girls' ability in STEM [2]	4.46 (.46)	4.49 (.47)	4.48 (.46)
Content of STEM instruction [2]	4.78 (.62)	5.25 [a] (5.59)	4.98 (.64)
Atmosphere and method of learning [3]	4.54 (.72)	--	4.54 (.72)

Note. [1] Scores of gender stereotypes range from 1 to 11, with higher scores representing more favourable attitudes toward girls' study of STEM. [2] Items were only completed by STEM teachers at both co-ed and girls' schools (n = 88). [3] Items were only completed by STEM teachers of co-ed schools (n = 51). [a] denotes the scores of teachers at girls' schools are significantly higher than that of teachers at co-ed schools.

STEM teachers' rating of factors that could contribute to improving students' learning in STEM showed different perceived importance of the three factors, namely professional support from stakeholders (e.g., government, experts, fellow teachers, school management and parents), equipment and resources (e.g., classroom facilities, science-subject equipment and facilities, computers and software, and textbooks and guidelines), and teaching arrangements (e.g., class duration, teaching load, number of students and assessment methods). STEM teachers rated equipment and resources ($M = 5.67$, $SD = .62$) as the most important factor, followed by teaching arrangements ($M = 5.39$, $SD = .63$), with professional support from stakeholders to be of least importance ($M = 4.79$, $SD = .68$) in their teaching of STEM (all $ps < .05$). The results were similar across girls' and co-ed schools and across male and female teachers.

INTEGRATION OF STUDENT AND TEACHER DATA

To test H5 whether the student's intention to study STEM subjects would be affected by the school environment, bivariate correlation analyses were first performed. In general,

- In the schools where the teachers held more positive self-concept about girls' study of STEM, their students showed greater intention to study chemistry/physics ($r = .10$, $p = .004$) and ICT ($r = .09$, $p = .008$).
- Teachers' attention to students' interest and capability in science and technology was also positively correlated with their students' intention to study biology ($r = .09$, $p = .013$), chemistry/physics ($r = .07$, $p = .049$), and ICT ($r = .10$, $p = .004$) respectively.
- In schools where the STEM teachers provided a supportive environment for STEM instruction and method of learning, the students exhibited greater intention to study chemistry/physics ($r = .11$, $p = .003$; and $r = .08$, $p = .026$, respectively) and ICT ($r = .12$, $p = .001$; and $r = .10$, $p = .005$, respectively).
- STEM teachers at girls' school (regardless of their gender) were more likely to pay attention to girls' interest and capability in science and technology ($M = 4.39$, $SD = 1.07$, and $M = 4.33$, $SD = .95$) than teachers at co-ed schools ($M = 3.86$, $SD = .94$, and $M = 3.80$, $SD = .86$)

Multilevel analyses were also conducted to test whether the above-mentioned effects of teacher responses would remain significant even after controlling for students' subjective task values, self-efficacy, expected success in, perception of others' attitudes and previous academic and affective experiences. Except for biology, intention to study chemistry/physics and ICT was not significantly predicted by the teachers' responses.

Table 11 presents the results of the multilevel analysis on intention to study biology. In addition to the influences of subjective task values, self-efficacy and expected success in biology, as well as mother and close friends' perceptions toward biology, the student's intention to study biology was also predicted by teachers' paying more attention to students' interest and capability in science and their positive attitudes toward girls' study of STEM subjects. However, teachers' self-concept of girls' ability in STEM, the content of their STEM instruction, and learning environment and method of learning were not predictive of the student's intention to study the three subjects, implying that the influences of teachers' beliefs and teaching method were minimal relative to the student's individual attributes.

Table 11. Multilevel analyses on intention to study biology

	Coefficient	SE
Level 1: Student responses		
Subjective task values	.42***	.08
Self-efficacy	.15*	.08
Expected success	.30***	.07
Father perception	.03	.05
Mother perception	.27***	.05
Close friends perception	.18***	.05
Past performance	.01	.05
Affective reactions	.06	.06
Student's gender stereotypes[1]	.02	.02
Level 2: School level - Aggregated teacher responses [2]		
Type of school	-.32	.26
Teacher's gender stereotypes [1]	.34*	.16
Attention to students' interest and capability in science	.49**	.18
Self-concept of girls' ability in STEM	-.01	.45
Content of STEM instruction	-.27	.37
Atmosphere and method of learning	-.29	.22

Note. SE denotes standard error. Type of school was coded as 1 = co-ed schools and 2 = girls' schools. [1] Scores of gender stereotypes range from 1 to 11, with higher scores representing more favourable attitude toward girls' study of STEM. [2] Teachers responses at each school were aggregated to represent the school's STEM learning environment. * p <.05; **p<.01; ***p<.001.

Table 12. Students' Responses to Perceived Parents', Teachers' and Close Friends' Attitudes toward and Gender Stereotypes about Science and Technology Domains

	Science subject (%)			Technology subject (%)		
	Unlikely	Neutral	Likely	Unlikely	Neutral	Likely
Father's attitudes	37.7	26.4	35.9	51.3	26.8	21.9
Mother's attitudes	32.7	24.7	42.6	48.4	28.4	23.2
Subject-teacher's attitudes	39.7	30.4	30.0	50.1	28.6	21.3
Close friends' attitudes	39.5	26.3	34.2	54.0	26.8	19.2

	Science subject (%)			Technology subject (%)		
	Males are more talented	Neutral	Females are more talented	Males are more talented	Neutral	Females are more talented
Parents' gender stereotypes	36.8	53.6	9.6	43.1	50.9	6.1
Subject-teacher's gender stereotypes	24.0	67.8	8.2	26.0	68.2	5.8
Close friends' gender stereotypes	28.2	60.2	11.6	32.7	59.4	7.9

By grouping participants' scores into unlikely (scores 1 to 3), neutral (4), and likely (scores 5-7), Table 12 presents the distribution of perceived father's, mother's, subject-teachers' and close friends' attitudes toward female students' study of science and technology subjects and gender stereotypes. A greater proportion of female students perceived their father, subject-teachers and close friends as being not supportive of their study of science and technology subjects than holding neutral and supportive attitudes, with students at girls-schools having even more pronounced perceptions of this lack of support. The phenomenon is more prominent for technology-related subjects. Female students also perceived their parents, subject-teachers and close friends as having stereotypical beliefs toward girls' study of science and technology subjects.

DISCUSSION AND RECOMMENDATIONS

EXPECTANCY VALUE MODEL SUPPORTED IN UNDERSTANDING STEM EDUCATION

This project aimed to identify factors influencing Form 3 female students' intention to study STEM subjects (mainly biology, chemistry/physics and ICT). The current research findings support the Expectancy Value Model's (Eccles, 2011) emphasis of the four core components in educational choice, namely, subjective task values, self-efficacy, expectation of success and cultural norms. To the best of our knowledge, this is the first local study to apply the EVM to educational choice of STEM subjects. The hierarchical regression analyses reveal that in addition to the first three factors (i.e., subjective task values, self-efficacy, expectation of success), cultural norms (especially mother and close friends' perception) also play a role in affecting adolescent girls' educational choice. Our findings are consistent with those in other developed countries. For example, Modi, Schoenerg, and Salmond (2012) found that high school girls with good academic achievement in the past, high confidence in STEM abilities, and encouragement from parents and teachers were more likely to pursue STEM subjects. Rosenthal, London, Levy, and Lobel (2011) found that perceived social support among female college students in single-sex STEM programmes can maintain their motivation to pursue their studies in a gender-atypical field.

The mediation and correlation analyses further demonstrate that positive past academic and affective experiences in the subject increase one's subjective task values, self-efficacy and expected success in studying the subject. This is consistent with the findings of Sadler, Sonnert, Hazari, and Tai (2012) which reported that US female high school students with good grades in mathematics are more likely to choose to pursue STEM subjects after high school.

ALL-GIRLS SCHOOLS ARE MORE SUPPORTIVE TO STEM

The study compared responses between students at co-ed and girls' schools. Results of the student assessment reveal that students at girls' schools in general exhibited significantly greater intention to study biology, chemistry/physics and ICT than students at co-ed schools, which was largely attributed to their higher levels of subjective task values, self-efficacy and expected success from studying these subjects. In addition, parents and close friends' perceived attitudes toward STEM subjects also strongly influence girls' intention to pursue STEM-related subjects/careers. To understand the effect of the school environment, the study canvassed the views of STEM and Form 3 class teachers and assessed their attitudes toward girls' study of STEM subjects. Data gathered from STEM and class teachers show that teachers at girls' schools paid greater attention to students' interest and capability in science and technology than their counterparts at co-ed schools, which overall positively influenced students' intention to study STEM subjects. Teachers' awareness of students' interest in science and teachers' positive attitudes toward girls' study of STEM subjects can also increase their students' intention to study STEM subjects.

GENDER STEREOTYPICAL BELIEFS HARM GIRLS' STEM LEARNING

The study found that gender stereotypical beliefs on the part of both students and teachers significantly impact girls' intention to study STEM subjects overall. This is consistent with past findings that gender stereotypical beliefs can undermine girls' interest and performance in STEM subjects (e.g., Shapiro & Williams, 2011). An exclusion of women from the STEM fields is not only harming women but is also a loss to the society (Milgram, 2011). At the same time, having more women in the STEM fields means more role models for young girls in their intellectual pursuits (Milgram, 2011). As female students' interest and career choice in STEM are rooted in their early experiences and attitudes towards STEM (Sadler, Sonnert, Hazari & Tai, 2012), it is crucial to remove gender barriers for girls who are interested in and show talent in STEM at the high school stage. Past research showed that men and boys receive more favorable treatment in class and in mentoring relationships than women and girls when it comes to science-related domain (Sadker & Sadker, 1994). Teachers have to be aware of their students' and their own gender stereotypical beliefs and find a way to address these stereotypical beliefs in their STEM teaching. Modi, Schoenerg, and Salmond (2012) found that some girls are motivated to challenge gender stereotypes in STEM. This indicates that building girls' confidence in their STEM ability and understanding the existence of gender stereotypes can greatly facilitate girls' pursuit of STEM subjects and careers.

RECOMMENDATIONS

From the above findings, we have the following recommendations:

1. Schools, teachers and parents need to help girls understand the importance of STEM knowledge for the future development of society and to students' future careers. Schools can invite scientists and researchers to share examples of recent innovations, and the application of advanced technology to everyday life. In addition, it is important to explain to students the implications of having a gender balance in the STEM fields and that women and men are equally capable when it comes to STEM. Other studies suggest that including more female role models, especially those who do not conform to the stereotypical image of STEM professionals, in STEM learning materials and providing girls with the opportunity to interact with successful female role models in STEM in socially meaningful tasks and activities can enhance female students' beliefs that they can also be successful in STEM careers (Sáinz, Pálmen, & García-Cuesta, 2012; Zhu, 2007).

2. To improve students' self-efficacy and expectations for success in STEM, teachers should consider adopting more of a problem-based learning approach and include more team projects related to STEM. A problem-based learning strategy has been found to improve students' STEM knowledge and interest (Lou, Shih, Diez, & Tseng, 2011). The completion of the project and the production of some tangible output can help build a sense of achievement among students and a more positive learning environment for STEM within the school.

3. As previous academic and affective experiences are important in female students' future STEM endeavors, schools and teachers should encourage collaborative learning and less direct competition in the teaching and learning of STEM.

4. Teachers need to be aware of gender stereotypes held by society, students and themselves. They need to be able and willing to openly discuss these gender barriers with students, and find ways to help students who are interested in STEM to build their confidence to challenge these barriers. Access to female role models can help combat negative stereotypes (Marx & Roman, 2002; Stout et al., 2011). Teachers should avoid using stereotypical STEM role models as these have been found to undermine women's beliefs about their ability in STEM (Cheryan, Siy, Vichayapai, Drury, & Kim, 2011).

5. Gender advocacy programs should be organized for students, parents and teachers to help establish positive attitudes and support for girls' pursuit of STEM subjects and careers.

6. From the responses of STEM teachers in evaluating factors that can contribute to improving students' interest and learning of STEM, we recommend that school management and the Education Bureau should regularly review the availability and conditions of facilities for teaching STEM including laboratories, computer hardware and software and textbooks. Sufficient funding should be provided to schools to update these facilitates and resources. In addition, schools and the Education Bureau should review the existing teaching arrangements of STEM so as to come up with appropriate class duration, teachers' workload, amount of content to be taught and number of students in each class to facilitate the optimal learning of STEM for students. More flexible teaching arrangements and assessments should be encouraged so that STEM teachers can have the freedom to adjust their teaching and assessment to suit the needs of their students.

7. The Education Bureau and policy-makers should be aware of the gender imbalance and prevalence of gender stereotypical beliefs in STEM learning and career development. They should increase their efforts to incorporate a gender perspective in their policies to encourage STEM education. In addition, they should inform and provide resources to schools and teachers so that they can implement initiatives to address the current gender imbalance in STEM.

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