Wang et al.
International Journal of STEM Education (2023) 10:59
https://doi.org/10.1186/s40594-023-00443-6

International Journal of STEM Education

RESEARCH Open Access

Gender differences in high school students' interest in STEM careers: a multi-group comparison based on structural equation model

Ning Wang[1], Aik-Ling Tan[2*], Xiaohong Zhou[3], Ke Liu[3], Feng Zeng[4] and Jiong Xiang[5]

Abstract

Background Females are underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields all over the world. To encourage more girls to choose STEM majors and careers, it is critical to increase their interest in STEM careers. Many studies have investigated the factors that influence females' entry into STEM fields, but few studies have explored the gender differences in the relationships between these factors. Therefore, based on the Social Cognitive Career Theory, this study explored the gender differences in the effects of environmental factors (school education, informal education, social support, and media) on high school students' interest in STEM careers through the mediating roles of STEM self-efficacy and STEM careers perceptions.

Results A questionnaire survey was conducted among 1240 high school students in Hunan Province, China, and the results of *t*-test, regression analysis, and structural equation model multi-group comparison showed that: Firstly, the scores of male students in all the dimensions except for STEM career perception were significantly higher than those of female students. Secondly, the environmental factor that had the greatest effect on male and female students' interest in STEM careers was different. Finally, there were gender differences in the mediating roles of STEM self-efficacy and STEM careers perceptions between environmental factors and interest in STEM careers.

Conclusions This study revealed the influence mechanisms and gender differences in male and female students' interest in STEM careers in the context of Chinese Confucian culture, and the conclusions are as follows: (1) Male students' interest in STEM careers was significantly higher than that of female students; (2) The environmental factors that had the greatest effect on male and female students' interest in STEM careers were social support and media, respectively; and (3) Environmental factors could affect male students' interest in STEM careers through the mediating roles of STEM self-efficacy and STEM career perception, while environmental factors could affect female students' interest in STEM careers through the mediating role of STEM self-efficacy. Finally, the mediating mechanisms of STEM self-efficacy and STEM career perception between environmental factors and interest in STEM careers, and the importance of STEM self-efficacy for female students were discussed.

Keywords Gender differences, Interest in STEM careers, Mediating role, Social cognitive career theory, Structural equation model

*Correspondence:
Aik-Ling Tan
aikling.tan@nie.edu.sg
Full list of author information is available at the end of the article

© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Introduction

With the advent of the fourth industrial revolution, STEM workers are more important than ever in supporting national economic development and improving the quality of human life. Many countries have enacted relevant policies to promote STEM education and re-skill workers to make them relevant for STEM related industries. Despite changes in policies to support STEM industries and workers, one issue of equity and equality persists—the problem of underrepresentation of women in STEM fields remains widespread. Female students account for only 35% of the total number of students in STEM-related fields in higher education all over the world (UNESCO, 2017). The attrition rate of females is particularly high during their studies, job search, and even in their careers, which results in a serious underrepresentation of women in STEM fields. For example, only 11% of positions in STEM fields in the UK are held by women (Kirsten, 2019). Women with a bachelor's degree or higher make up 44.2% of the STEM workforce, while women without a bachelor's degree make up 25.8% in the US (National Science Board, 2022). The China Science and Technology Statistical Yearbook 2021 shows that women account for only 26.27% of research and development personnel and 5.79% of the total number of academicians of the Chinese Academy of Sciences and Engineering in China (China Bureau of Statistics, 2022).

Education equity and gender equality are not only important components of the United Nations 2030 Agenda for Sustainable Development (United Nations, 2015), but also catalysts for achieving other sustainable development goals. Ensuring equal access for females to STEM education and increasing their representation in STEM fields are imperative. From a human rights perspective, all people are equal, and females should also have equal opportunities to study and work in STEM fields. From a scientific development perspective, the inclusion of females can unlock greater development potential from diverse perspectives and reduce bias in knowledge and solutions. From a long-term societal perspective, gender equality in STEM will ensure that males and females have equal access to skills and opportunities to contribute and benefit equally in STEM.

Interest in STEM careers could possibly predict whether a student will pursue a STEM career in the future (Bahar & Adiguzel, 2016; Miller, et al., 2018; Nugent et al., 2015). To encourage more girls to choose STEM majors and careers, it is critical to increase their interest in STEM careers. Studies have shown that the high school level is a critical period for the development of interest in STEM careers (Lindahl, 2007; Maltese & Tai, 2011; Sadler et al., 2012). Therefore, analyzing gender differences and exploring the key influencing factors in high school students' interest in STEM careers are particularly important in bridging the gender gap in STEM fields.

Literature review

Gender differences in STEM are a long-standing and pervasive problem. The proportion of females in STEM fields in higher education, especially in computing and engineering, remains low (Sax et al., 2017; Shi, 2018). Males are more likely to work in natural sciences such as physics, while females are more likely to work in humanities and social sciences such as education and health care (Kang et al., 2018; Su & Rounds, 2015). Females of all racial/ethnic backgrounds are less likely than males to find a future career in math (Howard et al., 2011). Young women may underestimate their abilities in math-related fields because of the general perception that these fields are male-dominated (Riegle-Crumb & Peng, 2021). According to the survey of Shi and Huang (2018), 20.5% of boys want to pursue science-related careers in the future compared with only 6.3% for girls. Numerous factors intersect and together influence female participation in STEM fields. Referring to the relevant report released by UNESCO (2017), this study reviewed these influencing factors at the individual, family, school, and societal levels.

Influencing factors at individual level

At the individual level, stereotypes, belonging, self-efficacy, and interest, are possible factors that influence whether girls enter STEM fields. Firstly, gender stereotypes about STEM are prevalent in the socialization of children's gender roles, and these biases negatively affect girls' STEM learning and career interest at an early age (Bian et al., 2017; Luo et al., 2021; Sadler et al., 2012). Females are less likely to have a sense of identity and belonging in STEM fields compared to males (Dasgupta & Stout, 2014; Smith et al., 2013). Secondly, self-efficacy significantly affects individuals' academic performance in STEM fields and their interest in related careers (Lv et al., 2022; Mohtar et al., 2019; Nugent et al., 2015; Wang et al., 2020). The PISA2015 results show that boys have significantly higher self-efficacy than girls in mathematics and science (OECD, 2015), and those females with strong gender stereotypes have significantly lower self-efficacy than males (Rabenberg, 2013). Finally, girls' choices of STEM majors and careers are strongly influenced by their interest in STEM careers (Su et al., 2009), and individual interest in STEM careers is directly influenced by self-efficacy and perceptions of STEM careers, and indirectly by environmental factors such as parents, peers, schools, and media (Wang & Duan, 2021).

Influencing factors at family and peer level

At the family and peer levels, family members such as parents and peers significantly influence girls' self-efficacy, interest in STEM, and whether they pursue STEM-related careers in the future. First, parents who hold traditional gender perceptions will constantly regulate their children's behavior to conform to popular gender stereotypes (Bandura & Bussey, 2004). Parents' differentiated treatment and support for boys and girls will lead to children's stereotypical perceptions of gender and STEM ability, which further lead girls to stay away from STEM fields (Wang & Degol, 2013). Second, in families with higher socioeconomic status, parents can break the shackles of traditional notions of gender roles and career choices, are able to provide more academic support for their children and they also have higher academic expectations for their children (Tenenbaum & Leaper, 2003). In comparison, families with lower socioeconomic status may not be able to provide opportunities for children to learn and experience STEM due to lack of funds, time or access. Studies have found that parents who engage in STEM careers will have an influence over their daughters' decisions to enter the STEM field, because these parents have more access and resources to provide more support to familiarize their daughters with STEM careers and to break the traditional concept that STEM careers and family life cannot be balanced (Tan et al., 2013). In addition, peers are important social relationships for adolescent girls, and whether girls choose STEM fields is also affected by peers' perceptions of STEM subjects and careers to some extent (Robnett, 2013).

Influencing factors at school level

At the school level, teachers, teaching strategies, curriculum, and textbooks can also influence girls' interest and achievement in STEM. First, teachers are important socializing agents who promote positive beliefs towards STEM fields, and their quality is positively associated with both student math and science achievement and motivation (Ekmekci & Serrano, 2022; Lee & Lee, 2020). Female teachers not only serve as role models for girls, but also break the stereotypes that males have innate abilities in certain areas, coupled with the fact that female teachers are more nuanced than male teachers and more concerned about gender equity in classroom instruction (Rabenberg, 2013). Therefore, female teachers can have a positive impact on girls' STEM education. Teachers' beliefs and attitudes, as well as their expectations of students (i.e., pygmalion effects; LaCosse et al., 2021; Rosenthal & Jacobson, 1968; Vedder-Weiss & Fortus, 2013), can profoundly affect girls' academic performance, interest in learning, and career aspirations in STEM subjects. Teachers' biases about gender competence may lead to gender inequality in the classroom and may also cause these gender stereotypes to be transmitted to students through instruction, reducing girls' self-efficacy in STEM fields and ultimately negatively impacting girls' participation in STEM. In addition, effective science and mathematics teaching strategies can create a favorable learning environment that motivate and attract girls into STEM fields (Hampden-Thompson & Bennett, 2013; Kang & Keinonen, 2017). Finally, the way male and female roles are represented in textbooks can also directly or indirectly convey gender differences in STEM competencies to students, further reinforcing gender stereotypes and discouraging girls from pursuing STEM careers (Benavot, 2016).

Influencing factors at informal learning level

Compared with formal learning, informal learning refers to learning activities that take place outside of the classroom and in other informal settings, such as participation in STEM competitions and camps, and visits to science and technology museums and galleries (Eshach, 2007). Some studies have shown that informal learning experiences could increase students' interest in STEM careers (Kitchen et al., 2018; Burack et al., 2019; Miller et al., 2018) and also increase students' STEM self-efficacy and STEM careers perceptions (Halim et al., 2017; Vela et al., 2020). Students who participate in STEM programs or competitions have higher interest in STEM careers than those who do not, and they are more likely to choose STEM-related courses and majors in college (Burack et al., 2019; Miller et al., 2018). Students who participate in summer STEM programs are 1.4 times more likely to pursue STEM careers in the future (Kitchen et al., 2018). There is little research on gender differences in the impact of informal learning experiences on boys' and girls' interest in STEM careers. Research has shown that informal activities where female students interact with female STEM experts not only improve girls' academic performance in STEM and mitigate gender stereotypes, but also increase their interest in STEM (McGuire et al., 2021). However, compared with girls, boys are given more opportunities for informal activities (Bonnette et al., 2019) and receive more explanations from their parents during informal scientific activities (Crowley et al., 2001). The reason for girls' lower interest in STEM is usually because they do not have equal access to STEM-related activities at home and in other settings (Sammet & Kekelis, 2016).

Influencing factors at societal level

At the societal level, sociocultural norms influence girls' perceptions of self-efficacy, social roles, and aspirations for career and life. STEM fields are often considered a "chilly climate" for female development (Seymour & Hewitt, 1997) and the reasons are as follows: Firstly, men play a dominant role in these fields, which is detrimental to women's development. Secondly, women are often perceived to be less competent than men in STEM fields. Furthermore, the society has different role expectations for men and women, and almost every country's sociocultural traditions assume that women's family responsibilities should take precedence over their social responsibilities (Wang & Degol, 2017). Some studies have suggested that the absence of females in STEM fields is caused by sociocultural factors rather than biological factors (Yang & Shen, 2020). Gender stereotypes portrayed in the media are easily internalized by both children and adults, which will affect the way they view themselves and others. Media has an important influence on adolescents' perceptions of scientists, shaping the image of scientists. Similarly, media also promotes students' understanding of STEM careers, which in turn affects students' expectations for STEM careers (Tan et al., 2015). Girls' perceptions of self-competence and interest in STEM careers are strongly influenced by gender stereotypes in the media, especially the image of STEM professionals portrayed by the media has a great impact on adolescent girls, because they are in a critical period of career identity and choice (Steinke, 2017). In addition, Wyss et al. (2012) studies have shown that watching videos of STEM professionals could improve students' interest in STEM careers and promote students' STEM careers perceptions.

Gender differences in interest in STEM careers in Chinese culture

Due to the long-standing influence of Confucianism, traditional Chinese gender norms assume that men should dominate outside matters and women are more responsible for taking care of the family and completing household chores (Jia & Ma, 2015; Liu, 2014; Yi et al., 2010). There are significant gender differences in STEM fields in China. In universities, although the number of female university students in China is slightly higher than that of male students (Ma et al., 2016), learners in STEM majors are mainly composed of male students, accounting for more than 80%, while learners in social science-related majors are mainly composed of female students, and the number of females in these majors is approximately twice that of males. In primary, middle, and high schools, there are also gender differences in interest in STEM careers between boys and girls. For example, the proportion of boys and girls who want to pursue STEM-related careers in the future is 20.5% and 6.3%, respectively (Shi & Huang, 2018). In a study conducted on 7th grade students in Zhejiang Province, the percentages of boys and girls who would like or very much like to be a scientist in the future were 43.3% and 19.6%, respectively, and boys had significantly higher science self-efficacy and participation in extracurricular science activities than girls (Zhai & Zhu, 2015). Influenced by Confucianism, most parents believe that girls should be good wives and mothers (Jia & Ma, 2015), and having stable jobs that can take care of the family are the best choice for girls, such as being teachers and doctors (He et al., 2020). Confucian culture emphasizes respecting teachers and valuing teaching, so students are mostly passive receivers of knowledge in the classroom. In addition, under the influence of pressure such as from examinations, teachers pay more attention to teaching academic knowledge and neglect the development of students' attitudes, interests, and career planning (He et al., 2020). Research has shown that current science curricula and teaching in China have not improved students' attitudes towards STEM (Zhou et al., 2019).

Overall, although many studies have explored gender differences and their influencing factors in STEM fields, most of them are limited to western cultural contexts. In addition, few studies have simultaneously explored the structural relationships between various environmental factors, individual psychological factors and interest STEM careers among different gender groups, especially in the context of Chinese Confucian culture. Therefore, this study used a structural equation model (SEM) multi-group comparison approach to explore the influence mechanisms and gender differences in Chinese culture that affect interest in STEM careers, which can provide guidance for us to design gender-responsive interventions and learning experiences in the future. This work has important implications for addressing the underrepresentation of women in STEM fields not only in China, but also internationally, as there are significant similarities in the global education issues.

Theoretical framework and research questions

This study is guided by the Social Cognitive Career Theory (SCCT) that was developed by Lent et al. (1994). The SCCT is designed under the influence of Bandura's social cognitive theory. The theory integrates external influences such as social and economic factors and individual cognitive factors (e.g., self-efficacy, outcome expectations, and career goals) to dynamically reveal the process of career choice, and has become one of the most explanatory theories for career choice and has been widely used in STEM career-related research (Bahar & Adiguzel, 2016; Kang & Keinonen, 2017; Kier et al., 2014; Maiorca et al., 2021; Mohtar et al., 2019; Nugent et al., 2015; Wang et al., 2021).

According to SCCT, external environmental factors can further influence career choices by affecting individuals' self-efficacy and outcome expectation. In addition, outcome expectation could also be affected by self-efficacy (Lent et al., 1994). For example, when an individual believes that he/she has the ability to complete an activity, he/she will have positive expectations for the outcome of the activity, which will make him/her interested in the activity. As outcome expectation refers to an individual's perceptions of what would happen if he or she engaged in a certain career, it is often replaced by career perceptions (Mohtar et al., 2019; Wang et al., 2021). As such, self-efficacy and career perceptions play key mediating roles in the formation of career interest and are the basis for the development of career interest (Wang et al., 2021). Environmental factors refer to the physical and social conditions in which individuals live and guide their lives. Due to the intricacies of environmental factors, this study classified the environmental factors (EF) that influence high school students' interest in STEM careers (ISC) into four aspects: school education, informal education, social support, and media, according to the division of environmental factors in a relevant study (Mohtar et al., 2019). Related studies have shown that school education, informal education, social support, and media can affect students' STEM self-efficacy (SSE) or students' STEM careers perceptions (SCP), which in turn affects their interest in STEM career (Kang & Keinonen, 2017; Mohtar et al., 2019; Nugent et al., 2015; Tan et al., 2015; Wang et al., 2021).

Overall, based on SCCT, this study explored the gender differences in the effects of the environmental factors (formal learning experiences, informal learning experiences, social support, and media) on high school students' interest in STEM careers through the mediating roles of STEM self-efficacy and STEM careers perceptions. The constructed theoretical framework of high school students' interest in STEM careers is shown in Fig. 1. The three research questions (RQ) that guided this study are as follows:

RQ1 Are there differences in interest in STEM careers between male and female students?

RQ2 Which environmental factor has the greatest effect on male and female students' interest in STEM careers respectively?

RQ3 Are there gender differences in the mediating roles of STEM self-efficacy and STEM careers perceptions between environmental factors and interest in STEM careers?

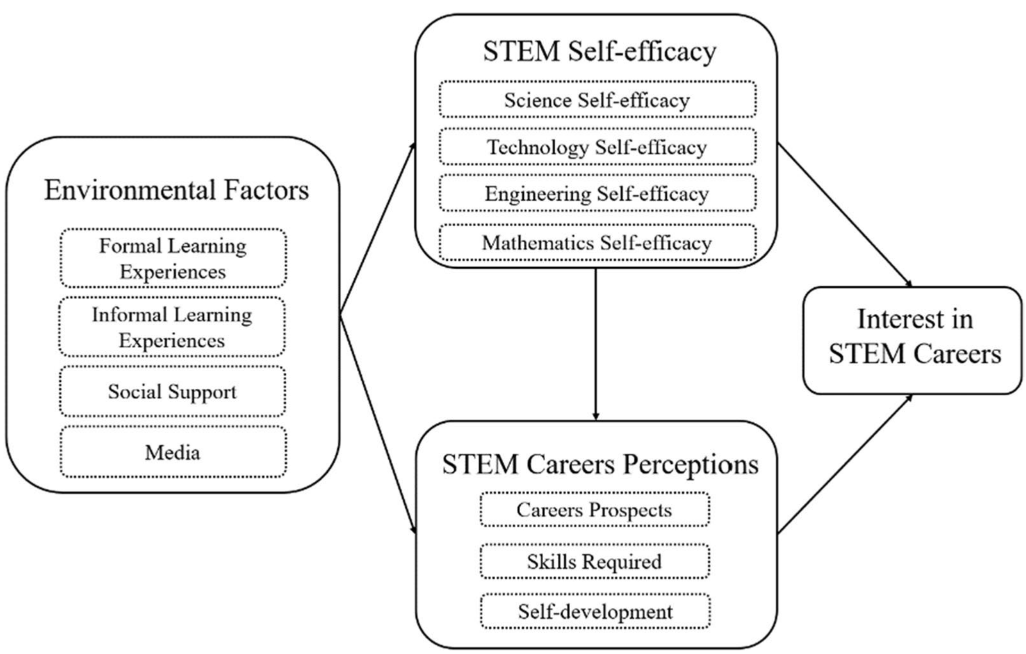


Fig. 1 Theoretical framework of the effect of environmental factors on interest in STEM careers

Research methodology

Participants

In China, basic education consists of 12 grades, among which grades 1–9 are compulsory (including grades 1–6 in primary school and grades 7–9 in middle school), and grades 10–12 are high school which is non-compulsory. At the end of high school education, students take the college entrance exam, which allows them to enter different universities based on their scores. Chinese high schools are divided into provincial demonstration high schools, municipal demonstration high schools and other high schools according to their comprehensive level in descending order. At present, STEM subjects (including mathematics, physics, chemistry and biology) are compulsory courses in Chinese high schools, and integrated STEM curriculum is not yet popular. Only a few schools carry out integrated STEM education in the form of school-based curriculum.

In this study, 10th grade students in Hunan Province, mainland China, were selected for the following reasons: Firstly, high school in China includes the 10th–12th grades, and in the context of the new Chinese college entrance examination reform, 10th grade students (who are usually 15 or 16 years old as Chinese education authorities require that students should be at least 6 years old to enter the first grade) need to choose their high school courses and subjects according to the college majors they are aiming for. By the 10th grade, the students would have already thought deeply about their career interests. Secondly, compared to younger students, high school students have more independent and stable thinking ability, and can assess the influence of various factors on their career interest relatively accurately. Finally, compared with other grades in high school, 10th grade students have less academic pressure and have enough time to answer the questionnaire carefully, thus ensuring the reliability and validity of the data.

Taking the differences in educational resources and levels in different regions, 10th grade students from 5 schools in Changsha, Changde, and Xiangxi Autonomous Prefecture in Hunan Province, China, were selected for the on-site questionnaire survey in this study. Changsha is the provincial capital of Hunan Province with a good economic and educational level, Changde is a medium non-capital city of Hunan Province with a medium economic and educational level, and Xiangxi is a mountainous area in the western part of Hunan Province with a low economic and educational level. In this study, students from 3, 1 and 1 schools (we selected 1Grade 10 class from each school) in the above three cities respectively were selected as participants. To protect the privacy of the participants, the questionnaires were anonymized after consent was obtained. The participants completed the questionnaires within a specified time (about 20 min) and the results were collected on-site after completion. In addition, a teacher in each class explained the instructions and requirements to the participants. Comrey and Lee (1992) suggested that a sample size greater than 1000 is optimal in the structural equation model, so a total of 1240 paper questionnaires were collected in this study and the data was input in SPSS23.0 software. After inspection, 108 questionnaires were excluded as they were incomplete. The final number of valid questionnaires was 1132, accounting for 91.29% of the total number of questionnaires collected. Among them, 549 were male students (48.5%) and 583 were female students (51.5%), and the number of students in provincial demonstration high schools, municipal demonstration high schools and other high schools were 382 (33.7%), 369 (32.6%), and 381 (33.7%), respectively.

Table 1 Constructs of the questionnaire

Construct	Sub-construct	Number of items	Examples of item
EF	Formal learning experiences	4	In class, teacher introduce STEM careers to us
	Informal learning experiences	4	I have participated in STEM-related competitions
	Social support	4	My parents encouraged me to pursue a STEM career
	Media	4	I often read STEM-related books, magazines, newspapers, etc
SSE	Science	4	I can carry out scientific experiments properly
	Technology	4	I can use everyday technological products easily
	Engineering	4	I can repair a broken toy
	Mathematics	4	I can draw a graph from the provided data
SCP	Careers prospects	3	Those in STEM fields can get jobs easily
	Skills required	3	STEM careers require creative problem-solving skills
	Self-development	3	STEM careers are conducive to self-development
ISC		4	I want to pursue a STEM career in the future

Instrument

The questionnaire was divided into four parts: EF, SSE, SCP and ISC (Table 1). All items are measured using the 5-point Likert scale, from "1-strongly disagree" to "5-strongly agree". Among the constructs, the EF and SCP parts were adapted from the instrument developed by Mohtar et al. (2019). The SSE part was adapted from the instruments developed by Buday et al. (2012), Kier et al. (2014) and Nugent et al. (2015). The ISC part was adapted from the instrument developed by ASPIRES Project Group, King's College London, UK (Archer et al., 2013). In order to avoid the differences in Chinese and English expressions, the original English questionnaires were translated into a Chinese questionnaire by a professor with an overseas study experience. Each item of the Chinese questionnaire was subsequently discussed and revised by the group made up of two experts engaged in scientific education, one expert engaged in education statistics, and three high school teachers. Finally, the backtranslation was conducted by a graduate student majoring in English, and the back translated questionnaire and the original English questionnaire were compared, discussed and revised, so as to align it to the original text as much as possible and conform to the Chinese cultural background and expression (Brislin, 1986). After that, there were three demographic variables and 46 items in the original questionnaire (See Appendix Tables 8 and 9). Firstly, exploratory factor analysis (EFA) was performed on each construct and item ISC5 was deleted. Then some items were parceled (Landis et al., 2000), and the EFA was performed again on all constructs. The EFA result showed that the *Kaiser–Meyer–Olkin* (*KMO*) was 0.911, and the value of Bartlett's test of sphericity is 10,888 ($df=105$, $p<0.001$), meeting the judgement standards ($KMO>0.70$, $p<0.05$) proposed by Howard (2016). The item factor loading of each construct was between 0.525 and 0.891, indicating that the structure of the questionnaire was well divided. The final constructs of the questionnaire shown in Table 1. EF, SSE and SCP include four, four and three sub-constructs respectively, and the score of each sub-construct was calculated by the average score of the items it includes. For example, the four sub-constructs of SSE are science self-efficacy, technology self-efficacy, engineering self-efficacy and mathematics self-efficacy. Each sub-construct of SSE contained four items, and the score of each sub-construct was calculated by the average score of the four items.

The reliability and validity of the questionnaire are shown in Table 2. First, the overall Cronbach's α reliability coefficient of the questionnaire was 0.952, and the Cronbach's α of each part EF, SSE, SCP, and ISC were 0.818, 0.833, 0.834, 0.929 respectively, indicating that the questionnaire had high internal consistency and high reliability. Second, confirmatory factor analysis (CFA) was used to test the validity. The results show that the standardized factor loading of all items were between 0.546 and 0.935, which reached the standard of 0.5 to 0.95, indicating that the items and constructs were effective. The composite reliability (CR) > 0.8 and the average variance extracted (AVE) > 0.5, indicating each construct

Table 2 Reliability and validity of the questionnaire

Construct	Item	Factor loading	Skew	Kurtosis	Cronbach's α		*CR*	*AVE*	EF	SSE	SCP	ISC
EF	FLE	0.733	− 0.131	− 0.308	0.818	0.824	0.823	0.538	**0.733**			
	ILE	0.769	0.732	− 0.072		0.812						
	SS	0.755	− 0.066	− 0.532		0.766						
	Media	0.673	− 0.298	− 0.426		0.891						
SSE	Science	0.846	− 0.170	− 0.333	0.833	0.839	0.830	0.557	0.603	**0.746**		
	Technology	0.546	− 1.067	0.729		0.835						
	Engineering	0.691	− 0.260	− 0.737		0.822						
	Mathematics	0.858	− 0.110	− 0.358		0.813						
SCP	Prospects	0.618	− 0.463	0.655	0.834	0.762	0.839	0.640	0.373	0.384	**0.800**	
	Skills	0.846	− 1.467	2.585		0.911						
	Development	0.907	− 1.131	1.280		0.867						
ISC	ISC1	0.916	− 0.195	− 0.806	0.929		0.929	0.768	0.581	0.352	0.404	**0.876**
	ISC2	0.935	− 0.121	− 0.880								
	ISC3	0.813	0.169	− 0.781								
	ISC4	0.835	− 0.386	− 0.757								

The bold number refers to the square root of *AVE* in each construct; EF: Environmental factors; LE: Learning Experiences; SS: Social Support; SSE: STEM self-efficacy; SCP: STEM careers perceptions; ISC: Interest in STEM careers had high convergent validity. The correlation coefficient between the constructs was less than the square root of *AVE* in each construct, indicating that the questionnaire had good discriminant validity. From the fitting index, $RMSEA = 0.060 < 0.08$, $SRMR = 0.075 < 0.08$, and all other goodness-of-fit indexes were greater than 0.9, indicating that the data fitted well. Finally, the absolute value of the skew of each item was less than 2 and the absolute value of the kurtosis was less than 7, indicating that the data conformed to normal distribution (Kline & Little, 2011).

Data analysis

SPSS23.0 and AMOS23.0 were used for data analysis. Firstly, the Harman single factor test (Podsakoff et al., 2003) was performed to ensure that there was no serious common method deviation in this study, and the intraclass correlation analysis was conducted to determine whether cluster data analysis and multi-level SEM analysis were necessary. In order to answer the three research questions in this study, the following methods were used: (1) For RQ1, the *t*-test was used to judge whether there were significant differences in the scores of male and female students in each construct, and the Cohen's *d* was used to judge the effect size (Cohen, 1988). (2) For RQ2, the correlation analysis was used to analyze the correlation between variables, and regression analysis was used to compare the effect size of each sub-construction of EF on ISC. (3) For RQ3, a multi-group comparison of the structural equation model was carried out and the fitting degree of the model was judged by the goodness-of- fit indexes. The *p*-value was used to judge whether the direct effects were significant, and the size of the effects were analyzed by the standardized path coefficient(β). To test whether the indirect effects were significant, the 95% confidence interval of Bootstrap mediation test (Preacher & Hayes, 2004) included 0 was used. The critical ratios (CR) for differences between parameters were used to judge whether the difference between male and female students on each path was significant.

Results

Common method bias test

To avoid common method bias, Harman's one-factor test was used to test the common method bias in this study (Podsakoff et al., 2003). The results showed that there were four factors with eigenvalues greater than 1, and parallel analysis results also suggested that four factors can be extracted (Franklin et al., 1995; O'Connor, 2000), which explained 74.27% of the variation in total, and the explanation rate of the largest factor variance was 46.12%, which was less than the 50% judgment standard recommended by Hair et al. (2014), indicating that there was no serious common method bias in this study.

Intraclass correlation analysis

Considering that the participants in this study came from 5 schools, participants from the same school may lead to biased results due to similar education levels (Geiser, 2013). Therefore, an intraclass correlation analysis was conducted to determine whether the data were clustered by the intraclass correlation coefficients (ICCs) of all constructs (Bowen & Guo, 2011; Silva et al., 2019). The results showed that the clustering effects for all constructs were not significant (*ICC* of EF $= 0.022$, $p = 0.760$; *ICC* of SSE $= 0.003$, $p = 0.451$; *ICC* of SCP $= 0.010$, $p = 618$; *ICC* of ISC $= 0.033$, $p = 0.139$) and their design effects were all less than 2, indicating that most observations were independent (McNeish & Stapleton, 2016). In addition, this study focuses on analyzing gender differences in structural relationships among EF, SSE, SCP, and ISC. Based on the above analysis, cluster data analysis and multi-level SEM analysis was not necessary.

Descriptive statistics and independent sample *T*-test

The descriptive statistical results such as the mean and standard deviation of each main variable and the *t*-test results are shown in Table 3. On the whole, the mean of ISC is 3.16, which shows that students' ISC are not high. The mean of EF is 2.89, which is slightly lower than the neutral level (In the questionnaire of this study, 3 means neutral). The mean of formal LE ($M = 3.25$) and Media ($M = 3.45$) are slightly higher than the neutral level, while the mean of informal LE ($M = 2.04$) is at a lower level, and the mean of SS ($M = 2.83$) is slightly lower than the neutral level. The mean of SSE was 3.49, slightly higher than the neutral level. The mean of SCP is 4.03, which is at a relatively high level. From the results of the independent sample *t*-test, the scores of male students in all the constructs are significantly higher than those of female students, except for SCP where there was no significant gender difference. Cohen (1988) suggested that the critical values of small, medium and large effects were 0.2, 0.5 and 0.8, respectively. Further from the *d*-values, there were small effect size gender differences in Environmental Factors, Media, STEM Self-efficacy, Science Self-efficacy, Engineering Self-efficacy, Mathematics Self-efficacy, and Interest in STEM Careers.

Correlation analysis

The correlation matrix for male and female is shown in Table 4, and all variables were significantly correlated. For male, EF ($r = 0.647$, $p < 0.001$), SSE ($r = 0.414$, $p < 0.001$), and SCP ($r = 0.491$, $p < 0.001$) were all significantly correlated with the male students' ISC, and the correlations sizes between EF sub-constructs and ISC in descending order were as follows: SS ($r = 0.602$, $p < 0.001$), Media ($r = 0.566$, $p < 0.001$), informal LE ($r = 0.504$,

Table 3 Descriptive statistics and *t*-test for all variables by gender

Construct/sub-construct	Full sample ($N=1132$) $M \pm SD$	Male ($N=549$) $M \pm SD$	Female ($N=583$) $M \pm SD$	*t*	*p*	*d*
Environmental factors (EF)	2.89 ± 0.75	3.00 ± 0.78	2.79 ± 0.71	4.56	***	0.281
Formal learning experiences (FLE)	3.25 ± 0.89	3.31 ± 0.92	3.20 ± 0.85	2.08	0.038*	0.124
Informal learning experiences (ILE)	2.04 ± 0.89	2.12 ± 0.94	1.96 ± 0.82	3.06	0.002**	0.181
Social support (SS)	2.83 ± 0.97	2.91 ± 1.01	2.76 ± 0.93	2.52	0.012*	0.155
Media	3.45 ± 0.99	3.65 ± 0.98	3.26 ± 0.96	6.84	***	0.402
STEM self-efficacy (SSE)	3.49 ± 0.74	3.65 ± 0.73	3.34 ± 0.73	7.29	***	0.425
Science self-efficacy	3.13 ± 0.90	3.33 ± 0.89	2.95 ± 0.87	7.21	***	0.432
Technology self-efficacy	4.25 ± 0.80	4.33 ± 0.80	4.18 ± 0.80	3.02	0.003**	0.188
Engineering self-efficacy	3.28 ± 1.05	3.49 ± 1.04	3.08 ± 1.02	6.65	***	0.398
Mathematics self-efficacy	3.22 ± 0.90	3.41 ± 0.90	3.03 ± 0.86	7.34	***	0.432
STEM careers perceptions (SCP)	4.03 ± 0.71	4.03 ± 0.75	4.04 ± 0.68	− 0.22	0.826	− 0.014
Careers prospects	3.67 ± 0.81	3.66 ± 0.82	3.67 ± 0.80	− 0.22	0.824	− 0.012
Skills required skills	4.32 ± 0.81	4.31 ± 0.86	4.32 ± 0.75	− 0.33	0.743	− 0.012
Self-development	4.22 ± 0.85	4.24 ± 0.89	4.21 ± 0.81	0.47	0.635	0.035
Interest in STEM careers (ISC)	3.16 ± 1.12	3.39 ± 1.12	2.95 ± 1.08	6.72	***	0.399

*** $p < .001$; ** $p < .01$; * $p < .05$. *d* means Cohen' *d*; $d > .2$ means small effect size; $d > .5$ means medium effect size; $d > .8$ means large effect size

$p < 0.001$), and formal LE ($r = 0.423$, $p < 0.001$). For female, EF ($r = 0.566$, $p < 0.001$), SSE ($r = 0.399$, $p < 0.001$), SCP ($r = 0.377$, $p < 0.001$) were also all significantly correlated with the female students' ISC, and the correlations sizes between EF sub-constructs and ISC in descending order were as follows: Media ($r = 0.553$, $p < 0.001$), SS ($r = 0.507$, $p < 0.001$), informal LE ($r = 0.381$, $p < 0.001$), and formal LE ($r = 0.338$, $p < 0.001$). Overall, there are significant correlations between all variables for both male and female, so further structural equation model testing could be carried out. In addition, in order to further explore "Which environmental factor (EF) has the greatest effect on male and female students' ISC respectively?", regression analysis was also needed.

Regression analysis

The results of the regression analysis of EF and ISC are presented in Table 5. For males, the regression equation model passed the *F*-test ($F = 110.242$, $p < 0.000$) and the model fit was good ($R^2 = 0.448$). The effect sizes of EF sub-constructs on the male students' ISC in descending order were as follows: SS ($\beta = 0.329$, $p < 0.000$), Media ($\beta = 0.295$, $p < 0.000$), and ILE ($\beta = 0.143$, $p = 0.001$), while the effect of FLE ($\beta = 0.024$, $p > 0.05$) on the male students' ISC was not significant. For females, the regression equation model passed the *F*-test ($F = 86.515$, $p < 0.000$) and the model fit was good ($R^2 = 0.375$). The effect sizes of EF sub-constructs on the female students' ISC in descending order were as follows: Media ($\beta = 0.387$, $p < 0.000$), SS ($\beta = 0.279$, $p < 0.000$), while the effect of ILE ($\beta = 0.043$, $p > 0.05$) and FLE ($\beta = 0.010$, $p > 0.05$) on the female students' ISC was not significant. In short, the environmental factors that had the greatest effect on male and female students' ISC were SS and Media, respectively.

Multi-group comparison of structural equation models

To further investigate the relationships among all variables and whether there were gender differences in the mediating roles of SSE and SCP between EF and ISC, this study used a structural equation modeling multi-group comparison to construct the following three models in AMOS 23.0 with gender as the grouping variable. First, the unconstrained model M1 was constructed (the parameters of each group were estimated freely); then, the model M2 was constructed on the basis of M1 (the measurement weights of each group were equal); finally, the model M3 was constructed on the basis of M2 (the measurement weights and path coefficients of each group were equal). The fit fitness and model comparison results of the three models are shown in Table 6. In the structural equation model, when the sample size is larger than 200, it is easy to cause the cardinality value of the model to be inflated, resulting in poor model fit (Bollen & Stine, 1993), so other goodness-of-fit indicators are recommended to evaluate the model (Bentler, 1990). Although the $\chi 2/df$ of this model was slightly higher than the standard value of 5 due to the large sample size, the other fit indicators were at adequate levels ($CFI > 0.9$, $TLI > 0.9$, $IFI > 0.9$, $NFI > 0.9$, $RMSEA < 0.08$, $SRMR < 0.08$) (Hu & Bentler, 1999; Keith, 2014; Wu, 2009), which indicated that the constructed model better reflected the effect mechanism of ISC of high school students. The

Table 4 Correlation matrix for male and female

Construct/sub-construct	EF	FLE	ILE	SS	Media	SSE	Science SSE	Technology SSE	Engineering SSE	Mathematics SSE	SCP	Careers prospects	Skills required skills	Self-development	ISC
1. EF	1	0.782***	0.811***	0.827***	0.759***	0.696***	0.703***	0.367***	0.535***	0.639***	0.371***	0.278***	0.295***	0.381***	0.566***
1.1 FLE	0.792***	1	0.598***	0.518***	0.408***	0.593***	0.634***	0.310***	0.418***	0.571***	0.316***	0.257***	0.243***	0.265***	0.338***
1.2 ILE	0.829***	0.604***	1	0.581***	0.442***	0.585***	0.570***	0.303***	0.480***	0.527***	0.216***	0.140**	0.177***	0.239***	0.381***
1.3 SS	0.851***	0.544***	0.622***	1	0.513***	0.538***	0.529***	0.298***	0.416***	0.500***	0.278***	0.224***	0.201***	0.296***	0.507***
1.4 Media	0.777***	0.450***	0.481***	0.580***	1	0.504***	0.509***	0.258***	0.395***	0.442***	0.359***	0.255***	0.308***	0.397***	0.553***
2. SSE	0.657***	0.542***	0.544***	0.513***	0.538***	1	0.824***	0.666***	0.850***	0.873***	0.422***	0.303***	0.386***	0.420***	0.399***
2.1 Science SSE	0.689***	0.573***	0.594***	0.544***	0.531***	0.814***	1	0.423***	0.549***	0.703***	0.290***	0.211***	0.262***	0.286***	0.430***
2.2 Technology SSE	0.366***	0.324***	0.236***	0.254***	0.377***	0.698***	0.437***	1	0.481***	0.463***	0.327***	0.254***	0.309***	0.312***	0.140**
2.3 Engineering SSE	0.452***	0.305***	0.373***	0.377***	0.410***	0.806***	0.495***	0.493***	1	0.679***	0.299***	0.195***	0.275***	0.319***	0.302***
2.4 Mathematics SSE	0.611***	0.524***	0.550***	0.475***	0.441***	0.866***	0.724***	0.517***	0.578***	1	0.434***	0.338***	0.374***	0.415***	0.416***
3. SCP	0.477***	0.367***	0.311***	0.423***	0.446***	0.456***	0.394***	0.335***	0.341***	0.425***	1	0.811***	0.877***	0.859***	0.377***
3.1 Careers prospects	0.342***	0.286***	0.222***	0.307***	0.296***	0.325***	0.274***	0.258***	0.252***	0.327***	0.786***	1	0.578***	0.539***	0.284***
3.2 Skills required skills	0.383***	0.306***	0.231***	0.332***	0.370***	0.389***	0.340***	0.273***	0.275***	0.360***	0.888***	0.582***	1	0.753***	0.287***
3.3 Self-development	0.465***	0.355***	0.306***	0.400***	0.446***	0.418***	0.391***	0.302***	0.300***	0.373***	0.870***	0.516***	0.783***	1	0.467***
4. ISC	0.647***	0.423***	0.504***	0.602***	0.566***	0.414***	0.490***	0.213***	0.247***	0.401***	0.491***	0.328***	0.382***	0.559***	1

*** $p < .001$, ** $p < .01$; The correlation matrix for female ($n = 583$) is showed above the diagonal, and the correlation matrix for male ($n = 549$) is showed below the diagonal

Table 5 Regression analysis of EF and ISC

Independent variable	Male ($N = 549$)			Female ($N = 583$)		
	β	t	p	β	t	p
Formal Learning Experiences (FLE)	0.024	0.583	0.560	0.010	0.234	0.815
Informal Learning Experiences (ILE)	0.143	3.194	0.001**	0.043	0.946	0.345
Social Support (SS)	0.329	7.223	***	0.279	6.312	***
Media	0.295	7.350	***	0.387	9.800	***
R^2	0.448			0.375		
F	110.242***			86.515***		

*** $p < 0.001$, ** $p < 0.01$; F means Ratio of mean square between groups to mean square within groups

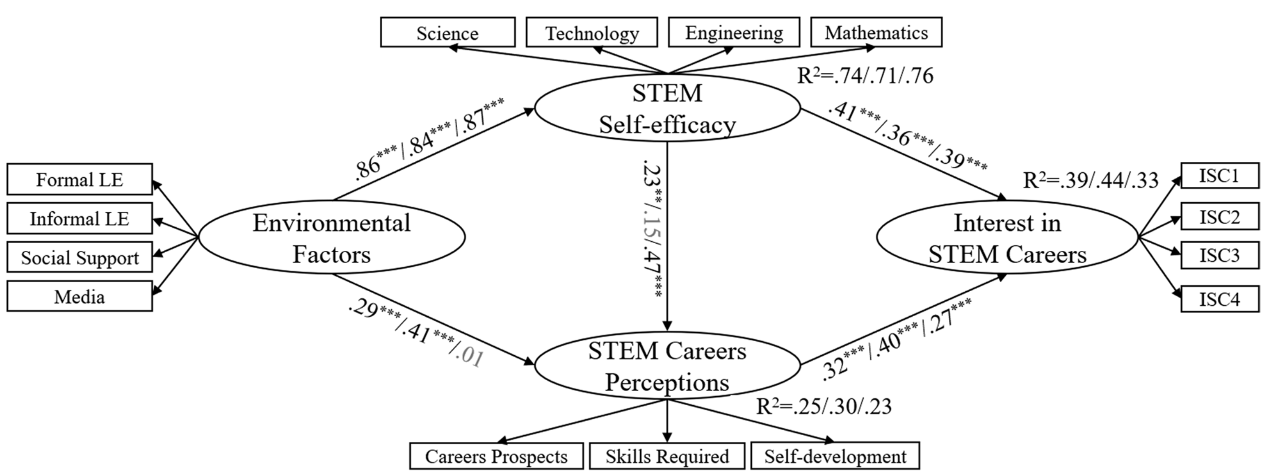
Table 6 Model fit indices for multi-group comparison

Model	χ^2	df	χ^2/df	CFI	TLI	IFI	NFI	$RMSEA$	$SRMR$	$\triangle\chi^2$	$\triangle df$	p
M1	969.928	170	5.705	0.925	0.907	0.925	0.911	0.065	0.075	–	–	–
M2	982.451	181	5.428	0.925	0.913	0.925	0.910	0.063	0.076	12.523	11	0.326
M3	997.702	186	5.364	0.924	0.914	0.924	0.908	0.062	0.080	15.252	5	0.009**

** $p < .01$; M1 is the unconstrained model; M2 is the model with equal measurement weights; M3 is the model with equal measurement weights and structural weights

model comparison results showed that the differences between M1 and M2 were not significant ($\triangle\chi 2 = 12.523$, $\triangle df = 11$, $p > 0.05$), indicating that the measurement weights of each question item in the questionnaire were equal across groups in the male and female samples, further indicating that the questionnaire was appropriate for both male and female students; the differences between M2 and M3 were significant ($\triangle\chi 2 = 15.252$, $\triangle df = 5$, $p < 0.05$), indicating that there were gender differences in the path coefficients. The specific paths that have gender differences needed to be analyzed in the next step.

The structural equation models for the total sample, male students, and female students are shown in Fig. 2. The numbers on each arrow in turn represent the path coefficients for the total sample, male students, and female students. From the total sample, all



Note: ***p<.001, **p<.01, *p<.05; The standardized path coefficients on each arrow is labeled in the following order: total sample, male, female; The path coefficients that are not significant are shown in gray. R^2 represents the proportion of the variance that can be explained for each latent variable, and it is also arranged in the order of full sample, male, and female.

Fig. 2 Structural equation models for full sample, male and female

Table 7 The direct and indirect effects test for full sample, male and female

Path	Full sample			Male			Female			*C.R*
	β	Bootstrap 95% *CI*		*β*	Bootstrap 95% *CI*		*β*	Bootstrap 95% *CI*		
		Lower	Upper		Lower	Upper		Lower	Upper	
Direct effects										
EF → SSE	0.858***			0.842***			0.872***			1.241
EF → SCP	0.290***			0.413***			0.013			− 2.078*
SSE → ISC	0.408***			0.360***			0.386***			0.800
SSE → SCP	0.228**			0.154			0.474***			1.987*
SCP → ISC	0.320***			0.401***			0.275***			− 1.680
Indirect effects										
EF → SSE → ISC	0.350**	0.281	0.420	0.303***	0.201	0.408	0.337***	0.243	0.439	
EF → SCP → ISC	0.093*	0.019	0.184	0.166**	0.051	0.310	0.004	− .077	0.127	
EF → SSE → SCP → ISC	0.063*	0.005	0.114	0.052	− 0.039	0.128	0.113**	0.046	0.195	
Total effects	0.506***	0.450	0.561	0.521***	0.438	0.598	0.454***	0.375	0.530	

C.R. critical ratios for differences between parameters, *EF* environmental factors, *SSE* STEM self-efficacy, *SCP* STEM careers perceptions, *ISC* interest in STEM careers

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

five path coefficients were significant, and the model explained 39% of the variance in ISC of the total sample. For male students, all paths were significant except for "SSE → SCP", and the model explained 44% of the variance in ISC of male students. For female students, all paths were significant except for "EF → SCP", and the model explained 33% of the variance in ISC of female students.

All direct paths coefficients and indirect paths coefficients for the total sample, male and female, and their significance are shown in Table 7. In this study, Critical Ratios (*CR* value) for differences between parameters was used to test whether there was a significant gender difference in each direct path coefficient. If the absolute $CR > 1.96$, the difference in direct path coefficients was significant. The results showed that there were significant gender differences in the two paths EF → SCP ($CR = -2.078$) and SSE → SCP ($CR = 1.987$). Specifically, on the path EF → SCP, the path coefficient of male students ($\beta = 0.413$, $p < 0.001$) is significantly higher than that of female students ($\beta = 0.013$, $p > 0.05$); on the path SSE → SCP, the path coefficient of female students ($\beta = 0.474$, $p < 0.001$) is significantly higher than that of male students ($\beta = 0.154$, $p > 0.05$). In order to test whether there are gender differences in the indirect effects of EF on ISC, that is, whether there are gender differences in the mediating roles of SSE and SCP between EF and ISC, this study further used the Bootstrap mediating effect test (Preacher & Hayes, 2004) with repeated sampling 5000 times and calculating 95% confidence intervals. If the 95% confidence interval did not include 0, the mediating effect of the path was significant. The mediating test results are shown in Table 7. The three mediation paths of the total sample are all significant. For male, the two mediations path were significant except for EF → SSE → SCP → ISC ($\beta = 0.052$, 95% *CI* [− 0.039, 0.128] including 0), indicating that EF can affect the ISC of male students through the following two mediating paths (EF → SSE → ISC, EF → SCP → ISC). For female, the two mediating paths were significant except for EF → SCP → ISC ($\beta = 0.004$, 95% *CI* [− 0.077, 0.127] including 0), indicating that EF could affect the ISC of female students through the following two mediating paths (EF → SSE → ISC, EF → SSE → SCP → ISC). In summary, there are gender differences in the effect mechanisms of EF on ISC, that is, there are gender differences in the mediating role of SSE and SCP between EF and ISC.

Discussion

Based on SCCT, this study investigated gender differences in high school students' ISC and answered three research questions: RQ1 Are there differences in interest in STEM careers between male and female students? RQ2 Which environmental factor has the greatest effect on male and female students' interest in STEM careers respectively? RQ3 Are there gender differences in the mediating roles of STEM self-efficacy and STEM careers perceptions between environmental factors and interest in STEM careers? In response to these three questions, the specific discussion and conclusions of this study are as follows.

RQ1: Are there differences in interest in STEM careers between male and female students?

The results of descriptive statistics and independent sample *t*-tests showed that there were gender differences in high school students' ISC. Specifically, male students have significantly higher ISC than female students, which is consistent with the results of similar studies (Archer et al., 2012; Lv et al., 2022) and with the current global underrepresentation of females in STEM fields. In addition, male students scored higher than female students on all environmental factors (school education, informal education, social support, media) and STEM self-efficacy, which is consistent with previous findings (Archer et al., 2012; Du, 2020; Li & Xie, 2016; Lv et al., 2022; Shi & Huang, 2018), indicating that girls are treated more or less unfairly in terms of school education, informal education, social support, and media. The results also showed that both male and female students scored relatively high and did not differ significantly in STEM careers perceptions. As the STEM careers perceptions questionnaire in this study was adapted from Mohtar et al. (2019), which includes three sub-dimensions "career prospects," "skills needed," and "self-development", the findings suggest that there is no gender difference in the perception of the value of STEM careers. That is, female students also believe that STEM careers have better prospects and are beneficial for their long-term self-development. Since there is no gender difference in the students' perceptions of the value of STEM careers, why are many female students still reluctant to enter STEM fields in the future? This study suggests that the reason may be due to the influence of environmental factors and STEM self-efficacy, which was also confirmed by Archer et al. (2012), who found that although most girls rated science highly, they were still reluctant to choose science-related careers. This is because STEM fields were generally perceived as "smart" and "masculine" fields, and this stereotype can be transmitted explicitly or implicitly through parents, teachers, peers, and the media (Fulcher, 2011).

RQ2: Which environmental factor has the greatest effect on male and female students' interest in STEM careers respectively?

The results also showed that the environmental factors that had the greatest effect on male and female students' interest in STEM careers were different. Specifically, the environmental factor that had the greatest effect on male students' interest in STEM careers was social support, while that for female students was media. The reason may be that, under the deep-rooted influence of traditional Confucianism, Chinese society generally believes that men are responsible for external affairs and women are responsible for internal affairs, and stable, low-intensity, family-centered careers are more suitable for females (Liu, 2014). Studies have found that parents tend to underestimate girls' ability in STEM subjects and overestimate boys' ability in the field (Eccles & Wigfield, 2002; Gunderson et al., 2012), and some teachers believe that mathematics is a male field and have higher expectations for boys' mathematical ability (Gunderson et al., 2012; Li, 1999). Therefore, parents and teachers are more likely to provide additional support and expectations for boys in STEM fields. As such, social support largely affects boys' interest in STEM careers. Under the influence of the slogan "women can hold up half of the sky" in China's early socialist stage and the one-child policy implemented in China since the 1980s, parents hold the same educational expectations for girls and increase investment and support for their education (Tsui & Rich, 2002). However, gender stereotypes widely existing in social and cultural norms still largely affect girls' interest in STEM careers and identity through a variety of media (e.g., most scientists in the media and textbooks are male). For example, through an assessment of curriculum frameworks in 78 countries, UNESCO found gender bias in many math and science textbooks and learning materials (Benavot, 2016). Tan et al. (2015) have divided media into entertainment media (such as movies and TV entertainment programs) and science media (popular science magazines, science documentaries, etc.). Although some media, especially entertainment media, convey sociocultural norms and gender stereotypes, positive and scientific media still could improve students' perceptions and interest in STEM careers (Wyss et al., 2012), and are useful for designing interventions to increase students' interest in STEM careers. For both boys and girls, school education had the least effect on their interest in STEM careers. A similar conclusion was obtained from a study in China that school factors had no significant effect on Chinese students' intention to pursue science-related careers (Xue et al., 2015). The reason may be that under the influence of exam-oriented education in China, teacher pay more attention to the teaching of academic knowledge, while ignoring the cultivation of literacy, self-efficacy, and career planning education (Lv et al., 2022; Zhou et al., 2019). In addition, this study and related studies have found that informal education has a greater impact on high school students' STEM career interest than school education (Halim et al., 2017; Kitchen et al., 2018; Miller et al., 2018; Wang et al., 2021); therefore, educators should actively seek interventions in informal education (museum education, summer camps, etc.) to improve students' interest in STEM careers. The study also found that the effect of informal LE on female students was not significant, possibly because female students had less access to informal LE, for example, they do not have equal access to STEM-related activities at home and in other settings (Sammet & Kekelis, 2016). Studies have shown that compared with girls, boys are given more opportunities for informal activities (Bonnette et al., 2019) and receive more explanations from their parents during informal scientific activities (Crowley et al., 2001). Informal education could offer the possibility for girls to be exposed to female STEM role models, which can eliminate gender stereotypes of girls in STEM fields, increase their STEM self-efficacy and positive perceptions of STEM careers, and in turn increase their interest in STEM careers. Parents should provide more opportunities and support for girls to participate in informal STEM education, as parents generally act as gatekeepers in the choice of their children's participation in informal education, deciding whether to support their children's participation in a particular informal STEM activity.

RQ3: Are there gender differences in the mediating roles of STEM self-efficacy and STEM careers perceptions between environmental factors and interest in STEM careers?

From the results of a multi-group comparison of structural equation model, there were gender differences in the effect mechanism of high school students' interest in STEM careers. In terms of the explanatory rate of the model, the model constructed in this study explained 44% of the variance in male students' ISC and 33% of the variance in female students' ISC, respectively, indicating that the effect mechanism of in female students' ISC is more complex. In addition, in terms of effect paths, the direct path (SSE → SCP) was not significant in the male group, and the direct path (EF → SCP) was not significant in the female group. EF could affect male students' ISC through the following two mediated paths (EF → SSE → ISC; EF → SCP → ISE), while EF could affect female students' ISC through the following two mediated paths (EF → SSE → ISC; EF → SSE → SCP → ISE). In other words, male students' ISC could be mediated by SSE or SCP, while the two mediating paths of female both include SSE, illustrating the importance of SSE in the formation of girls' ISC. A large number of studies also showed that women with low STEM self-efficacy are less likely to pursue STEM careers (Britner, 2008; Hartung et al., 2005; Litzler et al., 2014). A study by Cimpian et al. (2020) found that a large number of low-performing male students were majoring in STEM majors, the proportion of boys choosing STEM majors is much higher than that of girls among lower-performing students, and girls who enter STEM fields generally have better academic performance and higher self-efficacy. This also confirmed the importance of STEM self-efficacy for girls to pursue STEM. Based on all the above analysis, in order to improve girls' interest in STEM careers, it is crucial to develop girls' STEM self-efficacy. According to Bandura (1986), the information sources of self-efficacy include four major aspects: performance accomplishments, vicarious learning, social persuasion, and emotional arousal. First, performance accomplishments refer to the successful experience of individuals participating in activities in a certain field, and therefore girls need to be provided with more access to STEM projects to gain more successful experiences in problem solving in a real-world context. Second, vicarious learning refers to the experience of individuals seeing people similar to themselves, or role models complete a certain task. Due to the underrepresentation of women in STEM fields, girls need to be provided with more female role models and mentors to guide them. Third, social persuasion refers to the affirmation or encouragement of an individual's successful performance in a certain field by those whom the individual trusts and is close to, especially when the individual is self-doubting. Therefore, parents and teachers should give more affirmation and encouragement to girls in STEM subjects and fields, especially to encourage girls to break out of the traditional boundaries and break the gender stereotypes in STEM fields. Fourth, emotional arousal refers to the negative or positive emotional states that individuals experience when they are engaged in a task, so teachers, parents, and communities should create more positive emotional experiences for girls in STEM instruction or activities. The learning environment such as participation in STEM extracurricular activities, early experiences with STEM and family involvement in STEM have influence on students' decision to enroll in course with STEM as the major (Gossen & Ivey, 2023).

In addition, the mechanisms and potential causes of the mediating effects of SSE and SCP deserve further analysis. For both boys and girls, EF could positively influence SSE, and SSE could further influence ISC, which is consistent with SCCT and similar studies (Lent et al., 1994; Lv et al., 2022; Mohtar et al., 2019; Wang et al., 2021). The reason may be as follows: In Chinese high schools, STEM-related subjects (mathematics, physics, chemistry, biology, etc.) are all compulsory courses and included in the college entrance examination. Therefore, Chinese society, schools, parents, and students give support and efforts to STEM-related subjects, so there is no significant difference between boys and girls in the academic performance of STEM subjects. For example, the results of PISA2015 showed that the difference in math performance among Chinese adolescents was not significant (OECD, 2015). As both boys and girls were exposed to positive environmental factors in STEM subjects learning, these environmental factors would positively affect their SSE. SSE refers to individuals' judgment or confidence in their ability to engage in STEM jobs or complete STEM tasks, which would affect his/her interest in STEM careers positively (lv et al., 2022; Mohtar et al., 2019; Wang et al., 2021). However, SCP is a little different in groups of different genders. Specifically, for male students, EF could positively affect SCP, while for female students, the effect of EF on SCP was not significant. The reason may be that boys have more access to positive environmental factors related to STEM careers and activities than girls. For example, boys have more teacher support and parental support in STEM fields (Crowley et al., 2001; Lv et al., 2022), more access to informal education opportunities (Bonnette et al., 2019; Sammet & Kekelis, 2016), and the majority of scientists portrayed in the media are male (Steinke, 2017). The above positive environmental factors would promote the SCP of male students. However, for female students, the positive environmental factors of STEM careers they acquired were less, so the direct effect of EF on SCP was not significant. Although the path EF→SCP of female students was not significant, EF could still affect SCP through the mediating effect of SSE. The reason may be that the higher a girl's SSE is, the more positive and confident she is and can resist gender stereotypes in STEM fields, and then have a more positive perception of STEM careers. SCP could positively affect ISC for both male and female students, because when individuals have more positive perceptions of STEM careers and better outcome expectations, they are more interested in STEM careers (Mohtar et al., 2019; Wang et al., 2021).

Limitation and future research

The following limitations in this study still exist. Firstly, although the sample size of this study far exceeds the basic requirements of data analysis, the sample does not cover all provinces and cities in China due to the limitation of time, resources and labor. Generally speaking, Hunan Province belongs to a province with a moderate level of economic development in China, so the generalization of the conclusion of this study needs to be further verified, and further verification, improvement and generalization should be carried out in future studies in the provinces and cities with developed economic levels as well as those with more backward economic levels. Secondly, individual career interest will not be unchanged, and students' interest in STEM careers will also fluctuate from primary school to middle school and then to high school. Therefore, future studies can conduct long-term follow-up studies to find the points where girls' interest in STEM careers fluctuate more, and then select the corresponding age or grade to carry out targeted STEM career interest cultivation. Thirdly, a curriculum and teaching framework aimed at cultivating girls' interest in STEM careers can be designed and implemented in the future. Finally, based on the core constructs of Social Cognitive Career Theory (such as self-efficacy, outcome expectation, career interest, etc.) and the instruments of outcome expectation in related studies (Kier et al., 2014; Mohtar et al., 2019), this study did not include self-identity in the questionnaire design. However, self-identity is a very important factor contributing to an individual's interest in STEM, so future research on gender differences in STEM should include the self-identity construct in the questionnaire or include it in the outcome expectation construct.

Conclusions

Based on the Social Cognitive Career Theory, this study explored the gender differences in the effects of the environmental factors (school education, informal education, social support, and media) on high school students' interest in STEM careers through the mediating roles of STEM self-efficacy and STEM careers perceptions. The results of *t*-test, regression analysis, and structural equation model multi-group comparison showed that: Firstly, male students' interest in STEM careers was significantly higher than that of female students. Secondly, the environmental factor that had the greatest effect on male and female students' interest in STEM careers were social support and media, respectively. Thirdly, environmental factors could affect male students' interest in STEM careers through the mediating roles of STEM self-efficacy and STEM career perception, while environmental factors could affect female students' interest in STEM careers through the mediating role of STEM self-efficacy. Finally, the mediating mechanisms of STEM self-efficacy and STEM career perception between environmental factors and interest in STEM careers and the importance of STEM self-efficacy for female students were discussed.

Although this study was conducted at the high school education level in China, there are significant similarities at the global education level, particularly the underrepresentation of females in STEM fields and the low interest in STEM careers among girls. The findings of this study could provide some reference for teachers and policy makers in the STEM field, especially for researchers who want to conduct research on STEM career interest intervention for girls.

Appendix

See Tables 8 and 9.

Table 8 Overview of items used in the questionnaire in English

No.	Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
EF1	In the lab or at school, I often conduct experiments or STEM projects	1	2	3	4	5
EF2	In class, I learned how to analyze experimental results	1	2	3	4	5
EF3	In class, the teacher introduced us to STEM careers	1	2	3	4	5
EF4	In class, I often do exploratory activities with my group	1	2	3	4	5
EF5	I have entered many STEM contests	1	2	3	4	5
EF6	I have entered many STEM summer camps	1	2	3	4	5
EF7	I often visit STEM venues (such as Science and Technology Museum planetariums, museums, botanical gardens)	1	2	3	4	5
EF8	I have joined STEM associations	1	2	3	4	5
EF9	My parents encouraged me to pursue a STEM career	1	2	3	4	5
EF10	My parents encouraged me to participate in STEM activities outside of school	1	2	3	4	5
EF11	Many of my friends want to pursue STEM careers in the future	1	2	3	4	5
EF12	I have family members in STEM occupations	1	2	3	4	5
EF13	I like reading STEM books, magazines, newspapers and so on	1	2	3	4	5
EF14	I like watching STEM TV programs	1	2	3	4	5
EF15	I like watching STEM movies	1	2	3	4	5
EF16	I like browsing information about STEM on the Internet	1	2	3	4	5
SSE1	I do well in STEM. (Science, Technology, Engineering, Mathematics)	1	2	3	4	5
SSE2	I can write the experiment report correctly	1	2	3	4	5
SSE3	I can gather information about STEM concepts properly	1	2	3	4	5
SSE4	I can conduct STEM experiments correctly in the laboratory	1	2	3	4	5
SSE5	I can download pictures or videos from the Internet	1	2	3	4	5
SSE6	I can use daily technology products skillfully. (e.g. microwave oven)	1	2	3	4	5
SSE7	I can use digital devices correctly. (e.g. smart phone, iPad, computer)	1	2	3	4	5
SSE8	I can use social media correctly. (e.g. WeChat, QQ)	1	2	3	4	5
SSE9	I can build a robot out of Lego	1	2	3	4	5
SSE10	I can assemble small furniture (e.g. shoe racks, closets)	1	2	3	4	5
SSE11	I can design electronic circuits	1	2	3	4	5
SSE12	I can fix broken toys	1	2	3	4	5
SSE13	I do well in math	1	2	3	4	5
SSE14	I can collect and record data accurately	1	2	3	4	5
SSE15	I can draw a chart based on the data provided	1	2	3	4	5
SSE16	I can use a scientific calculator skillfully	1	2	3	4	5
SCP1	I think all STEM careers have a high reputation	1	2	3	4	5
SCP2	I think STEM careers pay well	1	2	3	4	5
SCP3	I think students majoring in STEM will find it easy to get a job	1	2	3	4	5
SCP4	I think STEM careers require high level thinking skills	1	2	3	4	5
SCP5	I think STEM careers require creative problem solving	1	2	3	4	5
SCP6	I think STEM careers require collaboration	1	2	3	4	5
SCP7	I think STEM careers are very fulfilling	1	2	3	4	5
SCP8	I think STEM careers can promote my long-term development	1	2	3	4	5
SCP9	I think STEM careers can contribute to human development	1	2	3	4	5
ISC1	I hope to pursue a career in STEM	1	2	3	4	5
ISC2	I will choose a major of STEM in college	1	2	3	4	5
ISC3	I want to be a scientist	1	2	3	4	5
ISC4	I want to work in a field where I can use STEM knowledge in the future	1	2	3	4	5
ISC5	I want to be a medical worker or work in medicine	1	2	3	4	5

EF environmental factors, *SSE* STEM self-efficacy, *SCP* STEM careers perceptions, *ISC* interest in STEM careers

Table 9 Overview of items used in the questionnaire in Chinese

序号	题目	完全不符合	比较不符合	一般	比较符合	完全符合
EF1	在实验室或学校中, 我经常进行实验或STEM项目。	1	2	3	4	5
EF2	在课堂上, 我学会了如何分析实验结果。	1	2	3	4	5
EF3	在课堂上, 老师会给我们介绍STEM相关的职业。	1	2	3	4	5
EF4	在课堂上, 我和小组经常一起进行探究活动。	1	2	3	4	5
EF5	我多次参加STEM相关的竞赛。	1	2	3	4	5
EF6	我多次参加STEM相关的夏令营。	1	2	3	4	5
EF7	我经常参观STEM相关的场馆 (如科技馆、天文馆、博物馆、植物园) 。	1	2	3	4	5
EF8	我参加了STEM相关的社团。	1	2	3	4	5
EF9	我的父母鼓励我从事STEM相关职业。	1	2	3	4	5
EF10	我的父母鼓励我参加与STEM有关的校外活动。	1	2	3	4	5
EF11	我的很多朋友以后都想从事STEM相关职业。	1	2	3	4	5
EF12	我的家庭成员中有人从事STEM相关的职业。	1	2	3	4	5
EF13	我喜欢阅读与STEM相关的书籍、杂志、报刊等。	1	2	3	4	5
EF14	我喜欢看与STEM相关的电视节目。	1	2	3	4	5
EF15	我喜欢看与STEM相关的电影。	1	2	3	4	5
EF16	我喜欢在网上浏览与STEM相关的信息。	1	2	3	4	5
SSE1	我的STEM (科学、技术、工程、数学) 成绩很好。	1	2	3	4	5
SSE2	我能正确地写实验报告。	1	2	3	4	5
SSE3	我能恰当地收集STEM方面的信息。	1	2	3	4	5
SSE4	我能在实验室中正确地进行STEM实验。	1	2	3	4	5
SSE5	我可以从网上下载图片或视频。	1	2	3	4	5
SSE6	我可以熟练使用日常科技产品(如: 微波炉)。	1	2	3	4	5
SSE7	我能正确使用数字设备(如智能手机、iPad、电脑)	1	2	3	4	5
SSE8	我能正确使用社交媒体(如: 微信、QQ)。	1	2	3	4	5
SSE9	我能用乐高积木造一个机器人。	1	2	3	4	5
SSE10	我会组装小型家具 (如: 鞋架、衣柜) 。	1	2	3	4	5
SSE11	我能设计电子电路。	1	2	3	4	5
SSE12	我会修理坏了的玩具。	1	2	3	4	5
SSE13	我的数学成绩很好。	1	2	3	4	5
SSE14	我能准确地收集并记录数据。	1	2	3	4	5
SSE15	我可以根据所提供的数据绘制图表。	1	2	3	4	5
SSE16	我能熟练使用科学计算器。	1	2	3	4	5
SCP1	我认为STEM相关职业都享有盛誉。	1	2	3	4	5
SCP2	我认为STEM相关职业收入很高。	1	2	3	4	5
SCP3	我认为STEM相关专业的学生很容易找到工作。	1	2	3	4	5
SCP4	我认为STEM相关职业需要高层次思维能力。	1	2	3	4	5
SCP5	我认为STEM相关职业需要创造性解决问题的能力	1	2	3	4	5
SCP6	我认为STEM相关的职业需要合作能力。	1	2	3	4	5
SCP7	我认为STEM相关职业很能实现自我价值。	1	2	3	4	5
SCP8	我认为STEM相关职业可以促进我的长远发展。	1	2	3	4	5
SCP9	我认为STEM相关职业可以为人类发展作贡献。	1	2	3	4	5
ISC1	我希望以后从事STEM相关职业。	1	2	3	4	5
ISC2	读大学时我将选择STEM相关的专业。	1	2	3	4	5
ISC3	我想成为一名科学家。	1	2	3	4	5
ISC4	我未来想从事可以运用STEM知识的工作。	1	2	3	4	5
ISC5	我想成为一名医护人员或从事医药方面的工作。	1	2	3	4	5

注: EF: 环境因素; SSE: STEM自我效能感; SCP: STEM职业认知; ISC: STEM职业兴趣。

Abbreviations

STEM	Science, Technology, Engineering, and Mathematics
EF	Environmental factors
LE	Learning experiences
SS	Social support
SSE	STEM self-efficacy
SCP	STEM careers perceptions
ISC	Interest in STEM careers
RQ	Research questions
SCCT	Social Cognitive Career Theory
EFA	Exploratory factor analysis
CFA	Confirmatory factor analysis
KMO	Kaiser–Meyer–Olkin
CFI	Comparative fit index
TLI	Tucker–Lewis index
IFI	Incremental fit index
NFI	Normed fit index
RMSEA	Root mean square error of approximation
SRMR	Standardized root mean square residual
95% bootstrap CI	95% Bootstrap confidence interval
C.R.	Critical ratios for differences between parameters
PISA	Programme for International Student Assessment
OECD	Organization for Economic Cooperation and Development
SEM	Structural equation model

Acknowledgements
The authors sincerely express gratitude to the teachers and students for their assistance in the survey process.

Author contributions
This research was completed by a team of researchers. NW designed the research, conducted the investigation, analyzed the data and results, and wrote the manuscript. AT supervised the research design, proofread and revised the manuscript. XZ and KL contributed to the data analysis. FZ and JX contributed to the data collection. All authors read and approved the final manuscript.

Funding
This research was supported by the National Natural Science Foundation of China (32171065) and National Social Science Foundation's Education Youth Project (CHA220291).

Availability of data and materials
The datasets used during the current study are not publicly available due to the request made in the consent forms issued to participants.

Declarations

Competing interests
The authors declare that "There is no conflict of interest in this article from any of the authors".

Author details
[1]MOE Key Laboratory of Modern Teaching Technology, Shaanxi Normal University, Xi'an 710062, China. [2]National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616, Singapore. [3]College of Life Sciences, Hunan Normal University, 36 Lushan Road, Changsha 410081, China. [4]Hunan Academy of Education Sciences, 11 Education Street, Changsha 410005, China. [5]Dongguan Songshan Lake Future School, 3 Jing'an Road, Dongguan 523000, China.

Received: 19 October 2022 Accepted: 21 July 2023
Published online: 09 October 2023

References

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). "Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science: Femininity, achievement, and science. *Science Education, 96*(6), 967–989. https://doi.org/10.1002/sce.21031

Archer, L., Osborne, J., Dewitt, J., Dillon, J., Wong, B., & Willis, B. (2013). *Aspires: Young people's science and career aspirations, age 10–14*. Kings College London. https://www.voced.edu.au/content/ngv%3A60856

Bahar, A. K., & Adiguzel, T. (2016). Analysis of factors influencing interest in STEM career: Comparison between American and Turkish students with high ability. *Journal of STEM Education, 17*(3), 64–69. https://www.learntechlib.org/p/173750/

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

Bandura, A., & Bussey, K. (2004). On broadening the cognitive, motivational, and sociostructural scope of theorizing about gender development and functioning: Comment on Martin, Ruble, and Szkrybalo (2002). *Psychological Bulletin, 130*(5), 691–701. https://doi.org/10.1037/0033-2909.130.5.691

Benavot, A. (2016). *Gender bias is rife in textbooks*. World Education Blog. https://world-education-blog.org/2016/03/08/gender-bias-is-rife-in-textbooks/

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238–246. https://doi.org/10.1037/0033-2909.107.2.238

Bian, L., Leslie, S. J., & Cimpian, A. (2017). Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science, 355*(6323), 389–391. https://doi.org/10.1126/science.aah6524

Bollen, K. A., & Stine, R. A. (1993). Bootstrapping goodness-of-fit measures in structural equation models. *Sociological Methods & Research, 21*(2), 205–229. https://doi.org/10.1177/0049124192021002004

Bonnette, R. N., Crowley, K., & Schunn, C. D. (2019). Falling in love and staying in love with science: Ongoing informal science experiences support fascination for all children. *International Journal of Science Education, 41*(12), 1626–1643. https://doi.org/10.1080/09500693.2019.1623431

Bowen, N. K., & Guo, S. (2011). *Structural equation modeling*. Oxford University Press.

Brislin, R. W. (1986). The wording and translation of research instruments. In W. J. Lonner & J. W. Berry (Eds.), *Field methods in educational research* (pp. 137–164). Sage.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching, 45*(8), 955–970. https://doi.org/10.1002/tea.20249

Buday, S. K., Stake, J. E., & Peterson, Z. D. (2012). Gender and the choice of a science career: The impact of social support and possible selves. *Sex Roles, 66*(3–4), 197–209. https://doi.org/10.1007/s11199-011-0015-4

Burack, C., Melchior, A., & Hoover, M. (2019). Do after-school robotics programs expand the pipeline into stem majors in college?. *Journal of Pre-College Engineering Education Research (J-PEER)*, *9*(2), Article 7. https://doi.org/10.7771/2157-9288.1244

China Bureau of Statistics. (2022). China statistical yearbook on science and technology 2021. China Statistics Press. http://cnki.nbsti.net/CSYDMirror/Trade/yearbook/single/N2022010277?z=Z018

Cimpian, J. R., Kim, T. H., & McDermott, Z. T. (2020). Understanding persistent gender gaps in STEM. *Science, 368*(6497), 1317–1319. https://doi.org/10.1126/science.aba7377

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis* (2nd ed.). Psychology Press.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science, 12*(3), 258–261. https://doi.org/10.1111/1467-9280.00347

Dasgupta, N., & Stout, J. G. (2014). Girls and women in science, technology, engineering, and mathematics: STEMing the tide and broadening participation in STEM careers. *Policy Insights from the Behavioral and Brain Sciences, 1*(1), 21–29. https://doi.org/10.1177/2372732214549471

Du, X. (2020). Views of roles played by two genders in the expectations of adolescents in science-related career empirical analysis of gender-based stereotypes in mathematics. *Journal of China Women's University, 32*(2), 84–93. https://doi.org/10.13277/j.cnki.jcwu.2020.02.013

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109–132. https://doi.org/10.1146/annurev.psych.53.100901.135153

Ekmekci, A., & Serrano, D. M. (2022). The impact of teacher quality on student motivation, achievement, and persistence in science and mathematics. *Education Sciences, 12*(10), 649. https://doi.org/10.3390/educsci12100649

Eshach, H. (2007). Bridging in-school and out-of-school learning: Formal, non-formal, and informal education. *Journal of Science Education and Technology, 16*(2), 171–190. https://doi.org/10.1007/s10956-006-9027-1

Franklin, S. B., Gibson, D. J., Robertson, P. A., Pohlmann, J. T., & Fralish, J. S. (1995). Parallel analysis: A method for determining significant principal components. *Journal of Vegetation Science, 6*, 99–106. https://doi.org/10.2307/3236261

Fulcher, M. (2011). Individual differences in children's occupational aspirations as a function of parental traditionality. *Sex Roles, 64*(1–2), 117–131. https://doi.org/10.1007/s11199-010-9854-7

Geiser, C. (2013). *Data analysis with Mplus*. The Guilford Press.

Gossen, D., & Ivey, T. A. (2023). The impact of in- and out-of-school learning experiences in the development of students' STEM self-efficacies and career intentions. *Journal of STEM Education Research, 6*(1), 1–30. https://doi.org/10.1007/s41979-023-00090-0

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3–4), 153–166. https://doi.org/10.1007/s11199-011-9996-2

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate data analysis* (7th ed.). Pearson.

Halim, L., Rahman, N. A., Ramli, N. A. M., & Mohtar, L. E. (2017). *Influence of students' STEM self-efficacy on STEM and physics career choice* [Paper presentation]. The 5th International Conference of Science Educators and Teachers, Phuket, Thailand. https://doi.org/10.1063/1.5019490

Hampden-Thompson, G., & Bennett, J. (2013). Science teaching and learning activities and students' engagement in science. *International Journal of Science Education*, *35*(8), 1325–1343. https://doi.org/10.1080/09500693.2011.608093

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior, 66*(3), 385–419. https://doi.org/10.1016/j.jvb.2004.05.006

He, L. Z., Zhou, G., Salinitri, G., & Xu, L. R. (2020). Female underrepresentation in STEM subjects: A study of female high school students in China. *EURASIA Journal of Mathematics, Science and Technology Education, 16*(1), em1802. https://doi.org/10.29333/ejmste/109657

Howard, M. C. (2016). A review of exploratory factor analysis decisions and overview of current practices: What we are doing and how can we improve? *International Journal of Human-Computer Interaction*, *32*(1), 51–62. https://doi.org/10.1080/10447318.2015.1087664

Howard, K. A., Carlstrom, A. H., Katz, A. D., Chew, A. Y., Ray, G. C., Laine, L., & Caulum, D. (2011). Career aspirations of youth: Untangling race/ethnicity, SES, and gender. *Journal of Vocational Behavior, 79*(1), 98–109. https://doi.org/10.1016/j.jvb.2010.12.002

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Jia, Y. Z., & Ma, D. L. (2015). Changes in a gender perspective from multifaceted perspective: The case with men dominating the outside while women dominating the inside of households. *Journal of Chinese Women's Studies, 3*, 29–36. https://doi.org/10.3969/j.issn.1004-2563.2015.03.003

Kang, J., Hense, J., Scheersoi, A., & Keinonen, T. (2018). Gender study on the relationships between science interest and future career perspectives. *International Journal of Science Education, 41*, 1–22. https://doi.org/10.1080/09500693.2018.1534021

Kang, J., & Keinonen, T. (2017). The effect of inquiry-based learning experiences on adolescents' science related career aspiration in the Finnish context. *International Journal of Science Education, 39*(12), 1669–1689. https://doi.org/10.1080/09500693.2017.1350790

Keith, T. Z. (2014). *Multiple regression and beyond: An introduction to multiple regression and structural equation modeling*. Routledge.

Kier, M., Blanchard, M., Osborne, J., & Albert, J. (2014). The development of the Interest in STEM careers survey (STEM-CIS). *Research in Science Education, 44*(3), 461–481. https://doi.org/10.1007/s11165-013-9389-3

Kirsten, B. (2019) *How far have women in STEM come in the last 100 years*. https://www.womeninstem.co.uk/engineering-maths/women-stem-come-last-years.

Kitchen, J. A., Sonnert, G., & Sadler, P. M. (2018). The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations. *Science Education, 102*(3), 529–547. https://doi.org/10.1002/sce.21332

Kline, R. B., & Little, T. D. (2011). *Principles and practice of structural equation modeling*. Guilford Press.

LaCosse, J., Murphy, M. C., Garcia, J. A., & Zirkel, S. (2021). The role of STEM professors' mindset beliefs on students' anticipated psychological experiences and course interest. *Journal of Educational Psychology, 113*(5), 949–971. https://doi.org/10.1037/edu0000620

Landis, R. S., Beal, D. J., & Tesluk, P. E. (2000). A comparison of approaches to forming composite measures in structural equation models. *Organizational Behavioral Research, 3*(2), 186–207. https://doi.org/10.1177/109442810032003

Lee, S. W., & Lee, E. A. (2020). Teacher qualification matters: The association between cumulative teacher qualification and students' educational attainment. *International Journal of Educational Development, 77*, 102218. https://doi.org/10.1016/j.ijedudev.2020.102218

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79–122. https://doi.org/10.1006/jvbe.1994.1027

Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: A review. *Educational Research, 41*(1), 63–76. https://doi.org/10.1080/0013188990410106

Li, W. Y., & Xie, Y. (2016). Gender difference in Chinese children's occupational aspiration. *Youth Studies, 1*, 75–83.

Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career* [Paper presentation]. Restructuring Science Education Through Research, New Orleans, Louisiana, United States. https://narst.org/conferences/2007-annual-conference

Litzler, E., Samuelson, C. C., & Lorah, J. A. (2014). Breaking it down: Engineering student STEM confidence at the intersection of race/ethnicity and gender. *Research in Higher Education, 55*(8), 810–832. https://doi.org/10.1007/s11162-014-9333-z

Liu, F. (2014). From degendering to (re)gendering the self: Chinese youth negotiating modern womanhood. *Gender and Education, 26*(1), 18–34.

Luo, T., So, W. W. M., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-021-00295-y

Lv, B., Wang, J., Zheng, Y., Peng, X., & Ping, X. (2022). Gender differences in high school students' STEM career expectations: An analysis based on multi-group structural equation model. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21772

Ma, L. P., You, Y., Xiong, Y., Dong, L., Wang, M. S., & Kou, K. Z. (2016). Gender gap in college major choice: A empirical study on 85 university. *Journal of Higher Education, 37*(5), 36–42.

Maiorca, C., Roberts, T., Jackson, C., Bush, S., Delaney, A., Mohr-Schroeder, M. J., & Soledad, S. Y. (2021). Informal learning environments and impact on interest in STEM careers. *International Journal of Science and Mathematics Education, 19*(1), 45–64. https://doi.org/10.1007/s10763-019-10038-9

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877–907. https://doi.org/10.1002/sce.20441

McGuire, L., Monzavi, T., Hoffman, A. J., Law, F., Irvin, M. J., Winterbottom, M., & Mulvey, K. L. (2021). Science and math interest and gender stereotypes: The role of educator gender in informal science learning sites. *Frontiers in Psychology, 12*, 503237. https://doi.org/10.3389/fpsyg.2021.503237

McNeish, D., & Stapleton, L. M. (2016). Modeling clustered data with very few clusters. *Multivariate Behavioral Research, 51*(4), 495–518. https://doi.org/10.1080/00273171.2016.1167008

Miller, K., Sonnert, G., & Sadler, P. (2018). The influence of students' participation in STEM competitions on their interest in STEM careers. *International*

Journal of Science Education, Part B, 8(2), 95–114. https://doi.org/10.1080/21548455.2017.1397298
Mohtar, L. E., Halim, L., Rahman, N. A., Maat, S. M., & Osman, K. (2019). A model of interest in STEM careers among secondary school students. *Journal of Baltic Science Education, 18*(3), 404–416. https://doi.org/10.33225/jbse/19.18.404
Sax, L. J., Lehman, K. J., Jacobs, J. A., Kanny, M. A., Lim, G., Monje-Paulson, L., & Zimmerman, H. B. (2017). Anatomy of an enduring gender gap: The evolution of women's participation in computer. *Journal of Higher Education, 88*(2), 258–293. https://doi.org/10.1080/00221546.2016.1257306
National Science Board. (2022). *Science and engineering indicators 2022*. National Science Foundation (NSB 2022-01). https://www.nsf.gov/nsb/sei/
Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C., & Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *International Journal of Science Education, 37*(7), 1067–1088. https://doi.org/10.1080/09500693.2015.1017863
O'Connor, B. P. (2000). SPSS and SAS programs for determining the number of components using parallel analysis and Velicer's MAP test. *Behavior Research Methods, Instrumentation, and Computers, 32*, 396–402. https://doi.org/10.3758/bf03200807
OECD. (2015). *The ABC of gender equality in education: Aptitude, behaviour, confidence.* Paris, Organization for Economic Co-operation and Development. https://www.oecd-ilibrary.org/education/the-abc-of-gender-equality-in-education_9789264229945-en
Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879
Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*(4), 717–731. https://doi.org/10.3758/BF03206553
Rabenberg, T. A. (2013). *Middle school girls' STEM education: Using teacher influences, parent encouragement, peer influences, and self-efficacy to predict confidence and interest in math and science* (Doctoral dissertation, Drake University).
Riegle-Crumb, C., & Peng, M. (2021). Examining high school students' gendered beliefs about math: Predictors and implications for choice of STEM college majors. *Sociology of Education, 94*(3), 227–248. https://doi.org/10.1177/00380407211014777
Robnett, R. D. (2013). *The role of peer support for girls and women in the STEM pipeline: Promoting identification with STEM and mitigating the negative effects of sexism*. University of California.
Rosenthal, R., & Jacobson, L. (1968). Pygmalion in the classroom. *The Urban Review, 3*(1), 16–20. https://doi.org/10.1007/BF02322211
Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411–427. https://doi.org/10.1002/sce.21007
Sammet, K. & Kekelis, L. (2016). *Changing the game for girls in STEM: Findings on high impact programs and system-building strategies*. http://ctesonomacounty.org/wp-content/uploads/2018/10/Changing-the-Game-for-Girls-in-STEM-White-Paper-FINAL-Compressed.pdf
Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Westview Press. https://doi.org/10.2307/2655673
Shi, Y. (2018). The puzzle of missing female engineers: Academic preparation, ability beliefs, and preferences. *Economics of Education Review, 64*, 129–143. https://doi.org/10.1016/j.econedurev.2018.04.005
Shi, C. H., & Huang, Z. Y. (2018). Gender differences and impact factors of S&T career aspirations of adolescents in China. *Journal of East China University of Science and Technology (social Science Edition), 33*(4), 76–83. https://doi.org/10.3969/j.issn.1008-7672.2018.04.010
Silva, B. C., Bosancianu, C. M., & Littvay, L. (2019). *Multilevel structural equation modeling* (1st ed.). SAGE Publications Inc.
Smith, J. L., Lewis, K. L., Hawthorne, L., & Hodges, S. D. (2013). When trying hard isn't natural: Women's belonging with and motivation for male-dominated stem fields as a function of effort expenditure concerns. *Personality and Social Psychology Bulletin, 39*(2), 131–143. https://doi.org/10.1177/0146167212468332
Steinke, J. (2017). Adolescent girls' STEM identity formation and media images of STEM professionals: Considering the influence of contextual cues. *Frontier Psychology, 8*, 716. https://doi.org/10.3389/fpsyg.2017.00716
Su, R., & Rounds, J. (2015). All STEM fields are not created equal: People and things interests explain gender disparities across STEM fields. *Frontiers in Psychology, 6*, 1–20. https://doi.org/10.3389/fpsyg.2015.00189
Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin, 135*(6), 859. https://doi.org/10.1037/a0017364
Tan, A. L., Jocz, J. A., & Zhai, J. (2015). Spiderman and science: How students' perceptions of scientists are shaped by popular media. *Public Understanding of Science, 26*(5), 520–530. https://doi.org/10.1177/0963662515615086
Tan, E., Calabrese Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities- in-practice in science. *Journal of Research in Science Teaching, 50*(10), 1143–1179. https://doi.org/10.1002/tea.21123
Tenenbaum, H. R., & Leaper, C. (2003). Parent–child conversations about science: The socialization of gender inequities? *Developmental Psychology, 39*(1), 34–47. https://doi.org/10.1037/0012-1649.39.1.34
Tsui, M., & Rich, L. (2002). The only child and educational opportunity for girls in urban China. *Gender & Society, 16*(1), 74–92. https://doi.org/10.1177/0891243202016001005
UNESCO. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*. https://unesdoc.unesco.org/ark:/48223/pf0000253479
United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development.* United Nations. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement
Vedder-Weiss, D., & Fortus, D. (2013). School, teacher, peers, and parents' goals emphases and adolescents' motivation to learn science in and out of school. *Journal of Research in Science Teaching, 50*(8), 952–988. https://doi.org/10.1002/tea.21103
Vela, K. N., Pedersen, R. M., & Baucum, M. N. (2020). Improving perceptions of STEM careers through informal learning environments. *Journal of Research in Innovative Teaching & Learning, 13*(1), 103–113. https://doi.org/10.1108/JRIT-12-2019-0078
Wang, M. T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 304–340. https://doi.org/10.1016/j.dr.2013.08.001
Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions'. *Educational Psychology Review, 29*(1), 119–140. https://doi.org/10.1007/s10648-015-9355-x
Wang, N., & Duan, W. (2021). What factors affect high school students' scientific career expectations. *Journal of Educational Science of Hunan Normal University, 20*(04), 39–48. https://doi.org/10.19503/j.cnki.1671-6124.2021.04.006
Wang, N., Tan, A. L., Xiao, W. R., Zeng, F., Xiang, J., & Duan, W. (2021). The effect of learning experiences on interest in stem careers: A structural equation model. *Journal of Baltic Science Education, 20*(4), 651–663. https://doi.org/10.33225/jbse/21.20.651
Wang, J. Y., Yang, M. Y., Lv, B. B., Zhang, F. X., Zheng, Y. H., & Sun, Y. H. (2020). Influencing factors of 10th grade students' science career expectations: A structural equation model. *Journal of Baltic Science Education*, *19*(4), 675–686. https://doi.org/10.33225/jbse/20.19.675
Wu, M. (2009). *Structural equation modeling: Operation and application of AMOS* (2nd ed.). Chongqing University Press.
Wyss, V. L., Heulskamp, D., & Siebert, C. J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental and Science Education, 7*(4), 501–522. http://www.pegem.net/dosyalar/dokuman/138438-2014010217923-1.pdf
Xue, P., Zhao, Y. D., & Wang, S. (2015). Willingness and factors of adolescents to become scientists. *Forum on Science and Technology in China, 3*, 36–41. https://doi.org/10.3969/j.issn.1002-6711.2015.03.007
Yang, J., & Shen, W. (2020). Master's education in stem fields in China: Does gender matter? *Higher Education Policy, 33*(4), 667–688. https://doi.org/10.1057/s41307-020-00203-z

Yi, X., Ribbens, B., & Morgan, C. N. (2010). Generational differences in China: Career implications. *Career Development International, 15*(6), 601–620. https://doi.org/10.1108/13620431011084439

Zhai, J. Q., & Zhu, H. X. (2015). A survey on Chinese secondary students' aspirations in science. *Science Popularization, 1*, 42–48+ 100. https://doi.org/10.19293/j.cnki.1673-8357.2015.01.008

Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (STEM) across genders and grade levels. *Journal of Baltic Science Education, 18*(3), 466–480. https://doi.org/10.33225/jbse/19.18.466

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen journal and benefit from:

► Convenient online submission
► Rigorous peer review
► Open access: articles freely available online
► High visibility within the field
► Retaining the copyright to your article

Submit your next manuscript at ► springeropen.com