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Middle- and Secondary-School Students' STEM Career Interest and Its Relationship to Gender, Grades, and Family Size in Kazakhstan

Abstract

Despite pervasive educational efforts, student interest in STEM careers continues to decline in many countries. The present study seeks to better understand this phenomenon by examining how internal factors (gender) and external factors (school grades, grade level, family size) relate to Kazakh students' STEM career interest. To this end, a newly developed instrument (STEM Career Interest Survey) based on social cognitive career theory was used to assess interest in STEM careers among middle- and secondary-students in Kazakhstan. The survey was completed by a sample of 396 Kazakh students in grades 7 to 12. Our statistical analyses revealed that (1) female students were generally less interested in STEM careers than male students; (2) students with higher grades in physics classes were significantly more interested in STEM careers than low-performing students; (3) students at higher grade levels were generally more interested in STEM careers than those in lower grade levels; (4) the number of siblings was positively associated with student interest in mathematics careers; and, (5) family support and role models were significantly correlated with student STEM career interest. Our findings suggest that student development of interest in STEM careers constitutes an epigenetic phenomenon that involves complex interactions between internal factors (e.g., self-efficacy) and external factors (e.g., gender stereotypes). Based on this, it is argued that the promotion of student interest in STEM careers is a multifaceted problem whose resolution requires, among other things, dispelling stereotypes in students' sociocultural context through systematic renegotiation of traditional gender-technology relations characteristic of a country's culture.

Keywords: Kazakh students; STEM career interest development; middle and high school; STEM career and gender; STEM career, family, and grades

Introduction

In a world of rapid technological advancement, improving a country's educational system in ways that can effectively foster the next generation's interest in scientific and mathematical professions can help improve the life quality of its population. However, despite extensive international efforts, student interest in STEM careers continues to decline in countries as varied as USA, Turkey, and Finland (Chuan et al., 2021; Halim & Meerah 2016; Saleh et al., 2019; Seidelin et al., 2019; Waters, 2022). Waning interest in STEM careers is particularly pronounced among women and non-White groups. This trend of underrepresentation of certain societal groups has been well documented in the US, where national statistics indicate that White males earn most bachelor's and doctoral degrees in STEM fields and occupy most STEM-related jobs (Hill et al., 2010; NSF, 2009). Such persistent disparities highlight a need for an improved, theory-based understanding of student development of interest in STEM careers.

Student STEM career interest has been linked to a multitude of factors. Several internal factors have been shown to influence student selection of STEM-related careers, including personal interest, motivation, and perception/attitude toward STEM (Chuan et al., 2021; Mohtar et al., 2019; Shahali et al., 2018; 2020; Seidelin et al., 2021; So; 2021). However, STEM career interest is not simply an innate quality possessed by some students with idiosyncratic predispositions as it can also be influenced by external factors such as the economic status of the student's family, parental education, the number of children in the family, the student's final grades in STEM classes, etc.) (Humayon et al, 2018; Ing, 2014; Ünlü, & Dökme, 2020). Studies also emphasize the important role of external factors like students' early exposure to STEM content and processes (Dou et al., 2019) and participation in STEM competitions (Bottia et al., 2017; Cohen et al., 2021; Miller, Sonnert, & Sadler, 2018). Relatively fewer studies have examined the role of sociocultural and demographic variables like the influence of parents (Ikkatai et al., 2019; Tzu-Ling, 2018), teachers, and peers (Tey et al., 2020) on student development of interest in becoming professionals with careers in STEM (e.g., Saleh et al., 2019). Consistent with epigenetic perspectives on human development (Weaver, 2019), this literature points to a long-term developmental process whereby students' experiences and the sociocultural environment interact with internal factors, producing individual differences in STEM Career interest. Internal and external factors are mutually influential.

Existing research has been conducted mainly in Southeast Asian countries (e.g., Malaysia, Korea, and Indonesia) while overlooking student populations in Central Asian countries like Kazakhstan (Ikkatai et al., 2019; Saleh et al., 2019). Filling this gap in our research base is critical as the emergence of a more complete picture of science education across Asia can enable more systematic international comparisons and ultimately contribute to worldwide educational efforts aimed at promoting student interest in STEM careers. For instance, Asian nations exhibit important cultural differences, with centrally located countries like Kazakhstan generally having (Western-like) individualistic cultures that value individual pursuit and autonomy more than the collectivistic cultures in South Asia, which tend to value group cohesion and kinship instead (Huff & Kelley, 2003). As such filling the above gap has the potential to generate new insights such as illuminating the role of collectivism and individualism (Triandis, 2001) in shaping students’ emergent interest in STEM careers across a broader cultural spectrum.

Motivated by the above and informed by recent research, the present study seeks to examine the relationship between internal and external factors (gender, grades in STEM classes, and family size) and Kazakh students’ STEM career interest across middle- and secondary-school grade levels. The study is based on an existing scale, the *STEM Career Interest Survey* (STEM-CIS), which was originally developed by Kier, Blanchard, Osborne, & Albert (2014). This scale is designed to generate separate measures for students’ interest in careers related to each individual STEM area, namely in Science careers, Technology careers, Engineering careers, and Mathematics careers.

Our main objective is to better understand how internal factors (gender) (Lent et al., 1994) and external factors (grades in STEM classes, family size) associate with Kazakh students’ interest in careers in each of the four STEM areas. Our research questions are:

1. What patterns of student STEM career interest emerge among middle- and secondary-school students in Kazakhstan?
2. What is the relationship (if any) between Kazakh students’ STEM career interest and gender, grade in STEM classes, and family size?

It is important to note that, as used in this paper, STEM is simply a general reference to the many disciplines in the fields of Science, Technology, Engineering and Mathematics. Despite present ambiguity and confusion surrounding this acronym (Sgro, Bobowski, & Oliveira, 2020), we chose to use it to stay consistent with Kier et al. (2014) whose research instrument is central to our research design. It should not be taken as a reference to transdisciplinary instructional approaches or any other alternative meanings that currently exist in the science education literature.

STEM Education in Kazakhstan

STEM education has been gaining momentum in Asian Countries (Fendos, 2018; Marginson et. al., 2013), being a central part of extensive reform efforts in Kazakhstan. After getting independence from the Soviet Union, there was an acute shortage of personnel in the STEM fields in Kazakhstan. Particularly between the years 1991 and 2005, most high-school graduates tended to select social sciences and humanities as their college major (Serkova, 2020). Since then, to solve this problem, the Ministry of Education of Kazakhstan has invested heavily in school reform and STEM education to increase the number of students pursuing careers in information technology, process manufacturing, construction, engineering, hard sciences, mathematics and statistics, among others (Erbolovna et al, 2019; Guzenkov, 2019).

As part of Kazakh reform efforts, new educational programs are being developed and implemented with the goal of making classroom instruction of STEM subjects more geared toward the development of knowledge and attitudes toward modern technologies. For instance, Kazakh middle- and high-school students now study "Technology" in Grades 7 to 11 (Shevchuk et al., 2019). In this subject, students develop their own technological projects using knowledge from mathematics and science subjects such as physics, chemistry, and biology.

In recent years, Kazakhstan students have been increasingly encouraged to become involved in youth STEM programs and competitions. For instance, since 2014, Kazakhstan has organized an Annual Olympiads in Robotics for students in grades 7 and above. Moreover, teaching laboratories for conducting science projects began to open in 2016, and now there are about a hundred such laboratories throughout the country. Additionally, professional training programs for teachers of STEM subjects can now be found in different regions of the country (Keniskhanova, 2020).

An important component of Kazakhstan's reform agenda was the recent establishment of autonomous *Nazarbayev Intellectual Schools* (NISs). Meant to offer high-quality education to gifted students, these schools enjoy considerably more freedom in terms of curriculum development than other schools in the country. Serving as a source of educational leadership for school reform, NISs are centers for pedagogical innovation that promote a shift away from the traditional content-driven curriculum by developing and sharing alternative curricula with regular schools (Gimranova, Shamatov, Sharplin, & Durrani, 2021). Overall, there are 22 Nazarbayev Intellectual Schools (NIS) in Kazakhstan comprising about 10,000 students. The present study was conducted in two of these schools in the metropolitan city of Almaty.

Since 2009, NISs have accepted new students through a competitive admission process that is open to all sectors of society. The entrance exams are conducted in Russian and Kazakh languages. Students start at NIS after graduating from the 6th grade and graduate from these schools in the 12th grade. Many NISs have boarding services and the schools are tuition-free, offering students meals, uniforms, and lodging free of charge (NIS, 2020). Teaching is trilingual, in Kazakh, Russian and English, transitioning entirely to English by the 11th and 12th grades. Classes are equipped with student laptops, electronic smart boards, and state-of-the-art services.

International teachers are commonly hired to teach subjects like chemistry, biology, physics, and information technology. These international instructors also serve as informal mentors for local teachers, sharing effective educational practices, team planning, co-teaching, etc.

STEM education in NIS schools is well funded. There are well-equipped laboratories for the study of STEM subjects such as physics, biology, and chemistry. The government funds these laboratories and supplies necessary devices and materials (NIS, 2020). There are about 24 students in each class. Regarding curricular materials, students in grades 11 and 12 use the University of Cambridge’s textbooks and supplementary materials in the A-Level program. There are also after-school STEM programs that students can attend to work on science projects, prepare for STEM Olympiads, etc. Once a year, in March, there is a local STEM event in which students present their science projects in preparation for national and international events (Shaikhina, 2017).

Though aimed at promoting student STEM career interest, the above educational reform efforts have taken place in a sociocultural context that discourages female students from selecting STEM as a future career. As indicated by Almukhambetova and Kuzhabekova (2020), the post-Soviet educational context in Kazakhstan is characterized by “conflicting societal expectations [that] confuse the young women wishing to pursue their education in STEM” (p. 950). Despite achieving equally well or better in STEM than their male counterparts (Cheng et al., 2021) and being encouraged to pursue higher education, female students are commonly discouraged from choosing ‘masculine’ STEM majors that may interfere with their ability to perform household responsibilities. Such a state of affairs raises questions about Kazakh girl’s development of interest in STEM careers which, as described above, can be influenced by both internal and external factors (e.g., family gender values). As such, Kazakhstan provides educational researchers with a crucial opportunity to examine the extent to which a nationally funded educational reform effort to broaden women's representation in STEM can in fact counter larger cultural forces that at the same time discourage Kazakh girls' interest in STEM careers.

Student Interest in STEM Careers

Drawing on previous scholarship on interest and interest development (Renninger & Su, 2012) as well as principles from social cognitive career theory (Lent et al. 1994), we conceive of *student STEM career interest* as a cognitive and affective motivational state characterized by an emergent disposition to independently re-engage with a particular class of ideas and activities (disciplinary content and practices in a STEM field). Rather than a stable psychological trait that some students inherently possess from birth, interest in STEM careers is viewed as a highly dynamic (variable) mental state that is externally sparked and that can fluctuate and shift over time as a result of students' school learning experiences and larger sociocultural factors. Like other epigenetic phenomena (intelligence, talent), we consider interest to be socio-ecologically emergent rather than simply determined by one's biological or psychological traits (e.g., genes, IQ, personality). As they progress to higher grade levels, students follow "trajectories of interest development" (developmental pathways) that can be systematically tracked.

Interest development begins with the sparking of *situational interest* (Hidi et al., 2004; Schiefele, 2009) – a temporary emotional and cognitive state aroused by specific features of a situation or task. This state involves focused attention, increased cognitive functioning, persistence, enjoyment or affective involvement, and curiosity (Hidi et al., 2004; Renninger, 2000; Silvia, 2006). Students experience what has been described as an "epistemic appetite," that is, an urge to find answers to personally meaningful questions that they care about – also known as *curiosity questions* (Renninger, 2000) – and in the process stretch their own understanding.

Over time, exposure to activities characterized by situational interest can lead to the development of an enduring interest in STEM careers or *individual interest* (Renninger & Su, 2012). Individual interest is driven by internal motivation in combination with the situation. Individual interest, amidst several factors, develops from a relationship of self-efficacy and outcome expectations (Bandura, 1986), which are both influenced by both internal factors (like gender, ethnicity) and external factors (like culture and family). *Self-efficacy* refers to students' beliefs in their ability to complete tasks ("Can I do this?"), whereas *outcome expectations* refer to what students anticipate as consequences of task completion ("If I do this, what will happen?" "What will I gain/lose?"), including rewards, approval, and self-satisfaction.

Self-efficacy and outcome expectations constitute a vital part of individual interest development. Students continuously evaluate their own ability to complete tasks and expectations of positive outcomes, adjusting based on each new exposure. One crucial aspect of this process is academic achievement. Students with higher grades in STEM classes are more likely to develop self-efficacy and outcome expectations (Blickenstaff, 2005; George-Jackson, 2013; Ing, 2014; Murcia et al., 2020; Ünlü & Dökme, 2020). Continued engagement in activities in which students perform well, in which they receive positive feedback, and that provide them with memorable/meaningful experiences leads to the development of individual interest. As STEM subjects become an object of individual interest, students develop feelings of competence, positive outcome expectations, and reengagement dispositions that are conducive to future pursuit of STEM careers (i.e., STEM career interest). Recent studies in the field have also used self-efficacy and outcome expectations theoretical framework to base their research methodology on measuring student's beliefs and attitudes towards STEM careers (e.g., Koomen, Hedenstrom, & Moran, 2021; Snodgrass Rangel, Vaval, & Bowers, 2020).

Student development of individual interest can be influenced by sociocultural factors such as personal identification and gender appropriateness. One important factor is identity formation. As a student's interest grows, s/he develops a discipline-oriented identity or sense of self, becoming a particular kind of person who is into mathematics, biology, or another STEM subject. Students' emerging identity and self-efficacy are developed through relational interactions with teachers, peers, and family members (Baker & Leary, 2003; Byrd et al., 2022; Sax & Shapiro, 2011). Complications may arise when this emergent sense of self is incompatible with gender-related differences in interests to which students are socialized in their cultural milieu. Like other activities, STEM occupations can be seen as socially gendered in the sense that they can be considered as more "appropriate" for boys than girls (Frenzel et al., 2010; Jacobs et al., 2005). Typically, reflective of the values held by family members (particularly parents), such cultural values can preclude formation of positive identities and negatively influence student interest development in STEM careers.

Influential Factors in Interest Development

In the background of STEM educational interventions, there is a multitude of external factors (economic status of the family, parental education, the number of children in the family, grades in STEM classes, etc.) that, combined, can foster, or deter student interest in STEM careers (Humayon et al, 2018; Ing, 2014; Ünlü, & Dökme, 2020; Japashov et al., 2022). Rather than being simply caused or determined by a single factor, student development of interest in STEM careers is an emergent and complex outcome proximally and distally linked to a vast array of influences (educational, psychological, and cultural). In the present study, we set out to statistically examine the relationship between Kazakh students' STEM career interest and four specific factors, namely gender, academic performance in STEM grades, and family size across both middle- and high-school grade levels. The literature on each of these factors is discussed below, as well as the corresponding hypotheses being tested.

Student Gender and Interest in STEM Careers

According to UNESCO (2015), the number of women in STEM careers is generally lower than the number of men. Consistent with this statistic, the share of women in the science and technology industry is small across Asian countries (Mahon & Murphy, 2019; Jean, Payne, & Thompson, 2015; McGee & Bentley, 2017; Yatskiv, 2017). In this regard, Kazakhstan is no exception. Recently Balta, Cessna and Kaliyeva (2020) showed that male high-school students in Kazakhstan had significantly more positive attitudes than that of female high-school students on the Colorado learning attitudes about science survey (Adams et al., 2006). In their research, Almukhambetova and Kuzhabekova (2020) identified four factors (self-efficacy, family values, school factors, and cultural influences) that influenced Kazakh girls' interest in STEM as a future career. The most important one was self-efficacy. Girls who had low self-efficacy often hesitated in choosing a STEM-related career. The second factor was family gender values. Most Kazakh families stereotypically believed that a STEM career was not for girls. As a third factor, the authors identified schools. Girls who graduated from schools where mathematics was emphasized and where extracurricular STEM subjects were regularly offered tended to become interested in STEM careers. Additionally, teachers had a positive effect on girls' STEM career interest. They reported that teachers who taught STEM classes in engaging ways fostered student interest in STEM. As the last factor, authors identified various cultural influences.

Similar trends have been reported by studies conducted in several other countries. A study involving 407 high-school students in Taiwan revealed a significant gap in STEM career interest between males and females with similar academic ability (Tzu-Ling, 2018). According to this study's findings, male students tended to develop greater STEM career interest because of receiving more support from their families than female students. Such differential amounts of family support were rooted in gender stereotypes in Taiwanese culture. Similar gender stereotypes have also been reported in Japan where parents often express negative attitudes toward their daughters' selection of STEM majors (Ikkatai et al., 2019). Significant gender differences in students' interest in STEM careers have been recently reported in China as well (Luo et al., 2019). In all these countries, girls are consistently shown to generally develop lower levels of STEM career interest than boys as a result of negative sociocultural influences.

Previous research has also sought to identify the reasons behind the above international trends. In studies from the 1990s, scholars simply attributed this difference in STEM career interest between boys and girls to their grades in science classes (Frost, Hyde, & Fennema, 1994; Gaulin, & Hoffman, 1998). However, females' grades in STEM subjects have improved substantially in the past 20 years, with girls outperforming boys in many countries (Blažev, Karabegović, Burušić, and Selimbegović, 2017), hence providing evidence that ability to perform well in STEM subjects does not constitute the sole deterring factor.

Emotional reasons have also been identified for gender disparities in students' STEM career interest. Research by Tan-Wilson and Stamp (2015) with university students showed that many girls are afraid to choose STEM careers because they believe that, if they get involved in

STEM professionally, they will not have time to get married and start a family, and this will negatively affect their future professional and personal life balance. Other studies link this fear to the stereotypical belief that the hard work of an engineer or technologist is not women’s work (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Kimmel, Miller, & Eccles, 2012). Mim (2020) attributes women’s underrepresentation in STEM careers to the socialization process of young female students who are expected to act according to their stereotyped gender roles both in the family and educational settings. Based on this literature on gender and STEM career interest, our first research hypothesis is stated as follows:

H1. Kazakh female students are significantly less interested in STEM careers compared to their male counterparts.

Academic Performance and Interest in STEM Careers

Students’ academic achievement has been shown to have a direct impact on many students’ STEM career interest. High-school students with high grades in mathematics and science have been shown to feel confident and to be more inclined to select a career in the STEM fields (Ing, 2014; Ünlü & Dökme, 2020). Blickenstaff (2005) identified middle- and high-school girls’ low grades in science and mathematics as the main factor influencing their avoidance of STEM careers. A qualitative study by Murcia et al. (2020) also showed that female students’ low learning achievement in science and mathematics classes negatively influenced their self-efficacy and interest in STEM careers. On the other hand, Lichtenberger and George-Jackson (2013) highlights the role of high grades in science subjects as the main factor influencing students’ early interest in STEM careers. These findings are consistent with our theoretical stance which emphasizes that development of interest in STEM careers can be influenced by student performance. Students who perform well in STEM subjects are more likely to develop self-efficacy and positive outcome expectations, and hence develop individual interest in STEM. Therefore, our second hypothesis is:

H2. Kazakh students who obtained high grades are significantly more interested in STEM careers compared to the students who obtained lower grades.

Grade Level and Student Interest in STEM Careers

Grade level has also been shown to be an important factor in student development of interest in STEM careers. In Western countries like the US, students' developmental trajectory has been shown to begin with high levels of interest in STEM careers at elementary school which is then followed by a sharp drop in female student interest at middle school (Harackiewicz et al., 2016). In other words, middle school seems to constitute a critical juncture in student development of interest in STEM, particularly among girls.

To counter the above trend, it is generally recommended that serious student engagement with STEM subjects should begin in Grades 6 or 7 (Ejiwale, 2013). Students in this age range have been shown to possess the necessary skills and foundational knowledge to participate in more authentic science activities (e.g., projects, modeling). It is also in middle school that many students begin making decisions about their future life goals and pondering their future career choice (Anderman, & Maehr, 1994; Shahali, Halim, Rasul, Osman, & Zulkifeli, 2016). Sadler, Sonnert, Hazari, and Tai (2012) shows that high-school graduates often choose future careers according to their interests in middle school.

Research shows that such an exposure to STEM subjects in middle school can increase female student interest and significantly contribute to the elimination of the gender gap in STEM disciplines (Cohen et al., 2021; Dou et al., 2019). Ünlü and Dökme (2020), Maltese and Tai (2011), Christensen and Knezek (2017) all showed that students at the lower grade levels of middle school had more interest in STEM careers. Christensen and Knezek, (2017) found that middle-school students with an interest in STEM careers tended to pursue careers in these fields later. These findings are aligned with our theoretical argument that interest in STEM fluctuates over time and that students follow "trajectories of interest development." As such, we were propelled to statistically test the third hypothesis:

> **H3.** There are statistically significant differences in Kazakh students' STEM career interest across different grade levels.

Family Size and Interest in STEM Careers

Several studies have examined the influence that family can have on student development of interest in STEM careers (Paa & McWhirter, 2000; Renninger & Su, 2012). According to past research, family is a very important factor in students' choice of a career (Blake, 1981; Heer, 1985). Encouragement and support from family plays a critical role in shaping student value toward STEM careers (Paa & McWhirter, 2000). Parental occupation and family hobbies can influence students' interest in science, and students from families who expect them to persist in science and who consider science learning to be socially desirable tend to develop higher interest in science (Dabney, Chakraverty & Tai, 2013). Other studies also show that parental education is positively associated with the number of mathematics and science courses students taken in high school (Simpkins, Davis-Kean, & Eccles, 2006). Chakraverty and Tai (2013) suggest that parents' occupation can create learning opportunities for their children and foster early interest in science courses and hence science career choices. This influence is usually explained in terms of role modeling, encouragement, exposure to science activities, and social networking (Chakraverty et al., 2018).

Empirical evidence also exists that family size plays a significant role in determining children’s career choice (Nugent et al., 2015; Shumba & Naong, 2012). When choosing their careers, adolescents often rely on the conditions in which they live and what they see around them, that is, their perception of the world around them (Shumba & Naong, 2012). Morand (1999) shows that family size and student success in natural sciences have a negative association. Nisbet (1953) suggests that this negative association is related to the fact that children in large size families interact less with their parents. Morand (1999) reports that children in large families tend to be shy and less interactive with peers. There is also recent evidence that younger siblings are more likely to choose a STEM field if their older sibling has attended a STEM program (Shahbazian, 2021). However, this study focused on Swedish families with only two-siblings, without considering variable family sizes. Therefore, given the available evidence and suggestions, we formulate the fourth hypothesis as follows:

H4. Students of larger families (in terms of number of siblings) are significantly less interested in STEM careers, compared to students of families with smaller sizes.

Overall, in the above literature, some findings contradict others, with several authors identifying the need for further research. For example, a few studies reported no significant difference in student STEM career interest across grade levels (Yerdelen, Kahraman, & Yasemin, 2016; Ünlü & Dökme, 2020). Plus, additional research is needed to determine whether the number of siblings may constitute an important familial factor that can influence students’ STEM career interest. Lastly, it is also important to determine whether student interest may vary across different STEM fields. As current statistics show, underrepresentation varies considerably across specific STEM fields, being considerably more prominent in the physical sciences (e.g., Physics) than in the biological sciences (e.g., Biology) (Hill et al., 2010; MacPhee & Canetto, 2015). Thus, it stands to reason that student career interest development in specific STEM fields is likely to vary as well. As described below, our instrument can make these more nuanced disciplinary distinctions. Rather than generating a single score for student interest in STEM at large, it produces a separate measure for student interest in science careers, technology careers, engineering careers, and mathematics careers.

Methodology

Instrument

In this study, we used a research instrument called *STEM Career Interest Survey* (STEM-CIS), which was originally developed by Kier, Blanchard, Osborne, & Albert (2014) to assess students' STEM career interest. The STEM-CIS is based on key aspects of Bandura's (1986) social cognitive theory of learning, conceptualizing student interest development in terms of a multiplicity of factors, including internal factors such as outcome expectations and self-efficacy (Lent, Brown, & Hackett, 1994, 2000), as well as external factors like contextual support and socio-institutional barriers. Validated on a sample of 1,061 students from grades 5-8 at seven schools in the south-eastern USA, the authors used Clark and Watson's (1995) six-stage approach for the development of scale items: (1) a literature review; (2) creation of a broad item pool to identify target aspect; (3) preliminary pilot testing of items; (4) structural analysis to eliminate irrelevant items from the pool of items; (5) factor analysis; and (6) creation of subscales.

STEM-CIS includes 44 items about science, technology, engineering, and mathematics. More specifically, respondents are provided a set of 5-point Likert scale scaled questions (1= “Strongly Agree”, 5= “Strongly Disagree”) measuring their interest in each of the four STEM domains (science, technology, engineering, and mathematics) separately. Each domain subscales consists of 11 items. Some examples of these items include: “I am able to get a good grade in my science class”; “I plan to use science in my future career”; “My parents would like it if I choose a mathematics career”; “I am interested in careers that use mathematics”; “I know of someone in my family who uses technology in their career”; “I am able to do well in activities that involve engineering”; and, “I know of someone in my family who is an engineer”.

We used this survey because: (a) it is a relatively new instrument; (b) it comprises science, technology, engineering, and mathematics subscales that allow for domain-specific measures of student interest; (c) the survey's psychometric properties had been tested with a sample of more than 1000 students; (d) its original pilot-testing sample comprised middle-school students, which was consistent with our sample; (e) test development stages were well implemented; (f) strong statistical analysis had already been conducted; and (g) in terms of language, survey items were very clear. Furthermore, STEM-CIS had been used in other recent studies (e.g., May et al., 2022) to evaluate the students' STEM career interest.

We used this survey to determine students' interest in careers in each of the four STEM domains and to determine whether it varied by gender, number of siblings, and grades in STEM subjects across middle- and secondary-school grade levels (i.e., to track students' interest development trajectory). The scale was adjusted after validation and evaluation in the examined sample of 396 Kazakh students, comprising 37 items, out of the initial 44, since 7 items did not meet the selected validation criteria of factor loading thresholds for the examined sample of participants. The scale was revalidated on the examined population based on previous literature suggestions on re-examining established scales on new populations (e.g., in different locations) to enhance them or test their appropriateness for the selected sample (Bahar-Ozvarıs et al., 2022; Vahidi et al., 2022).

Our participants were native speakers of Kazakh and Russian and had emerging proficiency in English. For this reason, the instrument was carefully translated to Kazakh and Russian by the second author who knows both languages at a native speaker level. Initial testing revealed that the wording of the translated items was sufficiently clear to participants, thus not requiring any further validation of the instrument. Additionally, two members of our research team were natives of Kazakhstan and as such approached this study from an emic perspective, whereas others adopted an etic perspective.

Participants and Data Collection

Convenience sampling techniques were used for recruitment of participants for this study due to their low-cost and timely nature (Balta, 2018). More specifically, three of the researchers involved in this study worked at the two NISs in Almaty at the time of data collection, and hence had ready accessibility to a student population of approximately 1200 students. To recruit participants, a Google Doc link to an online version of the instrument was sent via email to students. Two increase the response rate, we sent the email twice within a two-week interval and reminded students to fill in the survey during our classes. Overall, 416 students from grades 7th to 12th completed the online survey, which corresponds to a response rate of approximately 33%. After data cleaning, a total of 396 student responses were included in our analysis. Among these were 78 students from 7th grade, 46 students from 8th grade, 55 students from 9th grade, 75 students from 10th grade, 53 students from 11th grade, and 82 students from 12th grade.

The online survey also prompted students to fill in socio-demographic and academic background information like their age, gender, number of siblings, and previous grades in STEM classes. Students were also asked to rate their own academic performance in STEM classes they were taking at the time of data collection, using a 5-point Likert scale format that ranged from 1= "Fail" to 5= "Excellent." As depicted in Table 1, most students who participated in the survey had one sibling. Also, most of the students (56.6%) were female in the grade levels 12, 10 and 7. Table 2 depicts their average self-reported performance scores in Physics, Mathematics, Chemistry, and Biology.

This study was approved by the schools' Institutional Review Boards. Written consent was obtained from all students, and their parents were informed in advance about the benefits and risks of taking the online survey. Participation was completely voluntary, and students could withdraw from the study at any time. To ensure their anonymity, all survey data was securely stored and kept confidential.

Table 1. Students' socio-demographic characteristics (N=396).

Gender	N(%)	**Grade**	N(%)	**Siblings**	N(%)
Female	56.6	7th	16.4	1	68.9
Male	30.0	8th	9.7	2	26.3
N/A	0.9%	9th	11.6	3	3.3
		10th	16	4	1.0
		11th	11.6	5	0.5
		12th	18.1		

Table 2. Students' self-reported performance on STEM classes (range= [1-5]).

	Mean		SD
School Class	Statistic	Std. Error	Statistic
Physics	4.500	.030	.605
Mathematics	4.460	.032	.649
Chemistry	4.530	.0341	.690
Biology	4.56	.033	.669

Data Analysis

The test of normality ($p<0.05$) and the values of skewness and kurtosis revealed that the data was not normally distributed. In particular, the normal distribution of the data was not met in the measured variables for most of the categorical variables.

Before proceeding to the examination of the defined research hypotheses, we evaluated the research model for the selected sample. The model was evaluated through a partial least square structural equation modeling (PLS-SEM) confirmatory factor analysis (CFA) procedure. PLS was applied since it could consistently mimic common CB-SEM approaches (Dijkstra & Henseler, 2015) and it was considered more suitable for complex models and social science and exploratory research (Asyraf & Afthanorhan, 2013). The adopted research model (STEM-CIS) was evaluated in terms of reliability, validity, and internal consistency.

Nonparametric statistical methods were applied to examine the potential group-related differences in the student population. For this, a Mann-Whitney test was conducted to examine gender-based differences across the STEM-CIS components. A Kruskal Wallis Test was conducted to look for significant differences within grade-related groups, and groups with different family sizes. The software used for the PLS-SEM analysis was SmartPLS, while SPSS was used for the descriptive statistics and the analysis of the group differences.

Results

Validity of the Measurement Model

The PLS-SEM CFA results suggested a need for the modification of the initial 44 -items STEM-CIS scale (Kier et al., 2013) since some items resulted in nonvalid values of either Cronbach alpha or Average Variance explained (AVE) for the examined sample of students. Hence, all items scoring lower than 0.5 in factor loadings were removed from the model. Items S2, S6, S9 and S11 were removed from the Science component, M2 and M11 were removed from the Math component, and E11 was removed from the Engineering component. Although this adjustment might have affected the homogeneity of the components’ measurement, the following examinations reinforced the validity of the adjusted scale as adequate to measure the students’ levels of interest in careers in the four STEM domains.

The final items of the scale are depicted in Figure 1, along with their factor loadings and the Cronbach alpha value for every construct. The results demonstrated highly valid scores of factor loadings according to the recommendation of accepting 0.5 as the minimum value (Hoque & Awang, 2016). The values of Cronbach alpha were all above the accepted threshold of 0.7 (Dijkstra & Henseler, 2015).

[Insert Figure 1 Here]

As depicted in Table 3 all values of Composite Reliability (CR) were above 0.7 indicating internal consistency (Gefen, Straub, & Boudreau, 2000). Also, all values of Average Variance Extracted (AVE) were above 0.5 indicating convergent reliability (Chin, 2010; Fornell & Larcker, 1981).

Table 3. Reliability and validity results for the PLS-SEM CFA measurement model.

STEM Domain	Composite Reliability (CR)	Average Variance Extracted (AVE)
Engineering	0.946	0.640
Mathematics	0.900	0.502
Science	0.885	0.524
Technology	0.920	0.515

As shown on Table 4, the final measurement model also supported the discriminant validity between the STEM constructs/disciplines (Fornell, & Larcker, 1981). This result suggests that the adjusted scale supports the discriminant validity among the different contracts of STEM disciplines.

Table 4. Discriminant validity.

STEM Domain	Engineering	Mathematics	Science	Technology
Engineering	**0.800**			
Mathematics	0.474	**0.709**		
Science	0.460	0.499	**0.724**	
Technology	0.647	0.504	0.550	**0.718**

Finally, the resulting model fit indices (SRMR=0.069; Chi-Square=2.349.679, NFI=0.754,) indicated a good fit between the model and the observed data (Hair et al., 2010).

Descriptive Statistics

Table 5 below depicts the results of our statistical analysis of STEM Career Interest in each of the four domains (science, technology, engineering, and mathematics) for the entire student sample. Overall, students reported a medium level of interest (around 3.00/5.00) across all STEM domains. Science received the highest score, while Engineering received the lowest.

Tables 6, 7 and 8 show students’ interest in each STEM discipline categorized by gender (Male, Female) and grade level (from 7th to 12th grade) and number of siblings (from 1 to 3);

students with 4 and 5 siblings were excluded due to their extremely low number (N=4). As can be seen, males tended to express higher values of interest in all the STEM disciplines in relation to girls. Moreover, students in higher grade levels tended to be more interested in STEM careers in general. Students with more siblings tended to express higher levels of interest in certain STEM careers.

Table 5. Descriptive statistics for students' STEM career interest (whole sample)

	Mean		Std. Deviation
STEM Domain	Statistic [1-5]	Std. Error	Statistic
Science	3.773	.035	.709
Math	3.551	.037	.732
Technology	3.663	.036	.705
Engineering	3.256	.045	.864

Table 6. Descriptive statistics for students' STEM career interest by gender.

Gender	STEM Domain	Mean		Std. Deviation
		Statistic [1-5]	Std. Error	Statistic
Male	Science	3.834	.050	.648
	Math	3.678	.061	.775
	Technology	3.882	.050	.640
	Engineering	3.537	.069	.865
Female	Science	3.752	.049	.738
	Math	3.460	.047	.693
	Technology	3.520	.047	.698
	Engineering	3.049	.054	.7900

Table 7. Descriptive statistics for students' STEM career interest by grade level.

Science	Math	Technology	Engineering

Grade	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation
7th grade	3.661	.584	3.513	.577	3.428	.545	3.067	.593
8th grade	3.968	.699	3.577	.829	3.877	.609	3.365	.899
9th grade	3.789	.622	3.351	.609	3.451	.731	3.100	.750
10th grade	3.719	.760	3.408	.874	3.654	.773	3.160	.884
11th grade	3.807	.833	3.632	.763	3.721	.744	3.386	.894
12th grade	3.786	.733	3.790	.659	3.878	.686	3.511	1.045

Table 8. Descriptive statistics for students' STEM career interest number of siblings (1-5).

	Science		Math		Technology		Engineering	
Siblings	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation	Mean [1-5]	Std. Deviation
1.00	3.816	.716	3.576	.763	3.678	.732	3.2371	.906
2.00	3.674	.685	3.438	.624	3.629	.588	3.2860	.682
3.00	3.705	.767	3.969	.753	3.629	.588	3.5556	1.002
4.00	3.404	.125	3.148	.357	2.757	1.021	2.4000	1.979
5.00	4.285	1.010	4.166	.707	4.151	.685	4.6000	.688

Differences in Students' STEM Career Interest across Disciplines

Tables 8, 9, 10 and 11 show the results of the statistical analysis conducted to determine whether there were significant differences in student STEM career interest associated with gender, grades in STEM classes, and number of siblings.

As depicted in Table 9, there were significant differences in STEM career interest between genders ($p < 0.05$) across most of the STEM domains. Female students expressed significantly lower interest in the disciplines of mathematics, technology, and engineering (Table 6). In contrast, no statistically significant difference was detected in the domain of science.

Table 9. Mann-Whitney test (grouping variable: gender).

	Science	Math	Technology	Engineering
Mann-Whitney U	16953.500	14091.500	12046.000	11154.000
Wilcoxon W	41706.500	37527.500	34837.000	33309.000
Z	-.960	-3.064	-4.851	-5.226
p (2-tailed)	.337	**.002**	**.000**	**.000**

There were statistically significant differences in STEM career interest between students with high and low grades in physics, mathematics, chemistry, and biology classes. As depicted in Table 10, students with high grades in physics classes were significantly more interested in careers across all four STEM domains ($p<0.05$) than students with low grades in physics. Furthermore, students with high grades in mathematics and chemistry classes were also significantly more interested in careers in science, mathematics, and engineering ($p<0.05$) than low-performing students. Lastly, students with high grades in biology were significantly more interested in careers in the domains of science and engineering than low-performing students ($p< 0.05$).

Table 10. Kruskal Wallis test (grouping variable = class grades).

Grouping variable	Physics			Mathematics			Chemistry			Biology		
STEM Domain		df	p		df	p		df	p		df	p
Science	42.861	4	**.000**	37.640	4	**.000**	33.591	4	**.000**	54.899	4	**.000**
Math	29.214	4	**.000**	29.793	3	**.000**	9.734	4	**.045**	5.764	4	.218
Technology	35.321	4	**.000**	7.287	3	.063	5.163	4	.271	7.945	4	.094
Engineering	22.517	3	**.000**	13.951	2	**.001**	16.382	4	**.003**	9.081	3	**.028**

Regarding grade levels, it was found that there are significant differences in interest in mathematics, technology, and engineering ($p<0.05$) between students in higher and lower grade levels (see Table 11). Additionally, eighth-grade students were the most interested in careers in the science domain, while twelfth-grade students were the most interested in maths and engineering (see Table 7). In contrast, eighth- and twelfth-grade students were equally interested in technology careers.

Table 11. Kruskal Wallis test (grouping variable: grade levels).

	Science	Math	Technology	Engineering
χ^2	7.852	15.660	29.393	13.021
df	5	5	5	5
p.	.165	**.008**	**.000**	**.023**

As can be seen in Table 12 combined with Table 8, students from larger families with multiple siblings (2-3) were significantly more interested in mathematics careers than students from smaller families (1 sibling). Additional analysis in Table 3, revealed that all questionnaire items related to family and role model (e.g., M6= "My parents would like it if I choose a mathematics career," M9= "I have a role model in a mathematics career," and M11= "I know someone in my family who uses mathematics in their career") were significantly correlated with student interest in careers across all four STEM domains. This finding confirms the important role of family in influencing student interest in STEM careers in general, an issue that is discussed further in the later sections.

Table 12. Kruskal Wallis test (grouping variable: number of siblings).

	Science	Math	Technology	Engineering
χ^2	3.298	6.939	.929	.986
df	2	2	2	2
p	.192	**.031**	.628	.611

Table 13. Correlation test between family- and role-models-related items and students' STEM career interest.

		Science	Math	Technology	Engineering
M6	Correlation Coefficient	**.222****	**.666****	**.314****	**.372****
	Sig. (2-tailed)	.000	.000	.000	.000
M9	Correlation Coefficient	**.253****	**.674****	**.318****	**.332****
	Sig. (2-tailed)	.000	.000	.000	.000
M11	Correlation Coefficient	**.186****	**.362****	**.313****	**.124***
	Sig. (2-tailed)	.000	.000	.000	.018

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Note. M6= "My parents would like it if I choose a mathematics career.", M9= "I have a role model in a mathematics career.", M11= "I know someone in my family who uses mathematics in their career."

Discussion

We now discuss the significance of the findings derived from our statistical examination of each stated hypothesis.

Gender and Interest in STEM Careers

The first hypothesis stating that "*Kazakh female students are significantly less interested in STEM careers compared to their male counterparts*" was largely confirmed since Kazakh female students' career interest in the fields of mathematics, technology and engineering were indeed significantly lower compared to their male counterparts. This finding is consistent with previous research showing that female interest in engineering and computer science careers tends to be particularly low as evident by their pronounced underrepresentation in these STEM fields (Scantlebury, & Baker, 2007). STEM careers that involve physical, technical, or manual work (manufacturing, construction, etc.) such as engineering and technology are stereotypically viewed as 'masculine,' and hence not suitable for girls (Hill, Corbett, & St Rose, 2010; Association for Computing Machinery (2009). In contrast, female interest in scientific careers like biology and chemistry, which are stereotypically perceived as being more feminine and appropriate for girls, tends to be higher as evident by their relatively higher representation in these STEM fields (Luo et al., 2019; Riegle-Crumb et al., 2012; Wyer et al., 2008). As reported, similar trends are also prevalent in Kazakhstan.

In accounting for the above trend, Lubinski & Benbow (2007) argue that fields like biology and chemistry are commonly seen as being more closely linked with "people," whereas the engineering and computer science are perceived as being about "things" and often are not viewed as directly benefiting society (National Academy of Engineering, 2008). Because females are people-oriented, they tend to gravitate toward the former fields (Eccles & Wang, 2015; Haun-Frank, 2011). Also prevalent in Kazakhstan (Almukhambetova & Kuzhabekova, 2020), such stereotypes could have negatively impacted female students' interest, and thus biased their STEM career interest away from fields perceived to be more thing-oriented (Shapiro & Sax, 2011).

Scholars also report that negative stereotypes about women in mathematics are still prevalent and can negatively impact female students' career interest in STEM fields. One major stereotype identified by Hill, Corbett and St Rose (2010) is a general belief that girls are not as good in mathematics as boys, and secondly, that science is better suited to boys than girls. When women are exposed to these negative beliefs, their aspirations as well as their performance on academic measures are affected. This phenomenon is referred to as the *stereotype threat*. As a result of this threat, girls may attempt to reduce the likelihood that they will be judged through the lens of negative stereotypes by saying they are not interested and by avoiding these fields (Hill, Corbett & St Rose, 2010, p. 38). Stereotype threat also helps explain why fewer Kazakh girls than boys expressed career interest in STEM domains perceived to be more mathematically oriented.

To address the above stereotypes and increase female student interest in fields like engineering and mathematics, it is recommended for students to be introduced to female engineers and mathematicians (i.e., role models) who are improving society, offering solutions to real-world challenges, and helping promote health, happiness, and safety (Baker, 2013). Similarly, MacPhee, Farro and Canetto (2013) suggest that mentoring is one of the most promising means for improving female students' self-efficacy toward STEM fields. Female students with supportive mentors tend to develop STEM identities and increased self-efficacy, which are conducive to increased interest in STEM careers.

Family support is essential for girls to become interested in pursuing STEM careers in countries where gender stereotypes exist (Ikkatai et al., 2019; Tzu-Ling, 2018). In these countries, parents have an important role to play in countering sociocultural career expectations. Chakraverty (2018) describes how a father was able to successfully encourage his daughter to pursue medicine, a historically male-dominated field by actively deconstructing these gendered perceptions. Also, as suggested by Shahbazian (2021), young girls tend to be more interested in STEM careers if their older sisters are also interested. In close alignment, Maltese and Tai (2010) identify family as an important source of STEM career interest for a quarter of female students in the US. On the other hand, girls growing up in a boy-biased family tend to score lower on mathematics tests when compared to girls raised in other types of families (Dossi et al., 2021). These studies consistently highlight family as a key influence on young girls' development in

STEM career interest, being consistent with our finding that familial support and family role models were significantly correlated with Kazakh students' interest across all four STEM domains.

Previous research in Western countries has shown that, to develop STEM career interest, female students need supportive learning environments that have an altruistic orientation (focused on helping others) (Haun-Frank, 2011), that are aesthetically rich, and that integrate Art with STEM (STEAM) (Maeda, 2013; Radziwill, Benton, & Moellers, 2015). These have been shown to be essential pedagogical features of learning experiences designed to foster self-efficacy (Miles & Naumann, 2021). These pedagogical features can all be found at NISs. For instance, "art and technology" is emphasized in the school curriculum, being taught for 2-4 hours a week. As part of this subject, students learn to draw, design, and create various engineering structures. Students' best work is displayed in a school exhibition and national events (e.g., competitions). Additionally, students are given opportunities to participate in projects aimed at solving societal problems and draw connections between the content learned and real life through discussion and reflection.

After School programs have also been shown to increase female student self-confidence in STEM (Hayden et al., 2011). Similarly, all students have access to a collaborative afterschool program. As part of this program, female students can join small groups and participate in extra-curricular lessons in robotics, drawing, and pottery for approximately two hours a week.

Grades and Interest in STEM Careers

Regarding the second hypothesis ("*Kazakh students who obtained high grades are significantly more interested in STEM careers compared to the students who obtained lower* *grades*”), our results indicated several significant differences in STEM career interest between students with high and low performances in physics classes. Such a finding is consistent with previous research underscoring the importance of high school physics as a gateway to STEM fields. Hazari, Tai, & Sadler (2007) report that stronger grades in introductory physics can build confidence and interest in females and can also encourage females to become interested in STEM careers. Griffith (2010) shows that high school females who take more advanced courses in the STEM fields are more likely to major in STEM. Like the present study, this literature highlights the critical role that secondary school coursework can play in influencing female students’ future decisions to study STEM at the undergraduate level. During high school, female students’ career interest in STEM can be influenced by the specific courses they take. Taking courses such as physics can provide female students with critical opportunities to dispel stereotypes and to develop a new sense of self as individuals who are interested in STEM majors. Consistent with this recommendation, all NIS students, including girls, must take physics, chemistry and biology courses starting from the 7th grade, hence making it six years of learning science subjects upon graduation. Additionally, most NIS teachers of STEM subjects are female; the only exception is physics with only about 25% of female teachers.

Grade Level and Interest in STEM Careers

Our third hypothesis that “*there are statistically significant differences in Kazakh students’ STEM career interest across different grade levels*” was confirmed in three out of four STEM disciplines. As described above, students in the twelfth grade expressed the highest levels of interest in mathematics, technology, and engineering. In contrast, the lowest levels of interest in technology and engineering careers were reported by the younger students in seventh grade, and ninth grader were the least interested in mathematics careers.

Our findings are in accordance with previous studies reporting fluctuation in student STEM career interest across different grade levels (Christensen & Knezek, 2017; Cohen et al., 2021; Maltese & Tai 2011; Ünlü & Dökme, 2020; Yerdelen, Kahraman & Yasemin; 2016). Student career interest is continuously evolving during the middle- and high-school years. Maltese and Tai (2011) report that 10th grade may be a significant academic year in student development of interest in pursuing advanced study in STEM majors. MacPhee, Farro & Canetto (2013) also points out that female students’ self-efficacy in STEM drops in middle school and remains low through high school. Plant et al. (2009) provides evidence that girls’ self-efficacy and interest in engineering can be fostered as early as middle school. Combined, these studies underscore the importance of grade level as a critical factor that needs to be considered in any effort aimed at fostering interest in STEM fields.

Family Size and Interest in STEM Careers

Number of siblings was positively associated only with student interest in mathematics careers. However, our hypothesis that “*students of larger families (in terms of number of siblings) are significantly less interested in STEM careers, compared to students of families with smaller sizes*” was not confirmed. The reported finding is consistent with previous studies showing that family can play a significant positive role in increasing students’ interest in STEM careers (Crisp, Nora, & Taggart, 2009; Dossi et al, 2021; Ellington & Frederick, 2010; Maltese & Tai, 2010; Moore, 2006), including siblings (Shahbazian, 2021). Although previous research suggests that children in larger families tend to be shyer (Nisbet, 1953) and interact less with their parents (Morand, 1999) and for these reasons do not usually succeed in natural sciences, recent research underscores the complexities of family dynamics. For instance, in addition to family size, other important familial factors include the relationship between the siblings, and age and gender differences (Shahbazian, 2021).

As indicated above, previous research highlights the importance of family, particularly parents, as a source of support, mentoring, and motivation for students to persist in high school or select STEM careers (Ikkatai et al., 2019; Tey et al., 2020; Tzu-Ling, 2018). Stinson (2008) describes how student interest in STEM was connected to students' fear of disappointing family and the ability to observe a family member who had benefited from formal education by achieving financial success. The present study makes a novel contribution to this literature by expanding the research focus beyond parents. As our results suggest, siblings also seem to play an important role in shaping students' development of interest in mathematics careers. However, the exact nature of this influence remains to be qualified by future research.

Conclusion

Interest has been recognized as one of the most influential factors behind students' STEM career choices. Researchers overall agree that early exposure (beginning at middle school) and active participation in carefully designed STEM-related activities can significantly leverage students' interest in pursuing STEM as a profession. However, as our findings have shown multiple internal and external factors (some beyond the classroom and the school) should be simultaneously considered. Specifically, our statistical results demonstrated a set of significant differences in student STEM career interest:

- Female students were generally less interested in STEM careers than male students.

- Students with higher grades in physics classes were significantly more interested in STEM careers than low-performing students.
- students at higher grade levels were generally more interested in STEM careers than those in lower grade levels.
- Number of siblings was positively associated with student interest in mathematics careers.
- Familial support and family role models were significantly correlated with student STEM career interest.

Rather than being determined by a single internal factor (e.g., genetic predisposition), student development of STEM career interest was shown to constitute an epigenetic phenomenon, being simultaneously related to multiple external factors. Consistent with socio-ecological perspectives on schooling (Bronfenbrenner, 1979; Oliveira et al., 2013), STEM career interest was shown to be related to influences situated at multiple contextual levels, including students’ classroom microsystem, their school mesosystem, and their societal macrosystem.

Our results underscore the need for science educators interested in promoting student interest in STEM careers to go beyond implementation of isolated practices at the classroom microsystem level. Such an approach is not only too simplistic but also inconsistent with the highly complex and dynamic nature of student interest development. As emphasized by Stigler and Hiebert’s (1997), previous efforts

> aimed at engendering educational improvement have been excessively focused on discrete features of teaching such as materials, questioning type, and small group instruction rather than on the process as a whole that manifests itself as ‘‘a system of tightly connected elements’’ (p. 17).

Instead, what is needed is a more holistic approach informed by careful consideration of the myriad of internal and external factors (e.g., gender, self-efficacy, outcome expectations, family values, cultural stereotypes, etc.) that may influence student development of STEM career interest.

Rather than being reflective of academic ability, female underrepresentation in STEM fields such as computer sciences is a direct consequence of oppressive and undemocratic gender-technology relations engineering (Hill, Corbett, & St Rose, 2010). Throughout history, use of technologies has been socially constructed as either masculine (e.g., using mechanic tools to fix cars) or feminine (e.g., using the electric iron to press clothes) (Lohan, 2001). As such, technology and technical skill can be shaped by masculinist ideologies and prevalent gender stereotypes that too often discourage women from becoming engineers (Kvande, 1999; Gasmo, 2003). Bray (2007) illustrates this problem of inequitable co-production of gender and technology as follows:

> "An electric iron is not technology when a woman is pressing clothes, but it becomes technology when her husband mends it. A female engineer who tests microwave ovens is told by her male colleagues that her job is just cooking" (p.42)

Dispelling such long standing societal stereotypes is not a simple task as it requires renegotiation of traditional gender-technology relations characteristics of a country's culture through active participation of parents and other family members. This is essential if educators are to succeed in their efforts to increase female representation in the STEM fields. Female students are unlikely to grow interested in STEM careers if they continue to have to worry about questions such as "Is it appropriate for girls to become interested in STEM?", "Are my parents going to disapprove of this?" and "Am I going to be judged?"

Although we carefully designed and undertook this study, some findings should be interpreted with caution given methodological limitations. First, the results of this study may have been biased due to our reliance on self-reported and quantitative survey data. Future research would benefit from the inclusion of interviews/focus groups, observations, and qualitative methodology. Such a mixed-methods approach would likely provide phenomenological insights into students’ experiences in school as well at home and allow students to account for their STEM career interest development in a voice their own. This qualitative analysis could be conducted in a thematic or scalar manner as described in Luo and Chan (2022).

It must also be acknowledged that the generalizability of our results could be limited due to our use of convenience sampling (a non-representative sample) in two single schools in Kazakhstan that were attended by what can be considered a gifted student population, as well as cultural differences to other parts of the country. Like the present study, this additional research will likely provide science educators worldwide with new insights into how to inspire student interest in STEM, particularly those whose participation may be discouraged by inequitable cultural contexts.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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