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Research article

Examining STEM attitudes for Chinese senior pupils in primary school

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Abstract: This study aimed to determine pupils' attitudes about STEM (science, technology, engineering, and mathematics) in China. A survey questionnaire was used to collect data from senior primary school pupils for a quantitative research study into their attitudes towards STEM. The survey collated attitudes towards three STEM subject subdimensions (i.e. mathematics attitude, science attitude, engineering and technology attitude) and STEM career interest using 42 items. Online data were collected from 864 senior primary school pupils (664 fifth graders, and 200 sixth graders). The data analysis included descriptive analysis and correlation analysis, specifically Pearson's and Spearman's rank correlations. The descriptive analysis showed that the STEM attitudes of Chinese senior primary school pupils were at a moderate level. The correlation analyses showed significant relationships between STEM attitudes and gender, grade, STEM experience or a lack of STEM experience, and parents' educational background.

Keywords: STEM attitudes, senior pupils, primary school, China

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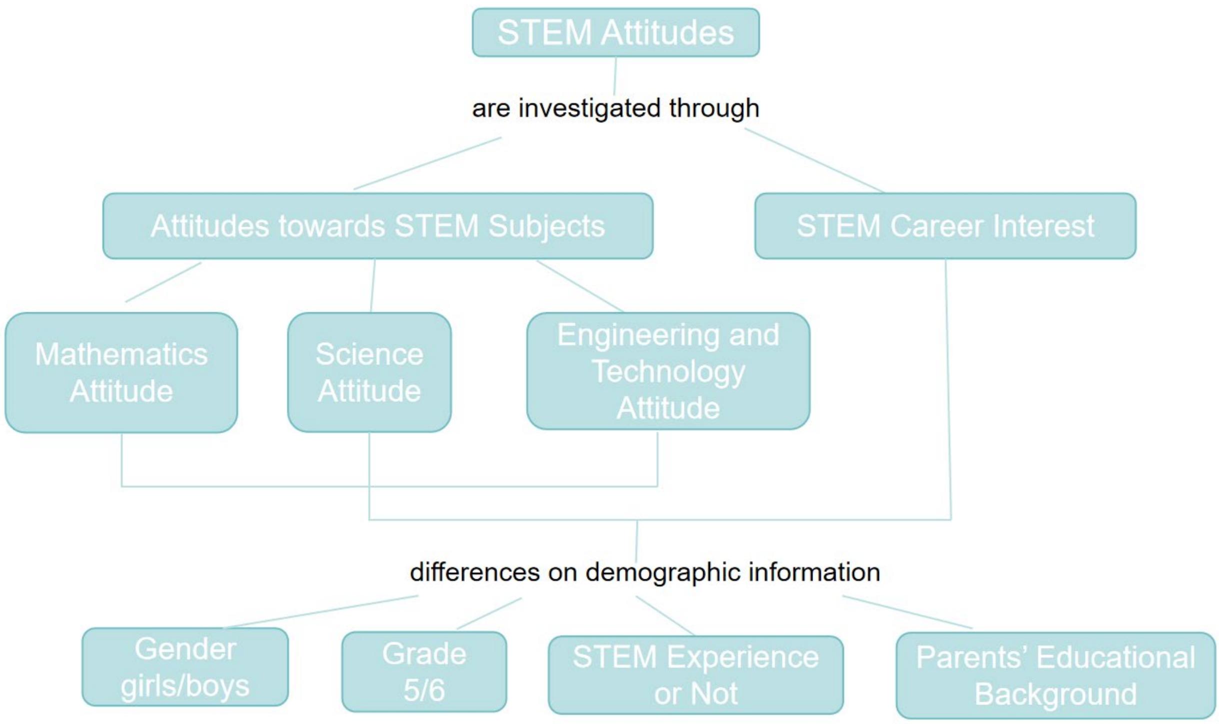

1 Introduction

STEM is an acronym that refers to the four educational disciplines of science, technology, engineering, and mathematics. STEM education is regarded as an effective strategy for solving social problems in the twenty-first century (Herranen et al., 2021). As essential components of the modern world of the industrial 4.0 era, it has been argued that STEM subjects should be incorporated into education to support pupils integration of knowledge across disciplines via formal or informal learning and to foster higher-order thinking, such as problem-solving, creativity, engineering thinking, etc. (Li et al., 2019; Rifandi & Rahmi, 2019; Sarican & Akgunduz, 2018; Supian et al., 2023). Quality STEM education is essential for assisting pupils to develop the necessary abilities to function in today's dynamic modern environment from an early age (Lundell et al., 2023).

The term "attitude" refers to the learning predisposition of a person to react favourably or unfavourably to an item, circumstance, concept, or another person (Kurniawan et al., 2019; Mazana, 2018). STEM attitudes refer to attitudes towards STEM subjects. According to Irwanto et al. (2024), STEM attitudes involve pupils' knowledge, feelings, and actions towards STEM subjects. They also reflect a mix of self-efficacy and expectancy-value beliefs in STEM (Ching et al., 2019; Eccles & Wigfield, 2002; Unfried et al., 2015). Based on expectancy-value theory, a person's internal opinion about how well they will succeed on an upcoming assignment, both in the present and the future, is referred to as their expectations for success (Wigfield & Cambria, 2010). Stated differently, expectancies encompass internal beliefs that could impact future motivation and task selection. For instance, a student who might think they have significant engineering-related abilities would be more likely to perform well on future engineering-related tasks (Ball et al., 2017).

The ABC model of attitude (Jain, 2014) consists of three components: affective, behavioural, and cognitive. The affective component refers to an individual's emotional reaction based on neural processing, such as whether they like or dislike an object. The behavioural component refers to a person's visible behaviours and responses, as well as their behavioural propensity towards an attitude object in the form of a favourable or unfavourable action. The cognitive component refers to a person's assessment of what has created their opinion (belief or unbelief) of the objects.

In this study, STEM attitudes refer to pupils' attitudes towards STEM subjects and STEM career interest (Erkut & Marx, 2005; Faber et al., 2013). When combined with the ABC model of attitude, pupils' attitudes towards STEM subjects encompass their enjoyment, performance, and achievements in these subjects, their perceptions of their usefulness, and their STEM abilities. From the perspective of the behavioural component of the ABC model of attitude, STEM career interest refers to pupils' behavioural tendency to work in a STEM career in the future.

There is an urgent need for STEM talents, as they are deemed to be able to solve resource shortages, environmental problems, military technology challenges, etc., which are global issues that are encountered by all countries, including China (National Institute of Education Science, 2017). Studies show a strong correlation between pupils' views towards STEM, their choice of subjects, and their subsequent involvement in STEM fields (Maltese & Tai, 2011; Regan & DeWitt, 2014; Simpkins et al., 2006). For example, Maltese and Tai (2011) found a link between children's increasing interest in science and mathematics in primary school and their choice of STEM degree. Similarly, late elementary school pupils' interest in mathematics and science predicts their high school course choices (Simpkins et al., 2006). Therefore, it is necessary to study the STEM attitudes of primary school pupils.

Achieving gender equality and empowering all women and girls is one goal of the Sustainable Development Goals 2030 Agenda. However, there is gender inequality in STEM fields in that, in the UK, only 22% of STEM talents are women (WISE, 2018); in the USA, this figure is only marginally higher at 24% (Noonan, 2017). STEM is usually considered to be a male-dominated field (Kurz et al., 2015). The Chinese Science Curriculum Standard for Compulsory Education in 2022 (Ministry of Education of the People's Republic of China, 2022) specifies that science education that incorporates technology and engineering in a broad sense and cultivates students positive science attitudes should cover all children and provide equal chances and opportunities for them. However, gender differences in pupils' attitudes towards STEM have been seldom studied in China.

Attitudes may change and develop over time (Syyeda, 2016), although a variety of researchers have confirmed the positive effects of STEM education on enhancing pupils' STEM attitudes (e.g. Blažev et al., 2019; Ching et al., 2019; Erkut & Marx, 2005; Guzey et al., 2014; Sun et al., 2021). Studies also show that pupils' motivation to study STEM subjects varies depending on their age, and there is a sharp decrease from elementary to secondary school (Hofer, 2021; Krapp & Prenzel, 2011; Laine et al., 2020).

Parents' involvement in education, social resources, financial support, and pupil cognition, may be vital factors for pupils' success in school (Schneider & Coleman, 2018). STEM attitudes are also probably influenced by parents' education level (Uerz et al., 2004) and people, such as parents and teachers, who are STEM professionals (Sjaastad, 2012) and who may help pupils' STEM selection process by setting goals, recognising the value of STEM, etc.

STEM attitudes develop at an early age. A person's interest in science has a significant role in their decision to pursue it and commonly develops from a young age (Ainley & Ainley, 2011; Maltese & Tai, 2011; Tai et al., 2006). Tai et al. (2006) indicate that a physical science and engineering degree is 3.4 times more likely to be obtained by undergraduates who had anticipated working in the scientific field by the age of 14 compared to those who did not. Most scientists state that their interest in science dates back to before middle school (Maltese & Tai, 2011).

The 2017 White Paper on STEM Education in China (National Institute of Education Science, 2017) highlights the significant shortage of high-level scientists, technologists, and engineers in China and emphasises the significant role that education plays in enhancing human resources and optimising China's infrastructure. In China, there are three elementary school stages: junior stage (Grades 1–2), middle stage (Grades 3–4), and senior stage (Grades 5–6). Even though the new science curriculum standard in 2022 for students in elementary school (Grades 1–6) and secondary school (Grades 7–9) requires a science curriculum from Grade 1, pupils in the current Grades 5–6 only began to take science classes from Grade 3 in most areas and schools.

Hence, in this study, we investigated Grades 5–6 students to guarantee them having at least two years of science learning experiences. Moreover, there are no special engineering and technology-related courses in most Chinese primary schools; therefore, students in Grades 1–4 have limited experience with it. In contrast, students in Grades 5–6, who are in the last two years of primary school, have accumulated certain experiences related to STEM in learning and their lives and can understand and complete the survey.

Additionally, Grade 5 and Grade 6 pupils both belong to the senior stage in primary school, but those in Grade 6 have more academic pressure due to their imminent entry to secondary school, and they typically pay more attention to traditional core courses, such as Chinese and mathematics. As aforementioned, the STEM attitudes of elementary school senior students play an important role in the selection of their major subject and career pathways related to STEM fields and have been studied in primary schools beyond China. However, the STEM attitudes of senior grades in Chinese primary schools remain unclear. Hence, this study aimed to identify the STEM attitudes of Grade 5 and Grade 6 students (aged 10–13 years old) in China using a cross-sectional survey. We also looked to examine the factors related to STEM attitudes: gender, grade, STEM experience or not, and parents' education qualifications.

The research questions are as follows:

1. What are the STEM attitudes of senior pupils in Chinese primary schools?
2. Is there any relationship between the STEM attitudes of Chinese senior primary school pupils and their gender, grade, STEM experience or not, and parents' educational background?

2 Methods

2.1 Design

This study was a quantitative research design, specifically a descriptive cross-sectional survey utilising a questionnaire, to examine senior primary school pupils' attitudes towards STEM in China. The differences in STEM attitudes were examined based on gender, grade, STEM experience or not, and parents' educational background.

The study employed a cluster sampling method. First, to identify the provinces participating in the study, China's 32 provincial administrative units were divided into four areas according to geographic position: north, south, east, and west provinces. One province was selected from each area at random to participate in the study: Shanxi

Province, Guizhou Province, Jiangsu Province, and the Nei Mongol Autonomous Region. Next, one city, from each province was selected at random. This was followed by a random selection of one district from each city, and finally, two primary schools (one rural and one urban) from each of the four districts, making eight schools in total. The participants were students in Grades 5–6 in these selected schools, who volunteered for the survey. There are over 30 million students in Grades 5–6 in Chinese primary schools. According to Krejcie and Morgan (1970), the sample size should be around 380 when the population is more than 25,000. There were 864 participants in this study.

2.2 Participants

In total, 864 senior primary school pupils took part in the online questionnaire from four provinces in China. The demographic information was as follows: girls 46.6% (n = 403), boys 53.4% (n = 461); 19.9% (n = 172) 10-year-olds, 42.9% (n = 371) 11-year-olds, 33.8% (n = 292) 12-year-olds, 3.4% (n = 29) 13-year-olds, 76.9% (n = 664) Grade 5, 23.1% (n = 200) Grade 6.

The percentage of mothers with a primary school educational background was 6.1% (n = 53), 31.1% (n = 269) achieved middle school, 27.3% (n = 236) high school, and 35.4% (n = 306) university and above. The percentage of fathers with a primary school educational background was 4.9% (n = 42), 28.1% (n = 243) achieved middle school, 29.5% (n = 255) high school, and 37.5% (n = 324) university and above.

2.3 Instruments

There were two parts to the Primary School Survey. Part 1 collected the senior primary school pupil's demographic information: province, gender, age, grade, STEM experience, and parents' educational background; Part 2 collected their attitudes towards STEM.

This study adapted the Upper Elementary School Student Attitudes toward STEM (S-STEM) Survey – 4–5th (Faber et al., 2013), which was designed to test upper primary school pupils' (Grades 4–5) attitudes towards STEM subjects and STEM career interest. The S-STEM Survey has two main dimensions: (1) Overall attitudes towards STEM subjects, which assesses overall STEM subject attitudes and three separate attitude subdimensions (mathematics, science, engineering and technology) and (2) STEM career interest. Overall, there are 42 items: 30 items for STEM subject attitudes (10 for mathematics, 11 for science, 9 items for engineering and technology), and 12 items for STEM career interest. Each item was assessed on a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree.

A minimum of three content experts are recommended for the validation of an instrument (Lynn, 1986). In this study, three experts audited and rated the S-STEM Survey using a score of 1-10 (Expert 1 was a doctor/professor, focusing on pedagogy, teaching and learning of science education, Expert 2 was an associate professor, focusing on curriculum and teaching, and Expert 3 was a doctor/senior lecturer, focusing on STEM education and basic education). The suggestion from Expert 1 that some items related to mathematics and science subjects' values should be added to the survey was considered.

The content validity index (CVI) was calculated according to the Aiken formula: $V = \frac{\sum S}{n(c-1)}$. The CVI of the S-STEM Survey was .86. Based on the categorisation of content validation by Guilford (see Divayana et al., 2019), the survey had a very high validity. Additionally, it was translated from English into Chinese. An associate professor, majoring in foreign language linguistics and applied linguistics, was invited to check the language validity of the instrument. The expert affirmed the feasibility of the Chinese version of the instrument, stating that the dimensions were clear, the language was well-organised and easy to understand, and the instrument could serve the research purpose well.

In a pilot study of senior primary school pupils, Cronbach's alpha was employed to assess the internal consistency and reliability of the instrument. Cronbach's alpha for the full S-STEM Survey was .89, for the overall attitudes towards STEM subjects dimension it was .89 (mathematics attitude = .85, science attitude = .78, engineering and technology attitude = .83), and for the STEM career interest dimension it was .83. As the Cronbach's alphas were all above .70 (Gliem & Gliem, 2003), it was determined that the reliability of the S-STEM Survey was acceptable.

2.4 Procedure

The questionnaire was delivered online via the Wenjuan Xing platform to obtain a wide range of participants. All the participants completed the survey voluntarily. The questionnaire was anonymous, and no private information, such as name, email address, etc., was collected. No reward or compensation was offered to the participants. The researcher asked primary school teachers to send the questionnaire link to potential participants and their parents, and pupils completed the questionnaire of their own choice and with the permission of their parents.

2.5 Data analysis

The collected data was analysed using IBM SPSS 26. According to Sullivan and Artino (2013), Likert scale ordinal data can be analysed using parametric tests when the sample size of each group is greater than 5–10 and the data is normally distributed. Furthermore, parametric tests for ordinal data, including Likert scales, are more robust than nonparametric tests, even if the data is not normally distributed (Norman, 2010). In this study, the mean score and standard deviation (SD) were used to report pupils' STEM attitudes by calculating the arithmetic mean of the items for the full survey and its various dimensions and subdimensions. The point-biserial correlation, a Pearson product moment correlation used for one continuous variable and one dichotomous variable, was used to check the relationship between STEM attitudes and gender, and STEM attitudes and STEM experience or not. In addition, the Spearman rank order correlation (*rho*) was employed to assess the relationship between STEM attitudes and pupil grade, mothers' educational background, and fathers' educational background. Assumptions regarding outliers, normal distribution, and Levene's test of equality of variances for equal variances were examined, with no serious violation.

3 Results and discussions

This study investigated senior primary school pupils' STEM attitudes in China; the findings are discussed below.

3.1 Senior pupils' STEM attitudes in primary school

As can be seen in Table 1, the mean score for the full S-STEM Survey was 3.44 (SD = .66). The mean score for the overall attitudes towards STEM subjects' dimension was 3.55 (SD = .66), while for the mathematics attitude subdimension it was 3.48 (SD = .78), for science attitude it was 3.57 (SD = .72), and for engineering and technology attitude it was 3.59 (SD = .88). The mean score for the STEM career interest dimension was 3.13 (SD = .88). The results show that Chinese senior primary school pupils' STEM attitudes were at a moderate level, for a response range from 1 to 5.

Based on Table 1, Chinese senior primary school pupils had neutral attitudes towards STEM. A survey of almost 10,000 fourth-grade to twelfth-grade pupils also showed moderately positive attitudes toward STEM (Faber et al., 2013). The results here were consistent with Ching et al. (2019), who reported that 18 fourth- to sixth-grade primary school pupils' mathematics and science attitudes were at a moderate level, while their engineering and technology attitudes were at a high level. Sun et al. (2021) also found that primary pupils' STEM learning attitudes were at an upper to mid-level, meaning that primary pupils had positive learning attitudes towards STEM. This finding is beneficial for teachers and educators looking to understand the current level of Chinese pupils' attitudes towards STEM and make informed decisions to improve it.

Table 1. Senior pupils' STEM attitudes in primary school

Dimensions	N	Min.	Max.	M
Overall attitudes toward STEM subjects	864	1.30	5.00	3.55
Mathematics attitude	864	1.10	5.00	3.48
Science attitude	864	1.09	5.00	3.57
Engineering and technology attitude	864	1.00	5.00	3.59
STEM career interest	864	1.00	5.00	3.13
Full S-STEM Survey	864	1.26	5.00	3.44

3.2 Relationship between senior primary school pupils' STEM attitudes and gender

Table 2 shows the point-biserial correlations, run to determine the relationship between STEM attitudes (full survey, dimensions, and subdimensions) and gender. The results showed that there was a positive correlation between STEM attitudes and gender, which was statistically significant in all cases ($p < .05$). Boys had more positive attitudes than girls in all cases.

Table 2. The Pearson correlation between senior pupils' STEM attitudes in primary school and gender

Dimensions	**Gender**	**N**	**M**	**SD**	**n**	**r**	***p* (2-tailed)**
Overall attitudes towards STEM subjects	Girls	403	3.41	.65	864	.20**	.00
	Boys	461	3.67	.64			
Mathematics attitude	Girls	403	3.32	.80	864	.19**	.00
	Boys	461	3.62	.74			
Science attitude	Girls	403	3.50	.69	864	.10**	.00
	Boys	461	3.64	.73			
Engineering and technology attitude	Girls	403	3.41	.79	864	.20**	.00
	Boys	461	3.74	.82			
STEM career interest	Girls	403	3.01	.86	864	.12**	.00
	Boys	461	3.23	.89			
Full S-STEM Survey	Girls	403	3.31	.65	864	.19**	.00
	Boys	461	3.56	.65			

Gender stereotypes favouring males in STEM fields may explain these differences; boys are considered to be more fit and capable in STEM than girls (Master & Meltzoff, 2016, 2020). The results here are in line with Zhou et al. (2019), who found that boys' STEM attitudes were higher than girls in primary school, but there were no statistical differences. The results are also consistent with Wiebe et al. (2018), who found that males have more positive attitudes towards STEM subjects than females (but again, there were no statistical differences); however, their results showed that in STEM career interest, males were more positive in the core STEM cluster, such as physics, mathematics, computer science, engineering, etc., which are commonly considered as STEM, while females were more positive in the bio/med STEM cluster, which contained biology and medical careers. In contrast with our results, Ugulu (2020) showed that gifted girls had more positive attitudes towards science than boys in Grades 5, 6, and 7 (but found no statistical difference), while Rezayat and Sheu (2020) report that both American and Chinese undergraduate females show more STEM career interest than males, but their results may be challenged by the social reality and cultural bias. However, another study claims that the same perception and interest in STEM differences appear between girls and boys in primary school (Kurz et al., 2015).

Our findings indicate that there is still a gap between genders in STEM attitudes for Chinese primary pupils. To narrow the gap, some measures have been confirmed to be effective, such as arranging the classroom environment to remove evidence of gender prejudice that favours males, such as Star Trek posters. Indeed, removing gendered objects from the classroom has been shown to make girls feel three times more capable of learning computer science (Master & Meltzoff, 2016) and resulted in a substantial correlation between women's sense of belonging in STEM disciplines and their motivation and interest in these subjects (Cheryan et al., 2017). In addition, females with STEM experience are more likely to have incremental belief in learning and success in STEM than those females without STEM experience (Moè et al., 2021).

3.3 Relationship between senior primary school pupils' STEM attitudes and grades

Based on Table 3, students in Grade 5 showed more positive attitudes toward STEM than those in Grade 6. The Spearman rank order correlation, run to determine the relationship between STEM attitudes and grades, showed statistically significant negative correlations between overall STEM attitudes, the mathematics and science dimensions, and grade ($p < .05$). However, while the correlations between grade and STEM career interest and engineering and technology attitude were also negative, they were not statistically significant ($p \geq .05$).

Table 3. The Spearman correlation between senior pupils' STEM attitudes in primary school and grade

Dimensions	Grade	N	M	SD	n	r	*p* (2-tailed)
Overall attitudes towards STEM subjects	5	664	3.58	.64	864	-.08*	.02
	6	200	3.45	.69			
Mathematics attitude	5	664	3.52	.75	864	-.08*	.03
	6	200	3.36	.88			
Science attitude	5	664	3.61	.70	864	-.08*	.02
	6	200	3.47	.75			
Engineering and technology attitude	5	664	3.61	.82	864	-.05	.17
	6	200	3.52	.84			
STEM career interest	5	664	3.14	.89	864	-.03	.38
	6	200	3.10	.69			
Full S-STEM Survey	5	664	3.47	.65	864	-.07*	.05
	6	200	3.36	.69			

According to Table 3, fifth graders' mean scores were higher than sixth graders in all cases. This finding is in line with Wiebe et al. (2018), who found that using the S-STEM Survey, Grade 5 pupils' mean scores were higher than Grade 6 for overall STEM attitudes, the mathematics and engineering and technology subdimensions, and STEM career interest; however, for the science subdimension, Grade 5 pupils' mean scores were slightly lower than pupils in Grade 6. Ugulu (2020) found the same result, in that the science attitude mean score of gifted pupils in Grade 5 was slightly higher than pupils in Grade 6; however, there was no statistical difference.

STEM education has been verified to be more effective in elementary school than high school through meta-analysis (Batdı et al., 2019; Chang et al., 2024; Saraç, 2018). According to self-determination theory, pupils' autonomy, focus, and interest in participating improve with decreased stress (Ryan & Deci, 2000). A possible explanation for this result is that sixth graders bear more academic pressure than fifth graders because they are due to enter junior high school. Teachers should look to better understand the key stages of elementary school to better implement STEM education and increase pupils' positive STEM experiences.

3.4 Relationship between senior primary school pupils' STEM attitudes and STEM experience or not

Based on Table 4, students with STEM experience reported having more positive STEM attitudes than those without STEM experience. A point-biserial correlation was run to determine the relationship between STEM attitudes and STEM experience or not. There was a positive correlation between STEM attitudes and STEM experience or not in all cases, which was statistically significant ($p < .05$). Furthermore, senior primary school pupils with STEM experience had more positive STEM subjects' attitudes and STEM career interest than those without STEM experience.

Effective STEM education fosters positive attitudes towards STEM subjects among students and is a benefit that can be enhanced through integrated STEM strategies (Guzey et al., 2014). Implementing STEM projects in primary school has shown consistent results in improving students' attitudes towards STEM (Zhou et al., 2019). The Women in Engineering (WIE) STEM programme has significantly improved attitudes toward science among eighth graders, aligning with the findings of this study (Erkut & Marx, 2005). However, the programme led to a decrease in positive attitudes about engineering and had no impact on attitudes toward mathematics. Meta-analyses further support the superiority of STEM education over traditional methods in enhancing student performance (see Batdı et al., 2019; Chang et al., 2022; Lynch et al., 2019; Saraç, 2018).

Table 4. The Pearson correlation between senior pupils' STEM attitudes in primary school and STEM experience or not

Dimensions	STEM experience	N	M	SD	n	r	*p* (2-tailed)
Overall attitudes towards STEM subjects	Yes	362	3.67	.66	864	.16**	.00
	No	502	3.46	.64			
Mathematics attitude	Yes	362	3.58	.81	864	.11**	.00
	No	502	3.41	.76			
Science attitude	Yes	362	3.71	.71	864	.16**	.00
	No	502	3.47	.70			
Engineering and technology attitude	Yes	362	3.71	.81	864	.13**	.00
	No	502	3.50	.82			
STEM career interest	Yes	362	3.27	.90	864	.14**	.00
	No	502	3.03	.85			
Full S-STEM Survey	Yes	362	3.57	.67	864	.16**	.00
	No	502	3.35	.65			

3.5 Relationship between senior primary school pupils' STEM attitudes and mothers' educational background

The Spearman rank order correlation was used to analyse the correlation between pupils' STEM attitudes, including each subdimension, and mothers' education. The results in Table 5 show a positive correlation between STEM attitudes and mothers' educational background in all cases, which was statistically significant ($p < .05$). Based on the mean scores shown in Table 5, the higher the mother's educational background, the more positive the pupils' STEM attitudes.

Table 5. The Spearman correlation between senior pupils' STEM attitudes in primary school and mothers' educational background

Dimension	Mother's education background	N	M	SD	n	r	p (2-tailed)
Overall attitudes towards STEM subjects	Primary school	53	3.15	.73	864	.21**	.00
	Middle school	269	3.43	.64			
	High school	236	3.59	.60			
	University and above	306	3.69	.66			
Mathematics attitude	Primary school	53	3.14	.78	864	.18**	.00
	Middle school	269	3.39	.75			
	High school	236	3.45	.76			
	University and above	306	3.65	.80			
Science attitude	Primary school	53	3.19	.77	864	.19**	.00
	Middle school	269	3.47	.67			
	High school	236	3.60	.72			
	University and above	306	3.72	.71			
Engineering and technology attitude	Primary school	53	3.13	.89	864	.18**	.00
	Middle school	269	3.43	.82			
	High school	236	3.72	.78			
	University and above	306	3.70	.80			
STEM career interest	Primary school	53	2.76	1.00	864	.15**	.00
	Middle school	269	3.01	.82			
	High school	236	3.19	.89			
	University and above	306	3.25	.88			
Full S-STEM Survey	Primary school	53	3.05	.75	864	.21**	.00
	Middle school	269	3.32	.65			
	High school	236	3.49	.61			
	University and above	306	3.58	.66			

3.6 Relationship between senior primary school pupils' STEM attitudes and fathers' educational background

The Spearman rank order correlation was used to analyse the correlation between pupils' STEM attitudes and fathers' education. Table 6 shows that there was a positive correlation between STEM attitudes and fathers' educational background, which was statistically significant ($p < .05$). Based on the mean scores shown in Table 6, the higher the father's educational background, the more positive the pupils' STEM attitudes.

Our results show that the pupils' STEM attitudes mean scores improve relative to parental education level; the more education parents have, the more positive the pupils' STEM attitudes become. This supports findings that parents' education level impacts children's school subjects and career choices (Ayalon, 1995) and that parents support their children by recognising the value of STEM subjects and careers (Lyons, 2006; Regan & DeWitt, 2014). Family involvement in pupils' science learning and parents' expectations of their children's future careers in science also help pupils conduct experiments better (Nursetiawati et al., 2020). In contrast, Taha and Subramaniam (2020) found that, in Malaysia, middle school students' enrolment in STEM-related courses was inversely impacted by the educational background of their parents, meaning that the lower the parents' education level, the more possibility there was of the students' choosing STEM-related subjects in high school. However, Rezayat and Sheu (2020) showed that, compared to parents and teachers, Chinese college students' STEM education readiness and career attitudes are more likely to be affected by their peers.

Table 6. The Spearman correlation between senior pupils' STEM attitudes in primary school and fathers' educational background

Dimension	**Father's education background**	**N**	**M**	**SD**	**n**	***r***	***p* (2-tailed)**
Overall attitudes towards STEM subjects	Primary school	42	3.10	.80	864	.25**	.00
	Middle school	243	3.39	.60			
	High school	255	3.53	.64			
	University and above	324	3.74	.63			
Mathematics attitude	Primary school	42	3.06	.74	864	.18**	.00
	Middle school	243	3.38	.72			
	High school	255	3.45	.80			
	University and above	324	3.64	.80			
Science attitude	Primary school	42	3.12	.95	864	.23**	.00
	Middle school	243	3.42	.63			
	High school	255	3.54	.71			
	University and above	324	3.77	.69			
Engineering and technology attitude	Primary school	42	3.12	.97	864	.24**	.00
	Middle school	243	3.36	.81			
	High school	255	3.61	.79			
	University and above	324	3.80	.77			
STEM career interest	Primary school	42	2.72	1.10	864	.20**	.00
	Middle school	243	2.92	.79			
	High school	255	3.15	.87			
	University and above	324	3.32	.87			
Full S-STEM Survey	Primary school	42	3.00	.82	864	.25**	.00
	Middle school	243	3.27	.59			
	High school	255	3.44	.65			
	University and above	324	3.63	.64			

4 Conlusion

In summary, Chinese primary school students exhibit moderate attitudes towards STEM, with boys showing more positive attitudes than girls and fifth graders showing more positive attitudes than sixth graders. Furthermore, STEM experience and parents' education level both positively influence students' STEM attitudes. Future research should expand the scope of this study to include students from various provinces in China to enhance its representativeness. Future research should also investigate the development and changes in STEM attitudes across all K-12 grades and examine how parental education impacts these attitudes.

5 Implications

The implications of these findings are significant for educators, policymakers, and parents involved in the STEM education of primary school students in China. The moderate attitudes toward STEM subjects suggest a need for targeted interventions to foster greater enthusiasm and engagement. The observed gender and grade-level differences highlight the importance of implementing tailored educational strategies to address the specific needs and challenges faced by girls and older primary school students.

The positive influence of STEM experience on students' attitudes underscores the value of hands-on, experiential learning opportunities in STEM education. This implies that curriculum developers and educators should prioritise the integration of interactive and project-based learning activities that provide students with meaningful STEM experiences. Furthermore, the positive correlation between parents' education level and their children's STEM attitudes points to the potential role of family background in shaping students' attitudes towards STEM. This suggests that parental involvement and education regarding the importance of STEM could be leveraged to support and enhance students' STEM learning experiences.

To build on these implications, future research should aim to provide a more comprehensive understanding of STEM attitudes across different regions of China and throughout the K-12 educational spectrum. This broader perspective will enable the development of more effective and inclusive STEM education policies, practices, and interventions that can support the success of all students in STEM fields.

Research ethics

Author contributions

Yasong Yan: conceptualisation, literature review, data collection, data analysis, writing.
Nur Jahan Ahmad: review and editing.

All authors have read and agreed to the published version of the manuscript.

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Informed consent statement

This investigation with children was voluntary completely. Children participated in this investigation under the informed consent and supervision of their parents. Because this is a large-scale quantitative online survey, the introduction to the questionnaire includes the statement: “All of your information is anonymous. If you would like to complete the questionnaire, you need to get the permission from your parents on this basis; if you do not want to complete the questionnaire, there will be no loss or penalty for you. The collected data will not be used for any academic performance assessment for any teacher or school.”

Data availability statement

The data is unavailable due to privacy issues.

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Conflicts of interest

The authors declare no conflicts of interest.

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