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Gender in mathematics: how gender role perception influences mathematical capability in junior high school

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Abstract

Based on the China Education Panel Survey, this study discusses how gender role perception influences the mathematical capability of female students from the multilevel perspectives of individual, family, school, and region. This study finds that the stereotypical view of gender roles held by students and parents has a significant impact on the mathematical capability of both sexes, with a positive effect on male students and a negative effect on female students. However, the threat of gender stereotypes does not have a negative impact on female students. In addition, the number and sex of children in the family and the local sex ratio have no significant impact on the mathematical capability of either male or female students. Therefore, the major factors affecting 'females' mathematics learning are the stereotypical views of the relationship between gender and mathematics held by female students and families rather than the tradition of favoring men over women.

Keywords: Gender difference, Mathematical capability, Stereotype, Son preference

Introduction

Women are often besieged by stereotypical remarks and views, such as "women are not good at math/science," throughout their years of education. People believe that women are good at linguistics, history, and similar art subjects that hinge on the capability of language or memory, while men are good at math, physics, and similar science subjects that require logical reasoning. If a girl performs well in math in elementary school, she is often told that "girls will not be good at learning math when they enter middle school." If the girl continues to perform well in middle school, she is often told that "women are not suitable for science studies." The results obtained from real-world observations also confirm these perceptions. In mathematics, female students score higher than male students in elementary school, but this gender gap narrows or even disappears in junior high school, and the math scores of male students become significantly higher than those of female students in senior high school (Wu 2016). In other words, there has never been a fundamental change in the gender gap in science subjects in high school.

In the long Chinese history, women were disadvantaged in terms of available educational opportunities and attainments. It was not until the twentieth century that women gained equal rights in education. The gender gap in educational attainment has been closed, and women have even surpassed men in some indicators after many years of effort. The 1982 census found that among young people aged 20–34, one-third of women (33.3%) were illiterate or semi-illiterate, more than twice the proportion of men (9.5%). Since then, women have made continuous strides, and by 2015, the illiteracy rate gap between young men and women had almost disappeared (0.6% for men and 0.8% for women). Meanwhile, the proportion of women who received higher education rose rapidly from 0.5% in 1982 (1.1% for men) to 31.3% in 2015, exceeding 29.8% for men.[1]

Gender equality was initially achieved in educational attainment at the national level, but there are still gaps in more profound and detailed aspects, such as the content and process of education. For example, there is significant gender segregation in the distribution of disciplines—the disadvantages of female students in science and engineering disciplines (including study and employment) have not been fundamentally reversed. In high school, the majority of female students who performed well in mathematics in elementary school nevertheless chose to study liberal arts, which determines that their college majors and career development can no longer be linked to the scientific and technological fields. In 2019, the proportion of women in scientific and technological research and development was only 26.0% at the national level (Department of Social Science, Technology, and Cultural Industry in the National Bureau of Statistics, Department of Innovation and Development in the Ministry of Science and Technology 2020).

The absence of women in science and technology will weaken their scientific and technological power and influence on future society. As science and technology are rapidly changing, people have profoundly realized that science and technology are the primary sources of productivity. Not only is the competition for science and technology between countries in full swing, but all regions in China are also competing to attract science and technology talent. However, the cultivation of talent comes first, and the cultivation of science and technology talent occurs in the field of education. Many Western countries have promoted science, technology, engineering, and mathematics (STEM) to the level of national strategy and have promulgated a series of policies to promote STEM education (Wang 2017).

Mathematical capability is the foundation of STEM disciplines and plays the role of a "filter" (Correll 2001). Mathematical knowledge is the indispensable basis for continuing STEM learning and STEM-related occupations.[2] The performance of a middle school student in mathematics is directly related to whether she or he will choose STEM-related majors and employment in the future (Ing 2014). Therefore, this study uses mathematics learning in junior high school as the basis to explore the social and cultural factors hindering Chinese females' progress in STEM education. It focuses on females' perception

[1] These results are calculated based on the 1982 census data and the 2015 national 1% sampling survey data.

[2] In July 2019, the Ministry of Science and Technology, the Ministry of Education, the Chinese Academy of Sciences, and the Natural Science Foundation Committee jointly issued the "*Work Plan on Strengthening the Research of Mathematical Science*" (No. 61 document of the State Science Office of PRC). It was mentioned at the beginning that "mathematics is the foundation of natural science and the foundation for technological innovation. Mathematical power often affects national power, and almost all important discoveries are related to the development and progress of mathematics.".

of gender stereotypes, that is, whether they believe males are better at mathematics than females at the student, family, school, and social levels. The data of this study are derived from the China Educational Panel Survey (CEPS) conducted by the National Survey Research Center (NSRC) at Renmin University of China.[3]

Physical and social factors affecting mathematics learning

The idea that "women are not good at math" or "men are better at math than women" is shared worldwide. The "Implicit Project" of Harvard University released a set of implicit association tests online. From May 2000 to July 2008, more than 500,000 people around the world participated in the tests, of whom more than 70% linked science/mathematics with men, while women were more often connected with literary subjects (Nosek et al. 2009).

Changeable gender gap in mathematics

The view that "mathematics is a male field" may be based on certain facts because it is often observed in daily life that women's mathematics performance is not as good as that of men or that more men are engaged in mathematics-related occupations. Various disciplines have explored the root cause of such gender differences from two perspectives: physical differences and the social environment.

Many explanatory studies either support or oppose the theory of physical differences (brain structure, androgens, and inborn preference etc.). In recent years, however, more studies have questioned the explanatory power of physical factors. Moreover, neither an inborn physical basis nor individual preference can produce actual competence without education, training, and learning, and whether there is a fundamental difference in physical structure related to mathematical capability between men and women is debatable. In addition, individual cognitive capability, including spatial and mathematical capability, can be improved through acquired learning and practice, both for males and females. In the long process of learning and training, it is difficult to distinguish the influence of inborn factors from acquired factors. Therefore, physical factors cannot be the only or decisive mechanism to explain the gender difference in mathematical capability (Halpern et al. 2007; Ceci et al. 2014).

Empirical research also demonstrates that the gender gap in mathematics learning is not unalterable, and the panel data show that the gap is shrinking. In the US, the gender gap in mathematics performance has disappeared in senior high school, but male students still have advantages in solving complex problems (Lindberg et al. 2010:1132). Research in the United States shows that the proportion of women among doctoral degree holders in mathematics/ statistics, and physics increased from 8% and 5.5% in 1970 to 32% and 30% in 2006 (Hyde and Mertz 2009: 8805).

The international comparison based on cross-sectional data also shows that although men still have advantages in mathematics in general, this is not always the case for specific countries/cultures/ethnicities. For example, among the 78 countries/regions

[3] For detail, please refer to http://ceps.ruc.edu.cn. We are grateful to Professor Weidong Wang and his colleagues for data collection.

participating in the 2018 Program for International Student Assessment (PISA),[4] 32 did not have significant gender differences in average math scores (accounting for 41%), while 32 were male leading (41%) and 14 were female leading (18%).[5] Similar findings are found in other comparative studies of transnational or cross-ethnic data. For junior high school students, male students are ahead of female students in mathematics in general, but the difference varies greatly among countries or ethnicities, and sometimes, the direction is reversed (Penner 2008; Baker and Jones 1993).

Both the panel data and the cross-sectional data have shown that the gender gap in mathematics learning, in both its direction and quantity, is not immutable. They also show that even if there were inborn physical differences between men and women, these physical differences could not be directly translated into gender differences in mathematics learning. At national and regional levels, the gender differences in mathematics learning in various countries/regions are related to the degree of gender inequality and gender cultural traditions—the more gender equal a country is, or the more its people do not agree that mathematics is a male field, the narrower the gender gap in mathematics learning in this country is, and female students even tend to surpass male students in mathematics (Nosek et al. 2009; Guiso et al. 2008). In short, gender inequality in a country or region constitutes a social structural factor that affects math learning (gender stratification hypothesis), while gender cultural tradition constitutes a social and cultural factor that affects math learning. The two factors are closely related. The former can influence females' mathematics learning by affecting their current educational opportunities or expectations for the future (for example, gender segregation in the labor market) (Baker and Jones 1993), while the latter can play a role by shaping the external context of individual action or the internalization of tradition by individuals.

One of the gender cultural traditions most directly related to women's mathematics learning is called the gender stereotype of mathematics; that is, the belief that women's mathematical capability is inherently inferior to that of men.

The gender stereotype of mathematics

A stereotype is a cognitive structure composed of knowledge, concepts, and expectations of certain social groups (such as gender, ethnicity, and religion). It is the product of cognitive, emotional, socio-motivational, and cultural factors and processes or their interaction (Mackie et al. 1996:42). Stereotypes can be positive or negative and can be self-stereotypes (stereotypes toward self) or other-stereotypes (stereotypes toward other people). The gender stereotype in mathematics learning, that is, "boys have better math performance than girls," is negative for female students but positive for male students.

Negative stereotypes can influence individuals of the target social group through internal and external channels. The external environment (such as family and school) can

[4] PISA was initiated by the Organization for Economic Cooperation and Development (OECD). The survey subjects are students aged 15 years old. Since 2000, the three fields of reading, mathematics, and science have been evaluated every three years (see details and previous reports in http://oecd.org/pisa/).

[5] There was no statistical significance in gender difference among the students in Shanghai who participated in the PISA assessment in 2009, the students in Tianjin who participated in the pilot assessment in 2012, and the students in the four provinces and cities who participated in the assessment in 2015. However, in the 2018 test, the average performance of males in mainland China was significantly higher than that of females. For relevant data, please refer to Guan (2017), Zhong (2014), Table I.5.8a in the PISA 2015 report, and Table II.B1.7.3 in the PISA 2018 report.

cause group members to internalize the stereotype through socialization, and the stereotype threat constitutes an external pressure on the individual. The negative self-stereotype held by female students, that is, the acceptance and internalization of "women are not good at mathematics," causes them to lack self-confidence in learning mathematics and leads to the loss of learning motivation, low self-efficacy in learning, and ultimately poor performance in mathematics (creating a self-fulfilling prophecy). Of course, not all female students would agree that "women are not good at mathematics," and some female students perform well in math. For this group of female students, the bias toward women's mathematics learning in daily life may constitute an external contextual pressure (stereotype threat) since they can sense this bias and fear that their own mistakes in math learning would provide others with the evidence that "female students are not good at learning mathematics." Thus, they may feel anxious, nervous, stressed out, and overcautious in learning and testing, which affects their performance, especially when they are dealing with difficult mathematical problems (Spencer et al. 1999). As female students tend to attribute their failure to capability, they may lose their interest, motivation, and perseverance in learning mathematics and become less confident in learning mathematics when they enter a higher level of school; furthermore, their subsequent learning results and major selection may be affected (Mok et al. 2011; Correll 2001).

Unlike female students, male students are often the beneficiaries of stereotypes in mathematics or science studies. In general, the idea that "men are better at mathematics" has a stereotype boost/lift[6] effect on men's mathematics learning, which can promote men's self-confidence in learning and their expectation of success (Smith and Johnson 2006). Empirical studies in the United States and Europe have found that males are more confident in math learning. After controlling for math performance, males' evaluation of their mathematical capability is higher than that of females, and they are more likely to take a STEM-related career path in the future (Correll 2001).

Psychologists have verified the existence of stereotype threat in mathematics learning with various experimental designs. It was found that the presence of male participants or the presence of psychological implications before the test ("men do better in math") will weaken females' performance in the experiment and thus affect their attitude toward participating in math tests, making them feel more burdened by the pressure of competition than men and less willing to participate in the competition. The researchers further reasoned that since females' performance and willingness in the competition are very vulnerable to the influence of their competitors' gender, the gender ratio of competitors is likely to affect the gender gap in the competition results (Spencer et al. 1999; Niederle & Lise 2010). Moreover, some studies have found that a higher proportion of female students in schools has a positive relationship with their math performance (Nollenberger et al. 2016).

However, a study conducted in China on students majoring in science and technology found that the results of mathematics tests of female students are higher when they

[6] In mathematics, men may encounter positive stereotypes (men are better at math than women). However, positive stereotypes may also have different effects. If this stereotype is very straightforward ("because you are a boy, you cannot be poor at math"), it may also constitute a stereotype threat and have a stifling effect. However, if the positive stereotype is subtle and does not directly constitute a pressure on the group members, it can promote the performance of the members (Smith and Johnson 2006).

receive negative psychological hints ("male performance is better than female performance") than when they receive positive psychological hints ("female performance is better than male performance"), although the difference was not statistically significant. The female participants claimed that "the only effect of being told that male students will do better than female students in the test is to make them work harder in the test so as to prove that this prediction is wrong" (Cui and Venator 2008). The authors conjectured that the "fighting spirit" shown by Chinese women against stereotype threat, as well as the Chinese only-child policy and the fact that Chinese students are more accustomed to the pressure of the examination environment, may indicate that different social and cultural environments shape different social mindsets. Thus, whether stereotype threat theory in mathematics learning applies to Chinese females needs further verification.

Gender attitudes in family and school

The factors influencing the gender view of female students' mathematics learning include not only their attitudes toward mathematics learning but also the gender views they encounter in their daily life. Since students have spent most of their time at home and school, the gender views held by their family and school also have an important impact on students' mathematics learning of students.

Family is vital for children to socialize and learn various social norms and traditions. As key influences in socialization, the values and ideas held by parents can either be internalized by children through daily interaction or constitute a form of contextual pressure on children, thus affecting their behaviors. Research has shown that the family's gender views or stereotypes will affect the parental judgment of the capabilities of their children of different sexes. For example, compared with boys' parents, girls' parents are more likely to attribute good math performance to acquired effort rather than inborn capability, thus reducing girls' recognition and expectations of their mathematical capability and further affecting their math performance and future career choices (Ing 2014).

Schools are responsible for transmitting knowledge and shaping students' value systems, and teachers are important actors in knowledge transmission and value shaping. School peer groups also play an important role in educational attainment and value formation (Palardy 2013; Legewie and DiPrete 2012). Therefore, the gender views of teachers and peer groups have also become an important starting point for investigating the gap between men and women in mathematics.

A number of studies on the gender views of mathematics teachers abroad have found that teachers tend to agree that mathematics is a male field. When evaluating male and female students with similar mathematics performance, teachers may have a higher evaluation of male students' mathematical capability. They are more inclined to attribute male students' excellent mathematics performance to their inherent capability and that of female students to their efforts (Li 1999). This clear-cut gender division is more common and straightforward in the research published in China. When explaining the difference between males' and females' mathematics scores, the following types of explanations are common: "in the aspect of thinking pattern, women tend to imitate, men tend to think independently; women are attentive, men are flexible … women are quiet, docile, and not good at communication; men are active and relatively independent; women pay attention to classroom teaching, and men pay attention to extracurricular knowledge" (Zhang and Zhang 2003:60). Some have even proposed that "the college entrance examination should take the characteristics and differences in the thinking patterns between men and women into consideration and pay attention to the issue of gender inclination… reducing the usage of technical language in favor of daily language will impose higher requirements for language expression and writing, and will become a great advantage for women who are good at using the left brain" (Ye 2011:42).

Although further studies have found that there is no significant difference between male and female mathematics teachers in gender perception (stereotype) and teaching attitude (Li 1999), female teachers have provided female students with daily role models with a mastery of mathematics, helping them realize that mathematics is not exclusive to men, thus boosting women's confidence in mathematics learning and encouraging them to overcome the negative influence of stereotypes and develop their capability in mathematics (Marx and Roman 2002). However, to date, no relevant research has proven whether the gender stereotypes of teachers directly affect students' achievement in mathematics.

Peer groups and teachers constitute significant others that affect the attitudes and behaviors of adolescents. Studies on secondary schools at home and abroad have confirmed that the peer effect has a significant effect on educational attainment in secondary school (Palardy 2013; Ding and Lehrer 2007), but the degree of validity may vary by gender. Some studies have found that boys are more vulnerable to the influence of peer group culture; therefore, a learning-oriented peer culture is more conducive to boys' learning, while a peer environment that does not respect learning may make boys more resistant to learning, whereas females are less influenced by peer culture (Legewie and DiPrete 2012). However, the above assertions have not been fully verified in research on mathematics learning. Studies on middle schools in the United States and Sweden have found that the attitude or achievement of same-gender peers or same-gender classmates toward mathematics/STEM has a positive impact on female performance in mathematics but has no effect on male performance in mathematics (Raabe et al. 2019; Riegle-Crumb et al. 2006). The gender-based peer effect may exist because female peers who perform well in mathematics/STEM courses act as role models for girls, helping them resist or eliminate the negative effects that stereotypes may bring about, while the stereotype of mathematics is beneficial to boys, so boys do not need the promotion effect of peer culture (Riegle-Crumb et al. 2006). However, a study of secondary schools in four European countries found that the mathematics performance of both male and female students was affected by the gender attitude of the class, and the mathematics performance of male students in the class that was more inclined to the traditional gender norms was higher, while that of female students was lower (Salikutluk and Heyne 2017).

Other family and social factors affecting mathematics learning

In addition to traditional social and cultural views of gender stereotypes, factors affecting women's mathematics learning include gender equality in countries or regions (Penner 2008; Guiso et al. 2008). Chinese society has a far-reaching and longstanding tradition of male superiority and son preference. Even though the slogan "women can hold up half the sky" has been put forward in China since the 1950s to promote equality between men and women in education, occupation, and other aspects, the traditional preference for sons has not been completely transformed from the perspective of family reproduction. The problem of gender ratio deviation has been included in the 13th five-year plan of the National Health Commission.[7]

Son preference in the family may affect children's educational attainment, especially that of girls. A study of Taiwanese families found that with limited family economic resources, parents are likely to sacrifice educational opportunities for girls, especially older girls. However, in recent years, the distribution of family educational resources has become increasingly independent of the number and gender of children, and boys and girls tend to be equal in educational opportunities (Parish and Willis 1993; Chu et al. 2007). This finding has also been partially verified in family studies in the Chinese mainland. The implementation of the family planning policy and rapid economic development have greatly promoted gender equality in education. Many studies on urban single-child families have found that even if parents with only one daughter believe that the capability of women is not as high as that of men, there is no significant difference between their education expectations and investment and that of parents with one son (Tsui and Rich 2002; Fong 2002). An analysis of families with multiple children also found that gender is no longer an important factor affecting access to education (Zhang and Xie 2015). However, an analysis of rural families also shows that although the reduction in the number of children has promoted the educational attainment of girls and narrowed the educational gap between boys and girls (Guo and Liu 2013), the son preference of parents and the concept of "raising sons for old age caring" still have a certain impact on the distribution of educational resources. The existence of sisters will not affect the educational attainment of boys, but the existence of brothers is not conducive to the educational attainment of girls (Zhang et al. 2013).

Research on the relationship between gender structure and the number of children and mathematics learning has not achieved consistent results. Some studies have found no significant difference in mathematics scores between urban single-child daughters and sons (Tsui and Rich 2002), and other studies have found that the math scores of single-child students are significantly higher than those of students having siblings (Zhang and Xie 2015). Some studies have found no significant difference in mathematics scores between rural single-child students and students with siblings (Nie et al. 2016). However, there are few studies on whether the influence of gender structure on mathematics learning is similar for female and male students.

Research hypotheses

Many scholars in physics, science, economics, and sociology have carried out extensive studies to explore the gender gap in mathematics and its development and causes, and the research results have continuously been summarized and updated. However, there are few studies on related topics in China, and most are concentrated in the fields of education and psychology. There are certain differences in research perspectives and methods between these fields and sociology. The data are mostly limited to local data, and the research findings are relatively fragmented. Hence, this study

[7] For more information, see https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201707/W020191104624349042474.pdf.

systematically investigates the gender gap and its impact on the mathematical capability of junior high school students in China based on national data. Our research will focus on the impact of gender perceptions at the individual, family, and school levels on junior high school students, especially girls' mathematics learning. The gender view discussed in this article mainly refers to the gender stereotypes related to mathematics learning.

According to the social psychology literature on the influences of positive and negative stereotypes and studies on the relationship between stereotypes and mathematics learning (Spencer et al. 1999), this article proposes hypotheses on gender stereotypes and mathematics learning from two perspectives: individual socialization and stereotype threat.

Hypothesis 1a Female students' recognition of gender stereotypes in mathematics has a negative effect on their mathematical capability.

Hypothesis 1b The gender stereotype threat in mathematics learning has a negative effect on female students' mathematical capability.

At the family level, the gender stereotype of the family can not only affect students' learning in daily life through internalization but also constitute an external contextual pressure on learning. Therefore, the following assumption is proposed.

Hypothesis 2 Gender stereotypes related to mathematics learning held by parents have a negative effect on female students' mathematical capability.

In addition, some studies have found that gender bias in the early education stage has a long-term impact on the development of students (Lavy and Sand 2018), but it is not clear how the impact will change dynamically, that is, whether the impact will change with the advancement of age or school grade. Given that the gender gap in mathematics shows a change from girls leading in elementary school to boys leading in middle school, we hypothesize that the impact of gender bias will increase with the advancement of age or school grade and propose the following assumption.

Hypothesis 3a The gender stereotypes related to mathematics learning recognized by students have a negative effect on female students' mathematical capability, which will increase with the advancement of grade/age.

Hypothesis 3b The gender stereotypes related to mathematics learning recognized by students' parents have a negative effect on female students' mathematical capability, which will increase with the advancement of grade/age.

School is an important part of students' daily lives, and we examine the impact of stereotypes on mathematics learning from the perspectives of school teachers and peer groups. As teachers' stereotypes may affect students' mathematics learning through their teaching behavior and implicitly influence students' learning attitudes, the investigation of teachers includes two aspects: teachers' attitudes toward stereotypes and the influence of female mathematics teachers' role as models in helping female students overcome negative stereotypes.

Hypothesis 4a Teachers' recognition of gender stereotypes has a negative effect on female students' mathematical capability.

Hypothesis 4b Compared with male mathematics teachers, female mathematics teachers are more likely to improve the mathematical capability of female students.

Based on the influence of same-gender peer groups on female mathematics learning discovered by researchers (Raabe et al. 2019; Riegle-Crumb et al. 2006), we put forward the following assumption.

Hypothesis 5 The female peer group's recognition of stereotypes has a negative effect on female mathematics ability.

This study controls for gender inequality, represented by the local sex ratio at birth, the gender gap in education, and the gender structure of offspring in the family, and controls for the social and economic conditions of the family, school, and community.

Data and methods

This study is based on the China Education Panel Survey (CEPS),[8] which uses probability proportionate to size sampling (PSS) to select 28 primary sampling units (PSUs) from 31 provinces, municipalities, and autonomous regions across the country. Four schools were selected from each PSU. Two classes were selected from grade 7 (classes of 2013) and grade 9 (classes of 2011) of each school in the first round of investigation. Finally, 438 classes (some schools do not have complete grades or classes) were selected from 112 schools. The first round of surveys interviewed the students, their families, teachers, head teachers in the selected classes, and school leaders. However, in the latter two rounds of follow-up visits, since some classes were reorganized due to reclassification and the students (in grade 7) may have entered different classes, their new teachers and new head teachers were also included in the interview.

The first round of the survey collected 19,487 valid student questionnaires (including 10,279 in the seventh grade) and the corresponding questionnaires of parents, teachers, and school leaders (see Wang 2016 for details). The second and third rounds of the survey, respectively, tracked down 9920 and 8862 former seventh-grade students (including newly transferred students) and their families, teachers, and school leaders. This study focuses on the performance of mathematical capability in the three years of learning (grades 7/8/9) and the changes during this period. Therefore, only the samples of the classes of 2013 (grade 7) are retained. After the samples with missing variables were eliminated, the three rounds of surveys obtained 9939 student samples, with a total of 26,903 analysis samples. The data structure is school/grade.

[8] The survey was carried out in 2013–2014 academic year. The second and third rounds of follow-up visits were conducted in 2014–2015 and 2015–2016 academic year. For details of sampling design, questionnaire\survey volume\project implementation, please refer to http://ceps.ruc.edu.cn.

Dependent variables

In the study of the gender gap in mathematics learning, there are controversies about how to measure the mathematics level. Some researchers believe that different test methods will lead to variations in gender differences, e.g., that girls are better at learning textbook knowledge. Therefore, in course examinations with familiar examination forms and related teaching content, girls' performance is likely to be better than that of boys. However, if the test contents are not closely related to textbook knowledge and the test methods are novel, male students are likely to perform better (Halpern et al. 2007). In other words, girls are better at mathematics knowledge derived from textbooks and classroom teaching, and boys are better at mathematical capability outside the classroom and textbooks. Since many studies focus on the math test results of students in schools, the differences between boys and girls in mathematical capability cannot be convincingly reflected even if the advantages of girls are found.

Given the above controversies, this study uses mathematical capability as the dependent variable, which is a time-varying variable; that is, the value of the variables varies with the change in grade (hereinafter referred to as "student/grade"). During each round of the CEPS survey, two sets of variables that can be used to measure mathematical capability are collected. One set is the results of midterm examinations organized by schools. This kind of examination may be considered an examination of book knowledge instead of measuring students' mathematical capability (Halpern et al. 2007). Moreover, it is difficult to compare across schools. Hence, we have adopted the second set of variables, that is, the results of the mathematical-related cognitive capability test implemented in each round of the survey, which includes two parts: "graphics and space" and "calculation and logic." The purpose is to "measure students' basic logical thinking and problem-solving capability…The content does not involve the specific knowledge taught in the school curriculum."[9] After obtaining the original scores of the test, the project team converted them into 3PL model standard scores based on item response theory (IRT) to compare different schools, regions, and rounds.

Independent variables

The independent variables used in this research are at three levels: individual, family, and school. Since CEPS asked the students and their families, "do you think that males are better at mathematics than females" only in the first round of the survey, we established a variable to measure the gender stereotype held by the students and parents. In addition, since the survey time of each round spans the whole academic year, this article calculates the time from September 2013 (seventh-grade enrollment) to the survey time point (junior high school, with the month as the unit of measurement) to control for the impacts of the time interval on the test results and the change in the age or grade of the students. The interactive variable of time and gender stereotypes of the students/parents is established.

The psychological test on stereotype threat confirmed the existence of stereotype threat from two perspectives: gender combination (with male participation or not) and

[9] The CEPS cognitive capability test includes language capability and mathematical ability. For specific information about the test, please refer to http://ceps.ruc.edu.cn/indeX.php?r=index/technologyReport.

psychological suggestion (Spencer et al. 1999; Niederle and Lise 2010). Other empirical studies have found that the traditional gender view of the class will affect students' academic achievements (Salikutluk and Heyne 2017). These studies inspired us to measure the threat of gender stereotypes through the gender attitudes of opposite-gender classmates. However, some schools rearranged the classes after the first round of the survey, and thus, information on some classes was not complete in the follow-up rounds. In addition, CEPS only inquired into the gender stereotypes of the students during the first round of the survey. Therefore, based on the class information in the second round of the survey, the average gender stereotype held by opposite-gender classmates in grade 7 was used to measure the stereotype threat faced by students.

The independent variables of the school include information on teachers and peer groups. We first include the gender variable of mathematics teachers (person/grade) to measure the role modeling of female teachers for female students. Second, since CEPS only inquired about the gender stereotype tendency of teachers in the third round (Grade 9), it could not be used to examine the influence of the gender attitude of mathematics teachers on the mathematics test in the first and second rounds of learning; therefore, we establish a variable of the general gender attitude of teachers in schools (the average score of all teachers in schools[10]). As an alternative variable of mathematics teachers' gender attitudes, the higher the score, the more teachers agree that males and females have different learning capabilities. However, as the question involves subjects of mathematics and English, some teachers may only agree that there is a difference in English proficiency. Therefore, there may be a large measurement error. Moreover, since the number of teachers participating in the survey varies from school to school and the number of teachers missing in the third round is relatively large, the representativeness of the score varies.

In terms of peer groups, we calculated the average score of the gender stereotype of the same-gender classmates based on the class information in the first round of the survey (excluding the interviewees themselves) to measure the gender attitude of the peer group. The higher the score, the higher the ratio of same-gender students who identify with gender stereotypes in the class. However, this variable may have measurement bias for students who changed classes in grades 8 and 9. In other words, it might measure the influence of peer groups in grade 7 on subsequent math learning.

Control variables

The control variables in this article are at four levels: individual, family, school, and PSU (county/district).

The control variables at the individual level include the household registration status (hukou) of students (student/grade). In addition, since the gender stereotype of students or parents may be affected by students' mathematics learning, we controlled for the degree of difficulty in mathematics learning in the sixth grade (the value is 1–4, and the higher the score, the less difficulty).

[10] CEPS asked the teachers about their attitude toward the saying that "boys and girls have different inborn capabilities in math and English" (choices include totally disagree, somewhat disagree, neutral, somewhat agree, and totally agree). Since there are few teachers who choose completely agree or completely disagree, the options are combined into "disagree", "neutral," and "agree.".

The control variables at the family level use the parents' highest education level to represent the family's socioeconomic status (person/grade). Since the parent's occupation and family's socioeconomic status are closely related to the education level, these variables are not included as control variables. In addition, we also measured the information of siblings (student/grade) to examine whether the number of children and gender structure would affect girls' mathematics learning. This variable consists of three options: "there is/are brother(s) in the family," "there are no brothers in the family, but only sister(s)," and "the respondent is a single child."

The control variables at the school level include a series of variables related to mathematics teachers and the school environment. The mathematics teacher variables include age and education level (person/grade).

There are two school environment variables. First is the overall socioeconomic status of the school. Based on the education level and occupation information of all the families (including grades 7 and 9) participating in the first round of the survey, we constructed the socioeconomic status index of the school by calculating the proportion of parents with an education level of junior college or above or whose occupation is management personnel or professional technical personnel of government organs, enterprises, and institutions. The higher the proportion is, the higher the overall socioeconomic status of the school is. The other is the local ranking of schools. In the third round of the survey, the CEPS asked the school principals about the enrollment rate, "What is the ranking of your school among the junior high schools in the county (district)?" and based on this, we constructed an index to measure the quality of the school, which is divided into three categories: "below medium," "medium," and "best."

It should be noted that since these variables use the class information in the seventh grade, while some classes were rearranged in the eighth or ninth grade, we calculated the proportion of seventh-grade students who were still in the same class in the second and third rounds of surveys as the control variable for the subsequent impact of the class.

At the PSU/county level, existing international comparative studies have found that females' mathematics performance is related to the degree of economic development (Guiso et al. 2008). In addition, the more equal the gender status of a country is, the more favorable it is to improving the mathematics performance of females and reducing the gender difference (Penner 2008). However, the tradition of son preference and skewed sex ratio at birth persists in Chinese society, although the traditional fertility mode has changed to some extent. Given this factor, we constructed three local-level control variables based on the national census data in 2010: The first is the gender ratio of the age group (10–14 years old) of the interviewed students (the gender ratio of the same group), which was used to measure the degree of son preference or gender inequality in the local society.[11] The second is the creation of an education gender equality index (the difference between the average education years of males and females divided by the average years of education in the local population aged six and above). The larger the value is, the greater the extent to which males lead females in education. Third, the proportion of the local people aged 15 and above who

[11] In consideration of the age cohort effect and the accuracy of the sex ratio data, we have not directly used the sex ratio at birth in 2000 or 2010. However, the variable replacement has no obvious impact on the statistical estimation.

have received a college education (undergraduate education) is used to indirectly measure the local education development and the local social and economic development.

Model specification

This study focuses on the individual, family, school, and social (regional) factors that affect the mathematical capability of students. CEPS initially sampled classes based on schools and tracked all the students in the class (grade 7) for three years. However, in the later tracking survey (grades 8 and 9), some schools had rearranged the classes, resulting in the inability to control class variables. Therefore, in this study, we will consider the factors of three levels: student, grade, and school. Since each student was observed for three rounds (grades), a three-tier data structure of school-student grades is formed. The mathematical capability score of the dependent variable belongs to the grade level (each student tests once per round). This study uses a multilevel linear model with a random intercept to accurately estimate the impact of each level's factors on students' mathematical capability.

First level: grade

$$\text{math\_cog}_{ijt} = \beta_{ij0} + \beta_{\text{X}} X_{ijt} + \beta_{\text{G}} G_{ijt} + \varepsilon_{ijt}$$

math_cog_{ijt} indicates the mathematical capability score of school i and the student j in grade t (t=7/8/9); X_{ijt} refers to independent variables at all grade levels (time-varying variables, variables that change with the survey grade, such as the gender of the math teacher); G_{ijt} indicates control variables at all grade levels; ε_{ijt} means the random error of grade level; β_{ij0} is the random intercept, which indicates the average mathematical capability score of student j of school i when the independent variables and control variables of all grade levels take zero values.

Second level: student

$$\beta_{ij0} = \gamma_{i0} + \gamma_{\text{Z}} Z_{ij} + \gamma_{\text{S}} \text{STU}_{ij} + \mu_{ij}$$

Z_{ij} represents the values of all individual-level independent variables of school i and student j, such as the degree of gender stereotype of the student and the family; STU_{ij} represents the control variable at the individual level of the student; μ_{ij} is the random error of individual level; γ_{i0} refers to the mathematical capability scores of students when the independent and control variables of all grades and individual levels take zero values.

Third level: school

$$\gamma_{i0} = \delta_0 + \delta_{\text{W}} W_i + \delta_{\text{S}} \text{SCH}_i + \tau_i$$

W_i represents the value of the independent variable at the school level of school i; SCH_i represents the control variable at the school level, and τ_i represents the random error at the school level. Since there is no separate regional level, the variables at the regional level are affiliated with the school level.

The influence of gender stereotypes on mathematics learning

Table 1 shows the descriptive statistics of each variable[12] divided by gender. In the final analysis sample, the proportion of male students (52.4%) was higher than that in the first round of sampling (51.4%).

The data show that in both the total results of the three-year junior high school and the statistics by grade, the mathematical capability test score of female students is generally higher than that of male students. Although further analysis shows that the difference between the two genders in grade 9 is no longer statistically significant, there is no sign at least that female students are weaker than male students in mathematical capability. However, the students, parents, teachers, and peer groups who participated in the survey generally regarded mathematics as a field in which boys are more or less dominant.

First, a considerable proportion of students and parents agree with gender stereotypes in mathematics learning, and there are obvious gender differences in attitude.[13] The data show that 52.4% of the students and 39.6% of the parents agree that boys are better at mathematics than girls. In particular, the proportion of female students who agree with this view is not low, reaching 44.2%, and more than one-third of the families of female students (35.2%) agree with this view. In addition, male students or their parents are more likely to hold stereotypes than female students or their families. Approximately 60% of male students think that males are better at math, approximately 16% higher than female students; 43.5% of the male student's parents agree with this statement, which is approximately 8% higher than that of the female students' parents.

Second, from the perspective of class, most students participating in the survey were currently or had been in a class with obvious gender stereotypes. Among the 221 classes participating in the second round of the survey, 125 classes (56.6% of the classes and 55.4% of the students) had an average stereotype score of more than 0.5 (not shown in Table 1). When students in the class are divided into two gender groups, the class environment of males and females is not different. The average stereotype score of male students in the class is approximately 0.60, and that of female students is approximately 0.44.

Third, consistent with the findings of some studies on foreign teachers (Li 1999), the teachers participating in CEPS also showed obvious gender stereotypes: 44.9% of the teachers completely agreed or somewhat agreed that "there is an inborn difference between males and females in mathematics or English learning" (the value is 3), 36.8% of the teachers completely disagreed or relatively disagreed (the value is 1), and 18.4% of the teachers chose "neutral" (the value is 2). The median score of teachers' attitudes in each school is 2, and the average is 2.06 points. Therefore, in general, teachers are slightly inclined to agree with the existence of gender differences related to stereotypes.[14]

[12] Due to page limit, this article only gives the descriptive statistics of some key variables. Readers can contact the author to obtain a complete table.

[13] The correlation coefficient between student stereotype and parent stereotype is approximately 0.40, which does not change after controlling for the student's gender. The correlation between the stereotype of male and female students and the same-gender peer group was 0.20 and 0.25, respectively.

[14] Among them, 46.0% of female teachers and 42.1% of male teachers agree with this statement, and the difference between them is not statistically significant. In addition, we interpret "neutral" to mean no objection; that is, less than 37% of the teachers definitely believe that there is no innate difference between men and women in mathematics/English learning.

Table 1 Descriptive statistics of variables

Variable	Male students		Female students		Total	
Variables at the individual level						
Students agree that "men are better at mathematics"	0.598	(0.490)	0.442	(0.497)	0.524	(0.499)
Parents agree that "men are better at mathematics"	0.435	(0.496)	0.352	(0.478)	0.396	(0.489)
Male classmates: average stereotype	0.598	(0.161)	0.601	(0.162)	0.599	(0.162)
Female classmates: average stereotype	0.449	(0.186)	0.443	(0.184)	0.446	(0.185)
Variables at individual/grade level (time-varying variable)						
Mathematics capability	0.326	(10.012)	0.364	(0.940)	0.344	(0.978)
Mathematics capability in grade 7	−0.101	(0.831)	−0.069	(0.777)	−0.086	(0.806)
Mathematics capability in grade 8	0.568	(1.058)	0.619	(0.958)	0.593	(1.011)
Mathematics capability in grade 9	0.598	(0.987)	0.604	(0.908)	0.601	(0.949)
The math teacher is female	0.550	(0.498)	0.558	(0.497)	0.554	(0.497)
Length of junior high school (month)	16.533	(10.939)	16.830	(11.007)	16.677	(10.973)
N (student, grade)	5211, 13,896		4728, 13,007		9939, 26,903	
Variables at the school level			*Variables at the district level*			
Teacher: average stereotype	2.062	(0.417)	Sex ratio (10–14 years old)		1.139(0.073)	
N (school)	112		*N* (district)		28	

Standard deviation in brackets

In addition, 75% of the districts and counties have a sex ratio of children aged 10–14 years old higher than 1.07, indicating that the tradition of son preference is generally maintained in these districts and counties.[15]

In terms of the gender structure within the family, approximately 45% of the students (students/grades) are single-child students, and boys (47.9%) are more likely to be a single child in the family than girls (41.4%). Girls are more likely than boys to face competition from their brothers. In the survey sample, 40.1% of the female students had brothers, which was higher than the 21.7% of the male students.

In conclusion, there are relatively obvious gender differences in the factors that we expect to examine their influence on mathematical capability. Therefore, the model construction below will examine these regression effects by gender.

Table 2 shows the estimation results of multilevel linear regression.[16] The series of Model 1 is for male students, and the series of Model 2 is for female students to investigate the impact of various relevant factors on boys or girls and to enable a comparison. Each series has three models (A, B, and C). Model B and Model C include the interactive variables of gender stereotypes of students/parents and the length of junior high school.[17]

[15] The natural sex ratio at birth is 1.02–1.07, which gradually decreases with age.

[16] Due to page limit, the effects of some control variables are not shown. Readers can contact the author for a complete table.

[17] Based on the zero model of this series of models, it is found that the characteristics of the individual level (the second level) and the school level (the third level) can explain approximately 28% and 23% of the variation in mathematical capability, respectively. The statistical test shows that the statistical method used is suitable for analyzing this data structure.

The statistical estimation results of the Model 1 series and the Model 2 series show that the influence of stereotypes from the students themselves, family members, teachers, peers of the same sex, and peers of the opposite sex on the mathematical capability of students is different, and most of the differences are significant.

First, the gender stereotypes held by students and parents on mathematics learning are closely related to the results of the mathematical capability test and have opposite effects on males and females (Model 1a and Model 2a). Male students who agree that "boys are better at math" have significantly higher scores on the mathematical capability test than boys who do not agree. In contrast, the results of female students who agree with this statement are significantly lower than those of female students who do not agree. This confirms that the self-stereotype of students in mathematics learning played a positive and noninhibitory role on male students but had a significant negative effect on female students. The gender stereotypes parents hold in mathematics learning also have similar significant effects. Family identification with gender stereotypes can significantly improve the scores of male students in mathematical capability tests, but it has a negative effect on female students.

In addition, there is a certain interactive effect between students' attitudes toward stereotypes and the length of junior high school (the effect on male students is significant at the level of 0.1), while the interactive effect between parents' attitudes and the length of junior high school is not significant for male students, and the effect on female students is slightly significant (the significance is at 0.1) (Models 1B, 1C and 2B, 2C), indicating that the influence of students' self-stereotyping on mathematics learning gradually increases with the advancement of age or grade, which can further support male students but hinder the development of female students' mathematical capability. The positive effect of parents' stereotypes on male students is fixed and does not increase with the advancement of age or grade, but the negative effect on female students increases. In comparison, it can be said that with the advancement of age and grade, the effects of negative gender attitudes from students or their parents against female students in mathematics learning gradually increase, while male students increasingly benefit from their positive gender attitudes. The positive and negative forces between genders may be part of why the gender gap in mathematics decreases, even disappears and reverses with the advancement of grade.

The average gender stereotype in the class based on the class information in the seventh grade reflects not only the gender attitude of peer groups toward mathematics learning (same-gender group effect) but also the stereotype threat (opposite-gender group effect) faced by the students. From the results of the model, it can be found that the average gender stereotype score of male students in the class promotes the mathematical capability of both male and female students, while the average score of female students has no significant effect on either male or female students. This shows that female students are not affected by peer groups (female students) or threatened by gender stereotypes (male students). The higher the gender bias held by male students in the class, the higher the female students' mathematical capability score. To a certain extent, this reproduces the findings of a study many years ago; that is, the gender bias of male students arouses the "ambition" of female students (Cui and Venator 2008). On the other hand, male students are significantly influenced by peer groups. The higher the

Table 2 Factors influencing mathematics capability, multilevel linear regression

Variable	Male students (1)			Female students (2)		
	(1A)	(1B)	(1C)	(2A)	(2B)	(2C)
Students agree that "men are better at mathematics"	0.048* (0.019)	0.017 (0.026)	0.048* (0.019)	−0.054** (0.019)	−0.021 (0.025)	−0.054** (0.019)
Parents agree that "men are better at mathematics"	0.060** (0.019)	0.060** (0.019)	0.043+ (0.025)	−0.041* (0.019)	−0.041* (0.019)	−0.013 (0.025)
Male classmates: average stereotype	0.377** (0.091)	0.377** (0.091)	0.376** (0.091)	0.194* (0.087)	0.192* (0.087)	0.193* (0.087)
Female classmates: average stereotype	−0.053 (0.073)	−0.051 (0.073)	−0.052 (0.073)	−0.011 (0.070)	−0.011 (0.070)	−0.011 (0.070)
School: teacher average stereotype	0.045 (0.077)	0.045 (0.077)	0.045 (0.077)	0.052 (0.073)	0.052 (0.073)	0.051 (0.073)
The math teacher is female	0.034+ (0.019)	0.033+ (0.019)	0.034+ (0.019)	0.047** (0.018)	0.048** (0.018)	0.048** (0.018)
Length of junior high school	0.022** (0.001)	0.021** (0.001)	0.022** (0.001)	0.022** (0.001)	0.023** (0.001)	0.023** (0.001)
Length of junior high school × stereotype of students		0.002+ (0.001)			−0.002* (0.001)	
Length of junior high school × stereotype of parents			0.001 (0.001)			−0.002+ (0.001)
School: socioeconomic status	1.123** (0.197)	1.124** (0.197)	1.123** (0.197)	0.943** (0.185)	0.942** (0.185)	0.943** (0.185)

(1) Standard deviation in brackets, (2) ** $P<0.01$, * $P<0.05$, + $P<0.1$, (3) Sample size information is in the descriptive statistics

proportion of male students in the class who agree that male students are better at mathematics than female students, the higher the score of male students' mathematical capability is. This also confirms the findings of other researchers that male students are more likely to be influenced by peer group culture than female students (Legewie and DePrete 2012), or it may also be because female students are only affected by close peer groups.

However, the average stereotype of school teachers based on school-level information has no significant effect on students' mathematics learning. Of course, this may also be due to inaccurate variable construction.

In addition, as for the modeling effect of mathematics teachers surveyed in this study, the results of the analysis (Model 2 series) show that female mathematics teachers are more likely to improve students' mathematical capability than male teachers, but the improvement of male students is only significant at the level of 0.1, while the improvement of female students is relatively more significant (the difference between them is probably not significant). From the perspective of female students, female teachers have a certain role in modeling female students' mathematics learning.

Among the control variables, we found that most of the control variables had the same effect on boys and girls.[18] For both male and female students, participating in a mathematics tutorial can significantly improve their performance on the mathematical capability test. Parents' education level and the average socioeconomic status of school can also significantly improve the mathematical capability of students. The higher the

[18] We investigated the interactions between all control variables and gender. Only the interactions between extracurricular courses, mathematics learning status in grade 6, and the socioeconomic status of the school and gender were significant. All the three interactions had a greater promotion effect on boys (not shown in this article due to page limit).

education level of parents or the average socioeconomic status of the school is, the better the mathematical capability of the students is. These findings are consistent with other researchers' findings (Halpern et al. 2007). In addition, when controlling for the socioeconomic status of schools, there is no significant relationship between the ranking of schools in the local enrollment rate and the mathematical capability of students; that is, the mathematical capability of students studying in schools with a relatively high enrollment rate is not significantly better than that of students studying in schools with a slightly lower enrollment rate.

According to the results, the effect of household registration is only limited to female students. The mathematical capability test scores of female students with urban hukou are higher than those of their rural counterparts, which indicates that urban female students enjoy various advantages over rural female students. The age of a teacher can be regarded as a proxy variable of teaching experience, and statistical estimates show that the mathematical capability of students is not related to the age or educational background of the teacher.

In addition, this study did not find that the gender ratio at the regional level or the gender equality index in education had a significant impact on the results of the mathematical capability tests of students. At the same time, the investigation of students' family structure failed to find an influence of the gender structure of brothers and sisters on the students' mathematical capability. Single-child students (either boys or girls) do not perform better than students with siblings in mathematical capability, and whether they have a brother will not significantly affect the mathematical capability of female students. Combining the two factors of region and family structure, we may conclude that although the fertility culture of Chinese families still holds a son preference, all families do their best in terms of the investment of education resources or the attitude toward education. Single-child students do not receive more resources than students with siblings, and families will not be biased because of gender, that is, the so-called son preference without daughter discrimination.

However, the study also found a confusing phenomenon: the level of education development or economic development (the proportion of people aged 15 and above who have received a college education or above) in various places is negatively related to the mathematical capability of local schools. The higher the local education level or economic development is, the lower the mathematical capability of local students is. However, according to PISA's mathematical test results over the years, the countries or regions (such as East Asian countries or regions) ranking high in mathematical capability tests are not all the most economically developed regions.

In summary, the effect of gender stereotypes of students and parents on mathematics learning proposed in this article has been verified; the hypothesis that the role of self-stereotype or parents' stereotypes increases with the advancement of grade or age has been partially verified; and the hypothesis that female mathematics teachers serve as role models for female students in mathematics learning has been verified to a certain extent. The hypothesis of peer groups' stereotypes has not been fully verified, and the effects of gender stereotype threat and teacher stereotypes have not been verified.

Conclusion and discussion

This article investigates the gender difference in junior high school mathematics learning and its relationship with views of gender. For a long time, there has been a traditional idea in society that women are inferior to men in mathematics learning. However, according to CEPS data, in junior high school, girls' mathematical capability is not weaker than boys'. The mathematical capability tested here does not examine textbook knowledge but includes graphics, space, and logic, which are not considered advantageous for boys.[19] However, these results coexist with the fact that a considerable proportion of students, parents and teachers are inclined to believe in males' inborn advantages in mathematics: 52% of students (60% of boys and 44% of girls), nearly 40% of parents (44% of boys' parents and 35% of girls' parents),[20] and 45% of teachers believe that males are better at mathematics. Of the 112 schools surveyed, there are 84 schools in which at least half of the students in each school believe that male students are better at mathematics.

The analysis shows that self-stereotypes and parents' stereotypes in mathematics learning will hinder the development of mathematical capability, and these negative effects tend to increase with the advancement of age or grade. Males are the beneficiaries of gender stereotypes. However, although the parents' gender attitude toward mathematics learning will affect the performance of their children's mathematical capability, the son's preference in the local fertility culture or the existence of brothers in the family has no significant impact on girls' mathematical capability, which indicates that there is a positive change in the resource allocation of Chinese society and families moving toward the trend of "son preference without daughter discrimination." Optimistically, value and social changes are inevitable as China transforms from materialism to the postmaterialist era. However, value and social changes may lag behind economic changes, and sometimes, they can only be realized by intergenerational population replacement (Inglehart et al. 2017). Therefore, time is needed to accumulate positive changes in the social attitude toward females' mathematics learning or females' self-pursuit and breakthrough in mathematics and other natural sciences learning.

Another valuable finding of this study is that the CEPS data show that junior high school girls in China are not affected by stereotype threat. Western psychological studies suggest that the gender stereotype of mathematics learning could apply to female individuals in two ways: the first is the internalization of ideas through the process of socialization, which affects the individual's behavior; the second is the contextual pressure on females, which causes inconsistent performance of women in competition and gradually diminishes their confidence, interest, and motivation in further learning. Some researchers have proposed same-gender mathematics classroom education (Niederle and Lise 2010). However, in China, neither the female college students participating in

[19] CEPS collected the mathematics midterm examination results of the surveyed students. Although it is difficult to compare among different schools due to different test papers and scoring standards, the rough descriptive statistics show that the mathematics examination results of female students are higher than those of male students.

[20] Among the ninth-grade students and their parents participating in the CEPS survey, 60% of the male students, 57% of the female students, and approximately 47% of the boys' parents, and 45% of the girls' parents agree that the boys were better at mathematics than the girls. The proportion of female students and their families who agree with such statement increased significantly compared with the that of the seventh grade students. Since CEPS did not follow up the relevant information, we do not know the dynamic relationship between stereotype and grade change.

the experiment (Cui and Venator 2008) nor the female junior high school students in the present survey when facing the explicit or implicit gender-biased situation/atmosphere, show the trend of "the greater the pressure is, the stronger they are."[21] This may, to some extent, indicate that for the females participating in these surveys, their reaction patterns to gender bias may differ fundamentally from those of females under other cultural traditions. This finding also means that we should further verify relevant theories and explore the boundaries of the theoretical applications and the impacts behind them.

Of course, this article only discusses the direct impact of gender attitudes toward mathematics learning held by students, families, schools, and society on mathematical capability. The findings need to be verified by further study with more empirical data, and this study can still be systematized and deepened in all aspects. For example, we need to analyze further the relationship between the gender of students and the gender attitude of parents or teachers and its impact on the mathematics learning of students, the dynamic interactive relationship between the mathematics performance of students and the gender attitude of students or parents toward mathematics learning, and the impact of the implicit gender attitude of parents or mathematics teachers (reflected in daily life, class roll calls, and examination papers) on the mathematics learning of students.

Furthermore, some foreign researchers have pointed out that with the improvement of females' situation in mathematics learning, the focus on the gender gap in mathematics performance has shifted from the average to the two ends of the performance distribution (low score and high score groups), especially the highest performing groups; that is, although there is no significant difference between males and females in the average performance (before secondary education) in math, the fact that there are more males and fewer females in the group with the best mathematics performance has not changed (Halpern et al. 2007). However, we believe it is still valuable to pay attention to the difference between the average scores of males and females in mathematics in China, which has not been sufficiently addressed. We are not very clear about the exact change trend and the underlying mechanism driving the difference between males and females in mathematics learning from elementary to senior high school, nor are we very clear about the process and influencing factors by which females are screened out the STEM fields. Therefore, while the concern of foreign researchers has gradually started to change from "why women cannot" to "why women are not willing to" enter STEM fields for study or employment, we still need to make efforts to solve the problem of "why they cannot."

In short, gender equality in education is not only equal educational attainment in the final stage but also the equality of opportunities, attitudes, and psychology, in which males and females can receive the same encouragement and treatment in the process of receiving education, have the same opportunities to develop and follow their interests, and give full play to their gifts and talents. For the young generation in China, although gender equality has been achieved in the distribution of educational resources

[21] Some researchers have compared the differences and influencing factors of the mathematics midterm examination results of male and female students in first round of CEPS, and proposed that the high educational expectations of female student's parents and the high self-discipline of female students can help them overcome the negative effects of gender stereotypes. The examination-oriented education also increases the possibility of female students to achieve good results through hard work (Chen and Bai 2020).

and the final attainment of education, there are still inequalities (at least in gender attitudes) in the education process, which limits their expectations and choices for their future professional development, especially leading females to actively or passively shy away from pursuing the STEM fields. This study demonstrates that the gender attitude toward mathematics at home and school should be changed, the view of "mathematics is the field of men" should be corrected, females' self-confidence in mathematics learning should be established, and their interest in learning should be raised to encourage females to enter STEM-related majors and occupations. Of course, whether females are willing and able to enter STEM-related majors or occupations also involves many other influencing factors, such as job characteristics, attitude toward family, and discrimination in the labor market, which are issues to be discussed in a follow-up study. However, since mathematics is the key to the STEM fields, our society should also encourage and trust females to participate in the search for this key so that they can have the opportunity to appreciate the grandeur and beauty of these fields. Thus, future scientific and technological development in China could expend more resources in this direction, and gender equality in China's education could be further improved.

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Author contributions
GX designed the study and conducted the research. XL contributed in literature collection and pilot study. Both authors read and approved the final manuscript.

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Availability of data and materials
We based our study on data, publicly available of the China Education Panel Study (CEPS, 2013-2015).

Declarations

Competing interests
The authors declare they have no competing interests.

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