RESEARCH ARTICLE

How Does Math Anxiety Affect Students' Academic Achievement in Mathematics? —A Meta-Analysis Based on 31 Experimental Studies

Xiaoyu Yan[1,*]

[1] School of Teacher Education, Fujian Normal University, Fuzhou 350007, China

Abstract

In the stage of compulsory education, there are still many researches on the relationship between math anxiety and students' math achievement. If we cannot understand the internal mechanism between students' emotions and learning performance, we cannot establish a microfoundation for monitoring the quality of compulsory education. In order to further identify the logical relationship between math anxiety and students' math achievement, we systematically collected 31 relevant literature from 2014 to 2024, including a total of 106,636 student samples, and conducted a meta-analysis based on the random effects model. The results show that the correlation coefficient between math anxiety and students' math achievement is -0.322, which is a moderate negative correlation. Further mechanism analysis based on the moderating variables showed that the three moderating variables, self-efficacy, teachers' independent support and teacher-student relationship, all contributed to the alleviation of students' math anxiety and had a certain positive impact on the improvement of students' math academic achievement. However, the influence of math anxiety on students' math academic achievement was not significantly moderated by gender and gender stereotype. The aim of this study is to alleviate the mathematics anxiety of students in the compulsory education stage, and to provide suggestions for improving the mathematics academic performance of students: self-regulation to enhance self-efficacy, improve teaching effect with teacher support, to optimize the environment and ease negative emotions.

Keywords: math anxiety, mathematics academic achievement, meta-analysis, self-efficacy, teacher-student relationship.

1 Introduction

With the inclusion of students' learning emotions in the "National Compulsory Education Quality Monitoring Program," the psychological well-being of students in basic education has become a focal point. From the perspective of subject teaching, attention to students' learning emotions is particularly critical. Compared to other subjects, mathematics tends to evoke higher levels of anxiety [1], and the impact of math anxiety on academic achievement is more pronounced in

Academic Editor:
Guojie Xie

Submitted: 27 November 2024
Accepted: 19 December 2024
Published: 30 December 2024

Vol. 1, **No.** 4, 2024.
10.62762/JSSPA.2024.672218

***Corresponding author:**
✉ Xiaoyu Yan
qsz20240792@student.fjnu.edu.cn

Citation
Yan, X. (2024). How Does Math Anxiety Affect Students' Academic Achievement in Mathematics? —A Meta-Analysis Based on 31 Experimental Studies. *Journal of Social Systems and Policy Analysis*, 1(4), 123–134.

mathematics than in other disciplines [2]. Thus, math anxiety is a significant variable affecting students' math achievement.

However, there is still no consensus on the effect of math anxiety on students' math achievement in the current academic circle, or it is believed that math anxiety has a positive impact on students' math achievement. For example, He et al. [3] pointed out that test anxiety in math anxiety has a weak positive impact on math academic achievement. It is also criticized that math anxiety is not conducive to the improvement of students' math scores, which is consistent with the research of Zhou et al. [4]. Or it emphasizes the regulating effect of different regulatory factors on math anxiety and students' math achievement. For example, Liu et al. [5] pointed out that differences in region and test type would affect the relationship between math anxiety and students' academic achievement.

1.1 The concept and measurement of mathematical anxiety

Since its inception, the measurement of math anxiety has garnered considerable attention. Self-report scale is often used to measure students' math anxiety, that is, to ask students how they feel when facing situations involving math. The measurement tools based on different theories are different in distinguishing students' math anxiety. According to their application scope and recognition degree, we choose to define math anxiety by task objective. It can be divided into mathematics learning anxiety and mathematics evaluation anxiety. The definitions are as follows: Mathematics learning anxiety means that students feel anxious in the mathematics class or when they are engaged in the mathematics task; Mathematics evaluation anxiety refers to that students feel anxious when taking math tests or doing math problems in front of others [6]. This broad definition was chosen to avoid restricting the selection of research samples during the meta-analysis.

1.2 The concept and measurement of academic achievement in mathematics

Academic achievement in mathematics reflects students' performance and mastery of mathematical knowledge, as well as their ability to apply this knowledge to solve problems. Academic achievement in mathematics can be measured in a variety of ways, such as standardized tests, in-class assessments, performance assessments, self-assessments, and qualitative and quantitative indicators. Most researchers' measurement of mathematics academic achievement is mainly based on standardized tests. For example, Wang et al. [7] used students' monthly, mid-term and final math scores as the basis for assessing students' academic achievement. Therefore, the research samples selected in this paper are also based on standardized tests.

1.3 The relationship between mathematics anxiety and mathematics academic achievement

Research indicates that math achievement is influenced not only by cognitive abilities but also by emotional factors, particularly math anxiety. A significant negative correlation between math anxiety and math achievement has been consistently observed. Studies on the relationship between math anxiety and students' math academic performance can be traced back to the 1950s and 1960s. From the perspective of psychology, foreign scholars found through empirical studies that math anxiety would directly affect students' math performance [8]. After many investigations, it is found that mathematics anxiety will bring adverse effects on students' mathematics achievement in their whole learning career. Hembree [9], Yu et al. [10]. Studies have found a negative correlation between math anxiety and students' math achievement. The research of Ashcraft and Ridley shows that when individuals have mathematical anxiety, that is, they will feel pressure and anxiety when facing math-related tasks, and may choose to avoid these tasks [11]. Therefore, for students, math anxiety may make them avoid math problems and reduce related exercises, which will lead to a decline in math performance. The PISA2012 report also pointed out that for every unit increase in math anxiety, math achievement decreased by 34 points [12].

Since the 21st century, students' mental health has become the focus of basic education, and learning anxiety, as one of the manifestations of students' emotions, has also been highly valued. Chinese scholars have conducted a survey of students at all levels and in all kinds of schools based on large-scale paper-and-pencil tests. A simultaneous test of students in grade 4, 5 and 6 of three primary schools in a township in Shandong Province found that math anxiety of primary school students was negatively correlated with math achievement [13]. A survey of students from Grade one to grade three of middle school in a town in Lishui City, Zhejiang Province found that there was a significant negative correlation between various dimensions of math anxiety and math

scores, and with the increase of math anxiety, math scores showed a downward trend [14]. A survey of students from three high school public schools in Tianjin found that math anxiety had a significant negative impact on math academic performance [15]. From the perspective of psychology, Skemp et al. [16] clearly pointed out that math anxiety with moderate motivation is most conducive to the improvement of math academic performance, and there is an "inverted U-shaped" relationship between the two.

1.4 The moderating variable of mathematics anxiety affecting mathematics academic achievement

Cemen put forward a mathematical anxiety response model and summarized three factors affecting mathematical anxiety: first, environmental factors, such as stereotypes, gender differences, and negative experiences in class; Second, individual factors, such as learning attitude, personality traits, etc.; The third is situational factors, such as teachers' teaching style, class atmosphere and so on. These factors will make individuals feel uncomfortable and have emotional or even physiological negative reactions [17].

Under the influence of different cultures and backgrounds, students in different countries have different characteristics, and the educational environment of our country is different from that of western countries, so is the correlation between students' math anxiety and math academic achievement. Therefore, it is necessary to integrate domestic and foreign samples. This study examines five moderating variables: self-efficacy, gender, gender stereotypes, teacher support, and teacher-student relationships.

Studies on individuals' self-efficacy show that math self-efficacy is negatively correlated with math anxiety, and math self-efficacy can affect math achievement through math anxiety [18]. As for gender differences in math anxiety, earlier studies have found that women are more likely to be negatively affected by math anxiety than men [19]. With regard to gender stereotypes, Wang et al.'s [20] research shows that girls with a higher level of stereotyped identity have a higher level of anxiety when faced with complex and changeable math problems, which leads to poor performance in math tests [7]. As for teacher support, based on large-scale tests, a survey of eighth grade students in Z province found that teacher independent support not only alleviates students' math anxiety, but also has a significant positive predictive effect on students' math academic achievement [3]. As for the relationship between teachers and students, Yu F. and Qi C.X. found that a good relationship between teachers and students can alleviate students' math anxiety, enhance students' math confidence, and thus improve their math scores [21].

2 Research method and design

In view of the demonstration of the relationship between mathematics anxiety and students' academic achievement in mathematics at the current stage of compulsory education, the meta-analysis method is used to conduct a quantitative and comprehensive analysis of the literature on this research topic [22], which can present a large number of research results in a detailed manner, thus obtaining a stable estimate of the overall effect, and having high evidence value in evaluating the overall effect [23]. In this study, Comprehensive Meta-Analysis V3 was used as a tool for data analysis, funnel plot and various effect data were used to present the final experimental results, and correlation coefficient (r) was used as effect value to evaluate the impact of chemical math anxiety on students' learning performance and the role of relevant mediating variables.

2.1 Literature retrieval and inclusion

2.1.1 Literature retrieval and screening

In order to select suitable studies, the following criteria were established: (1) published and peer-reviewed academic journal articles; (2) The publication period is from January 2014 to January 2024; (3) The research includes two themes: "math anxiety", "achievement" and "achievement"; (4) The full text of the article can be retrieved online; (5) Mainly written and published in English or Chinese. Through the web of science, China Knowledge Network (CNKI) two databases of advanced search. The English search subject words were "mathematics anxiety" and "performance". A total of 1148 literature were obtained through fuzzy search, including 887 literature from web of science and 261 literature from CNKI. The Chinese search subject word "mathematics anxiety" and "achievement" were fuzzy searched, and a total of 259 literature were obtained, including 15 literature from Peking University Core and CSSCI.

Based on the collected literature, EndnoteX9 was used as a literature management tool and the literature was screened according to the following criteria, as shown in Figure 1. (1) The research topic is the impact of math anxiety on students' academic achievement; (2) The research object is primary and secondary

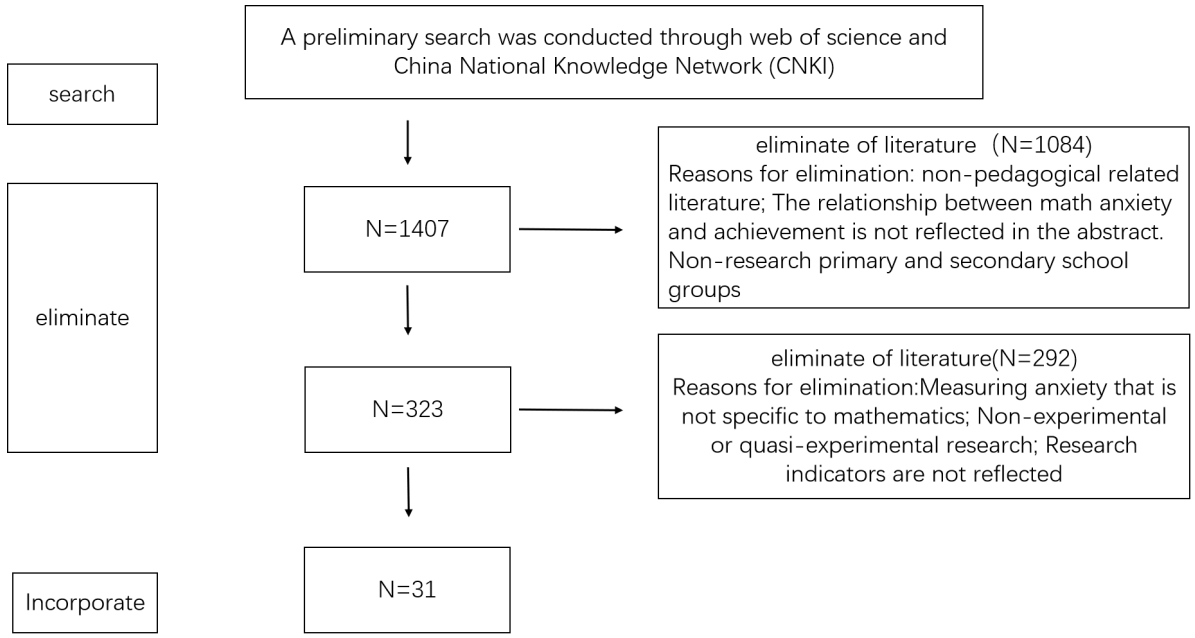

Figure 1. The process of literature screening.

school students, excluding students with bachelor's degree or above; (3) The research type is experimental or quasi-experimental research; (4) Effect values of relevant data are provided in the study, such as sample size (N), correlation coefficient (r), p-value, T-value, etc. After rigorous review, 31 study samples from 2014 to 2024 were eventually included.

2.1.2 *Document coding*

The coding mainly includes two aspects: First, the basic information of the literature is coded, including the author of the literature, the year, the number of experimental and control groups, the average value, the standard difference, etc.; The second is to encode the adjustment variables. Since it is impossible to exhaust all the moderating variables, this study learned from the moderating variable scheme adopted by Liu et al. [5] in the meta-analysis of number anxiety, combined with the characteristics of 31 sample literature, and selected five moderating variables of students' self-efficacy, gender, gender stereotype, teacher support, and teacher-student relationship for research. The specific coding situation is shown in Table 1.

Table 1. The modulating variables of the effect of math anxiety on students' academic achievement are summarized.

Regulating variable	k	n
Self-efficacy	11	13998
Male	5	36827
Female	5	34452
Gender stereotype	3	11717
Teacher support	4	45848
Teacher-student relationship	4	7501

Note: k is the number of studies with combined effect size; n is the cumulative number of k research samples.

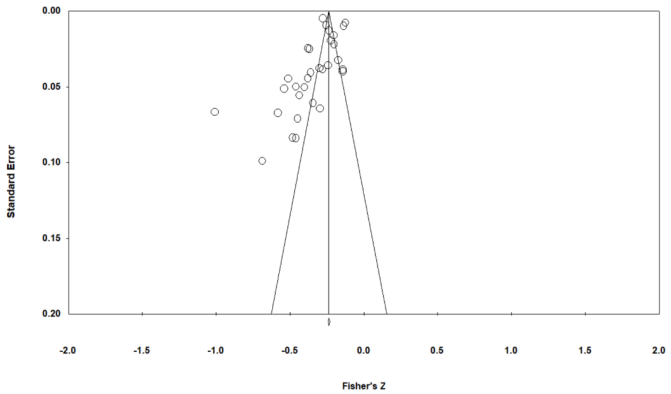

Figure 2. Funnel plot of math anxiety variables.

3 Research and analysis

3.1 Publication bias test

In order to make the research results more real and reliable, it is usually necessary to carry out bias detection on the research samples, so as to illustrate the reliability of statistical analysis of data. In this study, funnel-plot and Egger's test were used to evaluate publication bias of the sample literature. (1) CMA V3 software was used to draw the funnel diagram of sample publication bias detection. It can be seen from the statistical results that the effect sizes of most study samples are evenly distributed on both sides of the average effect size, indicating that there is no publication bias. Take the math anxiety variable as an

example, and its funnel diagram is shown in Figure 2. (2) The linear regression test was conducted, and the result showed that t=2.239, p=0.017, which met the condition that there was no publication deviation, that is, p greater than 0.05 [24]. Therefore, as shown in Table 2, the P-values of the samples were all greater than 0.05, so there was no publication bias.

3.2 Heterogeneity test

Due to the differences in researchers, research objects and evaluation criteria, there may be heterogeneity among studies, which will affect the stability of the average effect size, so it is necessary to conduct heterogeneity tests on research samples. The degree of heterogeneity is tested using I^2. 0% < I^2< 50% is low heterogeneity, 50% 75% is high heterogeneity, and 75% 100% is high heterogeneity [25]. In general, the fixed effects model is used when the sample literature is of low heterogeneity, and the random effects model is used when the sample literature is of medium or high heterogeneity. In this study, in addition to teachers' support I^2= 30.207%<50%, which is low heterogeneity, fixed-effect model was adopted to eliminate heterogeneity; for other samples whose I^2 is greater than 50%, random effect model was adopted to eliminate heterogeneity, so as to ensure the reliability of the study. As shown in Table 3.

Taking variable mathematical anxiety as an example, its I^2=96.396, and its interval is 75%~100%, indicating great heterogeneity, so the random effects model is adopted. At the same time, according to the random effects forest diagram, as shown in Figure 3, it can also be seen that there is a large heterogeneity.

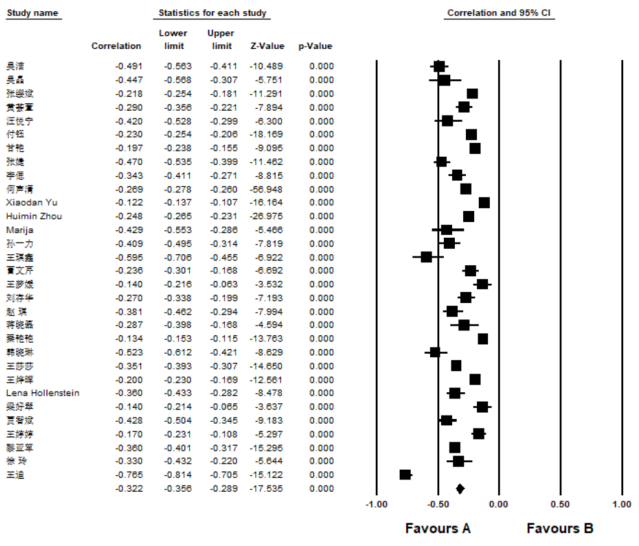

Figure 3. Random effects model forest map.

3.3 Effect size selection

In this study, the correlation coefficient r was used as the effect value to evaluate the impact of math anxiety on students' math academic achievement. According to the principles proposed by Cohen to judge the strength of correlation, R-values ranging from 0.00 to 0.09 indicate basically no correlation, R-values ranging from 0.10 to 0.29 indicate weak correlation, R-values ranging from 0.30 to 0.49 indicate moderate correlation, and R-values ranging from 0.50 to 1.00 indicate strong correlation [26].

3.4 Analysis of the influence of mathematics anxiety on students' mathematics learning performance

In this study, Cumulative Meta Analysis V3 was used to explore the overall impact of math anxiety on students' math academic performance. Cumulative meta-analysis was performed on 103,613 data from 31 literature included in the study, as shown in Table 4. The statistical results show that the final correlation is r=-0.322, ranging from 0.3 to 0.49, indicating that there is a moderate correlation between math anxiety and students' math learning performance, and p=0.000<0.05, reaching a statistically significant level. It can be considered that math anxiety has a moderate negative effect on students' math academic performance. That is, math anxiety is not conducive to improving students' math academic performance.

3.5 An analysis of the moderating effect of moderating variables on students' mathematics learning performance

In order to understand the factors that influence math anxiety on students' math learning performance, this study analyzed the influence of math anxiety on students' math learning performance under the following five moderating variables.

3.5.1 An analysis of the moderating effect of self-efficacy on students' mathematics learning performance

The study on the influence of self-efficacy on students' academic achievement in mathematics selected 11 samples with 13998 data. As shown in Table 5. The results of statistical analysis of self-efficacy on students' mathematics academic performance show that: The 95% interval of the effect value was [0.294, 0.489], and the correlation r was 0.396, between 0.3 and 0.49, indicating that self-efficacy had a moderate correlation strength on students' mathematical academic performance, p =0.000<0.005, which reached the statistically significant level. These results indicate that self-efficacy has a moderate influence on

Table 2. Publication offset check.

Variable	k	n	Intercept	95% interval		t-value	p-value
				Lower limit	Upper limit		
Math anxiety	31	103613	-3.090	-5.579	-0.601	2.339	0.017
Self-efficacy	4	13998	4.407	-3.791	12.605	1.216	0.255
Male	5	36827	-0.981	-20.512	22.475	0.145	0.894
Female	5	34452	-0.910	-23.656	21.837	0.127	0.907
Gender stereotype	3	11717	-2.286	-10.815	6.243	3.406	0.182
Teacher support	4	45848	-0.144	-4.550	4.262	0.141	0.901
Teacher-student relationship	4	7501	-2.052	-8.773	4.668	1.314	0.319

Note: k is the number of studies with combined effect size; n is the cumulative number of k research samples.

Table 3. Heterogeneity test.

Variable	k	n	I^2
Math anxiety	31	103613	96.396
Self-efficacy	4	13998	97.792
Male	5	36827	98.465
Female	5	34452	98.599
Gender stereotype	3	11717	66.367
Teacher support	4	45848	30.207
Teacher-student relationship	4	7501	75.446

Note: k is the number of studies with combined effect size; n is the cumulative number of k research samples.

Table 4. Results of effect value analysis of principal variable mathematical anxiety.

Variable	k	n	r	95% interval		Test of null(2-Tail)	
				Lower limit	upper limit	Z-value	P-value
Math anxiety	31	103613	-0.322	-0.356	-0.289	-17.535	0.000

Note: k is the number of studies with combined effect size; n is the cumulative number of k research samples.

the improvement of students' mathematics academic achievement, and the heterogeneity Q=452.905, p=0.000<0.05, reaching the statistically significant level, indicating that the influence of math anxiety on students' mathematics academic achievement is regulated by self-efficacy.

3.5.2 An analysis of the moderating effect of gender on students' mathematics learning performance

The study on the effect of gender on students' academic achievement in mathematics selected 10 samples with 71,279 data. As shown in Table 6. The study on the effect of gender on students' academic achievement in mathematics includes two variables: boys and girls. The statistical analysis results of male students' mathematics academic achievement show that: 95% interval of effect value is [-0.332, -0.127], correlation r=-0.232, between 0.10 and 0.29, indicating that males have a weak correlation with students' academic performance in mathematics, p =0.000<0.005, reaching a statistically significant level of influence, the Heterogeneity Q=452.905. p=0.000<0.05, which was statistically significant. The results of girls' statistical analysis of students' academic achievement in mathematics show that: The 95% interval of the effect value was [-0.407, -0.198], and the correlation r=-0.306 was between 0.30 and 0.49, indicating that females had a moderate correlation with students' academic performance in mathematics, p =0.000<0.005, reaching a statistically significant level of influence, and the heterogeneity Q=452.905. p=0.000<0.05, which was statistically significant. On the whole, no matter boys or girls, their math anxiety has a negative impact on students' math academic performance. From the correlation, it can be seen that compared with boys, girls are more susceptible to the impact of math anxiety.

3.5.3 An analysis of the moderating effect of gender stereotypes on students' mathematics learning performance

The study on the effect of gender stereotypes on students' academic achievement in mathematics selected 3 samples with 11,717 data. As shown in Table 7. The results of statistical analysis of gender stereotypes on students' academic achievement in mathematics show that: The 95% interval of the effect value is [-0.125, -0.010], and the correlation r=-0.068, which is between 0.00 and 0.09, indicating that gender stereotypes have basically no correlation with students' mathematical academic performance, and the p=0.021 > 0.005 does not reach the statistically significant level of influence. These results indicated that gender stereotypes did not have a certain effect on the improvement of students' mathematics academic achievement, and the heterogeneity Q=5.947, p=0.051 > 0.05, did not reach the statistically significant level, indicating that the effect of math anxiety on students' mathematics academic achievement was not moderated by gender stereotypes.

Table 5. An analysis of the moderating effect of self-efficacy.

Variable	k	n	r	95% interval		Test ofnull(2-Tail)		Heterogeneity		
				Lower limit	upper limit	Z-value	P-value	Q-value	df(Q)	P-value
Self-efficacy	11	13998	0.396	0.294	0.489	7.084	0.000	452.905	10.000	0.000

Note: k is the number of studies with combined effect size; n is the cumulative number of k research

Table 6. Analysis of sex regulation effect.

Variable	k	N	r	95% interval		Test of null(2-Tail)		Heterogeneity		
				Lower limit	upper limit	Z-value	P-value	Q-value	df(Q)	P-value
Male	5	36827	-0.232	-0.332	-0.127	-4.254	0.000	260.636	4.000	0.000
Female	5	34452	-0.306	-0.407	-0.198	-5.345	0.000	285.469	4.000	0.000

Note: k is the number of studies with combined effect size; n is the cumulative number of k research

Table 7. An analysis of the moderating effect of gender stereotypes.

Variable	k	n	r	95% interval		Test of null(2-Tail)		Heterogeneity		
				Lower limit	upper limit	Z-value	P-value	Q-value	df(Q)	P-value
Gender stereotypes	3	11717	-0.068	-0.125	-0.010	-2.299	0.021	5.947	2.000	0.051

Note: k is the number of studies with combined effect size; n is the cumulative number of k research

Table 8. Analysis of moderating effect of teacher support.

Variable	k	n	r	95% interval		Test of null(2-Tail)		Heterogeneity		
				Lower limit	upper limit	Z-value	P-value	Q-value	df(Q)	P-value
Teacher support	4	45848	0.225	0.202	0.248	18.755	0.000	4.298	3.000	0.231

Note: k is the number of studies with combined effect size; n is the cumulative number of k research

Table 9. An analysis of the moderating effect of teacher-student relationship.

Variable	k	n	r	95% interval		Test of null(2-Tail)		Heterogeneity		
				Lower limit	upper limit	Z-value	P-value	Q-value	df(Q)	P-value
Teacher-student relationship	4	7501	0.195	0.125	0.263	5.397	0.000	12.218	3.000	0.007

Note: k is the number of studies with combined effect size; n is the cumulative number of k research

3.5.4 An analysis of the moderating effect of teacher support on students' mathematics learning performance

The study on the influence of teacher support on students' academic achievement in mathematics selected 4 samples with 45,848 data. As shown in Table 8. The results of statistical analysis of students' academic achievement in mathematics supported by teachers show that: The 95% interval of the effect value is [0.202, 0.248], and the correlation r=0.225, between 0.10 and 0.29, indicating that teacher support has a weak correlation with students' academic performance in mathematics, p =0.000<0.005, reaching a statistically significant level of influence. This indicates that teacher support has a certain degree of influence on the improvement of students' mathematics academic achievement, and the heterogeneity Q=4.298, p=0.231 > 0.05, which does not reach the statistically significant level, indicating that the influence of math anxiety on students' mathematics academic achievement is uncertain due to the moderating effect of teacher support.

3.5.5 An analysis of the moderating effect of teacher-student relationship on students' mathematics learning performance

The study of the influence of teacher-student relationship on students' academic achievement in mathematics selected 4 samples with 7501 data. As shown in Table 9. The results of statistical analysis of the influence of teacher-student relationship on students' mathematics academic achievement show that: 95% interval of effect value is [0.125, 0.263], correlation r=0.195, between 0.10 and 0.29, indicating that teacher-student relationship has a weak correlation with students' academic performance in mathematics, p =0.000<0.005, reaching a statistically significant level of influence. This indicates that the teacher-student relationship has a certain degree of influence on the improvement of students' mathematics academic performance, and the heterogeneity Q=12.218, p=0.007<0.05, reaching the statistically significant level, indicating that the influence of math anxiety on students' mathematics academic performance is moderated by the teacher-student relationship.

4 Discussion

4.1 Mathematics anxiety has an obvious negative effect on the improvement of students' mathematics academic achievement

On the whole, math anxiety has a moderate negative impact on the improvement of students' math academic performance, and the overall correlation is -0.322, indicating that math anxiety can significantly reduce students' math academic performance, which is similar to previous studies. The negative effect of math anxiety on students' math achievement can be analyzed from several aspects. First, it will bring huge psychological pressure and distress to students, for example, fear and aversion to mathematics, that is, students will have a great fear and rejection of mathematics, think that mathematics is difficult and not interested, and may even produce physiological reactions such as heartbeat racing and sweating when taking math classes or doing math homework. Second, distraction. Anxiety not only seriously affects students' attention and concentration, making it difficult for them to devote themselves to the study of mathematics, but also affects their understanding of the problem and grasp of problem-solving ideas, leading to problem solving errors. Third, the lack of self-confidence, math anxiety makes students doubt their own math ability, that is, they think they are not good at math, and do not believe that they have the ability to learn math, and then affect their more in-depth learning. In July 2021, the "double reduction" policy proposed by the General Office of the Communist Party of China Central Committee and the General Office of the State Council means that the homework burden and tutoring burden of students should be greatly reduced in the compulsory education stage, which reflects the current situation of education and teaching in the basic education stage in China, and aims to reduce the academic pressure of students, eliminate students' bad emotions, and promote the all-round development of students. At the same time, as a highly abstract and rigorous subject of thinking [27], most students think that mathematics is difficult to understand, and they are full of fear of mathematics, and their fear of math classes and math exams has become the most real psychological portrayal of many students. It can be seen that math anxiety will not only affect students' math learning, but also adversely affect their overall academic performance and mental health, so it is of great significance to find and help students overcome math anxiety in time.

4.2 The mechanism of mathematics anxiety affecting students' mathematics academic achievement

Firstly, the effect of math anxiety on students' math achievement is moderated by self-efficacy, teacher support and teacher-student relationship. The correlation coefficient between each adjustment variable and students' mathematics academic achievement is shown in Figure 4. From the correlation of the moderating variable of self-efficacy, r=0.396, indicating that self-efficacy has a moderate influence on the improvement of students' math academic achievement, and the influence of math anxiety on students' math academic achievement is regulated by self-efficacy. The reason for this may be that, from the root, math anxiety comes from students themselves, and the most important thing to help students solve math anxiety is to help students change their negative perceptions of themselves and math. Math self-efficacy emphasizes the assessment of an individual's confidence in whether he can successfully complete a specific math task or problem [28], and is also one of the important factors in predicting students' core literacy and happiness [29]. The more students believe in their own math ability, the stronger the sense of math self-efficacy, the more they can overcome their own negative emotions about math, that is, math anxiety, give play to their subjective initiative, and then have better performance in the process of math

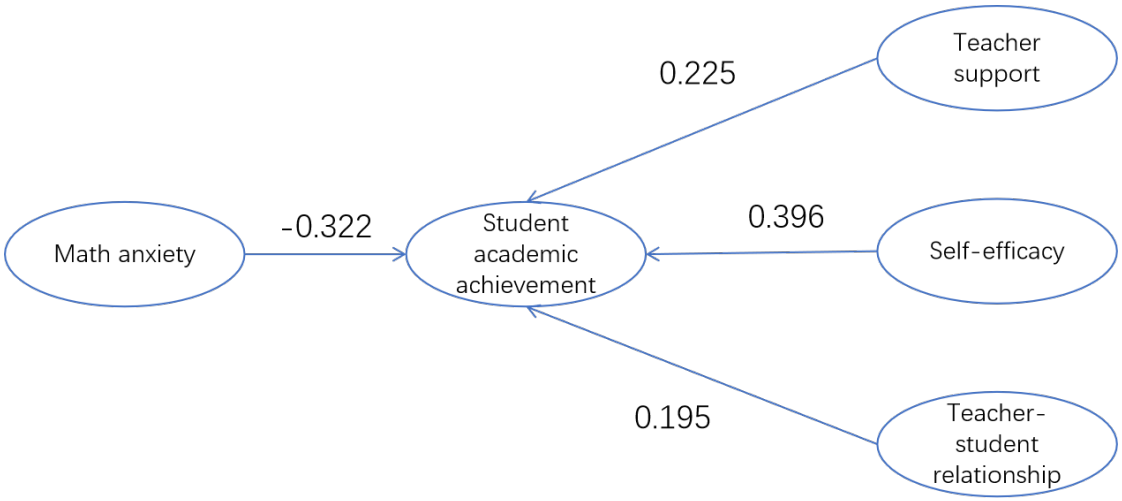

Figure 4. Influencing factors and relationship strength of students' academic achievement.

learning. It can be seen that self-efficacy can play a key and powerful role in students' academic performance. From the perspective of correlation of teacher support moderating variable, r=0.225, indicating that teacher support has a certain degree of influence on the improvement of students' mathematics academic achievement, but the moderating effect of teacher support variable is uncertain. The reason may be that teacher support is not only academic help, but also emotional and social care, aimed at promoting the overall development of students, enhancing their learning motivation and academic achievement. For example, teachers use positive words to make students fully feel the teacher's care for them and other positive emotions in their learning life [30], help students overcome the fear of mathematics caused by math anxiety, build students' self-confidence, and further improve students' academic performance. From the correlation of the regulating variables of teacher-student relationship, r=0.195, indicating that teacher-student relationship has a certain degree of influence on the improvement of students' mathematics academic performance. The reason may be that the teacher-student relationship is the most basic and important interpersonal relationship in the process of education and teaching activities [19]. A supportive learning environment can promote students to establish a trusting relationship with teachers, enhance students' sense of belonging and create a sense of security. In such an environment, students may relieve their learning anxiety and release pressure.

Secondly, the effect of math anxiety on students' math achievement is not significantly moderated by gender and gender stereotype. On the whole, no matter boys or girls, math anxiety has a negative impact on students' math academic performance. As can be seen from the correlation, compared with boys, girls are more susceptible to math anxiety, but it is not significant. The reasons may be as follows: On the one hand, math anxiety, as a manifestation of personal emotions, is more likely than boys to use emotional concentration strategies to immerse themselves in negative emotions when regulating emotions, making them more susceptible to emotions in the cognitive process. On the other hand, the public has gender cognitive bias in the field of mathematics, that is, most people believe that girls are at a disadvantage in the field of mathematics and that girls' mathematical ability is inferior to that of boys [31]. If such bias persists for a long time, it will have a negative impact on girls. It follows that women are more affected by emotions, namely math anxiety.

To sum up, math anxiety has not only internal factors but also external factors that affect math academic performance. Internally, gender and gender stereotypes are one of the reasons for the difference between male and female perception of math anxiety, and self-efficacy is an important factor for an individual to overcome math anxiety and improve math performance. It is also an important force to promote the progress of students' academic performance.

5 Educational implications

The results of the meta-analysis of the sample literature show that math anxiety has a negative inhibitory effect on the improvement of students' math academic achievement, but the relationship between math anxiety and students' math academic achievement will

show different effects under different conditions. The enhancement of students' sense of self-efficacy, the improvement of teachers' independent support and the good relationship between teachers and students can all have a positive impact on students' math anxiety and math academic performance. Therefore, the alleviation of students' math anxiety and the improvement of math academic performance can be started from the following aspects.

5.1 Self-regulation to enhance self-efficacy

There is a close relationship and interaction between students' self-regulation ability and self-efficacy. Self-regulation, including self-monitoring, self-evaluation and self-reflection, can help students better manage their learning process. Self-efficacy refers to students' judgment of their ability to organize and execute learning tasks to be completed in the future . Students with high self-efficacy can properly explain the difficulty of learning tasks, often devote themselves to learning with full positive emotions and self-confidence, and obtain higher mathematical achievements. In the learning process, students can improve the effective self-regulation of their learning behavior, mobilize the enthusiasm of learning, so as to improve self-efficacy. In the classroom, teachers can provide encouragement, set appropriate challenges, give timely feedback, etc., so that students have stronger confidence in their learning ability, and then enhance students' self-efficacy.

5.2 Improve teaching effect with teacher support

Teacher support is an important form of teacher-student interaction in school teaching [32]. Teacher support can promote the positive psychological factors such as students' learning interest and motivation, and can also dissolve the negative psychological factors of students. Mathematics anxiety, as an important threat in the process of students' mathematics learning, will have a negative impact on students' learning. When students receive active teacher support, students can perceive more care and respect, which can help eliminate students' math anxiety. Therefore, in the teaching process, teachers should fully understand, support and help students at the academic level, promote students to show more active learning motivation, have more participation in the classroom, and improve the teaching effect.

5.3 To optimize the environment and ease negative emotions

In the process of growing up, students will be influenced by various environments, such as society, school, family, etc. In the school environment, the relationship between teachers and students is an important part of it, and students' views on the quality of teacher relationship will affect their academic engagement and learning outcomes. A good teacher-student relationship helps students feel supported and encouraged in the learning process, and helps them enhance their learning motivation and self-confidence. The tense relationship between teachers and students may cause students to feel isolated and have bad emotions, which will lead to a decline in learning motivation, and then affect academic performance. Therefore, students' math anxiety can be relieved by shaping a good environment and creating a good atmosphere between teachers and students.

6 Conclusion

This study used a meta-analysis method to assess the extent to which math anxiety affects students' math academic achievement. Through quantitative analysis of 31 experimental research samples, the overall effect value of math anxiety on students' math academic performance was obtained, so as to draw the research conclusion that math anxiety has a significant negative effect on students' math academic performance, and then respond to the problem that whether math anxiety can reduce students' math academic performance in the current field. At the same time, this study analyzed the differences in the effect of self-efficacy, gender, gender stereotype, teacher support and other moderating variables on the improvement of students' mathematics academic achievement, and answered the question "What factors regulate the impact of math anxiety on students' mathematics academic achievement". The results of this study are based on extensive collection of domestic and foreign experiments and have a certain credibility. However, due to the limited number of literature included in the analysis, more empirical studies on the impact of math anxiety on students' math academic performance need to be added in future studies.

Data Availability Statement

Data will be made available on request.

Funding

This work was supported without any funding.

Conflicts of Interest

The author declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

References

[1] Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology, 7*, Article 508. [CrossRef]

[2] Punaro, L., & Reeve, R. (2012). Relationships between 9-Year-Olds' Math and Literacy Worries and Academic Abilities. *Child Development Research, 2012*(1), 359089. [CrossRef]

[3] He, S. Q., & Qi, C. X. (2023). How students' perceived teacher autonomy support and math anxiety affect academic achievement: Evidence from 42,643 students in Province Z. *Educational Science Research, (2)*, 60–68.

[4] Zhou, S. Z., Han, C. C., & Chen, Y. H. (2014). The mechanism of how math anxiety affects academic achievement in mathematics: The mediating role of mathematical metacognition. *Journal of Mathematics Education, 23*(5), 14–18.

[5] Liu, Y. X., Hu, H. B., & Guo, K. (2024). The relationship between math anxiety and academic performance among basic education students in China: A meta-analysis of 68 Chinese studies. *Journal of Educational Studies, 20*(2), 165–178.

[6] Plake, B. S., & Parker, C. S. (1982). The development and validation of a revised version of the Mathematics Anxiety Rating Scale. *Educational and Psychological Measurement, 42*(2), 551–557. [CrossRef]

[7] Wang, T. T., Yang, M. Z., & Si, J. W. (2018). The relationship between gender stereotypes in mathematics, math anxiety, and math performance among high school students. *Journal of Youth Studies, (1)*, 23-30.

[8] Dreger, R. M., & Aiken, L. R., Jr. (1957). The identification of number anxiety in a college population. *Journal of Educational Psychology, 48*(6), 344–351. [CrossRef]

[9] Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*(1), 33–46. [CrossRef]

[10] Yu, X., Zhou, H., Sheng, P., et al. (2024). Math anxiety is more closely associated with math performance in female students than in male students. *Current Psychology, 43*, 1381–1394. [CrossRef]

[11] Ashcraft, M. H., & Ridley, K. S. (2005). Math anxiety and its cognitive consequences: A tutorial review. In J. I. D. Campbell (Ed.), *Handbook of mathematical cognition* (pp. 315–327). Psychology Press.

[12] OECD. (2015, February 1). Does math make you anxious? *OECD Education Working Papers*.

[13] Zhang, J., Huang, B. J., & Si, J. W. (2018). Math anxiety and math performance in rural primary school students: The chain mediating role of math self-efficacy and math metacognition. *Psychological Development and Education, 34*(4), 453–460.

[14] Wu, J., Ying, Y. F., Liu, L. H., et al. (2017). A study on the relationship between mathematics anxiety and mathematics achievement in urban junior high school students. In *Proceedings of the 12th Academic Annual Conference of Zhejiang Psychological Health Association and the 3rd Psychological Consultant Conference of Zhejiang Province* (pp. 68-75). Psychological Counseling Center of Lishui Second People's Hospital.

[15] Huang, H. X. (2023). *A study on the relationship between teacher-student relationship, mathematics anxiety, and mathematics academic performance among high school students* (Master's thesis, Tianjin Normal University). CNKI.

[16] Skemp, R. R. (2012). *The psychology of learning mathematics: Expanded American edition*. Routledge.

[17] Cemen, P. B. (1987). The nature of mathematics anxiety. *Journal of Counseling Psychology, 34*(3), 212–218.

[18] Wang, Y. H., Zhang, Y. M., & Du, C. H. (2023). The impact of mathematical self-efficacy on primary school students' math performance: The mediating role of math anxiety and math interest. *Educational Measurement and Evaluation, (5)*, 92–101.

[19] Bander, R. S., & Betz, N. E. (1981). The relationship of sex and sex role to trait and situationally specific anxiety types. *Journal of Research in Personality, 15*(3), 312–322. [CrossRef]

[20] Song, S. J. (2017). Gender stereotypes in mathematics, math self-efficacy, and their impact on female students. *Secondary School Mathematics Teaching, (4)*, 1-3.

[21] Fu, Y., & Qi, C. X. (2023). The relationship between teacher-student relationships and math performance: The mediating role of self-efficacy and math anxiety. *Journal of Mathematics Education, 32*(1), 25-30.

[22] Van, D.N, W., & Onghena, P. (2005). Parametric and nonparametric bootstrap methods for meta-analysis. *Behavior Research Methods, 37*(1), 11–22. [CrossRef]

[23] Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist, 53*(3), 145-164. [CrossRef]

[24] Shan, J. H., Gong, L. L., & Li, Y. (2019). The impact of educational robots on student learning outcomes: A meta-analysis of 49 experimental or quasi-experimental studies. *China Educational*

Technology, (5), 76–83.

[25] Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ, 327*(7414), 557–560. [CrossRef]

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

[27] Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in Cognitive Sciences, 16*(8), 404-406. [CrossRef]

[28] Lent, R. W., Brown, S. D., & Larkin, K. C. (1986). Self-efficacy in the prediction of academic performance and perceived career options. *Journal of Counseling Psychology, 33*(3), 265–269.

[29] Zhao, Y. Y., & Hu, N. (2021). The impact of well-being on adolescents' academic literacy: An empirical study based on PISA 2018 data from four Chinese provinces. *Research in Educational Development, 41*(6), 74–84.

[30] Li, W., & Bai, Y. Y. (2018). How does perceived teacher support affect academic performance in eighth graders? A multiple mediation analysis of academic self-efficacy and learning engagement. *Education and Economy, (6)*, 86–92.

[31] Zhang, Y. (2021). *A study on the relationship between gender stereotypes in mathematics and mathematics anxiety among junior high school students* (Master's thesis, Tianjin Normal University). CNKI.

[32] Zhang, Y. Y., Liu, S. C., & Ren, P. (2020). How do students' academic and behavioral characteristics affect teacher support? Evidence from individual and group levels. *Psychological Development and Education, 36*(3), 318–328.

Xiaoyu Yan is studying for a master's degree in primary education at Fujian Normal University. (Email: qsz20240792@student.fjnu.edu.cn)