Cognitive and Behavioral Science Digest
WISDOM ACADEMIC ISSN: 3104-6436 | E-ISSN: 3104-6444 *Volume 2 , Issue 1*

Article

The Relationship Between Mathematics Anxiety, Mathematics Self-Efficacy, and Mathematics Achievement Among Middle School Students in Xingtai City, China

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CITATION

Zhang QY, Lim CH, Tay M, Zhang X, Liang HB & Zheng D. The Relationship Between Mathematics Anxiety, Mathematics Self-Efficacy, and Mathematics Achievement Among Middle School Students in Xingtai City, China. Cognitive and Behavioral Science Digest. 2026; Vol 2 (No. 1): 286.

https://doi.org/10.63808/cbsd.v2i1.286

ARTICLE INFO

Received: 4 December 2025
Accepted: 8 December 2025
Available online: 21 January 2026

Abstract: The paper analyzes the relationship of the anxiety of mathematics and mathematics self-efficacy with academic performance of Chinese students in middle schools. In particular, it will examine the presence of gender and grade level differences in these constructs and whether self-efficacy is the cause which moderates between the relationship of anxiety and performance. An Xingtai City cross-sectional survey among 724 students was carried out. Data analysis was done based on descriptive statistics, t-test, ANOVA, Pearson correlation, and moderation analysis in structural equation modeling (SEM). The findings indicated that anxiety about mathematics had a negative predictive value in achieving performance and that self-efficacy had a positive predictive value in achieving performance. The differences between gender and grade-level were statistically significant. Besides, self-efficacy mediated the impact of anxiety on achievement. These results indicate that special intervention towards the various

ISSN: 3104-6436 | E-ISSN: 3104-6444 Volume 2 , Issue 1

groups of students is necessary and that, there is a need to promote self-efficacy in order to counteract the deleterious effects of anxiety.

Keywords: mathematics anxiety; self-efficacy; academic achievement; moderation

1. Introduction

Achievement in mathematics is popularly understood as a baseline academic skill, which largely determines the life path of the student, and their future career path, especially in STEM (science, technology, engineering, and mathematics) disciplines. Emotional barriers to learning affect a good percentage of students although it is an essential matter. One of them, mathematics anxiety-a psychological condition manifested as a feeling of tension, fear, or apprehension about approaching math-related tasks-has repeatedly been determined to be a key barrier to performance (Ramirez et al., 2023). According to neurocognitive research, math-anxious subjects have been shown to have more amygdala activity that interferes with working memory in the process of solving mathematical problems.

By comparison, academic resilience, persistence, and higher performance have been positively linked to mathematical self-efficacy, or the belief of a student that he or she can successfully complete mathematics tasks (Bandura, 1997; Marsh et al., 2023). The results of meta-analysis and longitudinal studies in different countries prove that self-efficacy increases readiness to address challenges among students and has the power to reduce the adverse outcomes of stress and anxiety (Lin et al., 2022).

Notably, new studies promote the idea that mathematics self-efficacy can be more than a predictor of performance: it can also be a mediating factor that removes the negative effect of mathematics anxiety on achievement (Liu and Zhang, 2023; Sun and Jiang, 2023). This interaction is most applicable in the high-pressure educational systems.

There is complexity of gender and developmental variables. It has always been observed that girls express more mathematics anxiety and a lower degree of self-efficacy than boys and, in most cases, is influenced by societal stereotypes and school dynamics (Tan et al., 2022). Also, the levels of anxiety can be most significant in periods of critical academic shifts, including the transition between middle and

high school, where the students are exposed to escalating cognitive load and external pressure (Cheng & Wang, 2023).

It is however noteworthy that, as a rule, these findings are a result of Western environments. By comparison, the literature on East Asian students specifically-Chinese adolescents- is comparatively scant, even though the academic pressure is ardent, and the math education of the Chinese education system is high-stakes (Zhao et al., 2024). To fill this gap, this paper examines the constructs under a Chinese middle school setting.

Precisely, the research questions examined in the study are the following:

1. Is the mathematics anxiety and self-efficacy between Chinese middle school students dependent on gender and grade level?

2. What is the association between the self-efficacy and achievement of math anxiety?

3.Is there a moderation of relationship between mathematics anxiety and achievement by self-efficacy?

Through the analysis of these questions, the study will enhance the knowledge of emotional and cognitive antecedents to academic outcomes and provide practical implications of academic intervention of differentiation based on the culturally specific context.

2. Methods

2.1. Participants

There were 724 middle school students (365 boys and 359 girls) in the Xingtai Middle School in the Hebei Province who took part in this study (students in the 7th, 8th, and 9th grade of the school). Stratified cluster sampling was used to select the sample because of its rigor and practicality. Considering the high and geographically spread-out number of the student population in the Xingtai City, it would have been logistically difficult and time consuming to list the whole number of students and use simple random sampling. A two-stage cluster sampling strategy was used instead where schools were sampled in stage one and then random selection of intact classes in the sampled schools was done. This method was highly effective in collecting data in a large scale (Kish, 1965). In addition, sampling was simplified and easily

manageable as it was more feasible to get lists of schools as opposed to individual students (Lauren, 2020). The responses were collected using questionnaires in classes and the quality control was assured by the elimination of invalid answers.

2.2. Instruments

(1) Mathematics Anxiety Scale: 27 questions that refer to test anxiety, fear of pressure, worry in a classroom, and anxiety. The first dimension is the dimension of fear of pressure that measures the fear of pressure among students in three areas: mathematics subjects, mathematics questions, and mathematics tests; the second dimension is the dimension of emotional worry; it is the fear of pressure among students; the third dimension is the level of anxiety in the classroom, which is a survey of student anxiety on mathematics classes. The questionnaire questions 24, 25, and 26 are reverse questions and these may be used to identify whether the filling in of students is not inconsistent. In case of contradiction, a characteristic of invalid questionnaire will be considered. The method used in this questionnaire was the five point Likert scale. These will be the following; completely disagree, basically disagree, generally, basically agree, and completely agree. The scores are 1, 2, 3, 4, and 5; the scores of the reverse question are 5, 4, 3, 2, and 1. The alpha coefficient in the questionnaire is 0.95 meaning that the questionnaire is high in consistency and data reliability is high in quality. Moreover, Exploratory Factor Analysis (EFA) on the questionnaire, found the KMO=0.87, Bartlett test 2=138.54, P<.01. The factor loadings of the questionnaire questions were all>0.4, indicating that the questionnaire had good structural validity.

(2) Mathematics Self-Efficacy Scale: 12 items of ability-based and behavior-based efficacy. It was founded on Teacher Efficacy Scale as joined by Gibson and Dembo and has two dimensions of mathematical self-efficacy, being ability self-efficacy and behavioral self-efficacy. Ability self-efficacy describes the belief of a person towards the ability to perform good grades and not fail in mathematics academically. On the other hand, behavioral self-efficacy is self-judgment made by an individual about whether or not his own learning behavior can attain the goals of learning. The questionnaire was completed in using a five-point Likert scale methodology, which is based on three possibilities of response as completely disagree, completely agree, and scores of 1 to 5. The scores of the reverse question were 5 to 1. There was a good internal consistency of the questionnaire with

a good 0.92 of alpha coefficient and a high quality of data reliability. More so, Exploratory Factor Analysis (EFA) of the questionnaire revealed that: KMO=0.84, Bartlett test 2 =168.84, P<.01. Factor loadings of the questionnaire questions were all >0.4, indicating that the questionnaire had good structural validity.

(3) Mathematics Achievement: Final standardized mathematics examination scores.

2.3. Procedure and Data Analysis

There was the cleaning and standardization of data (z-scores). The use of SPSS was through descriptive statistics, independent samples t-tests, one way ANOVA and Pearson correlation. Mplus moderate testing with SEM bootstrapping were applied in order to test confidence intervals.

3. Results

3.1. Descriptive Statistics

Table 1 indicates the demographic breakdown of participants based on their gender and grade level that indicated almost equal gender breakdown and comparatively even distribution among the three grade levels. The research sample was comprised of 365 students who were male (50.4 percent) and 359 students who were female (49.6 percent). The distribution of grades at the grade level was as follows; Grade 7 (43.5) Grade 8 (38.5) Grade 9 (18.0).

Table 1

Demographic Characteristics of Participants

Variable	N	%
Gender		
Male	365	50.4
Female	359	49.6
Total	724	100
Grade		
Grade 7	315	43.5

Male	161	22.2
Female	154	21.3
Grade 8	279	38.5
Male	154	21.3
Female	125	17.2
Grade 9	130	18
Male	50	6.9
Female	80	11.1
Total	724	100

Table 2 presents the descriptive statistics of mathematics anxiety, mathematical self-efficacy, and mathematical achievement respectively between the two genders and the different grade levels. The statistics are useful in the interpretation of the general distribution of the main variables in the research. It is important to note that the value of mathematics anxiety was lower (-0.191) among male students than the female students (0.194) and mathematics self-efficacy (M = 0.223 and 0.226) was greater among male students than that of the female students (0.226). Analysis of data at Grade 8 level showed that Grade 8 students had the worst mathematics anxiety (M = 0.179) and mathematics self-efficacy (M = -0.195) whereas Grade 9 students were better in mathematics self-efficacy (M = 0.017) and mathematics achievement (M = 0.380).

Table 2

Mean and standard deviation of key variables

	Mathematics anxiety	Mathematics self-efficacy	Mathematics achievement
Gender	M(SD)	M(SD)	M(SD)
Male	-0.191(1.022)	0.222(10.2)	0.035(1.031)
Female	0.194(0.944)	-0.226(0.944)	-0.035(0.967)
Grade	M(SD)	M(SD)	M(SD)
Grade 7	-0.101(0.972)	0.165(0.949)	0.167(0.933)
Grade 8	0.179(1.041)	-0.195(1.078)	-0.365(0.970)

Grade 9	-0.139(0.925)	0.017(0.870)	0.380(0.979)

There was almost an equal distribution of the gender. Anxiety in mathematics (M =.194) and lower self-efficacy (M = -.226) were higher among female students than male students. The Grade 8 students were more anxious and low achievement than Grade 7 and 9 students.

3.2. Gender and Grade-Level Differences

3.2.1 Gender-Level Differences

The results of the independent samples t -test are provided in **Table 3**; they are used to test the significance of the difference in mean scores of males and females. The findings show that math anxiety among females was higher than among males (t = -5.281, p =.001) and for males the level of self-efficacy was much higher (t = 6.197, p =.001).

Table 3

Independent Samples t-test for Gender Differences

	t	P	Mean Difference	Std. Error Difference
Mathematics anxiety	-5.28	<.01	-3.85	0.07
Mathematics self-efficacy	6.20	<.01	0.45	0.07

3.2.2 Grade-Level Differences

The outcomes of a one-way ANOVA that has been used to compare the two grade levels are given in **Table 4**. There were great differences between grade levels in mathematics anxiety (F = 7.437, p <.001), with Grade 9 experiencing higher anxiety levels than Grade 7 and 8. In the same way, self-efficacy differed significantly by grade level (F = 9.866, p <.001), with Grade 9 students having the lowest levels.

Table 4

ANOVA Results for Grade-Level Differences

	Sum of Squares	df	Mean Square	F	P

Mathematics anxiety	Between Groups	14.61	2	7.31	7.44	<.01
	Within Groups	708.39	721	0.98		
	Total	723.00	723			
Mathematics self-efficacy	Between Groups	19.26	2	9.63	9.87	<.001
	Within Groups	703.74	721	0.97		
	Total	723.00	723			

Independent samples t-tests showed that gender differences were significant in mathematics anxiety ($t = -5.28$, $p < .001$) and self-efficacy ($t = 6.20$, $p < .001$). The statistical significance of mathematics anxiety ($F = 7.44$, $p = .001$) and self-efficacy ($F = 9.87$, $p < .001$) on grade-level based on ANOVA is significant.

3.3. Correlation Analysis

The Pearson correlation coefficient between mathematics anxiety, self-efficacy and academic achievement is shown in **Table 5**. The findings show that mathematics anxiety and academic achievement have a negative relationship, which is significant ($r = -0.604$, $p < .001$). However, achievement is strongly positively related to self-efficacy ($r = 0.562$, $p < .001$). Also, the mathematics anxiety is strongly correlated with the self-efficacy showing negative correlation ($r = -0.811$, $p < .001$).

Table 5

Pearson Correlation Matrix

	1	2	3
1 Mathematics anxiety	1	-0.81***	-0.61**
2 Mathematics self-efficacy		1	0.56**
3 Mathematics achievement			1

Note. * Means $p < 0.05$; ** means $p < 0.01$; ***means $p < 0.001$

3.4. Moderation Analysis

To test the moderating/modifying effect of mathematics self-efficacy on the relationship between mathematics anxiety and academic performance, structural equation modeling (SEM) via the Mplus was considered. The results, as revealed in **Table 6** indicate that, the term of interaction was significant indicating the mathematics self-efficacy moderates the impact of mathematics anxiety on achievement.

Table 6

Moderation Effect Analysis

Variable Path	β	SE	p-value
Mathematics Anxiety → Mathematics Achievement	-0.50	0.08	0.001
Mathematics Self-Efficacy → Mathematics Achievement	0.35	0.07	0.002
Interaction (Mathematics Anxiety × Self-Efficacy) → Mathematics Achievement	0.20	0.05	0.018

The findings indicated that mathematics anxiety negatively influences mathematics performance (= -0.50, p =.001). The significant positive influence of mathematics self-efficacy on mathematics achievement (= 0.35, =.002) happens. The term of interaction is important (0.20, 0.018), meaning that mathematics self-efficacy enters the relationship between mathematics anxiety and mathematics achievement.

3.5. Bootstrap 95% Confidence Intervals (Table 7)

Table 7

Bootstrap 95% Confidence Intervals for Path Coefficients

Path	Standardized Coefficient (β)	95% CI Lower Bound	95% CI Upper Bound
Mathematics Anxiety → Achievement	-0.50	-0.65	-0.35
Self-Efficacy → Achievement	0.35	0.20	0.50
Interaction (Anxiety × Self-Efficacy)	0.20	0.05	0.35

Note. All confidence intervals exclude zero, indicating robust moderation effects.

3.6. Model Fit Indices

Model fit indices indicated an adequate model fit (**Table 8**):

Table 8

Model Fit Indices

Fit Index	Value	Reference Threshold
χ^2/df	1.98	< 3
CFI	0.95	> 0.90
TLI	0.93	> 0.90
RMSEA	0.05	< 0.08

Note. The model demonstrates excellent fit, supporting the hypothesized moderation effect.

3.7. Interpretation of Moderation Effect

The findings indicated that mathematics anxiety negatively influences mathematics performance (= -0.50, p =.001). The significant positive influence of mathematics self-efficacy on mathematics achievement (= 0.35, =.002) happens. The term of interaction is important (0.20, 0.018), meaning that mathematics self-efficacy enters the relationship between mathematics anxiety and mathematics achievement.

4. Discussion

In this study it is stipulated with strong empirical evidence that mathematics anxiety is one of the major determinants of poor academic performance especially in student with low self-efficacy levels. We can state that our findings correspond to the cognitive interference model (Ashcraft and Kirk, 2001) where anxiety is harmful to mathematical reasoning and problem solving. Neurocognitive studies in the recent past also support this fact, stating that highly mathematics anxious students have a higher amygdala activation but less functioning of the prefrontal cortex, worsening

executive control and numerical operations (Pizzie and Kraemer, 2023; Ramirez et al., 2023).

On the other hand, mathematics self-efficacy seems to become a protective psychological tool, which contributes to persistence, goal orientation, and intrinsic motivation (Marsh et al., 2023; Zimmerman, 2000). The recent results confirm the hypothesis of Bandura (1997), who believes that self-efficacy and its related theory influence not only the academic behavior of students, but also influence the way students are able to control their emotions in difficult circumstances. As reflected in our moderation analysis, such students with high self-efficacy have weakened negative influences of anxiety on achievement, and this points at self-efficacy buffering effect. This is reminiscent of the more recent literature that highlights that psychic resources can avert the effects of emotional menaces on the learning performance (Liu and Zhang, 2023; Sun and Jiang, 2023).

Gender Differences and Social Stereotyping: Gender-based differences in this study, increased math anxiety and reduced self-efficacy among the female students, are similar to those found in various educational systems (Devine et al., 2012; Ganley and Lubienski, 2016). Studies indicate that these differences were established in the gender stereotypes towards math, which are instilled at an early age (Cvencek et al., 2011). Girls might use failure in mathematics as such that are personal, whereas boys tend to place the blame on the outside factors, like the difficulty of the tasks (Gunderson et al., 2022; OECD, 2019).

Similar gendered beliefs have also been reported in recent Chinese research, whereby girls get less encouragement on STEM-related backgrounds, which inflates the performance anxiety and lowers self-efficacy (Tan et al., 2022). Equity-based pedagogical changes, including gender-sensitive teaching as well as a higher presence of female role model in mathematics lessons and the enlightenment of implicit biases by teacher training, are recommended based on these results (Wang and Degol, 2017).

Among the differences in development, our findings indicate that students in Grade 8 mentioned the most levels of mathematics anxiety and least self-efficacy, which is also corroborated in the previous literature regarding the significance of the impact associated with stress at middle school (Eccles et al., 1993; Lin et al., 2022). This phase usually goes along with increased academic pressure, identity formation, and accumulating stress associated with school application tests and college changes. Such stress can occur in accordance with the theory of Stage-Environment Fit, when

the school demands are higher and the adolescents are domed to the needs of cognitive and emotional development.

This is the reason why interventions at critical transition stages in education are needed at the right time. As an example, peer mentoring, emotional support programs, and classroom-based coping skills training have proved beneficial in enhancing the results in the context of transitional academic periods (Chen et al., 2024).

The most prominent contribution of the research consists in the fact that self-efficacy has been proven to be a valuable moderator in the correlation between mathematics anxiety and academic results. According to the recent structural modeling investigations (Lai and Tang, 2024), our results indicate that students who have a stronger self-efficacy can be better prepared to take the symptoms of anxiety as challenges to conquer instead of a threat and retain cognitive functioning and performance under pressure. This is the same as in the protective-stabilizing model of coping, according to which robust belief systems buffer the negative impact of stress factors (Putwain et al., 2013).

The results provide a number of practical suggestions to the educational business: Integrative intervention programs must not be designed to reduce anxiety (e.g., by introducing relaxation, cognitive restructuring) but must have the elements that are thought to provide mathematics self-efficacy, including the mastery experiences, positive feedback, and modeling (by peers, etc.); (Schunk & Pajares, 2002). The curriculum designers might think of implementing the metacognitive strategies and reflection practices in the realm of mathematics instruction, which helps students monitor their progress and manage emotions. The issue of parental involvement also ought to be considered because it has been proved that the attitudes of parents in mathematics and their level of anxiety can affect mathematics confidence and achievement among children (Maloney et al., 2021).

The research has various weaknesses despite the strength. It is cross-sectional and does not allow causal inference. Longitudinal research should be conducted in future to investigate how the interaction among anxiety, self-efficacy, and achievement changes with time. Moreover, any data were self-reported, which can cause biasness. Validity could be strengthened by the inclusion of multimethod measurements (e.g. physiological measurements, behavioral tasks).

Lastly, ecological conditions, like classroom climate, peer competition, and teacher expectations, are moderators that need to be investigated in future studies to

learn the extent to which these ecological situations affect the anxiety-efficacy-achievement nexus. Comparative cross-cultural studies can also include finding distinct protective processes that are incorporated into various educational traditions.

5. Conclusion

This study obtains significant relationship between mathematics anxiety, self-efficacy, and performance. It demonstrates that with the increasing levels of mathematics anxiety, academic success is negatively related, and with stronger self-efficacy, academic success is positively predicted and may be used as counteracting performance impairments of anxiety. Also, it was found that mathematics anxiety among female students was higher and self-efficacy was lower and students in Grade 8 were the highest in terms of anxiety. On the basis of these findings, it is proposed that the self-efficacy and mathematics anxiety should be offered though educational interventions with an emphasis on female students and Grade 8 students to improve their academic performance.

Author contributions: Conceptualization, QZ and CHL; methodology, QZ; software, QZ; validation, QZ, CHL and MT; formal analysis, QZ; investigation, HL, XZ and DZ; resources, QZ; data curation, QZ; writing-original draft preparation, QZ; writing-review and editing, QZ, CHL and MT; visualization, XZ; supervision, CHL and MT; project administration, QZ; funding acquisition, QZ. All authors have read and agreed to the published version of the manuscript.

Acknowledgment: We acknowledge the support of Xingtai City's middle schools and the participants in this study. We would like to thank the teachers and administrators who facilitated the data collection process. Special thanks to the students who participated in the study.

Conflict of interest: The authors declare no conflict of interest.

Funding: This research received no external funding.

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