INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

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ISSN: 2226-6348

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v11-i3/14721 DOI:10.6007/IJARPED/v11-i3/14721

Received: *17* June 2022*,* ***Revised:*** *19* July 2022*,* ***Accepted:*** *06* August 2022

Published Online: *25* August 2022

In-Text Citation: (Ruijia et al., 2022)

To Cite this Article: Ruijia, Z., Talib, O., Burhanuddin, N. A. N. binti, & Wenling, L. (2022). The Effect of Math Self-Concept and Self-Efficacy on the Math Achievement of Sixth-Grade Primary School Students: The Mediating Role of Math Anxiety. *International Journal of Academic Research in Progressive Education and Development*, *11*(3), 767–778.

Vol. 11(3) 2022, Pg. 767 - 778

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Zuo Ruijia, Othman Talib, Nur Aimi Nasuha binti Burhanuddin, Li Wenling

Faculty of Educational Studies, Universiti Putra Malaysia, 43400 Serdang, Malaysia

Abstract

The relationship between math self-concept, self-efficacy, math anxiety, and math achievement was investigated using 450 sixth-grade students in Sichuan Province, China as subjects. The results showed that: math self-concept and self-efficacy positively predicted students' math achievement, and math anxiety negatively predicted students' math achievement. Mathematics anxiety played a partial mediating role in the relationship between mathematics self-concept and mathematics achievement, mathematics self-efficacy, and mathematics achievement. Mathematical self-efficacy and math anxiety played a mediating chain role in the relationship between math self-concept and math achievement. To improve students' math achievement, it is necessary to pay attention to the positive significance of math self-concept and self-efficacy and reduce the adverse effects of math anxiety.

Keywords: Math self-Concept, Math self-Efficacy, Math Anxiety, Math Achievement

Research Background

Since the reform of the Chinese mathematics curriculum in 1999, mathematical literacy has become an indispensable factor for human progress and development. In recent years, the affective and non-intellectual factors that influence students' mathematical literacy have attracted the attention of many researchers in education and psychology.

Mathematics anxiety refers to negative emotional experiences such as tension, fear, and worry caused by mathematical problems or academic situations, accompanied by low self-confidence, fear of failure, and negative mental stereotypes about mathematics learning (Bandalos et al., n.d.). It affects students' enthusiasm for mathematics learning and makes students avoid mathematics-related courses, which is one of the factors affecting the improvement of mathematics literacy (Birgin et al., 2010). Studies have shown that there is a significant negative correlation between high mathematics anxiety and mathematics

academic achievement, and the mathematics achievement of students with high mathematics anxiety is significantly lower (Chasseigne et al., 1997).

Individuals' beliefs about their own abilities (such as self-concept and self-efficacy) are important incentives to trigger academic emotions (such as anxiety). Improving students' self-belief and reducing their learning anxiety can effectively improve their academic achievement. With the continuous development of quality education in China, the importance of mathematical literacy has become increasingly prominent, and sixth-grade students in primary schools are facing pressure to enter junior high schools, which has correspondingly higher requirements for their mathematical ability (He & Qi, 2018) Therefore, investigating the relationship between mathematics anxiety, mathematics self-concept and self-efficacy and mathematics achievement in the sixth grade of primary school has certain theoretical reference and practice for enriching the research on the influencing factors of mathematics achievement and improving the learning efficiency and mathematics achievement of primary school students. Reference meaning.

Literature Review

Self-concept refers to a relatively stable self-perception and judgment formed by an individual through experience. It is an individual's comprehensive view of himself and is essentially a kind of self-consciousness. (Shavelson et al., 1976). Self-concept is divided into academic self-concept and non-academic self-concept, and academic self-concept can be further divided into self-concept into specific content areas such as Chinese self-concept and math self-concept (Du et al., 2020), math self-concept is an important factor affecting individual academic achievement. Kishor（1997）meta-analysis pointed out that the average correlation coefficient between math self-concept and math achievement was r=0.23. There are also studies showing that with the improvement of students' self-concept level, their mathematics achievement shows an upward trend (Liang, 2016). Not only that, positive self-concept is closely related to positive psychological and behavioral outcomes. (Lu et al., 2017) found that students with high self-concepts usually have good self-efficacy, which is an important predictor of self-efficacy. The research of VanderBeek et al (2017) found that math self-concept can significantly reduce mathematics anxiety and improve the individual emotional experience.

Self-efficacy refers to an individual's confidence or belief in his ability to achieve behavioral goals in a specific field when he engages in a certain behavior in a particular situation. Simply put, a person believes in his or her ability to succeed (Ahmad & Safaria, 2013). From the existing literature, self-efficacy plays an important role in moderating academic achievement, and there is a significant correlation between it and academic achievement (Kaskens et al., 2020). Positive self-efficacy is closely related to behavioral choices, motivation, and emotional responses (Vongkulluksn et al., 2018). Research by Voica et al (2020) found that students with high self-efficacy are willing to put more effort into solving math problems and can persist longer when repeatedly testing problems. In addition, self-efficacy has a significant direct negative effect on mathematics anxiety and a significant direct positive effect on mathematics academic performance (He & Qi, 2018). Not only that, Jain & Dowson (2009) found that self-efficacy has a strong direct effect on mathematics anxiety and is an important mediating variable affecting mathematics anxiety. As one of the special subjects of anxiety, mathematics

anxiety is the tension and anxiety that interferes with mathematics teaching and solving mathematics problems. The sixth-grade students at primary school face the pressure of entering junior high school. If they are not intervened in time, they may develop into mathematics avoidance and mathematics fear. It has obvious adverse effects on mathematics achievement and students' actual development (Gierl & Bisanz, 1995).

He & Qi (2018) found a negative correlation between mathematics anxiety and mathematics achievement in primary and secondary school students. The research of Ramirez et al (2016) also showed that mathematics anxiety is not conducive to the development of students' mathematics achievement. Some studies have pointed out that mathematics anxiety is usually caused by the inability to objectively self-evaluate and lack of self-confidence when studying or working in a mathematics environment, and anxiety is highly positively correlated with negative self-concept and self-efficacy (Morony, 2013). In summary, many researchers have recognized that students' mathematics achievement is strongly influenced by their mathematics self-concept, self-efficacy, and mathematics anxiety, but there are relatively few studies on how these variables interact and jointly influence mathematics achievement. In view of this, this study examines the relationship between math self-concept, self-efficacy, math anxiety, and math achievement in the sixth grade of elementary school based on the actual situation of Chinese elementary school students by using research methods such as structural equation modeling, based on the analysis and reference of related studies at home and abroad.

Based on the above analysis, the following research hypotheses were proposed, as shown in Figure 1.
H1: Math self-concept and self-efficacy have a significant positive effect on math achievement, and math anxiety has a significant negative effect on math achievement.
H2: Math self-concept can have an indirect effect on math achievement through math anxiety.
H3: Mathematical self-efficacy can have an indirect effect on math achievement through math anxiety.
H4: Mathematical self-efficacy and math anxiety play a mediating chain role between math self-concept and math achievement.

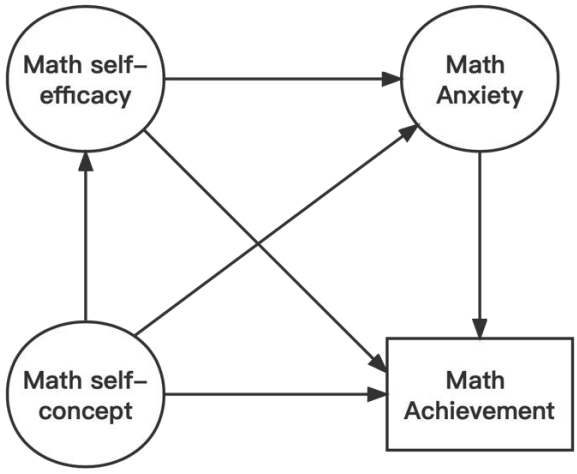

Figure1 Hypothetical model

Research Methodology

Research Population

A total of 450 sixth-grade students from three elementary schools in Mianyang City, Sichuan Province, China, participated in the survey. Among them, 207 boys (46%) and 243 girls (54%) were enrolled. Before the study began, teachers from the three schools were trained and went into the classes to explain the purpose of the test to the students face-to-face and the precautions for completing the questionnaire. The students were given a monthly test using a 45-minute mathematics paper followed by the questionnaire for this study.

Research Instruments

Student Questionnaire

The student questionnaire was adapted from the PISA 2012 student questionnaire. The questionnaire was first translated by experts in Chinese as a foreign language to check the accuracy of the questions and then prepared by two interviews (six in total), 10 pre-tests (30 in total), data analysis, and questionnaire revision in each school.

Influencing Factors Questionnaire, the influencing factors examined in this study included three aspects of math self-concept, self-efficacy, and math anxiety, each containing five matching questions. The questionnaire was in the form of a 5-point Likert scale, with increasing levels of recognition from lowest to highest. Internal consistency coefficient analysis was conducted using Cronbach's alpha coefficient as an indicator, and the results showed high homogeneous reliability for all dimensions of the questionnaire (math self-concept alpha=0.911, and validation factor analysis showed a largely acceptable fit *(χ2/df=1.805, RMSEA=0.095, CFI=0.990，TLI=0.980, SRMR=0.051)* were treated as latent variables in the structural equation model. Self-efficacy α=0.934, validated factor analysis showed good fit *（χ2/df=1.894,RMSEA=0.044,CFI=0.990，TLI=0.979，SRMR=0.058）*, and was treated as a latent variable in the structural equation model. The math anxiety α=0.872 and the validation factor analysis showed that the fit was acceptable *（χ2/df=2.506, RMSEA=0.180, CFI=0.936, TLI=0.872，SRMR=0.049）*, which were treated as latent variables in the structural equation model, and as latent variables in the structural equation model. The internal consistency coefficient of the total scale *α=0.825.*

Student Examination Papers

The student test paper was based on the Compulsory Education Mathematics Curriculum Standards (2022 Edition) promulgated by the Chinese Ministry of Education and drew on the experience of international large-scale tests in mathematics to examine the academic performance of Grade 6 students in mathematics in several dimensions: content dimensions (number and algebra, graphing and geometry, and statistics and probability) and cognitive dimensions (integrated application). A matrix sampling method was used to divide all questions in this test into two parallel sets of test papers (Paper A and Paper B). The classical measurement theory (CTT) and item response theory (IRT) were combined to calculate the index parameters of the test papers (including the questions) and estimate the students' ability values and transform them to obtain the standard scores, thus achieving the equivalence of the two sets of test scores. The internal consistency coefficient analysis showed that both sets of test papers had high homogeneous reliability *(Cronbach's alpha = 0.892 for paper A; Cronbach's alpha = 0.886 for paper B)* and that the item characteristic

curves and information content of each question met the basic requirements of measurement.

Data Analysis

Statistical analysis of the data was performed using SPSS 26.0 and MPLUS 8.3.

Research Results

Test of Common Method Bias

Controlling for effects of an unmeasured latent methods factor was used to conduct the test of common method bias (Wen et al., 2018). First, the three variables in the study were modeled as three factors. Then, a two-factor model was established by adding a method factor to the three-factor model. Finally, comparing the fit indices of the two models, it was found that the improvement of the fit indices of the models was not high after adding the method factor to the three-factor model, and both CFI and TLI only improved by 0.03, which was less than 0.1; SRMR decreased by 0.03 and RMSEA decreased by 0.01, which were both less than 0.05. Therefore, there was no serious common method bias.

Descriptive Statistics and Correlation Analysis

Descriptive statistics and correlation analyses were conducted using SPSS 26.0 for math self-concept, mathematical self-efficacy, math anxiety, and math achievement. As shown in Table 1, math self-concept was significantly and positively correlated with mathematical self-efficacy *(r=0.688, p<0.01)* and math achievement *(r=0.560, p<0.01)*. Mathematics self-efficacy was significantly and positively correlated with math achievement *(r=0.535, P<0.01)*. math anxiety was significantly and negatively correlated with math self-concept *(r=0.-760, P<0.01)*, self-efficacy *(r=-0.653, P<0.01),* and math achievement *(r=-0.587, P<0.01).* Therefore, hypothesis H1 was accepted.

Table 1
Correlation coefficients and descriptive statistics between variables

Variables	Math self-concept	Math self-efficacy	Math anxiety	Math achievement
Math self-concept	1			
Math sele-efficacy	.688**	1		
Math anxiety	-.760**	-.653**	1	
Math achievement	.560**	.535**	-.587**	1
M	2.613	2.771	3.343	41.867
SD	1.094	1.172	1.166	19.662

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

Analysis of Mediating Effects

The structural equation model (SEM) was used to test the hypothetical model. The structural equation model uses the maximum likelihood estimation method, and the calculated results are shown in Figure 2. *The RMSEA=0.045, CFI=0.966, TLI=0.912, and SRMR=0.059.* It means that the fit indices of the SEM model meet the psychometrically acceptable criteria and the hypothesis model can be accepted.

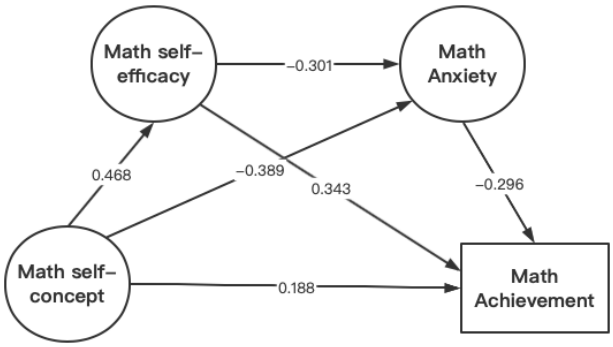

Figure 2 Mediation model with normalized path coefficients

The results in Figure 2 show that math self-concept can positively predict mathematical self-efficacy *(β=0.468, P<0.001)* and math achievement *(β=0.188, P<0.001)* and can negatively predict math anxiety *(β=-0.389, P<0.001)*; mathematical self-efficacy can positively predict math achievement *(β=0.343, P<0.001)* and can negatively predict math anxiety *(β=-0.301, P<0.001*); and math anxiety can negatively predict math achievement *(β=-0.296, P<0.001).* To further examine the mediating effects of math self-efficacy and math anxiety, a bias-corrected nonparametric percentile Bootstrap method test was used to calculate 95% confidence intervals by repeatedly sampling 1000 times (Taylor et al., 2008). The results and confidence intervals of each path are shown in Table 2. The confidence intervals of all five mediated paths do not contain 0, so it can be confirmed that math anxiety exerts a significant partial mediating effect between math self-concept and math achievement, math self-efficacy, and math achievement, and math self-efficacy and math anxiety exerts a significant chain mediating effect between math self-concept and math achievement. Thus, hypotheses H2, H3, and H4 are accepted.

Table 2
Standard path coefficients of the SEM mode

Intermediary path	Standardized estimates	Effect size	Confidence interval	
			Lower bound	Upper limit
math self-concept → self-efficacy → math achievement	0.18	36.7%	0.111	0.216
math self-concept → math anxiety → math achievement	0.06	19.3%	0.043	0.123
math self-concept → mathematical self-efficacy → math anxiety	0.04	6.2%	0.014	0.041
math self-concept → mathematical self-efficacy → math anxiety → math achievement	-0.14	23.7%	-0.161	-0.057
math self-concept → math anxiety → math achievement	0.09	13.5%	0.019	0.076

Discussion and Conclusion

The study results show that math self-concept and self-efficacy have a significant positive predictive effect on math achievement, and math anxiety significantly negatively impacts

math achievement. That is, the higher the math self-concept and self-efficacy, the lower the math anxiety, and the better the math achievement of students. This is consistent with the results of many previous studies(Du et al., 2020; Liang, 2013). As a result, they gain self-confidence, self-actualization, and academic success (Yulikhah et al., 2019). In contrast, mathematically anxious students always think about their shortcomings and potential deficiencies in awareness when coping with mathematical tasks and focus excessively on self and behavioral outcomes, which can significantly take up students' mathematical cognitive processing resources and cause high working memory load, leading to poor mathematical performance (Passolunghi et al., 2019).

In addition, it was found that math self-concept can indirectly influence math achievement through math anxiety, i.e., math anxiety partially mediates the relationship between math self-concept and math achievement. This result confirms that math anxiety is a key factor in explaining the influence of self-concept on academic achievement, consistent with the findings of Khalaila (2015); Fathi-Ashtiani et al (2007), and partially validates Pekrun's control value theory, which states that individuals generate academic emotions through their assessment of subjective control over learning activities and their outcomes (e.g., anxiety), which in turn affects academic performance (Goetz et al., 2010). An effective self-concept allows individuals to authentically perceive and accept their self-acquired experiences, resulting in positive emotional experiences such as psychological feelings of confidence and pleasure, while an ineffective self-concept distorts and rejects the self-experience, thus creating contradictions and conflicts between the two, and individuals are prone to anxiety and fail to achieve good academic success (Du et al., 2020). The results of this study also suggest that individuals with poor math self-concept do not know themselves objectively, doubt their mathematical abilities, worry about learning outcomes, and develop math anxiety, which leads to learning difficulties and low achievement. It was also found that mathematical self-efficacy can indirectly affect math achievement through math anxiety, i.e., math anxiety partially mediates the relationship between mathematical self-efficacy and math achievement. This result confirms (Gao & Chen, 2017) that mathematics anxiety can explain the effect of self-efficacy on mathematics achievement and to a certain extent validates Bandura's social cognitive theory. In contrast, students with low self-efficacy always question their ability to generate effective responses to difficult situations, resulting in an avoidance of the task, which distracts and dissipates the ability and energy to solve the difficulty, leading to anxiety, tension, and even fear and anxiety, which can affect their academic performance and prevent them from achieving better academic achievement. Therefore, as mathematical self-efficacy increases, students' math anxiety decreases accordingly, their concentration and self-regulation of learning increase, and they are more likely to experience positive affective processes and be willing to give more behavioral and emotional input to their goals, leading to good math achievement (Galla & Wood, 2012).
Furthermore, it is worth noting that the results of this study also showed that mathematical self-efficacy and math anxiety play a chain mediating role in the relationship between math self-concept and math achievement. This suggests that math self-concept not only has an indirect positive predictive effect on math achievement through the mediating role of math anxiety but also has an impact on math anxiety through its direct positive effect on mathematical self-efficacy, which in turn again constitutes an indirect positive prediction of math achievement. This result answers the question of the pathway mechanism by which the

self-concept indirectly influences mathematics achievement, as proposed by (Zhang et al., 2015). Bandura (1979) stated that self-efficacy determines individuals' behavioral choices and behavioral outcomes, and it generally influences individuals' motivational and affective response patterns, the formation of which is influenced by individuals' perceptions and orientations about themselves, their self-awareness in the process of getting along with peers, their self-confidence in Its formation is influenced by the individual's perception and orientation, self-awareness in the process of getting along with peers, self-confidence in-class participation, and the level of development of self-evaluation skills, which are closely related to self-concept. Thus, the individual's self-concept strongly influences the effective enhancement of self-efficacy, and positive self-efficacy helps individuals focus on the demands of the environment and problem-solving, effectively regulating their learning behavior and reducing the interference of negative emotions such as anxiety (Bandura, & Wood, 1989).

Based on the above findings and analysis, some suggestions are made in the study as follows.
At the six grade student level
First, students should be encouraged to set reasonable learning goals that match their individual learning bases and abilities. A reasonable and feasible learning goal can help students see the hope of learning, generate the right learning motivation, and make students work hard toward their learning goals, but if students set learning goals for themselves that exceed their learning ability, at the beginning students may be excited and full of motivation to learn, but after a period of time when they find that they can't reach their learning goals no matter how hard they try, students The student's confidence in learning will suffer a considerable blow, and is more likely to develop anxiety in learning mathematics. Therefore, students should set challenging learning goals that are consistent with their learning abilities, and gradually achieve higher goals to facilitate their progress in mathematics.

Second, help students establish a correct view of learning and examinations. The final step in the sixth grade is the Primary to Middle School exam, to which parents and students attach great importance, but there are many students whose view of learning and exams is thus affected. The purpose of learning mathematics is not only to master mathematical knowledge and help students pass the necessary exams but also to develop, exercise, and improve students' logical thinking and core mathematical literacy in the process of learning mathematics.

Third, to establish the correct attribution. Many studies at home and abroad have shown that students' attribution is closely related to their psychological health. If they fail in mathematics or have poor test results, they attribute it to their own lack of ability, and they will easily acquire a sense of learning helplessness, believing that they will fail in learning no matter how much effort they put in, thus leading to a lack of motivation and negative emotions or even anxiety. In mathematics learning, if students attribute their learning success to their own ability and effort it helps to enhance students' learning self-efficacy, making them more confident and engaged in learning with a more positive attitude. Therefore, it is necessary for students to develop a correct attribution style, i.e., attribute success to their own ability and effort, and attribute failure to bad luck or too much difficulty.

Fourth, actively seek help. Sixth graders are prone to negative emotions and math learning anxiety due to the high content, difficulty, and pressure of math learning compared to other grades in elementary school, which is very detrimental to mental health and learning. When this happens, students should boldly communicate with their teachers and try to express their inner thoughts more often; actively communicate with their classmates and exchange learning methods and experiences to obtain good learning strategies, improve their confidence in learning mathematics and relieve their anxiety.

At the teacher level

First, let students have successful experiences. Among the four factors that influence learning self-efficacy, the influence of "past achievements" on self-efficacy cannot be ignored. If students have had successful experiences in the learning process or in mathematics exams in the past, their interest in learning and motivation will be greatly enhanced to a certain extent, and they will be confident in their own learning ability. Conversely, if students are frequently frustrated and experience failure in the learning process, their confidence in learning will also plummet and they will doubt their abilities. Therefore, it is essential for teachers to let students have some successful learning experiences in their teaching activities. On the one hand, teachers can improve teaching methods according to students' ability level, pay attention to the creation of situations in the introduction stage of new lessons to stimulate students' curiosity and desire to know the content of learning, and then encourage students to explore and speak independently. In the problematic part of the teaching, students should be observed and given active guidance and help for any doubts and learning difficulties. On the other hand, teachers should create more opportunities and platforms for students to express their ideas and show their talents, which is beneficial to the establishment of good teacher-student relationships and the acquisition of students' self-efficacy. Teachers can also create more opportunities for students to interact with each other during the teaching process. Besides making the classroom more active and allowing them to discover the highlights of improved teaching, it can give students a sense of achievement and enhance their confidence in learning mathematics.

Second, use diversified assessment. Teachers should first of all not overemphasize the status and role of mathematics test results or scores but should help students get out of the misconception that "test results are the most important" and guide them to recognize the importance of mathematics learning itself. Secondly, teachers should also adopt diversified assessment methods for students, recognizing that each student has his or her own merits and strengths, paying attention to students' performance in the process of learning mathematics, affirming, and encouraging students' efforts, and relieving their anxiety about learning mathematics.

Significance and Limitations of the Study

This study explores the role and mechanism of math self-concept, self-efficacy, and math anxiety in jointly affecting math achievement, which theoretically enriches the public's understanding of the psychological process of mathematics learning among primary school students and can also provide certain suggestions for the teaching of sixth-grade mathematics. Compared with other grades in elementary school, the sixth grade belongs to the graduating class, which faces the pressure of moving to junior high school and a large increase in learning tasks and is prone to anxiety in the face of heavy learning tasks,

mathematical knowledge, and a learning environment that is detrimental to students' learning and development. Therefore, as far as the findings of the study are concerned, on the one hand, students' mathematical anxiety can be directly reduced by changing teaching strategies and learning atmosphere, etc., and on the other hand, the negative effects of mathematical anxiety can be weakened by improving their mathematical self-concept and self-efficacy, thus indirectly contributing to the improvement of students' mathematical ability. This study also has some shortcomings. The study was a cross-sectional study, and no causal relationship could be obtained in a strict sense. In addition, the subjects included only sixth-grade students in one city, and future studies could expand the selection of subjects to enhance the findings' generalizability.

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