Relationships Between Mathematics Anxiety, Mathematical Performance, and Teacher-Related Factors

Amartuvshin Deleg[1], Altanchimeg Zanabazar[2(✉)], and Magsar Ravdan[1]

[1] Department of Mathematics and Science, Teacher's School, Mongolian National University of Education, Ulaanbaatar, Mongolia
[2] Department of Management, National University of Mongolia, Ulaanbaatar, Mongolia
`altanchimegz@num.edu.mn`

Abstract. The number of students who are afraid of mathematics has risen year by year, and their negative attitude toward mathematics is also increasing due to several factors. This has led us to conduct research on mathematics anxiety at all levels, both among university and secondary school students. The objective of this study is to define the relationship between teacher-related factors, students' mathematical anxiety, and mathematical performance. A random sample of students (n = 916) who were admitted into the National University of Mongolia and Mongolian National University of Education by taking the General Entrance Exam (GEE) in mathematics were selected for the survey. Numerous tests were used to verify the proposed hypothesis, such as factor analysis, reliability analysis, regression analysis, and PLS analysis. The Abbreviated Mathematical Anxiety Test (A-MARS) which was developed by the researchers Richardson and Suinn was used to measure mathematics anxiety while the matrix was developed based on the General Entrance Examination (GEE) scores in mathematics to measure mathematical performance in this research. According to the results of this research, it was proven that teacher-related factors increase students' mathematical anxiety and that these factors are illustrated the negative linear correlation. Moreover, mathematics anxiety has been shown to hurt students' mathematical performance. In another world, the results show that methodology, communication, and ability of teachers and educators affect students' mathematics anxiety and mathematical performance, and it was also found that mathematics anxiety negatively affects students' mathematical performance.

Keywords: Mathematics anxiety · Mathematical performance · Teacher-related factors

1 Introduction

In the 21st century, learning mathematics greatly affects people's self-control and regulation. However, students tend to avoid mathematics classes as much as possible due to a common perception that mathematics is truly challenging.

Avoidance of mathematics severely limits students' potential fields, majors, and future careers, and rapidly widens the gap between those who learn mathematics relatively easily and those who do struggle with it. Year by year, students have come to perceive that mathematics is a suffering that they have to endure, leading scientists to conduct research at all levels, both university and high school students [2]. Recent researchers are increasingly focusing on the fact that mathematics anxiety negatively affects students' mathematical performance and achievement, and well-being [3, 4].

The research was conducted to find out how teacher-related factors affect students' fear and anxiety of mathematics and mathematical performance for students, who were admitted into the National University of Mongolia and the Mongolian National University of Education and by taking the General Entrance Exam (GEE) in mathematics, and the relationship between students' mathematical performance and mathematics anxiety.

2 Literature Review

Various studies conducted over the years in different regions suggest that the phenomenon is frequently prevailing among students of all educational institutions. Dreger and Aiken initially introduced the new term- math anxiety which refers to the students' incapability of handling mathematics.

The researchers viewed the negative phenomena as anxiety about numbers which not only involves the feeling of tension but also anxiety that interferes with manipulation and solving mathematical problems [5]. Over the years, there is some evidence suggesting that researchers have studied math anxiety from different perspectives and explained it in different ways.

In 1980 Tobias and Weissbrod defined math anxiety as the panic, helplessness, paralysis, and mental disorganization that arises among some people when they face solving a mathematical problem. Further scholars described the phenomena displayed by loss of self-confidence, nervousness, shyness, low interest in getting external support, and dislike of math [6]. According to Hembree math anxiety is a fear that arises when someone's handling mathematics while Ashcraft and Faust considered the feeling of tension, apprehension, or fear that interferes with solving math problems. Ashcraft (2002) observed that students demonstrated a strong negative emotional response to situations that involved numerical and mathematical activities, referred to as math anxiety [7–9].

Math anxiety is a fear that evokes unpleasant feelings towards mathematics as well as dyscalculia development. It often leads to negative outcomes and prevents the students from handling math solutions. Therefore, diagnostics of math anxiety and taking preventive measures in building feelings of competence in math skills are vital [10].

2.1 The Relationship Between Teacher-Related Factors and Mathematics Anxiety

Teachers are one of the factors that cause students' mathematics anxiety, and their teaching method, inability to solve mathematics problems, poor teacher-student communication, giving an excessive amount of homework, and not using appropriate and effective teaching materials lead students to develop the fear of mathematics [11].

Mathematics anxiety is not considered to be derived from mathematics itself, but from the way that mathematics class is taught in school, and students develop fear and anxiety from school teachers [12]. Being extremely demanding but less supportive of cognition and motivation when teaching not only causes mathematics anxiety but also leads students to avoid mathematics [13].

A teacher's misbehavior in mathematics class and blaming students' mistakes have a significant effect on developing mathematics anxiety. Also, inexperienced teachers' fear and anxiety of mathematics have a direct negative effect on students [14]. Teachers' teaching methodology and their fears not only cause students to develop mathematics anxiety, but also affect their brain function [15]. Recent research has shown that students' mathematical skill is affected by their mathematics anxiety which developed due to the spatial orientation and competencies of primary school teachers [16].

2.2 The Relationship Between Mathematical Performance and Mathematics Anxiety

Many types of research have shown that various factors of mathematics anxiety affect students' mathematical performance. In 1957, Dreger and Aiken conducted the first research regarding the relationship between mathematics anxiety and mathematical performance and found that there is an inverse relationship between them [2]. After that, Richardson and Suinn, Suinn et al., and Fennema proved in their research that mathematics anxiety hurts mathematical performance and success [1, 17, 18].

Ashcraft and Kirk found that students with a high level of mathematics anxiety encounter problems such as anxiety, pain, and fear when doing mathematics tasks, which affect their ability to understand the subject content, and their ability to approach and perform the subject [19]. Students who have mathematics anxiety feel anxious and stressed when performing simple mathematics tasks, and their mathematical success and performance are poor [14, 20]. Moreover, Macher et al. also found, in their research which was conducted in the Netherlands, that mathematics anxiety plays a crucial role in mathematical performance [21]. Mathematics anxiety hurts learning success by avoiding mathematics, choosing non-mathematical careers and fields of knowledge, combining negative feelings about anything that may be related to calculation and arithmetic, and negatively affecting mathematical motivation and self-confidence [22].

Ifamuyima and Rosanwo found that students with low mathematics anxiety had higher achievement, interest in mathematics, and a positive view of mathematics, while students with high anxiety had poor performance in math-related problems [23]. It was said that there is a negative relationship between mathematics anxiety and mathematical performance. The level of fear of mathematics is inversely related to mathematical ability. In other words, if the basic mathematical skill is weak, the level of the fear of mathematics is high, and if the mathematical skill is good, the level of the fear of mathematics is reduced [24].

Mathematics anxiety is a strong negative emotional response (tension, panic, fear, anxiety, doubt, irritability, impatience, confusion, mental blockage) that prevents students from finding solutions to mathematical problems in their daily lives and at the academic level, and this feeling increases their self-awareness of the inability to perform

computational tasks [25]. Excessive mathematics anxiety leads students to avoid mathematics class which negatively affects students' ability to perform the subject effectively and their academic performance. [19, 25–30].

3 Research Methodology

3.1 Research Design

Based on the literature review, the following research model is proposed to achieve the objectives of the study (Fig. 1).

3.2 Research Design

We proposed the following hypothesis for the study:

H1: Teacher-related factors exposure causes mathematics anxiety.
H2: Teacher-related factors affects the students' mathematical performance.
H3: Students' mathematics anxiety negatively affects their mathematical performance.

3.3 Research Method

The objective of this study is to define the relationship between teacher-related factors and students' mathematical anxiety and mathematical performance at the level of Mongolian mathematics students. The research was conducted on a random sample of students who were admitted into the National University of Mongolia and the Mongolian National University of Education by taking the General Entrance Exam (GEE) in mathematics, by using a questionnaire, descriptives analysis, regression analysis, and PLS analysis were used to release the result.

Sample: We assumed the confidence level of our survey at 95% with a confidence level of 5%. The estimated sample size for the survey was 379 which is considered fully
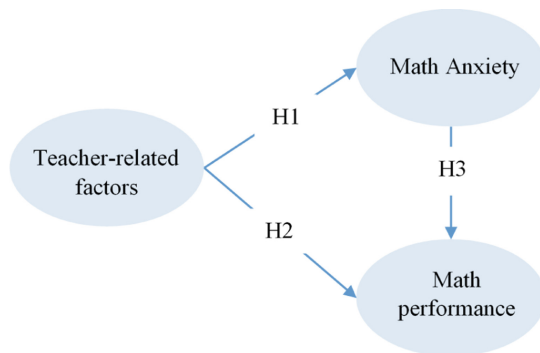

Fig. 1. Research model.

Table 1. Background of the respondents

Gender status		Age status		Attending university		Year of the study	
Gender	%	Age	%	University	%	Year	%
Male	13.2	17–18	9.6	NUM	46.9	1st year	29.4
		19–20	51.3			2nd year	16.5
		21–22	33.6			3rd year	29.5
Female	86.8	23–24	3.9	MNUE	53.1	4th year	23.9
		25 above	1.5			5th year	0.8

Source: Researchers' estimation

capable to represent the population. We considered that the data used in the study fully satisfies the quality of requirements as we used data from 916 respondents.

Data Collection: The questionnaires were collected online from April 26, 2021, to June 21, 2021, and the responses of 916 participants were used in the research. To determine the level of students' mathematics anxiety, the summary test (A-MARS) to measure mathematics anxiety, developed by Richardson and Suinn (1972), was used and assessed by the Likert 5-point scale.

Teacher-related factors include teacher teaching methods, ability, math problem-solving skills, teacher-student relationships, homework, effective use of teaching materials, and teacher turnover.

Participants' mathematical performance was measured by the results of the General Entrance Exam (GEE) in mathematics. The General Entrance Exam (GEE) is an annual examination held in Mongolia to admit graduates of the current year and previous years to universities and colleges. In the study, the changes in demographic factors include age, gender, attending university, and year of study.

According to Table 1, 13.2% of the respondents are male and 86.8% are female, while 9.6% are 17–18 years old, 51.3% are 19–20 years old, 33.6% are 21–22 years old, 3.9% are 23–24 years old and 1.5% are over 25 years old.

When it comes to the university they are currently attending, 53.1% were students at the MNUE and 46.9% were students at the NUM, also first-year students were 29.4%, second-year students were 16.5%, third-year students were 29.5%, fourth-year students were 23.9% and fifth-year students were 0.8%.

4 Results

4.1 Reliability Analysis of Variable

In any study, before conducting analysis there is a need to ensure the reliability and validity of variables. To test the reliability, Cronbach's alpha value is tested for validating the reliability of variables and the minimum cut-off points showed 0.7 and it proved that the data is acceptable for further measurements [31].

Afterward, CR (Composite reliability) is used to examine internal consistency. Hair et al. suggest that the CR value should be above 0.7, as such, all constructs are qualified for the test of internal consistency (see Table 2). Moreover, the validity of the questions demonstrated above of 0.3. AVE (Average Variance Extracted) coefficient is also shown for 0.5 for composites which means it is acceptable for measurement [32, 33].

Confirmatory factor analysis was used to validate the instrument which demonstrated a coefficient of 0.5 and higher showed that the measurement of the model fitted with the collected data or less than 0.5 values should be excluded from the model [32, 34]. The factor loadings express the relationship of each variable to the underlying factor. Teacher-related factors measurement questions TRF1,2's factor loading, and math anxiety measurement questions MA1,2,15,16's factor loading were less than 0.5 values excluded from the test because they were not grouped into relevant factors [35]. The summary of the reliability test is presented in Table 2.

4.2   Structural Equation Modeling

To ensure the reliability of data and evaluation of the model we estimate R-Squared to better predict the structural equation modeling. Through an estimate of relations between movements of dependent variables based on an independent variables movement, we found that the data and predictions were unbiased or significant ($p < 0.05$). The results of the analysis are summarized in Table 3.

As the results show that teacher-related factors affect the students' mathematics anxiety [$\beta = -0.193$; $p < 0.01$], and mathematical performance [$\beta = -0.180$; $p < 0.01$] for the participants.

P-value is the level of marginal significance within a statistical hypothesis test, representing the probability of the occurrence of a given event. All moderating variables ($p < 0.05$) were statistically significant.

The coefficient of determination, R^2, is used to analyze how differences in one variable can be explained by a difference in a second variable. The determination coefficient (R squared) of 0.237 can be explained that these factors explain the relationships by 23.7% and the remaining are explained by other factors that are not included in the equation.

It was proven that mathematics anxiety negatively affects students' mathematical performance [$\beta = -0.250$; $p < 0.01$]. The determination coefficient (R squared) of 0.312 can be explained that these factors explain the relationships by 31.2% and the remaining are explained by other factors that are not included in the equation. The standardized calculation is shown in (Fig. 2).

As the results show that teacher-related factors affect the students' mathematics anxiety and mathematical performance for the participants and are statistically significant ($p < 0.05$). It can thus be concluded that the hypotheses formulated are valid.
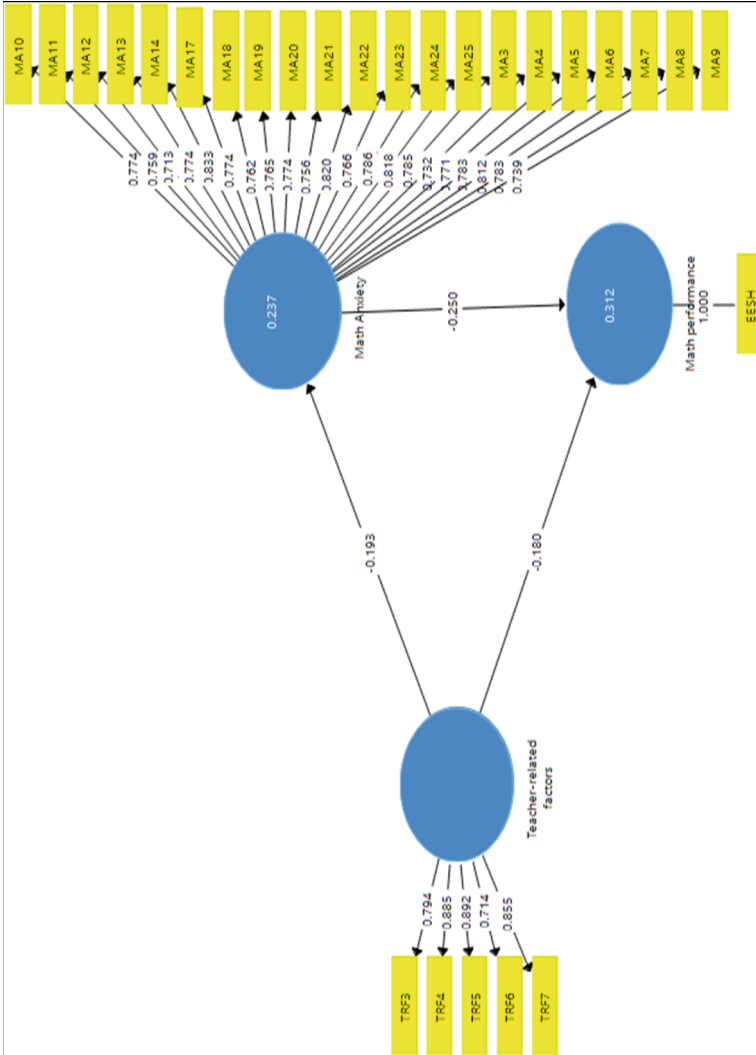
Fig. 2. Path Model and PLS-SEM Estimate *Source: Researchers' estimation*

Table 2. Questionnaire reliability analysis

Set of items	Number of questions	Factor loading	Cronbach's α	AVE	CR
Teacher-related factors- TRF	5	.714–.892	.904	.893	.630
Math Anxiety- MA	21	.713–.833	.968	.602	.969

Table 3. Research result PLS-SEM

Hypothesis	Path	Standardized Beta	t value	P value
H1	TRF → MA	-0.193	7.492	.000
H2	TRF → MP	-0.180	6.359	.000
H3	MA → MP	-0.250	5.879	.000

5   Discussion

In the 21st century, learning mathematics has become an important part of people's self-control and regulation. However, students tend to avoid mathematics class as much as possible due to a common perception that mathematics is truly challenging. Avoidance of mathematics severely limits students' potential fields, majors, and future careers, and rapidly widens the gap between those who learn math relatively easily and those who do not.

In this research, we focused on how families, schools, teachers, and students affect the fear and anxiety of mathematics, both among students majoring in mathematics at the National University of Mongolia and the Mongolian National University of Education. The first mathematics anxiety measurement test, the (A-MARS), developed by Richardson and Suinn, was used to determine the level of mathematics anxiety in the research [1].

Considering the Impact of Research Factors
According to the result of the research, it was proven that teacher-related factors [β = -.193] affect students to cause mathematics anxiety, and these factors are inversely related. To be specific, teachers' teaching methods and inability to solve mathematics problems, poor teacher-student communication, giving an excessive amount of homework, and not using appropriate and effective teaching materials cause students to develop a fear of mathematics. This result is consistent with the research findings of Nwoke and Charles, Suarez-Pellicioni, Núñez-Peña and Colomé, and Burte et al. [11, 15, 16].

It was also proven that teacher-related factors [β = -.180] have a weak negative effect on students' mathematical performance. In other words, effective teaching methods, negative teaching methods, and teachers' inability to solve mathematics problems8 poor teacher-student communication, giving an excessive amount of homework, and not using appropriate and effective teaching materials hurt students' mathematical performance.

Mathematics anxiety has been shown to hurt students' mathematical performance [β = -0.250], and as the level of the fear and anxiety of mathematics increases by one unit, mathematical performance appears to decrease by 0.250 beta units. High level of mathematics anxiety lead students to avoid mathematics subject, which is consistent with the findings of many researchers, such as Ashcraft & Kirk, Cates & Rhymer, Ma & Xu, Miller & Bichsel, Buckley & et al., Villamizar & et al., Mutegi & et al., who stated that it negatively affects students' ability to perform mathematics effectively and their academic performance [19, 25–30].

6   Conclusion

Many researchers have shown in their research results that mathematics anxiety not only limits students' mathematical performance but also their potential field of study, major, and future career. Therefore, it is necessary for parents, teachers, and educators to be aware of simple ways to diagnose students' fears and difficulties in mathematics, and use them to develop and implement action and methodological solutions to identify and correct students' learning difficulties.

Teachers shall avoid transmitting negative and anxious attitudes toward mathematics. Since mathematics anxiety is authentic to many students, educators ought to be aware of its causes, help students cope, and introduce various teaching methods. It is also crucial to pay close attention to the messages that students receive, as teachers have a huge impact on students. For instance, when students make a mistake, it is important to send a comforting message, such as 'It is okay, not everyone can be good at this kind of problem' [36]. Moreover, teachers shall try to prevent students, facing difficulties with mathematics, from developing a negative attitude toward mathematics [7]. They must emphasize the importance of mathematics and highlight positive qualities associated with each student. In addition, teachers and educators ought to know simple ways to diagnose students' fears and difficulties in mathematics, use them to identify students' learning difficulties, introduce a variety of activities and teaching methods, and develop, and implement methodological solutions to overcome the fears and difficulties.

Educators can learn more about the consequences of mathematics anxiety by reading relevant research papers and participating in training and seminars on this topic. It is important to note that, in this research, the measurement of mathematical performance was limited to the General Entrance Exam (GEE) scores in mathematics alone.

Further research, to measure students' mathematical anxiety and to study other factors that contribute to mathematics anxiety to improve the mathematical performance and skills of students with mathematics anxiety, will be considered a practically important research field.

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