A study of factors causing math anxiety among undergraduate students

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Abstract

Mathematics is a subject with numerous applications in everyday life but it is often viewed as difficult leading to math anxiety among students. This anxiety can limit students' career options and affect their success. To address this issue, we investigated the factors contributing to math anxiety among university and college students. This study focused on students from the National University of Mongolia (NUM) and the Mongolian State University of Education (MSUE). We used the Mathematics Anxiety Rating Scale questionnaire (A-MARS) developed in 1972 by Richardson and Suinn and conducted various statistical tests including factor analysis, correlation analysis and regression analysis to analyze the data. Our results show that teacher-related factors have a strong negative correlation with math anxiety ($\beta=-0.583$) while family-related factors ($\beta=-0.311$) and student-related factors ($\beta=-0.133$) have weaker correlations. Possible explanations for these findings include inadequate teaching and professional skills, poor communication between students and teachers, heavy task loads and outdated resources. This study highlights the importance of these factors to reduce math anxiety and promote success in mathematics education.

Keywords: Family-related factors, Learner-related factors, Math anxiety, School-related factors, Teacher-related factors, Undergraduate students.

1. Introduction

Although an increase in worldwide dependency on technology boosts the demand for professionals with mathematical science backgrounds and logical thoughts. However, there is a growing tendency among students to avoid studying mathematics. The current inclination is related to the common perception of math as a complex discipline and a difficult subject. Various researchers have researched the new trend prevalent among students. It prevents students from achieving

good mathematical performance and this type of fear limits the students' opportunities in selecting professions and studying in prospective fields.

In recent years, many scholars have been addressing the effects of math anxiety on students' math performance and achievements [1]. The circumstances require that instructors learn simple diagnostic methods for revealing math anxiety among the students and practice new approaches to assist them in overcoming the challenges. Identifying the factors affecting math anxiety and implementing activities that enable solving the challenges will facilitate equal learning opportunities for the students. Previous studies on math anxiety mainly addressed the conditions that lead to developing challenges [2-4]. The latest studies examined various factors that affect math anxiety including low math proficiency, attention disorder, memory incapacity, a genetic factor, family atmosphere and a math teacher's attitude towards math and teaching methods.

We proposed to examine how family, school and teachers contribute to math anxiety based on the cases of students at NUM and MSUE who primarily enrolled in math courses.

1.1. Math Anxiety

Math anxiety is a fear that evokes unpleasant feelings towards mathematics as well as dyscalculia. It often leads to negative outcomes and prevents the students from handling math solutions. Therefore, identifying math anxiety and taking preventive measures that promote feelings of competence in the skills are vital [5]. Math anxiety can be defined as a special condition caused by several factors such as personal causes including low self-confidence and avoidance of asking questions, environmental causes such as negative experiences in math, negative attitudes of parents, teachers and cognitive causes such as the perception of possessing poor cognitive ability in math, a lack of knowledge in using math techniques and inconsistency in teaching methods and students' learning objectives. A person who suffers from a high level of anxiety tends to struggle with a lack of quality decision-making regarding personal finance and health care. Math competence and math anxiety have a reverse correlation: those with math competence tend to be invulnerable to math anxiety while incompetent ones are more exposed to it.

The research on mathematics started in the 1950s and continued in the following eras of its development:

1. *The math anxiety measurement research era covers studies conducted from the mid-1950s until the beginning of the 1990s.* The researchers mainly explored methods and tools for measuring math anxiety. Some researchers attempted to explain failure in mathematics in contrast to achievements in other subjects. Among them was Gough [6] who coined the concept "math phobia" which refers to a feeling of tension or fear when dealing with number manipulation. Many researchers have investigated these phenomena and described them from physical, emotional and cognitive perspectives such as Lazarus [7] who described it as an irrational and impeditive dread of mathematics while 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. Furthermore, scholars described the phenomena displayed by loss of self-confidence, nervousness, shyness, low interest in getting external support and dislike of math [8]. Fear and stress arise when one faces solving math problems. Similarly, Ashcraft and Faust [9] considered it a feeling of tension, apprehension or fear that interferes with solving math problems. The Math Anxiety Measurement Scale (MARS) with 98 questions was developed by Richardson and Suinn [10] and became the most widely used tool in empirical studies.

2. *Studies investigating the relationship between math anxiety and mathematical performance, the factors affecting math anxiety and tests on rating math anxiety development periods were taken from the beginning of the 1990s to 2010.* The studies conducted in these years recognized four main factors that influenced math anxiety: students' personalities, teachers, families and schools [11]. The meta-analysis conducted by Caviola, et al. [12] revealed negative effects of math anxiety on math performance. Numerous studies have been conducted on developing tests to measure math anxiety including the MARS-E test for revealing math anxiety in primary school students by Ashcraft and Kirk [13], the sMARS diagnostic and the shortened AMAS test developed by Hopko, et al. [14]. The Abbreviated Math Anxiety Scale (AMAS) is a measure to capture the psychological reactivity, negative cognitions, avoidance behaviors and anxiety experienced when presented with a math stimulus.

3. *Diagnostics of math anxiety with the use of information technology and estimation of the relationships between cognition and affective factors in the research era starting from 2010 up to the present.* Suárez-Pellicioni, et al. [15] examined brain correlates of math anxiety using functional magnetic resonance imaging (fMRI), and later on, Pizzie, et al. [16] used fMRI to investigate the effectiveness of cognitive reappraisal as a strategy to alleviate the effects of math anxiety.

Math anxiety is categorized as process-oriented including participation in math class and fear or anxiety before handling math-related work such as fear that comes before actual work like 'I need to make a presentation on math tomorrow' [17].

1.1.1. Learner-Related Factors

Students who feel nervous presenting and communicating in front of other students tend to be more vulnerable to math anxiety [18]. Emotional states are correlated with math skills and achievement [19]. Thus, math anxiety causes negative emotions that negatively influence the math performance of the students and may even impact the etiology [20]. Mental factors such as abstractive thinking and visual conceptualization also increase math anxiety [21]. Math anxiety is related to the students' meta-cognitive skills as well as self-management [22]. Recent researchers in brain studies have made attempts to explain the phenomenon of how the central nervous system functions [15, 16].

1.1.2. Family-Related Factors

Hembree [23] and Ashcraft [18] are considered the parents of the students as the main factor contributing to the math anxiety as it is inherited from parents to their children. Numerous in-depth studies conducted in the area confirmed that parents' involvement was a significant factor in math anxiety. Parents' fear or anxiety with math often served as the primary factor of math anxiety among children Festa and Ginsburg [24]; Radišić, et al. [25] and Soni and Kumari [26]. Frenzel, et al. [27] identified a correlation between a parent's perception of the importance of math and their children's attitude towards math as well as math anxiety. According to other researchers, teachers and parents often transfer their fear of math to the next generation. Parents' hesitation about the child's math skills impacted the child's self-esteem and reduced their interest in math leading them to avoid math or even fear handling it. On the other hand, parents who maintain an open and warm communication atmosphere are less vulnerable to math anxiety [28]. It showed that girls tended to suffer the most in the first year of school which is often inherited from their fathers who have similar challenges while the math anxiety of mothers and teachers affected all children regardless of sex, starting in the third year of school [29]. Although the inheritance of math anxiety remains questionable, it is almost certain that it is contagious. As math anxiety contributes unfavorably to math achievements, it remains an important subject matter both for parents and students [30].

1.1.3. Teacher-Related Factors

The teacher is one of the causal factors in students' math anxiety and their lack of proficiency in teaching, inability to solve math problems, poor communication between teacher and students, heavy load of assignments and insufficient use of efficient training materials result in math fear or anxiety among their students [31]. Math anxiety resulted from the teaching methods and teachers [32]. According to Turner, et al., teaching with too high requirements and with less cognitive and motivational support often discourages students from learning. Unpleasant communication patterns of a teacher and students' fear of being scolded for their mistakes play an important role in developing math anxiety. Moreover, a fear of inexperienced math teachers negatively impacts the students [2]. Teaching methodology and the teachers' fear serve as conditions for developing math anxiety among their students. They negatively impact the brain function of the children [15]. A recent study confirmed the relationships between the spatial reasoning skills of primary school teachers and the math anxiety of the students. The present skill impacts the students' math skills [34].

1.1.4. School-Related Factors

The school is the main social environment for the children which may influence math anxiety among the students depending on school policy, teaching staff policy and activities organized by the administration. The overall environment of the school and the class have contributed to the math anxiety [25]. Some schools organize various events and activities that aim at reducing stress and increasing confidence among the students. An experience at a Turkish school can be cited as an example where they introduced a meditation class to reduce math anxiety among the students. Evident outcomes have resulted from the activity [28].

1.2. Research Model

The following research model is proposed in the study based on the theories and concepts of previous studies conducted in this area. Figure 1 illustrates the research model.
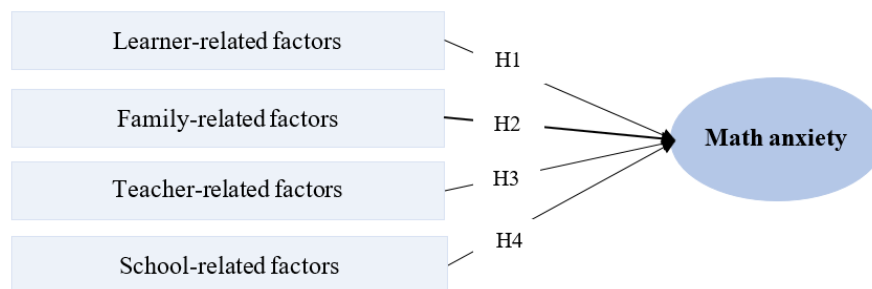
Figure 1.
Research model.

The hypotheses developed based on the literature discussed above are as follows:
H1: Student-related factors contribute to causing math anxiety.
H2: Family-related factors contribute to causing math anxiety.
H3: Teacher-related factors contribute to causing math anxiety.
H4: School-related factors contribute to causing math anxiety.

2. Research Methodology

2.1. Research Method

This study is aimed at examining the learner, family, teacher and school-related factors that impact math anxiety among students. We surveyed the students of the National University of Mongolia (NUM) and Mongolian State University of Education (MSUE) who enroll in the program with in-depth math courses. The data from the survey is processed with

SPSS 23.0 and Smart PLS 3.0. Numerous tests and analyses such as factor analysis, regression analysis and PLS analyses were conducted to obtain the results.

2.2. Sample Size

We assumed the confidence level of our survey to be 95%. The estimated sample size for the survey was 379 which are considered fully capable of representing the population. The data used in the study fully satisfied the quality requirements as we used data from 916 respondents.

2.3. Data Collection

The survey was conducted online between April 26 to June 21, 2021 and collected data from 916 respondents.

2.4. Instruments

We used an adapted version of Richardson and Suinn [10] math anxiety rating scale instrument (A-MARS) for measuring responses on a 5-point Likert scale. For assessing mathematical anxiety, General Entrance Exam (GEE) results in mathematics are compared against anxiety.

2.4.1. Demographic Information Form

Demographic characteristics such as age, gender, institutional affiliation and level of study are cautiously examined in the study. Table 1 illustrates background information on the survey respondents.

Table 1.
Background information on the survey respondents.

Gender		Age segment		Institutional affiliation		Year of Study		Grade point average	
Sex	**%**	**Age**	**%**	**Affiliation**	**%**	**Year**	**%**	**GPA**	**%**
Male	13.2	17-18	9.6	NUM	46.9	1st Year	29.4	1.0-1.4	0.1
		19-20	51.3			2nd Year	16.5	1.5-1.9	1.2
		21-22	33.6			3rd Year	29.5	2.0-2.3	3.4
								2.4-2.7	12.0
Female	86.8	23-24	3.9	MSUE	53.1	4th Year	23.9	2.8-3.1	30.7
								3.2-3.6	42.2
		25 Above	1.5			5th Year	0.8	3.7-4.0	9.7
								4.0 and above	0.7

From the above table, it is seen that by gender, 13.2% of the respondents were male while the majority of the respondents (86.8%) were female. By age, the majority of respondents who participated in the survey were 19-20-year-old students (51.3%) followed by 21-22-year-old respondents (33.6%) and the minority were 23-24-year-old participants (3.9%) and those who were 25 or older than respondents (1.5%).

By affiliation, 53.1% of respondents studied at MSUE and the remaining ones or 46.9% were students at NUM. By levels of study, 29.4% of respondents were in their first year, 16.5% were enrolled in their second year, 29.5% studied in their third year and only 0.8 % of them studied in their fifth year.

3. Results

3.1. Reliability Test

A reliability test is carried out to verify the reliability of the factors considered in the study. The results Cronbach α presented were higher than 0.7 and we decided to proceed with the proposal. The composite reliability coefficients all demonstrated values higher than 0.5 which means the questionnaire was properly developed and the construct is capable of measuring the proposed items. Moreover, the average variance extracted coefficient of each latent variable was higher than 0.5 for the other correlated variables which proved to be reliable. Confirmatory factor analysis was used to validate the instrument which demonstrated a coefficient of 0.5 and higher and showed that the measurement of the model fitted with the collected data or less than 0.5 values should be excluded from the model. Items with less than 0.5 values were excluded from the test to proceed with further analysis. The summary of the reliability test is presented in Table 2.

Table 2.
Results of reliability test.

Factors	Number of questions	Factor loading	Cronbach's α	AVE	CR
Learner-related factors -LRF	3	0.768-0.913	0.802	0.688	0.868
Family-related factors -FRF	5	0.710-0.789	0.815	0.567	0.867
Teacher-related factors -TRF	4	0.739-0.905	0.893	0.691	0.899
School-related factors -SRF	3	0.766-0.905	0.973	0.718	0.970
Math anxiety –MA	22	0.715-0.845	0.973	0.594	0.594

3.2. Correlation Analysis

To present the correlation between the factors considered in the study, we carried out a correlation analysis and the results of the analysis are presented in Table 3.

Table 3.
Results of correlation analysis.

Correlations						
Variables		**LRF**	**FRF**	**TRF**	**SRF**	**MA**
LRF	Pearson correlation	1				
	Sig. (2-Tailed)					
FRF	Pearson correlation	0.445**	1			
	Sig. (2-Tailed)	0.000				
TRF	Pearson correlation	0.442**	0.553**	1		
	Sig. (2-Tailed)	0.000	0.000			
SRF	Pearson correlation	0.373**	0.551**	0.551**	1	
	Sig. (2-Tailed)	0.000	0.000	0.000		
MA	Pearson correlation	-0.180	-0.325**	-0.562**	-0.118**	1
	Sig. (2-Tailed)	0.000	0.000	0.000	0.000	

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

According to the correlation analysis, teacher-related factors [r=-0.562, p<0.05], parent-related factors [r=-0.325, p<0.05], student-related factors [r=-0.180, p<0.05] and school-related factors [r=-0.118, p <0.05] have a negative linear correlation with math anxiety.

3.3. Structural Equation Modeling

To test the validity of the data and the model, the R-square is estimated. It is beneficial for predicting the model capability in PLS analysis. The results showed that all hypotheses proposed in the study were supported and the regression values were positive (p <0.05). The results of PLS-SEM are summarized in Table 4.

Table 4.
Results of PLS-SEM.

Hypothesis	Path	Standardize beta	t value	P value	Remarks
H1	LRF →MA	-0.133***	3.578	0.010	Supported
H2	FRF →MA	-0.311***	3.671	0.000	Supported
H3	TRF →MA	-0.583***	4.741	0.000	Supported
H4	SRF →MA	-0.088***	2.741	0.005	Supported

Note: *** significant at 0.001 level.

The results of the study demonstrated that teacher-related factors had a strong impact [β=0.583; p<0.01] on developing math anxiety while parents-related [β=-0.311, p <0.01] and student-related factors [β=-0.133, p <0.01] had a weak impact. However, school-related factors played no significant role in developing math anxiety. The determination coefficient was 0.568. These factors are capable of explaining the phenomenon by 56.8% and the remaining percentage is responsible for explaining other factors that were not considered in the equation. The path model and PLS-SEM estimate are presented below in Figure 2.

The impact of related factors are positive (beta coefficient) or statistically significant (p <0.05) which we can conclude that all hypotheses proposed in the study are supported.

4. Discussion

Studying mathematics is becoming essential to maintain self-control and self-management for people in the 21st century. However, the generally accepted perception that "math is a hardship" tends to prevent students from avoiding math courses. Fears of math keep students from handling math limit the possibility of choosing a prospective job and future career opportunity and widen the gap between math-dexterous and math-incapable people faster than ever. Identifying the factors contributing to math anxiety and implementing appropriate methodological solutions will support the students in overcoming the challenges and creating equal learning opportunities.

We used the A-MARS test developed by Richardson and Suinn [10] for measuring math anxiety. In our survey, we proposed to test the effects of factors such as family, school, teacher and learner on math anxiety in the case of NUM and MSUE students who enrolled in programs that dealt heavily with mathematics.
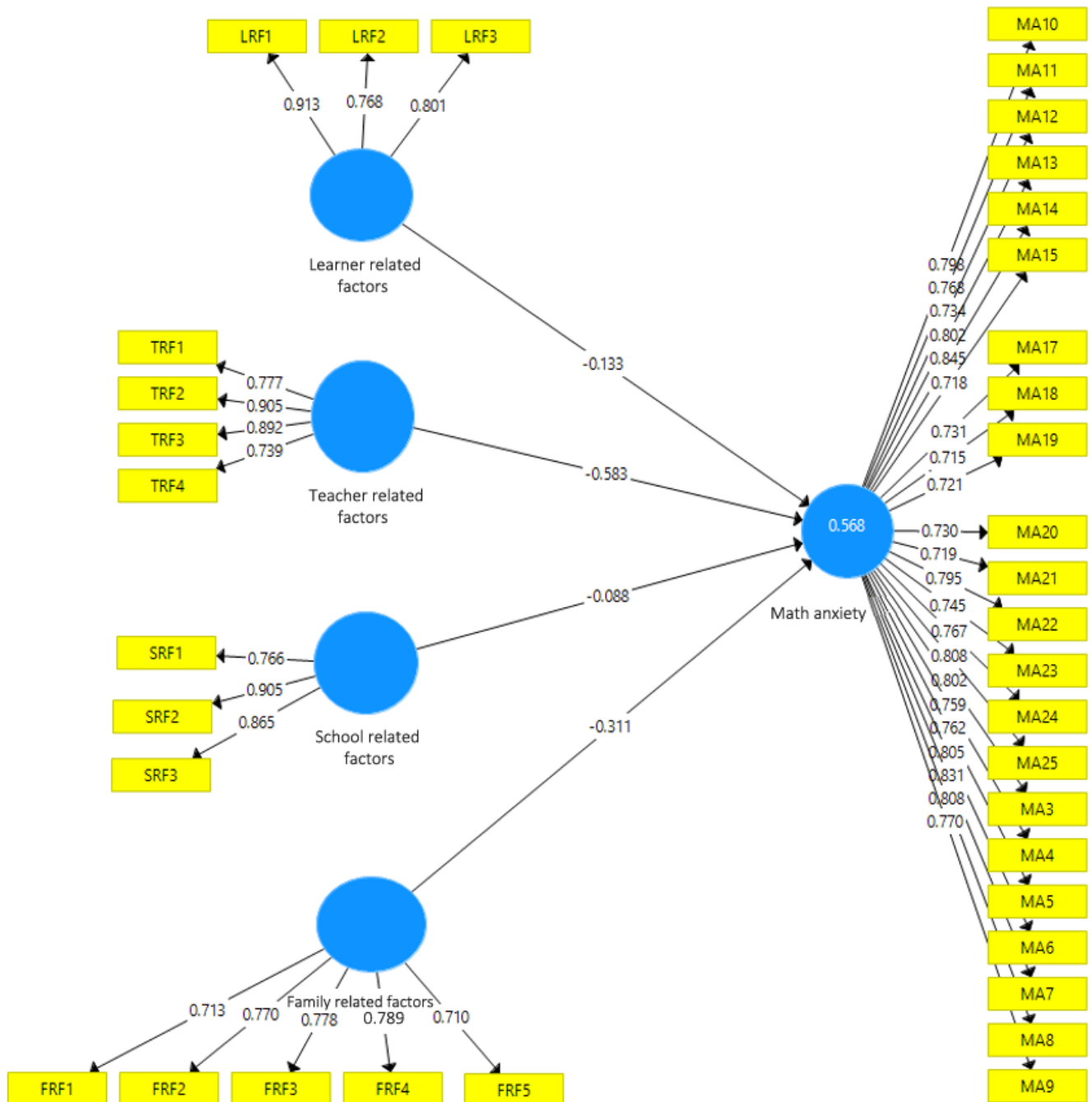
Figure 2.
Path model and PLS-SEM estimate.

4.1. Factors Considered in the Study

The survey results demonstrated that teacher-related factors strongly impact [β=0.583] the development of math anxiety among students. Various teacher-related factors including proficient teaching skills and math proficiency, poor communication with the students, a heavy load of assignments and improper use of state of art teaching texts and materials undoubtedly contributed to the development of math anxiety among students. The results are consistent with the results of earlier studies by Nwoke and Ugwuegbulam [31]; Suárez-Pellicioni, et al. [15] and Burte, et al. [34].

Parents as a factor contributing to the math anxiety condition proved to be true [β=-0.311] and the results of our study presented similar results to previous studies that concluded parents can be a primary factor in developing math anxiety [24-26]. The parent's attitude, their math anxiety and their communication style with their children were prominent factors in developing math anxiety in their children.

A learner-related factor demonstrated a weak correlation [β=-0.133] with math anxiety. Although nervousness to present and appear in front of other students and the public played some role in contributing to the fear, it could not be directly linked to developing math anxiety. Scholars such as Radišić, et al. [25] verified the learner and math anxiety correlation in their study. However, we could not find compelling verification of a strong correlation between them [β=-0.088]. The participants in our study considered that school policy, teaching personnel policy and activities implemented by institutions have no strong impact on math anxiety among students.

5. Conclusion

Various scholars suggest that math anxiety hinders not only the math performance of students but also limits their selection of a prospective field of study with promising career opportunities. The phenomenon necessitates parents and teachers to learn simple diagnostic methods for revealing math anxiety and use them properly to disclose the challenge and provide support to overcome it. Math anxiety is a psychological issue and implementing preventive actions is the most compelling approach [13]. Hence, understanding the individuality of students' math anxiety might be the most effective approach to improve math performance and nurturing a positive attitude towards mathematics among the students. Parents should be aware that conveying messages to their children can trigger math anxiety especially negative passages like 'We are not skilled at math at all', 'I have been thinking that math is the most difficult subject' or 'I have never liked math'. Parents' support, understanding and involvement are essential in reducing math anxiety levels among children. Therefore, creating a comfortable working environment to complete the assignment can be supportive for the children. Moreover, parents' involvement in developing their children's math understanding and skills to handle math and open communication about their expectations about their achievements are important to prevent math anxiety.

Improving teachers' awareness of not conveying negative messages about the subject can be a good preventive measure. Math anxiety is a real challenge for many students. Teachers need to improve their understanding of the subject and develop themselves to better cope with the challenges by nurturing essential knowledge and skills to support the students. Moreover, attention needs to be paid to the reaction and reflection of the students on the messages conveyed by her or him. Conveying positive cheering messages such as 'It is ok, mistakes are common" is essential to soothe the students [35]. It is important to take preventive actions when the teacher recognizes early signs of anxiety among the students. Making a persuasive remark on the significance of mathematics, highlighting each student's strong attributes will motivate them to study and handle mathematics with ease. For math teachers, it is essential to identify the problem at the earliest stage which will be beneficial not only for the teachers themselves in handling the challenges but also for the students who experience the hardship of avoiding math and losing their opportunity. Hence, professional development of teachers, raising awareness of math anxiety and building skills to handle challenges are becoming vital these days among teachers.

5.1. Limitations and Future Research

This study has some limitations. First, the sample of the study was 916 mathematics school students from NUM and MSUE. Due to the convenience sampling method, this study cannot be generalized to all students. Therefore, future research should include a larger sample size from different schools. Second, this study was designed using a quantitative research model and used the A-MARS test developed by Richardson and Suinn [10]. Third, this study focuses on only four factors such as family, school, teacher, and learner related to math anxiety and does not take other factors into account. This study might involve students from other professions and other factors can be considered in addition to these four to gain more knowledge on this topic.

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