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Original Article

Prediction of Mathematical Anxiety Based on Meta-Cognitive Beliefs and Mathematical Self-Efficacy in Female High School Students

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Abstract

Background and Objective: This study aimed to predict math anxiety based on task self-efficacy, knowledge, and cognitive regulation in female students.

Materials and Methods: The statistical population in this descriptive-correlational study included all female first-grade high school students (n=510) in Tuyserkan City of Hamedan, Iran, in the academic year 2018-2019, of whom 217 students were selected as the sample using multi-stage cluster sampling method. Data collection tools included the Usher and Pajares Mathematics Self-Efficacy Scale, Abolghasemi Mathematical Exam Anxiety Scale, and Meta-cognitive Beliefs Questionnaire of Schraw and Dennison. Pearson correlation coefficient and simultaneous multiple regression model were used to test the research hypotheses. Data were analyzed using SPSS software (version 20).

Results: The results of the analysis indicated a positive and significant relationship between meta-cognitive (cognitive knowledge and cognitive regulation) beliefs and students' mathematical task self-efficacy with mathematical anxiety. However, the models of meta-cognitive beliefs and mathematical self-efficacy could not predict the students' mathematical anxiety. In addition, each variable of meta-cognitive belief and mathematical self-efficacy alone could not explain the mathematical anxiety in students.

Conclusions: Based on the findings of the present study and those obtained in the previous studies, it can be concluded that students with high self-efficacy can control their anxiety in anxious situations better than those with low self-efficacy.

Keywords: Knowledge and cognitive regulation, Mathematical anxiety, Metacognitive beliefs, Task self-efficacy

Background

Anxiety, as an inseparable part of human life, even during childhood and adolescence, is a component of personality structure, and some of the anxieties experienced during childhood and adolescence can be considered normal from this perspective. The naming of the present century as the century of global stress and anxiety indicates the importance of these issues in various aspects of life [1]. Mathematics is one of the subjects in school, and the proper performance of students in this subject has always been of great importance to them and their parents [2]. However, mathematical anxiety is one of the factors that can hinder the process of studying this subject and the positive factors associated with it [3].

Mathematical anxiety results in weakened mental processes and low mathematical performance, as well as students' confusion and negative perspective. Students with mathematical anxiety avoid learning this subject by skipping mathematics classes. Moreover, they are unable to perform mathematical exams and experience excessive anxiety and worry [4]. Mathematical anxiety occurs as a state of discomfort when a student wants to do his/her mathematical homework [5]. The main characteristics of this disorder include feeling dislike, worry, and fear toward this subject, along with specific behavioral manifestations, such as stress, frustration, distress, disability, and mental disorder when embarking on mathematical tasks [6]. Mathematical anxiety is a complex phenomenon that affects an individual's emotional, behavioral, and cognitive responses. In fact, one of the personality traits that can prevent the development of mathematical anxiety is metacognitive beliefs [5]. Metacognition is a multifaceted concept that

includes knowledge (beliefs), processes, and strategies for evaluating, monitoring, or controlling cognition. Metacognitive psychology is a new field of thought dating back to the 1970s [7]. Metacognitive skills play an important role in a variety of cognitive activities, such as verbal exchange of information, verbal comprehension, and writing [8].

In recent years, metacognition has been studied as the basis for many psychological disorders. One of the reasons why many researchers are interested in the field of metacognition is that they believe that this field has important implications in the field of education. A meta-analytic study conducted by Wong et al. [9] on factors that affect the students' learning showed that among 228 factors affecting learning, cognitive and metacognitive processes have the greatest impact on the students' learning.

A previous study [10] showed the relationship between metacognitive beliefs and stress, anxiety, thoughts unrelated to the exam, physical symptoms, and exam anxiety. In addition, three metacognitive components related to exam anxiety include cognitive self-awareness, positive beliefs about worry, and negative beliefs about the thought's uncontrollability. A significant relationship was also found between metacognition and exam anxiety with educational success. A significant positive relationship between self-efficacy beliefs and students' progress in mathematics was reported in a study performed by Kadivar [11]. The results of another study indicated that [12] self-esteem had a positive association with educational performance and a negative relationship with exam anxiety. Amini [13] reported a relationship between some metacognitive beliefs and students' mathematical anxiety.

Research has indicated that students with mathematical anxiety have well-known motivational and emotional characteristics that can be considered predicting factors of mathematical anxiety. One of these factors is one's self-efficacy beliefs [14]. The role of beliefs and especially self-efficacy beliefs has been highlighted in new motivational theories [15]. Self-efficacy is a key variable in Bandura's (1997) social cognitive theory. It is the belief that a person has the competencies required to organize and execute specific behaviors to achieve the desired results [16]. Self-efficacy is attributed to a sense of self-esteem and value and a sense of adequacy and efficiency in dealing with different circumstances in life [17]. This construct can affect behaviors associated with educational achievement, including job selection, as well as one's efforts, persistence, and performance [18].

Self-efficacy is the confidence in one's ability to control thoughts, feelings, and activities, and therefore, it affects the consequences of our actions. Self-efficacy expectations affect people's actual performance, emotions, behavior selection, and ultimately, the amount of effort spent on each activity [19]. In a study entitled "A study of the relationship between teacher self-efficacy and students' mathematical self-efficacy with their education performance", Madraki indicated that teaching metacognitive strategies to individuals affects positively educational performances (e.g., the performance of homework) and achievements [20]. Burke [21] believes that a person's self-efficacy plays a sensitive role in inhibiting or sustaining his/her behavior in various situations. Woll has reported that if the students believe that they can learn with an acceptable effort, they will make more effort and persevere more in the face of problems [22]. The students with high educational self-efficacy have higher educational motivation, are more successful, and are more likely to be able to overcome educational challenges [23].

Social-cognitive theorists have defined students' personal self-efficacy beliefs as self-assessment of their ability to organize and perform the behavior needed to achieve certain types of performances that affect educational motivation and are considered to be strong predictors of educational outcomes. Some researchers, including Hackett, studied the role of personal self-efficacy in educational fields, such as mathematics [24]. Betz [25] have defined the mathematical self-efficacy as: An assessment of a particular problem or situation that demonstrates a person's confidence as to his/her ability to successfully complete a mathematical problem or task. Galla [26] showed in a research that anxiety in students with low emotional self-efficacy is a negative predictor of mathematical performance, but in the ones with high emotional self-efficacy, such a negative relationship was not observed. They also concluded that the emotional self-efficacy is beneficial in managing the negative effects of anxiety. Mathematical anxiety is a topic that has recently entered the field of educational and psychological research.

Objectives

In this study, an attempt has been made to take a step toward the existing gap in this field by investigating the relationship between mathematical anxiety, metacognitive beliefs, and mathematical self-efficacy. Therefore, the present study seeks to respond to the question of whether metacognitive beliefs and mathematical self-efficacy can predict mathematical anxiety.

Materials and Methods

The statistical population in this descriptive and correlational study included all female first-grade students of Tuyserkan City in Hamadan province of Iran, in the academic year 2018-2019. To select the sample, a multi-stage cluster random sampling method was performed. The information was collected through questionnaires. According to Morgan's table, 217 individuals were selected as the sample. The following tools were used to collect the data:

Mathematical Self-efficacy Scale

This questionnaire has 24 items with a spectrum of six degrees that measures self-efficacy for specific tasks [27]. The validity of this test has been shown by the authors through investigating the correlation between efficiency and motivational indicators. The correlation coefficient of this scale and the average grade marks reported by the students ($P<0.01$, $r=0.40$) also proved its content validity. Cronbach's alpha coefficients calculated for this scale by the authors were between 0.91 to 0.93 and it was 0.90 in the study conducted by Khayyer [28]. In addition, the reliability coefficient of this scale using Cronbach's alpha method has been estimated at 0.85 by Middleton [29].

Mathematical Exam Anxiety Scale

This scale consists of 25 four-choice questions that measure students' mathematical anxiety. The minimum and maximum total scores are zero and 75, respectively. The higher the person's score, the higher the amount of anxiety. Thus, the scores less than 12, between 13 and 37, between 38 and 62, and higher than 63 indicated no anxiety, low anxiety, moderate anxiety, and high anxiety, respectively. The standard validity of the questionnaire (0.72) was acceptable. The test-retest reliability was 0.88 and its internal consistency was 0.95 [30]. The Cronbach's alpha coefficient of the questionnaire was reported to be 0.73 in a study performed by Keramati [31].

Metacognitive Beliefs Questionnaire

This 52-item questionnaire has been developed by Schraw [32] to investigate the metacognitive strategies of adolescents and adults. The questionnaire measures distinctive factors including two aspects of metacognition, namely cognitive knowledge and cognitive regulation through eight sub-processes of metacognition. The factors related to cognitive knowledge include three sub-processes of expressive knowledge, trend knowledge, and conditional knowledge, and factors related to cognitive regulation include five sub-processes of planning, information management strategies, controlling, monitoring, and evaluating the learning process. The test scoring is on a five-point scale. The total scores of this questionnaire range from 52 to 260. The total scores are from 17 to 85 for the metacognitive knowledge component and from 35 to 175 for the metacognitive regulation scale. Schraw [32] reported the reliability coefficient of the questionnaire by Cronbach's alpha method to be 0.93. The correlation coefficient between the components for the whole scale was 0.95, according to the study conducted by Delavarpour [33]. The correlation coefficient between the components was reported to be 0.87 by Safari [34]. Motahedi [35] also calculated the correlation coefficient between the two general aspects of metacognition and metacognitive control as 0.91 and 0.98, respectively.

Results

After investigating the assumptions of parametric statistics, regression and Pearson's correlation coefficient were used to analyze and investigate the research hypotheses. Table 1 shows the number, mean, and standard deviation of the research subscales.

As can be seen in Table 1, the highest mean belongs to the metacognitive beliefs scale (190.15) and the lowest mean belongs to the process knowledge subscale (14.54).

Hypothesis 1: There is an association between students' metacognitive beliefs and their mathematical anxiety.

Table 1. Descriptive data of the research variables

Variable	N	$\bar{X}$	S
Mathematical anxiety	110	14.91	4.154
Expressive knowledge	110	29.11	5.659
Process knowledge	110	14.54	3.043
Conditional knowledge	110	18.16	3.595
Planning	110	24.25	5.393
Information management strategies	110	36.84	6.734
Review	110	19.72	3.839
Evaluation	110	22.03	4.306
Control	110	25.52	5.138
Metacognitive beliefs	110	190.15	30.182
Mathematical self-efficacy	110	88.54	15.146

Table 2. Correlation coefficients matrix between the aspects of metacognitive beliefs and mathematical anxiety

Item	Variable	1	2	3	4	5	6	7	8	9	10	11
1	Mathematical Anxiety	1										
2	Expressive knowledge	0.047	1									
3	Process knowledge	0.047	**0.621	1								
4	Conditional knowledge	0.110	**0.645	**0.607	1							
5	Planning	0.150	**0.651	**0.587	**0.261	1						
6	Information management strategies	*0.201	**0.675	**0.594	**0.466	**0.695	1					
7	Review	0.155	**0.512	**0.412	**0.856	**0.395	**0.076	1				
8	Evaluation	*0.213	**0.678	**0.546	**0.868	**0.693	**0.416	**0.493	1			
9	Control	*0.192	**0.845	**0.955	**0.956	**0.165	**0.853	**0.441	**0.765	1		
10	Metacognitive beliefs	*0.195	**0.558	**0.375	**0.682	**0.977	**0.185	**0.967	**0.348	**0.175	1	
11	Mathematical self-efficacy	*0.196	**0.944	**0.240	**0.241	**0.564	**0.343	**0.836	**0.344	**0.235	**0.352	1

0.01**

As can be seen in Table 2, the correlation between mathematical anxiety and metacognitive beliefs (r=0.195) is significant at p<0.05.

Therefore, there is a positive and significant relationship between the metacognitive beliefs of first-grade high school students and their mathematical anxiety.

Hypothesis 2: There is a relationship between students' mathematical self-efficacy and their mathematical anxiety.

As can be seen in Table 2, the correlation coefficient between mathematical anxiety and mathematical self-efficacy (r=0.196) is significant at p<0.05. Therefore, there is a positive and significant relationship between the mathematical self-efficacy of first-grade high school students and their mathematical anxiety.

Hypothesis 3: The models of metacognitive beliefs and mathematical self-efficacy can explain the variance of students' mathematical anxiety.

As can be seen in Table 3, the value of coefficient B between metacognitive beliefs and mathematical anxiety is 0.025% and the value of coefficient β is 0.181.

The coefficient B between mathematical self-efficacy and mathematical anxiety and the coefficient β is 0.047% and 0.171, respectively. Therefore, only 17% of the variance of the students' mathematical anxiety is explained by the mathematical self-efficacy variable. This value for the explained variance is not statistically significant (P>0.05), based on the F-value observed in the table.

Table 3. Results of regression analysis of metacognitive beliefs and mathematical self-efficacy on mathematical anxiety

Predictor variables	B	ʙ	P	R	R2	Corrected R	F	P
Expressive knowledge	-0.247	0.336-	0.032					
Process knowledge	0.203-	0.149-	0.270					
Conditional knowledge	0.135-	-0.117	0.443					
Planning	0.049	0.063	0.660	0.374	0.14	0.062	1.807	0.076
Information management strategies	0.132	0.213	0.158					
Review	0.060	0.056	0.651					
Evaluation	0.206	0.214	0.172					
Control	0.149	0.186	0.146					
Metacognitive beliefs	0.025	0.181	0.058					
Mathematical self-efficacy	0.047	0.171	0.126					

Discussion

The present study aimed to predict mathematical anxiety based on task self-efficacy, knowledge, and cognitive regulation in female first-year high school students and determine the contribution of each component in predicting mathematical anxiety. The following results were obtained after statistical analysis.

Hypothesis 1: The results of the analysis showed that the Pearson correlation coefficient between the metacognitive beliefs of female first-grade high school students and their mathematical anxiety is statistically positive and significant. Therefore, the first hypothesis of the study was confirmed. Other researchers have provided evidence to confirm the relationship between metacognitive beliefs and emotional disorders such as anxiety and worry [36,37,38,39].

In explaining this finding, it can be mentioned that students, with the help of their positive metacognitive beliefs, involve in the interpretation of social environment's events and attempt to monitor and control their actions, behavior, and emotions including the mathematical anxiety, accordingly. The opposite applies as well, that is, the students have no control over their actions and

behaviors using negative metacognitive beliefs, and they do what they like aimlessly. Such students do not plan for situations such as exams, regardless of the consequences that this may have for them; therefore, they become very anxious during the exams.

Hypothesis 2: The results of the analysis showed that the Pearson correlation coefficient between the mathematical self-efficacy of female first-grade high school students and their mathematical anxiety was positive and statistically significant. Therefore, the second hypothesis was confirmed as well. The results confirm the findings of some previous studies [40,41], but contradict others [14, 42, 43,44, 45].

In explaining this finding, it can be mentioned that self-efficacy, as an institutionalized factor, controls the actions of the individual [15], [41]. On the other hand, the findings reported by Lazarus and Folkman [41] show that individuals' cognitive processes and personal beliefs play an important role in considering a situation challenging or threatening. In general, it can be concluded that people with high self-efficacy consider mathematics-related tasks as challenges due to their cognitive processes and beliefs. However, for people with low self-efficacy, their cognitive processes make them consider mathematical homework as a threat and cause an increase in their anxiety. In fact, self-efficacy has a mediating impact on attitude and progress in mathematics. The impact on motivation and behavior may be the result of the mediating impact of self-efficacy, because when one aims to explore or engage in an action, his/her judgment about his/her ability may affect one's thinking, emotion, and action. Individuals with exam anxiety usually have low levels of self-efficacy. A person with exam anxiety feels helpless and is unable to control and influence exam events. In other words, the student's level of self-efficacy has a negative correlation with their mathematical anxiety [18].

Hypothesis 3: The results of the analysis showed that the models of metacognitive beliefs and mathematical self-efficacy are not able to explain the variance of students' mathematical anxiety. Therefore, the third hypothesis of the study was not confirmed. The obtained results are inconsistent with some reported findings [24, 25,46], indicating that measuring the level of feeling self-efficacy in mathematics and students' expectations of themselves can be an accurate predictor of mathematical anxiety and their grades in this subject. However, these studies confirm the result [10] that there is no significant relationship between self-efficacy and exam anxiety.

The results of another study showed that [47] the students' self-efficacy and goal orientation can significantly predict mathematical anxiety [26,45]. The role of these variables in predicting mathematical anxiety was found to be about 41%, and the remaining factors of mathematical anxiety (59%) would be explained through other variables, such as emotional and cognitive factors.

One of the reasons for the rejection of this hypothesis could be related to research tools. Subjects usually feel more freedom when answering the questions in a questionnaire; therefore, they may exert their personal opinions on the questions more compared to clinical and interview tests. Therefore, the error rate in questionnaire-based studies is always higher compared to non-questionnaire-based studies. Another reason for the rejection of the above hypothesis could be due to the education program. The statistical population in this study included first-year high school students. Since first-grade high school students are in the transition phase from the sensitive phase of adolescence to youth, many of their emotions will be unpredictable. Therefore, it would not be possible to predict their mathematical anxiety with regard to their metacognitive beliefs and self-efficacy. The small sample size is another limitation of the present study which limits credibility and, consequently, the generalizability of the results. Therefore, the results have been affected by the sample size in the present study which is indicated by the slight correlation among the subscales of metacognitive knowledge (i.e., process knowledge, expressive knowledge, and conditional knowledge).

Conclusions

According to the finding of this study and those obtained in the previous studies, it can be concluded that students with high self-efficacy can control their anxiety in anxious situations better than those with low self-efficacy.

Compliance with ethical guidelines

All ethical principles were observed in this study. The participants were informed about the study objectives and procedures and written informed consent was obtained from them. They were also assured about the confidentiality of their information and were allowed to leave the study at any time and for any reason. The participants can have access to the study results.

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Authors' contributions

The final manuscript draft was reviewed by all authors, who also gave their approval.

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Conflicts of Interest

The authors declared that they have no conflict of interest to declare.

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