PREDICTING NON-ROUTINE MATHEMATICAL PROBLEM-SOLVING ANXIETY OF NINTH GRADERS

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ABSTRACT

This study investigated how motivational orientations and learning strategies predict ninth graders' non-routine mathematical problem-solving anxiety. Non-routine mathematical problem-solving anxiety classification and prediction were investigated through TwoStep cluster analysis, linear discriminant analysis, and logistic regression. 274 ninth graders participated in the study. The participants were clustered based on their problem-solving achievements and test anxiety levels: high-level and low-level problem-solving anxiety. Extrinsic goal orientation, rehearsal, and peer learning were significant classifiers. Intrinsic goal orientation, self-efficacy, rehearsal, and help-seeking were significant predictors for ninth graders' non-routine mathematical problem-solving anxiety.

KEYWORDS

High School Education, Motivation, Problem-Solving, Rehearsal, Peer Learning, Help-Seeking

1. INTRODUCTION

In the current high school education, academic performance, including mathematics performance, is predominantly measured through students' test scores (e.g., Breslau et al., 2009; Suárez-Álvarez et al., 2014). Accordingly, test anxiety acts as a negative factor that decreases academic performance (Rana & Mahmood, 2010; von der Embse et al., 2018) and mathematics success (Morosanova et al., 2020; Wang & Davaanyam, 2012). In terms of math problem-solving, research (e.g., Sharp et al., 2000) reports that reduced anxiety is positively associated with increased math problem-solving achievement. In addition, many studies support this association between anxiety and mathematical problem-solving while adding additional findings such that motivational factors, including self-efficacy, mediate the effects of anxiety (Hoffman, 2010; Irhamna, 2020). Considering that motivational strategies influence ninth graders' mathematical problem-solving achievements (Dinc et al., 2020), this study examined test anxiety and mathematical problem-solving achievement simultaneously, named *mathematical problem-solving anxiety* (hereafter *problem-solving anxiety*).

Many studies have been conducted on high school students' academic motivation and learning strategy use. In general, they are considered highly extrinsically motivated to learn and give high value to learning tasks, while they have a low level of test anxiety (Gbollie & Keamu, 2017). For their mathematics achievements, task value, time and study environment, self-efficacy, extrinsic goal orientation, peer learning, and organization are significant predictors (Erdem-Keklik & Keklik, 2013). Regarding learning strategies, high school students utilize rehearsal and organization strategies while learning along with less help-seeking from their peers or instructors compared to other strategies (Gbollie & Keamu, 2017).

Ninth graders, in particular, are more worried about mathematics, their dropout rate is higher than other grade levels, and they struggle academically (Benner, 2017; McGee-Carlton, 2018; Wigfield & Meece, 1988). Also, they are seen to have moderate levels of intrinsic and extrinsic goal orientation, task value, control of learning beliefs, and self-efficacy (El-Adl & Alkharusi, 2020). On the other hand, Gasco et al. (2014) investigated motivational orientations and learning strategies in mathematics during the transition from eighth to ninth grade. Ninth graders got higher scores in rehearsal, elaboration, organization, metacognitive self-regulation, time and study environment, and help-seeking strategies.

1.1 Math Problem-Solving, Motivational Orientations, and Learning Strategies

Math problems have a significant place in mathematics and mathematics learning (Verschaffel et al., 2020). In mathematics literature, there are routine and non-routine mathematical problems. Routine mathematical problems are the ones that can be solved with "existing knowledge of method, algorithm, technique or formula" (Abdullah et al., 2014, p. 19). Non-routine mathematical problems are the ones challenging the solver to think and reason more and differently (Lee & Chen, 2009). Non-routine mathematical problems are encouraged to develop reasoning abilities (Bibi et al., 2019). Snyder (1998) underscored problem-solving as the core of mathematics, which requires a problem-solver to be creative to find the appropriate strategies during the problem-solving process. The mathematical problem-solving process helps students' critical thinking skill development and vice versa (Firdaus et al., 2015; Peter, 2012). Effendi and Fatimah (2020) indicated that problem-solving is one of the characteristics of higher-order thinking and investigated creative problem-solving in mathematics concepts. Students who received creative problem-solving instruction showed high-level mathematical thinking skills, which coincide with reasoning and critical thinking. According to Puteh and Ibrahim (2010), learners usually demonstrate a high level of extrinsic goal orientation and task value but a low level of intrinsic goal orientation during mathematical problem-solving.

Peer learning is effective in learning mathematics, particularly during planning and facilitating the learning process (Cheng & Walters, 2009). Peer learning is encouraged among groups of students at the same age level but can be successfully achieved either among groups of students with different academic capabilities or with a similar level of capability (Robinson et al., 2005). Academically more capable students would help others who are less academically capable, or the students who have the same academic capability would study and learn together. Peer learning supports knowledge construction through mathematical problem-solving (Sezgin-Memnun et al., 2019). Help-seeking is looking for support from others. The assistance can come from a peer or instructor. So, help-seeking may lead to peer learning.

1.2 Purpose of the Study and Research Questions

Test anxiety, which is related to evaluation in general, and math anxiety, which is anxiety toward mathematics, have long been research subjects in the educational field (Ahmed et al., 2012; von der Embse et al., 2018). Students' mathematical problem-solving achievements were examined in the light of learning approaches and strategies before (Effendi & Fatimah, 2020). Test anxiety during mathematical problem-solving is the central point of this study. We studied ninth graders' non-routine mathematical problem-solving achievements and test anxiety levels since the transition from middle school to ninth grade affects students' academic achievements, and ninth grade is also vital for high school education (McCallumore & Sparapani, 2010; McIntosh & White, 2006; Warren et al., 2011). These research questions guided the study:

1. How can ninth graders be clustered according to mathematical problem-solving success and test anxiety?
2. How can ninth graders' problem-solving anxiety be classified using motivational orientations and learning strategies?
3. How do motivational orientations and learning strategies predict ninth graders' problem-solving anxiety?

2. METHOD

2.1 Participants and Setting

Two hundred and seventy-four ninth graders participated in the study. They were from four different high schools in eastern Turkey, and all participants had taken the national examination for high school after the eighth grade. One of the four high schools was Science High School (N = 59; n(female) = 35, n(male) = 24), which is a type of high school with high academic success, and three were Anatolian High School (N = 215; n(female) = 112, n(male) = 103), which is a type of high school with moderate academic success in Turkey.

2.2 Data Collection

Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991), scored on a 7-point Likert scale, was used in the study, and the scale was translated to Turkish by Karadeniz et al. (2008) for 12-18-year-old students. The MSLQ's Turkish version has 70 items and 15 subscales: intrinsic goal orientation (IGO), extrinsic goal orientation (EGO), task value (TV), control of learning beliefs (CLB), self-efficacy for learning and performance (SE), test anxiety (TA), rehearsal (R), elaboration (E), organization (O), critical thinking (CT), metacognitive self-regulation (MSR), time and study environment (T/S), effort regulation (ER), peer learning (PL), and help-seeking (HS). The original subscales' alpha levels ranged between 0.52 and 0.93. The Turkish version's corrected item-total correlations ranged between 0.15 and 0.68. The Cronbach alpha values for the subscales with five or more items raged between 0.66 to 0.85 in this study. The inter-item correlations for the subscales with less than five items ranged between 0.23 and 0.38, which are ideal (Clark & Watson, 1995). *The non-routine mathematical problem-solving test* consists of ten problems. The researchers prepared the test by reviewing the mathematics course books. Each question addressed at least one different problem-solving strategy. Two mathematics teachers' opinions were taken on the problems' language proficiency, clarity, comprehensibility, and scope. The problems were revised according to the teachers' feedback. The Cronbach's alpha value for the problem-solving test was 0.80 in this study.

2.3 Data Analysis

An answer key was prepared to assign scores to problem-solving test responses. Correct answers got 2 points, incomplete answers got 1 point, and not answered or incorrect answers got 0 points. The possible score range in the problem-solving test was 0-20. Test anxiety subscale in MSLQ was used for clustering participants along with problem-solving test scores. For this purpose, a TwoStep cluster analysis was used. A linear discriminant analysis was conducted to investigate how motivational orientations and learning strategies classify problem-solving anxiety. Logistic regression was performed to examine how motivational orientations and learning strategies predict ninth graders' problem-solving anxiety. SPSS 27 was used.

3. RESULTS

3.1 Research Question 1: How can Ninth Graders be Clustered According to Mathematical Problem-solving Success and Test Anxiety?

The participants were clustered into two groups with Schwarz's Bayesian Criterion and log-likelihood distance measure. 0.5 (good) Silhouette score and 1.42 ratio of cluster sizes for two groups demonstrated the appropriateness of the two groups.

The participants were grouped according to problem-solving success and test anxiety levels. The ones with a low level of problem-solving success and a high level of test anxiety (= high-level problem-solving anxiety; Group A) are 161 (58.8%) students. The ones with a high level of problem-solving and low level of test anxiety (=low-level problem-solving anxiety; Group B) are 113 (41.2%) students. There were large significant differences between groups' test anxiety levels ($t(272) = 4.20$, $p < 0.001$, Cohen's $d = 0.51$). and problem-solving success ($t(167) = 25.49$, $p < 0.001$, Cohen's $d = 3.25$).

3.2 Research Question 2: How can Ninth Graders' Problem-solving Anxiety be Classified Using Motivational Orientations and Learning Strategies?

A linear discriminant analysis was conducted to identify how motivational orientations and learning strategies can classify problem-solving anxiety levels. Pearson correlation was calculated to see the intercorrelation levels among variables (Table 1), and one strongly related variable pair was found:

elaboration and metacognitive self-regulation ($r > 0.7$ = strong) (Moore et al., 2013). This relationship would make the interpretation of the results difficult if one or two of these two significantly classified the participants' problem-solving anxiety. (None of the two variables were found significant.)

Table 1. Correlations between variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.IGO	-												
2.EGO	.38**	-											
3.TV	.59**	.44**	-										
4.CLB	.36**	.29**	.31**	-									
5.SE	.44**	.20**	.52**	.27**	-								
6.R	.34**	.43**	.30**	.20**	.30**	-							
7.E	.43**	.26**	.41**	.09	.43**	.58**	-						
8.O	.39**	.38**	.38**	.12*	.42**	.65**	.67**	-					
9.CT	.39**	.20**	.30**	.13*	.40**	.48**	.65**	.54**	-				
10.MSR	.50**	.30**	.45**	.20**	.53**	.66**	.72**	.68**	.63**	-			
11.T/S	.45**	.32**	.41**	.27**	.42**	.47**	.55**	.57**	.43**	.68**	-		
12.ER	.28**	.23**	.30**	.15*	.35**	.24**	.27**	.39**	.14**	.41**	.49**	-	
13.PL	.15*	.22**	.12*	.03	.19**	.37**	.37**	.34**	.43**	.32**	.22**	-.02	-
14.HS	.35**	.24**	.22*	0.19**	.23**	.40**	.46**	.34**	.32**	.48**	.47**	.21**	.49**

Notes. **p < 0.01 (two-tailed), *p < 0.05 (two-tailed)

According to the log determinants and homogeneity of covariance matrices as a result of the discriminant analysis for problem-solving anxiety, log determinants were similar, Group A = 39.489, Group B = 39.225, Pooled within Groups = 40.108, and Box's *M* is 197.848 with F = 1.779 ($p < 0.001$). In studies with large samples, a significant result for Box's M can be ignored (Burns & Burns, 2008). These indicate that the covariance matrices are equivalent. The discriminant analysis provided one discriminant function because we have only two groups: Group A and Group B. The canonical correlation (= 0.405) is the correlation between the variables and the discriminant function. The proportion of variance explained was 16.4% of the grouping variables' variation. Wilks' Lambda (= 0.836, $\chi 2(14) = 47.439$, $p < 0.001$) indicated a highly significant function.

Table 2 shows the structure matrix and canonical discriminant function coefficient values resulting from discriminant analysis for problem-solving anxiety. The values under Structure Matrix indicated the relationships between the predictors and the discriminant function and were also considered discriminant loadings. *Rehearsal, extrinsic goal orientation,* and *peer learning* loaded the discriminant function more than others (0.3 was taken as the cutoff value).

Table 2. Structure matrix and canonical discriminant function coefficient

	Structure matrix	Canonical discriminant function coefficient
	Function 1	Function 1
Rehearsal (R)	0.597	0.151
Extrinsic goal orientation (EGO)	0.451	0.076
Peer learning (PL)	0.346	0.083
Self-efficacy (SE)	-0.250	-0.082
Intrinsic goal orientation (IGO)	0.239	0.089
Effort regulation (ER)	-0.216	-0.043
Critical thinking (CT)	0.208	0.001
Organization (O)	0.195	-0.039
Elaboration (E)	0.182	0.009
Metacognitive self-regulation (MSR)	0.136	-0.009
Task value (TV)	0.122	0.013
Control of learning beliefs (CLB)	0.107	0.010
Time and study environment (T/S)	0.011	-0.011
Help seeking (HS)	0.008	-0.103
Constant		-1.198

Table 3 shows the classification results of discriminant analysis for problem-solving anxiety. Classification results showed that 66.8% of the participants were correctly classified into the defined groups: Group A (high-level problem-solving anxiety) and Group B (low-level problem-solving anxiety). Those with high-level problem-solving anxiety (78.3%) were grouped more accurately than those with low-level problem-solving anxiety (50.4%). According to the cross-validated classification, 62.8% of the students were correctly classified. Misclassification rates for students from science high school (schools with high academic achievement) were 42.37% and for students from Anatolian high schools (schools with moderate academic achievement) was 31.63%.

Table 3. Classification results

			Predicted group membership		
			Group A	Group B	Total
Original	Count	Group A	126	35	161
		Group B	56	57	113
	%	Group A	78.3	21.7	100
		Group B	49.6	50.4	100
Cross-validated	Count	Group A	121	40	161
		Group B	62	51	113
	%	Group A	75.2	24.8	100
		Group B	54.9	45.1	100

3.3 Research Question 3: How Do Motivational Orientations and Learning Strategies Predict Ninth Graders' Problem-solving Anxiety?

Logistic regression was conducted to identify how motivational orientations and learning strategies predict participants' problem-solving anxiety levels. The model was statistically significant ($\chi2(14) = 50.392$, $p < 0.001$). Hosmer and Lemeshow test ($\chi2(8) = 8.472$, $p = 0.389$) indicated the fit of predictions made by the model through observed memberships to the low-level and high-level problem-solving anxiety groups. The model explained 22.6% (Nagelkerke R^2) of the variation in problem-solving anxiety. The model's accuracy rate in classification for low-level and high-level problem-solving anxiety groups is 67.2%. Table 4 shows the significant variables in the regression equation for high-level (Group A) and low-level (Group B) problem-solving anxiety groups. *Intrinsic goal orientation* ($B = -0.094$, $p = 0.040$), *self-efficacy* ($B = 0.079$, $p = 0.003$), *rehearsal* ($B = -0.143$, $p < 0.001$), and *help-seeking* ($B = 0.101$, $p = 0.030$) were found to be the significant predictors of problem-solving anxiety.

Table 4. Significant variables in the regression equation

	B	S.E.	df	Wald	p	Exp(B)	95% C. I. for EXP(B)	
							Lower	Upper
IGO	-0.094	0.046	1	4.233	0.040	0.910	0.832	0.996
SE	0.079	0.027	1	8.762	0.003	1.082	1.027	1.140
R	-0.143	0.039	1	13.632	<0.001	0.867	0.804	0.935
HS	0.101	0.046	1	4.703	0.030	1.106	1.010	1.211
Constant	1.272	1.057		1.448	0.229	3.567		

4. DISCUSSION

The goals of this study were two-fold. First, we wanted to examine how prospective ninth graders' problem-solving anxiety levels can be classified using motivational orientations and learning strategies. Second, we wanted to investigate how different motivational orientations and learning strategies predict ninth graders' problem-solving anxiety. To this end, we first clustered ninth graders according to their problem-solving anxiety. Students were grouped as high-level problem-solving success with low-level test anxiety and low-level problem-solving success with high-level test anxiety. The discriminant analysis was administered to classify whether a ninth grader had low-level or high-level problem-solving anxiety.

Rehearsal, extrinsic goal orientation, and peer learning significantly contributed to ninth graders' problem-solving anxiety classification as low and high. *Rehearsal* was the strongest contributor to the classification. Rehearsal improves the activation of prior knowledge (Pintrich et al., 1991). As a result, students who use a high level of rehearsal strategies demonstrate high performance in their learning (Gbollie & Keamu, 2017) and high mathematics success (Wang & Davaanyam, 2012). So, we consider this strategy to be highly associated with students' problem-solving ability and anxiety level when taking mathematical problem tests. *Extrinsic goal orientation* was another significant variable that classifies problem-solving anxiety as low and high. Since high schoolers have a high level of extrinsic goal orientation during mathematical problem-solving (Puteh & Ibrahim, 2010) and end-goals such as test results and grades are valued in extrinsic goal orientation (Pintrich et al., 1991), we see this motivational orientation as critical while learning and practicing mathematical problem-solving and experiencing anxiety. *Peer learning* was also a significant variable that classifies problem-solving anxiety as low and high. The effectiveness of peer learning in mathematics (Cheng & Walter, 2009) and peer learning in supporting knowledge construction (Sezgin-Memnun et al., 2019) were reported in the literature. According to our results, peer learning can effectively predict prospective students' membership in high-level or low-level problem-solving anxiety groups. However, considering this factor in classifying students' problem-solving anxiety also should be approached carefully because there is a report that students may not prefer peer learning during mathematical problem-solving (Puteh & Ibrahim, 2010). Further study for peer learning is needed.

Using logistic regression analysis, we also found that *intrinsic goal orientation* and *rehearsal* were significant negative predictors for ninth graders' problem-solving anxiety. The increases in intrinsic goal orientation and rehearsal strategy use decreased the likelihood of being in a low-level problem-solving anxiety group. Intrinsic goal orientation is related to students' engendered "challenge, curiosity, [and] mastery" (Pintrich et al., 1991, p. 9). The exam-oriented concepts for passing classes and high school entrance exams in education systems may hinder students' curiosity, challenge, and mastery. Also, for these exams, rehearsal as memorization by repetition would become more frequently used for students, which, unlike elaboration and organization strategies, could prevent them from developing genuine problem-solving skills. Previous studies that examined low-level intrinsic goal orientation and high-level extrinsic goal orientation (Puteh & Ibrahim, 2010), moderate-level intrinsic goal orientation (El-Adl & Alkharusi, 2020), and high-level rehearsal strategy use (Gasco et al., (2014) support intrinsic goal orientation and rehearsal being significant predictors for ninth graders' problem-solving anxiety.

Self-efficacy was a significant positive predictor for ninth graders' problem-solving anxiety. Self-efficacy as a critical factor for learning (Pajares & Kranzler, 1995) and self-efficacy as a significant predictor of math success (Erdem-Keklik & Keklik, 2013) were reported in the literature. *Self-efficacy for learning and performance* is based on students' performance and confidence levels for the expected achievement (Pintrich et al., 1991). Accordingly, the increase in self-efficacy increased the likelihood of being in a low-level problem-solving anxiety group.

Help-seeking is a strategy that ninth graders highly use during problem-solving (Puteh & Ibrahim, 2010). According to our results, the increase in the use of the help-seeking strategy increased the likelihood of being in a low-level problem-solving anxiety group. Collaboration between peers could be helpful in knowledge and understanding sharing; however, peer judgment should be considered when considering students' anxiety. Johnston et al. (2018) drew attention to judgment between peers, causing bullying, and Bishop and Pflaum (2005) found peer judgment as a negative factor for academic engagement. Peer learning as a significant classifier for problem-solving anxiety and help-seeking as a significant predictor for ninth graders' problem-solving anxiety can be examined further and together with regard to ninth graders' mathematical problem-solving and anxiety level.

5. CONCLUSION AND RECOMMENDATIONS

Predicting membership of ninth graders' problem-solving anxiety level in advance can help their successful transition from middle to high school mathematics education system. The present study discovered how ninth graders' problem-solving anxiety could be classified and predicted. Our classification results demonstrated relatively low misclassification rates and that those with high-level problem-solving anxiety were classified considerably more accurately with extrinsic goal orientation, rehearsal, and peer learning than the other

group. However, these three components also classified students' low-level problem-solving anxiety to some extent. These results have important implications for the dynamic assessment of prospective ninth graders engaging in mathematical problem-solving, indicating which students might need help with their mathematical problem-solving skills and support for overcoming anxiety. We suggest that educators monitor students' motivational orientations and learning strategies such as rehearsal, goal orientation, and peer learning to anticipate problem-solving anxiety. Nevertheless, since motivational orientations and learning strategies explained 16.4% of the grouping variability of problem-solving anxiety, other strategies and factors such as self-regulated learning strategies, demographic factors, and personality types in the literature could explain the remained proportion of students' classification.

Intrinsic goal orientation and rehearsal were the negative predictors among motivational orientations and learning strategies. We consider this result as the effect of the exam-oriented educational system still clearly remains in them since these ninth graders passed a national examination and just found a place for themselves in a high school. However, our results confirm that students' self-efficacy and help-seeking behavior positively impact their problem-solving anxiety. In sum, mathematics teachers need to give more attention to students' comprehension in mathematics lessons while teaching and practicing mathematical problem-solving. Strategies for intrinsic motivation, self-efficacy, and help-seeking should be considered more to encourage students to have a genuine interest in mathematics and improve their academic performance.

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