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Investigation of the relationship between problem-solving achievement and perceptions of students

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ABSTRACT

This study examined the relationship between secondary school students' problem-solving success and perceptions using a relational survey model. This study investigated 378 students (212 girls and 166 boys) in the sixth, seventh, and eighth grades between 11 and 14 years old using the convenience sampling method. The problem-solving inventory for children, routine and non-routine problem tests, and problem evaluation rubric were used for data collection. Descriptive and inferential analyzes were utilized. The results indicated that students tended to avoid the problem-solving process. Variables of trust, self-control, and avoidance regarding problem-solving perceptions significantly predicted students' success in solving routine and non-routine problems.

Keywords: problem-solving perception, routine problem, non-routine problem, secondary school students, problem-solving achievement

INTRODUCTION

Recent changes in economic, social, technological, and scientific fields affect the needs of individuals and problems they face. In order for curriculum to adapt to modern developments, it should enable individuals to cope with complex problems encountered in daily life, think critically, analyze events, and have mathematical skills. Mathematical skills are not just arithmetic four-operation skills, but problem-solving activities that are modeled on real-life situations. It improves the thinking, discussion, and reasoning skills of the problem-solver. These problems can be expressed as a situation that a person encounters, which requires a solution that is not immediately known. Schoenfeld (1992) defined a problem as a situation where the answer must be found or is confusing or where the solution is not easily found. Adair (2007) expressed it as a situation that is thrown in front of people, which creates an obstacle. Fan and Zhu (2000) defined a problem as a situation that requires a solution regardless of the availability of the problem solver's existing knowledge. Krulik and Rudnick (1989) defined the problem as a quantitative or other form of situation faced by a person or group, requiring a solution that cannot be seen clearly. Fülöp (2015, 2021) stated that the problem changes based on the person assigned the task and emphasized that the person should be willing to solve the problem. As such, particularly in mathematics education, students are expected to make sense of mathematical algorithms and solve four operations problems as well as associate this information with daily life based on available data, analyze, make inferences, and gain advanced thinking skills.

Anderson (2009) defined problem-solving as an important life skill that covers various processes, such as analyzing, interpreting, predicting, evaluating, and reasoning. Problem-solving is a complex process that includes cognitive skills as well as affective and behavioral characteristics (Frey et al., 2000). In this process, the individual's difficulties and obstacles consist of complex stages that must be overcome (Heppner, 2008). Therefore, including non-routine problems that students can use in daily life is crucial, allowing them to develop creative and critical thinking skills, rather than procedures solved with standard rules and formulas (Lee et al., 2014). Through the process of problem-solving, students learn to solve a problem systematically and reveal how they think while solving it (Han & Kim, 2020).

Research on problem-solving generally classifies problems as routine and non-routine (Anderson, 2009; Lee & Kim, 2005). Routine problems are situations that require the application of a learned formula to a new situation that can be solved with a certain algorithm in mathematics textbooks, which enables students to develop four operations skills (Polya, 2004). Non-routine problems are unstructured, with complex questions that cannot be solved with a specific algorithm (Apostol, 2017; Elia et al., 2009; Evans et al., 2020). Non-routine problems are challenging for students as they require the use of many metacognitive skills, such as organizing existing knowledge with data in the problem, establishing appropriate hypotheses, and interpreting problems. Many

researchers argue that non-routine problems are more effective in developing and evaluating students' problem-solving skills (Polya, 1981; Lee et al., 2014). Since there are various problems in daily life, students should be provided with many types of problems, enriching student thinking, reasoning, relating to real life (Temiz & Ev Cimen, 2017).

The individual's perception of their problem-solving performance plays a significant role. As such, an individual's problem-solving performance depends on their prior knowledge, experience, education, and environmental factors, making it a complex process (Heppner et al., 2004; Zeidner & Endler, 1996). Individual perception influences thoughts, feelings, and behaviors in problem-solving (Larson et al., 1993). An individual's belief or judgment about performance in the problem-solving process is defined as problem-solving skill perception (Kaplan et al., 2016). In addition, it has been observed that individuals who perceive their problem-solving skills as high have a high sense of self-confidence, are not overly anxious about the events they encounter, and approach the problem cautiously to derive an effective solution (Heppner et al., 2004; Rosenberg, 1989).

Individuals with high problem-solving perception tend to be more successful than others in coping with the problems they encounter. In other words, individuals who exhibit effective problem-solving are flexible and develop effective methods to solve problems and achieve their goals (Heppner et al., 2004). In addition, individuals who perceive themselves as good at problem-solving spend more time on problem-solving than others, engage more, and develop thoughts appropriate for the task (Serin et al., 2010). According to Heppner et al. (2004), individuals with a high perception of problem-solving are psychologically and physically healthier and feel safe and successful, while individuals with a low perception of problem-solving tend to be reluctant, anxious, and insecure in the face of the problems. Heppner and Petersen (1982) emphasized that problem-solving perceptions they observe in individuals should be handled in the dimensions of trust, approach-avoidance, and personal control. The trust dimension shows the individual's belief that they can solve a problem when faced with it. Individuals who do not rely on problem-solving skills spend less time focusing on the task and cannot develop appropriate ideas (Heppner & Petersen, 1982). This increases anxiety further, making the individual unable to solve the problems they encounter effectively (Jerath et al., 1993).

On the other hand, self-confident individuals have high self-efficacy and positive emotions when solving problems (Bandura, 1997; Betoret & Artiga, 2010; Karademas & Kalantzi-Azizi, 2004; Morales-Rodríguez & Pérez-Mármol, 2019; Weiten et al., 2018). The second dimension, approach-avoidance, is related to the individual's tendency to stay near or far from problem-solving activities. Individuals who feel confident in their ability to solve the problem engage in these activities, using effort and time (Betoret & Artiga, 2010; Heppner, 2008; Larson et al., 1994; Stephanou & Oikonomou, 2018). Finally, the personal control dimension refers to the individual's ability to control their emotions and behaviors during the problem-solving process. Individuals are more successful academically if they have positive evaluations based on a sense of trust and personal control in the problem-solving process (Betoret & Artiga, 2010).

Studies on student perceptions of problem-solving generally include perception levels and metacognitive skills (Bakioglu et al., 2015; Kaplan et al., 2016; Karakelle, 2012; Kozikoglu, 2019; Ozcakir Sumen & Calisici, 2016), intelligence (Karakelle, 2012), academic self-efficacy (Kozikoglu, 2019), functional and scientific literacy (Ozenc & Carkit, 2021), automatic thinking and decision-making styles (Tezel & Tezgoren, 2019), assistance in the learning process (Koc, 2014), thinking styles (Gokmen, 2019), and general academic achievement (Alci, 2011; Alci et al., 2008; Berkant & Eren, 2013; Biber & Kutluca, 2013). However, research examining the relationship between problem-solving success and problem-solving perception is scarce. Ceylan (2008), for instance, concluded that there is a significant relationship between 6th grade students' problem-solving perceptions and their success in solving problems related to daily life. Biber and Kutluca (2013) found a significant difference between the students' problem-solving perceptions and their general academic achievement. However, Alci (2011) observed no significant relationship between problem-solving perceptions and undergraduate graduation success. Similarly, Alci et al. (2008) found that students' perceptions of problem-solving did not make a significant difference in predicting mathematics achievement.

This study aimed to investigate the correlation between secondary school students' problem-solving achievement and perception. The following research questions were posed:

1. Is there a correlation between students' routine and non-routine problem-solving achievement and problem-solving perceptions?
2. Do students' perceptions of problem-solving predict their achievement in routine and non-routine problem-solving?

METHOD

Research Model

This study utilized the relational survey model, a quantitative research model, to examine the relationship between students' problem-solving success and perceptions. The relational survey model determines changes between two or more variables and the degree of change (McMillan & Schumacher, 2014). Therefore, this model was used to examine the relationship between students' routine and non-routine problem-solving achievement and perceptions and predictive ability of these variables for routine and non-routine problem-solving achievement.

Participants

This study examined 378 (212 girls and 166 boys) secondary school students belonging to the 2018-2019 academic year from a large province in eastern Turkey, who were selected using the convenience sampling method. Convenience sampling provides quick collection of information, utilizing easily accessible and suitable individuals at the time to form a sample (Fraenkel et al., 2012; McMillan & Schumacher, 2014). Of the total, 32% (121) of the students were in the sixth grade, 32% (122) were in the seventh grade, and 36% (135) were in the eighth grade. All students were between 11 and 14 years old.

This study was conducted with the approval of the Ministry of National Education and the ethical committee of the university (#66109502, dated May 3rd, 2020) Informed consent was obtained from the parents of students who volunteered to participate in the study.

Data Collection Tools

This study used the problem-solving inventory for children to evaluate perceptions, the routine and non-routine problem tests to examine problem-solving, the problem evaluation rubric to evaluate problem solutions.

Problem-solving inventory for children

The problem-solving inventory for children, developed by Serin et al. (2010), was used to determine students' perception levels of their problem-solving skills. This inventory consists of 24 items marked on a 5-point Likert scale that evaluate problem-solving skill in three categories: confidence, self-control, and avoidance. An example item in the confidence category was, "I believe that I will solve problems I encounter by thinking about all the possible solutions." An example item in the self-control category was, "sometimes I do not stop and take time to deal with my problems, but just kind of carry on in a muddled manner." An example item in the avoidance category was, "I make up many excuses to from my work and responsibilities." Cronbach's alpha values of the scale were .85 for the confidence category, .79 for the self-control category, and .66 for the avoidance category. The value for the whole scale was .80 (Serin et al., 2010). Similarly, within the scope of this study's data, Cronbach's alpha values were .89 for the confidence category, .78 for the self-control category, .75 for avoidance category, and .72 for the whole scale.

Routine and non-routine problem tests

The routine and non-routine problem tests consisted of six routine problems and six non-routine problems based on previous studies (Cai, 2000; Verschaffel et al., 1994; Xin et al., 2007). It consisted of open-ended questions including numbers, fractions, proportions, patterns, generalization, areas, and lengths. Routine problems focused on questions in textbooks that allow certain operations, such as addition, subtraction, multiplication, and division, which students frequently encounter in their daily lives. Non-routine questions focused on including questions that are not frequently encountered and unfamiliar in textbooks, which develop advanced thinking skills beyond the students' operational skills, such as reorganizing data and classifying and seeing relationships.

An example routine problem was, as follows:

> A group of 10 people go on a three-day scout camp. Since there is no water at their destination, they have to take water with them. The scout guidebook said that eight liters of water was enough for five people for one day. How much water should a group of 10 people take with them? Show how you found the answer.

An example non-routine problem was, as follows:

> A primary school decides to rent a bus and travel to Istanbul. There are a total of 1,128 people participating in the school trip. If there are 36 seats on each bus, how many buses are needed in total? Describe your solution.

To test the validity of the problems, opinions were obtained from two math educators, and a linguist. A pilot test was conducted with 64 students. As a result of the pilot application, it was concluded that the problem test was valid in terms of validity and reliability.

Problem evaluation rubric

The routine and non-routine problem tests were evaluated using five-point scoring criteria (from zero to four) developed by Cai (2000). Answers with correct and complete explanations and solutions were given four points. Answers were largely correct explanations and solutions containing minor errors and uncertainties were given three points. Answers that indicated some understanding but provided no solution or explanation of the problem were given two points. Answers indicating limited knowledge of the subject were given one point. Incorrect answers or unanswered questions were given zero point.

Procedure

Descriptive and inferential analyzes were utilized. Descriptive and inferential analyzes were utilized. In the descriptive analysis, the general tendencies of the participants about the situations of interest are explained (Creswell, 2012; Sezgin Selcuk, 2019). In this context, the relationship between the scores the participants got from the problem-solving inventory and the scores they got from the routine and non-routine problems was calculated with the Pearson correlation value. On the other hand, inferential analysis is the situation where the researcher reaches conclusions and generalizations about the population based on the data obtained from the sample (Creswell, 2012). In this context, it was analyzed with multiple regression how much the scores of the students participating in the sample from the problem-solving inventory predicted their routine and non-routine problem-solving achievement

Data Collection

The problem-solving inventory for children and the routine problem test were administered in one lesson, while the non-routine problem test was administered in another lesson. The data were collected in two lesson hours (40 minutes each).

Table 1. Descriptive and relational analysis values between variables

Variables	Bivariate correlation		Descriptive statistics				
	Routine	Non-routine	n	Mean	Standard deviation	Skewness	Kurtosis
Confidence	.37**	.31**	378	2.79	1.45	-.800	-.626
Self-control	.38**	.27*	378	2.78	1.44	-.837	-.178
Avoidance	.38**	.28**	378	3.49	1.55	-.232	.335

Note. **p<.01

Table 2. Multiple regression analysis results for predicting routine and non-routine problem-solving achievement

	Variable	B	Standard error	Beta	t	p	Pearson r	Partial R^2
Routine	Confidence	5.361	1.033		5.192	.000		
	Self-control	1.031	.296	.198	3.486	.001	.379	.177
	Avoidance	1.073	.355	.187	3.027	.003	.387	.155
	Total	.888	.365	.154	2.431	.016	.382	.125
	R=0.454; R^2=0.206; F(3-374)=32.400; & p=0.00							
Non-routine	Confidence	2.068	.742		2.788	.006		
	Self-control	.733	.212	.206	3.451	.001	.318	.176
	Avoidance	.362	.255	.092	1.421	.156	.272	.073
	Total	.461	.263	.117	1.756	.080	.289	.090
	R=0.353; R^2=0.124; F(3-374)=17.712; & p=0.00							

Data Analysis

IBM SPSS 22 (IBM Corp, 2017) software was used to analyze the data. First, the dimensions of the problem-solving inventory for children and the normal distribution of the data obtained from routine and non-routine problem tests were examined. In this context, the normal distribution of the data was analyzed with skewness and kurtosis tests. Accordingly, the skewness value for the problem-solving inventory for children was calculated as .332 and the kurtosis value as .870. The skewness value of the routine and non-routine problem form was -.281, the kurtosis value was -.989. It is accepted that there is a normal distribution when the skewness and kurtosis values are between -1.5 and 1.5 (Tabachnick & Fidell, 2013). In this context, Pearson correlation analysis was applied because the data showed normal distribution. On the other hand, multiple regression analysis was utilized to examine results of the routine and non-routine problem tests and determine the predictive level of problem-solving perception.

RESULTS

The correlation coefficients and descriptive analysis between students' routine and non-routine problem-solving achievements and their perceptions of problem-solving are presented in **Table 1**.

The results indicated a positive, moderate, significant correlation between routine problem-solving achievement. In addition, there was a positive, moderate, significant correlation between non-routine problem-solving achievement and the confidence category of perception. However, the correlation with self-control and avoidance was positive, low, and significant (p<.01).

The results of multiple regression analysis for predicting the students' routine and non-routine problem-solving achievement are presented in **Table 2**.

The perception of problem-solving in the categories of confidence, self-control, and avoidance significantly predicted achievement of solving routine problems (R=.454, R^2=.206, F=32.400, p<.01=). Confidence, self-control, and avoidance variables together explained approximately 20% of the total variance in routine problem-solving achievement. In addition, perception in the categories of confidence, self-control, and avoidance together significantly predicted the achievement of non-routine problems (R=.353, R^2=124, F=17.712, p<.01). Confidence, self-control, and avoidance together explained approximately 12% of the total variance in non-routine problem-solving achievement. However, the regression coefficients indicated that, among the predictor variables, only confidence was significant and predictive of the achievement of solving non-routine problems.

DISCUSSION AND CONCLUSION

This study examined the correlation between secondary school students' problem-solving achievement and perceptions. At the end of the study, it was found out that students generally use avoidance in the problem-solving process, and that confidence and self-control in the problem-solving process were moderate. These results are in line with existing studies (Erdem & Genc, 2014; Kaplan et al., 2016; Koc, 2014; Tezel & Tezgoren, 2015). Kaplan et al. (2016) found that secondary school students participated at a moderate level in the dimensions of confidence, self-control, and avoidance in problem-solving. Similarly, Koc (2014) determined that secondary school students demonstrated high avoidance of problem-solving and moderate confidence and self-control.

There was a positive, moderate, significant correlation between students' routine and non-routine problem-solving achievement and categories of problem-solving perception (p<.01). In other words, it can be said that as students' routine and non-routine problem-solving achievement increases, they have more confidence in problem-solving and can control themselves

better. In this regard, Heppner and Peterson (1982) reported that those who perceive themselves as successful in problem-solving are more determined, consistent, motivated to solve problems, see problems as a part of life, and do not avoid finding solutions. Similarly, Ceylan (2008) found a significant positive correlation between the problem-solving perceptions of sixth grade students and their achievement in solving mathematics problems. The acquisition of problem-solving skills is extremely important in mathematics lesson and in daily life, making it a basic skill that should be acquired by students. Students who are successful in solving mathematical problems are likely to be confident and controlled in solving problems they encounter in daily life. Biber and Kutluca (2013) revealed a significant relationship between students' problem-solving perceptions and general academic achievement. However, unlike this study and previous research, Alci (2011) concluded that there is no significant relationship between the problem-solving perceptions of graduate students and their general academic achievement. Likewise, Berkant and Eren (2013) concluded that there is no significant relationship between the general academic achievement and problem-solving perceptions of undergraduate students in the department of elementary mathematics.

This study had some limitations. First, this study was limited to the relationship between students' routine and non-routine problem-solving success and problem-solving perceptions. Future studies should consider various variables, such as metacognitive awareness, reading skill, belief in mathematics, self-efficacy, which are factors affecting problem-solving success. In addition, this study was limited to secondary school students in a particular region, selected based on a homogeneous sampling method. Comparisons should be made by examining the problem-solving perceptions of students at different grade levels.

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Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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