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Factors influencing mathematical problem-solving achievement of seventh grade Turkish students

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ABSTRACT

It is known that there are many factors affecting students' problem-solving abilities. In this study, the influence of seventh-grade students' affective factors, their academic success, their gender and their families' educational levels on their problem-solving achievement was examined. To achieve this aim, a Problem-Solving Attitude Scale, a Mathematics and Problem-solving Belief Scale, a Mathematics Anxiety Scale, a Self-efficacy Perception for Mathematics Scale and a Problem-Solving Achievement test, which were developed according to the literature and the opinions of experts, were applied to one hundred fifteen seventh-grade students. The data were analyzed using the correlation method, and the direct and indirect factors affecting problem-solving achievement were examined. In the results, a highly significant relationship between academic successes and problem-solving achievements was found, while a moderately significant relationship between students' problem-solving attitudes, problem-solving beliefs, mathematics anxiety and self-efficacy perception for mathematics factors and their problem-solving achievements was observed. No significant relationship between the indirect factors and problem-solving achievements was found.

1. Introduction

Today's societies are required to produce well-educated people who have the ability to adapt themselves to the rapidly changing and developing world. It is necessary to educate the individuals who will power the world of the future, therefore countries have been implementing comprehensive curricular reform, particularly in the field of mathematics, for the last 20 years (Güven, Çakıroğlu, & Akkan, 2009). Furthermore, the National Council of Teachers of Mathematics (NCTM) (1989) has underscored a shift in focus of mathematics education from content to problem-solving abilities. As a result of the dramatic changes in mathematics education around the world, the mathematics curriculum at both the elementary and secondary school levels in Turkey has been revised since 2005. While the previous curriculum emphasized a set of facts, formulas and procedures, the current curriculum focuses on the processes of exploration, communication and conceptualization through hands-on classroom activities. The aim of the reform is inquiry mathematics. In contrast with traditional classroom activities that emphasize repetition, practice, and routine as a means to some specified endpoint, inquiry mathematics instruction encourages student engagement in problem-solving of mathematical situations (Güven et al., 2009). This shift in the mathematics education paradigm has led researchers to focus more on problem-solving, as well as motivating teachers to enrich their classes with problem-solving activities.

Schoenfeld (1992) supports the notion that problem-solving based learning environments enable students to develop deep mathematics knowledge and give them the opportunity of building their own mathematics. Schoenfeld outlined a framework of different factors that affect students' problem-solving abilities as four components: (1) *resources* are formal and informal knowledge about facts and routines; (2) *heuristics* are rules of thumb for making progress on unfamiliar problems; (3) *control* is metacognitive knowledge of how to select resources and heuristics; and (4) *belief systems* are students' world-views, including their self-perception. On the other hand, Alan (2009) examined the factors affecting problem-solving as cognitive, affective and experience factors. According to Alan, the cognitive factors affecting students' problem-solving processes consist of the stages of cognitive coping strategies, managing behaviors by cognitive processes and conscious control of cognitive processes. Alan also indicated that age, previous knowledge, and familiarity with both the content of a problem and the solution strategy are experience factors, while emotional coping strategies – emotions' preventive or supportive effects on the actions and the relationships among behavior–evaluation–emotion concepts – are affective factors. Mason (2003) further expressed that students' mathematics and mathematical problem-solving beliefs are important, noting that as problem-solving beliefs increase, their achievements will increase accordingly. On the other hand, according to Fisher, Allen, and Kose

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(1996), anxiety and fear towards mathematics are also among the factors affecting students' problem-solving achievements. In their investigation into the relationship between anxiety and problem-solving skills in children without learning disabilities, they studied low, medium and high pretest anxiety levels on the social and nonsocial problem-solving performance with 90 boys who ranged in age from 9 to 11 years. They concluded that there is a negative relationship between students' anxiety and fear directed at mathematics and their problem-solving achievements. Likewise, in their experimental study, Hoffman and Schraw (2009) demonstrated that there is a positive relationship between students' self-efficacy for problem-solving and their metacognition.

1.1. Problem-solving and affective factors

Almost all of the existing research states that affective factors are influential on problem-solving. These affective factors include problem-solving beliefs, attitudes towards mathematics, anxiety about mathematics, and self-efficacy towards mathematics (Bindak, 2005; Pimta, Tayruakham, & Nuangchalerm, 2009; Uğurluoğlu, 2008; Umay, 2001). Although these affective concepts cannot be completely separated from one another, they do have certain distinctive features.

Variations in the definitions of belief and belief system concepts have been observed in the research concerning mathematics education (Ishida, 2002; Kloosterman & Stage, 1992; Schoenfeld, 1992). Schoenfeld (1992) contends that belief refers to the individual insights and emotions that affect ways of showing mathematical behaviors. Similarly, Kloosterman and Stage (1992) characterize students' problem-solving beliefs as follows: I can solve time-consuming problems; I can solve word problems not directly, but step by step; understanding concepts is very important in mathematics; word problems are very important for mathematics; effort can increase mathematical skills; and mathematics is used in daily life. The fact that students' problem-solving beliefs are influential on their problem-solving achievements has led to other research in this area. For instance, Kloosterman and Stage (1992) applied the system of beliefs they developed to students in the U.S. and reached the conclusion that beliefs regarding problem-solving are effective on problem-solving achievement. Likewise, Ishida (2002) evaluated students' problem-solving skills in a four and a half year problem-solving course for primary school students, concluding that problem-solving beliefs have an effect on the ability to solve problems correctly. Callejo and Vila (2009) also studied the role of the belief system in students' approaches to mathematical problem-solving with 61 participants ranging from 12 to 13 years of age. They found that a dualistic belief system originating in the student's school experiences and motivation has an effect on a student's approach to the problem-solving process. Schommer-Aikins, Duell, and Hutter (2005) examined the effects of students' general epistemological and mathematical beliefs on their mathematical problem-solving performance. They found that students' beliefs in the usefulness of mathematics have a moderate relationship to their problem-solving performance ($r = 0.11$).

While there are many definitions of attitude in the literature, one of the most accepted definitions is that attitude is an "individual's inclination which is shown before behavior and which is related to his knowledge and experience against objects, incidents or situations around himself" (Başer & Yavuz, 2003). Mathematics, being one of the subjects towards which many students develop negative attitudes, has been the subject of many studies. In the related literature, the reasons for these negative attitudes towards mathematics are characterized as follows: mathematics education and teaching methods used; attitudes of teachers; attitudes of parents; and effects of the social and cultural environment (Uğurluoğlu, 2008). The literature also indicates that there is a significant positive relationship between students' problem-solving achievements and their attitudes (Higgins, 1993).

According to Bandura (1997), self-efficacy can be defined as an individual's self-judgment about his capacity to deal with a particular problem. It has also been argued that self-efficacy is a factor in increasing motivation (Pimta et al., 2009), and that it affects the four fundamental psychological processes which have an important place in human life: (a) cognitive processes, (b) motivational processes, (c) emotional processes and (d) choice processes (Bandura, 1997, p. 5). From this perspective, a high perception of self-efficacy leads to individuals' determining higher aims for themselves and exercising consistency in their decision-making; thus, this affects their cognitive processes and results in high levels of motivation (Locke & ve Latham, 1990). Additional studies have also indicated that students' self-efficacy affects their mathematics and problem-solving achievements in a positive manner (Bune, 1998; Chen, 2002; Günhan-Cantürk & Başer, 2007).

Furthermore, Usher (2009) examined the sources of students' self-efficacy in mathematics, conducting semi-structured interviews with eight middle school students, as well as their parents and mathematics teachers. He concluded that teaching structures, course placement and students' self-regulated learning are important factors in self-efficacy. In another study, Williams and Williams (2010) applied a reciprocal determinism model of self-efficacy and performance to 33 nations on the basis of data on the mathematics self-efficacy and mathematics achievement of 15 year-olds. They found that the model was a good fit to the data in 30 nations and was supportive of reciprocal determinism in 24 of these, suggesting a fundamental psychological process that transcends national and cultural boundaries.

On the other hand, Cleary and Chen (2009) studied the effects of students' self-regulation and motivation on their math achievement in middle school. They examined with 880 suburban middle-school students. They found that motivation and self-regulation played an important role during the early middle school years.

Bandura (1997) mentioned two expectations of individual behavior; these include self-efficacy belief and result expectation. Result expectation, in this case, is the ability of an individual to predict approximately what results will stem from a behavior. Self-efficacy is the belief of an individual concerning whether he can act successfully in order to attain a desired result or not. What is important according to Bandura is self-efficacy belief. Since individuals who have high self-efficacy beliefs can attain their desired results, their result expectations will be formed accordingly.

Mathematics anxiety refers to the belief of students that they will not be able to solve the mathematical problems they face (Hoffman, 2010). The fact that mathematics anxiety is the most important affective factor negatively affecting students' mathematics achievement has led researchers in mathematics education to examine the reasons for this issue (Bindak, 2005; Hoffman, 2010). Hoffman (2010) stated that the most common reason for mathematics anxiety is low perception of skills. Other reasons were listed as previous lack of success, non-adaptive behaviors, inadequate studying, lack of ability to prepare for tests, and genetic characteristics like perception.

Studies have also demonstrated the effects of the affective factors mentioned above on students' problem-solving achievement. When the literature is examined, it can be seen that, apart from affective factors, variables like gender, family's educational level, and students' academic success are also influential on students' problem-solving achievement. Özsoy (2005) investigated the relationship between students' problem-solving abilities and their mathematical achievement, applying a "mathematical problem-solving test" and a "problem-solving ability test" to fifth grade students. According to the findings, there was a positive and significant relationship between fifth grade mathematical achievement and problem-solving ability. Similarly, Saracaloğlu, Serin, and Bozkurt (2002) examined the relationship between postgraduates' problem-solving achievements and overall achievements, concluding that students' problem-solving abilities and their overall achievements differ in a significant way.

The factors which are thought to affect mathematical problem-solving are summarized in Fig. 1. While mathematics anxiety, attitudes and beliefs towards problem solving, and mathematical self-efficacy are among the affective factors, students' problem-solving and academic successes