

The Relationship of STEM Attitudes and Reflective Thinking Skills on Problem-Solving

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Abstract

The purpose of this study is to examine the relationship between STEM attitudes of middle-school students and their reflective thinking skills on problem-solving. For this aim, a survey was administered to a total of 576 students, including between 5-8 grades. In this study, the “STEM Attitude Scale” and the “Reflective Thinking Skill on Problem Solving Scale” were used as the data collection tools. The results showed that significant differences were found for the students’ reflective thinking skills on problem-solving in terms of gender, questioning, and reasoning dimensions in favor of female students. Also, significant differences among grade-levels were found in the questioning and evaluation dimensions of the reflective thinking skill on the problem-solving scale. Besides, significant differences were found in the engineering and technology dimensions in favor of female students and also in the mathematics and 21st-century skills dimensions in terms of grade-levels. Based on the findings obtained from this study, implications for teaching are made.

Keywords: STEM attitude, Problem-solving, Reflective thinking

STEM Tutum ve Problem Çözme Yönelik Yansıtıcı Düşünme Becerisi Arasındaki İliřki

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Öz

Bu çalışmanın amacı ortaokul öğrencilerinin STEM tutumları ile problem çözme üzerine yansıtıcı düşünme becerileri arasındaki ilişkiyi belirlemektir. Arařtırmada betimsel model olan tarama modeli kullanılmıştır. Çalışmaya 576 öğrenci dahil edildi. Öğrencilerin notları açısından dağılımları incelendiğinde 140'ı 5. sınıf, 140'ı 6. sınıf, 160'ı 7. ve 136'sı 8. sınıf öğrencisi olarak değerlendirilmiştir. Bu öğrencilerin 300'ü kadın, 276'sı erkektir. Arařtırmada veri toplama aracı olarak STEM Tutum Ölçeđi ve Problem Çözme Yönelik Yansıtıcı Düşünme Beceris Ölçeđi kullanılmıştır. Arařtırma sonucunda, öğrencilerin cinsiyete göre problem çözme üzerine yansıtıcı düşünme becerilerinde ve sorgulama ve akıl yürütme boyutlarında kız öğrencilerin lehine anlamlı farklılıklar bulunmuştur. Ayrıca, problem çözme ölçeđinde yansıtıcı düşünme becerisi üzerine yapılan analizlerde sorgulama ve değerlendirme boyutlarında sınıf düzeyi deđişkeni açısından anlamlı farklılıklar bulunmuştur. STEM tutum puanları üzerinde yapılan analizlerde, mühendislik ve teknoloji boyutlarında cinsiyet deđişkeni açısından kız öğrencilerin lehine, matematik ve 21. yüzyıl becerisi boyutlarında sınıf seviyesi deđişkeni açısından anlamlı farklılıklar bulunmuştur.

Anahtar Kelimeler: *STEM tutum, problem çözme, yansıtıcı düşünme*

Introduction

Today, the rapid development in science and technology has started to take effect in the area of education. Numerous countries have been working on new approaches to understanding how they can integrate science and technology which go under continuous change and development to education. One of these new approaches on the agenda is STEM (Science-Technology-Engineering-Mathematics) education, in which science, mathematics, engineering, and technology are included in the teaching-learning process in an integrated manner. STEM education is an approach that embodies the activities an individual carries out throughout his/her educational life in the areas of STEM (Gonzalez and Kuenzi, 2012). It is also defined as the individual's ability to produce solutions to a problem he/she faces using the four disciplines of STEM (Stohlmann, Moore and Roehrig, 2012).

Some studies argue for effective STEM education. These debates focus on whether or not the four disciplines need to be used together to increase the efficiency of education (Bybee, 2010; Dugger, 2010; Sanders, 2009). However, in certain cases, it is quite difficult to include all the disciplines of STEM in practice. Therefore, the integration of at least two STEM areas into the practice is important. The main point which needs to be given importance is to choose the cases presented to the students from problems which are related to daily life (Asghar, Ellington, Rice, Johnson and Prime, 2012; Breiner et al., 2012; National Research Council, 2014; Chiu, Price and Ovrachim, 2015). Educators state that as students find solutions to daily life problems that are presented to them in STEM education, they will have the opportunity to develop their analytical thinking, communication, and top-level thinking skills (Morrison, 2006; Brophy et al., 2008). Analytical thinking skills, problem-solving skills, communication skills, entrepreneurship, and social skills are noteworthy as 21st-century skills. Different organizations have classified 21st-century skills in different ways. For example, in a report published by the Ministry of Education of the Republic of Turkey (MoNE), 21st-century skills are defined as being creative and innovative, solving problems and making decisions, working cooperatively, and being technology literate (MoNE, 2011). Many countries throughout the world like the MoNE in Turkey have been emphasizing the importance of the 21st-century skills in education (ACTS, 2007;

Partnership for 21st Century Skills, 2013; OECD, 2005; World Economic Forum, 2015).

Integration for cognition and learning may be effective in terms of developing the relationships between these concepts and transferring these structures in new situations (Honey, Pearson and Schweingruber, 2014). However, curricula integration is a double-edged knife and should be seen as a tool to reach educational aims, rather than the aim itself (Venville, Malone, Wallace and Rennie, 1998). The most discussed issue on STEM education practice is related to how STEM education should be integrated into the existing programs. For this, educators have suggested some principles including the inclusion of STEM lessons in the curricula, designing assessment and evaluation accordingly, focusing on the 21st-century skills, and strengthening interdisciplinary cooperation.

It has been stated that problem-solving is the process that involves a time slice which begins the moment students face the problem and ends the moment when that problem is solved. Problem-solving in daily life is a basic method of survival (Tambychik and Meerah, 2010). A problem-solving approach is related to different methods students use to solve problems regarding experience, perception, and understanding of a certain phenomenon (Walsh, Howard, and Bowe, 2007). Problems that develop students' problem-solving skills, in general, require analysis, synthesis, and evaluation (Ültay, 2017). As suggested by Capraro and Slough (2008), children need, in particular, acquire problem-solving skills with STEM education at an early age.

In recent years, it has been underlined that by developing students' 21st-century skills they can solve problems related to daily life (Hmelo-Silver, 2004; Dewaters & Powers, 2006; Tseng et al., 2013). Capraro & Slough (2008) emphasize that STEM education allows students to learn problems based on daily life and makes it possible for them to solve these problems.

Reflective thinking is defined in two different ways. Different definitions have been made on it before and after teaching. During the teaching process, it allows teachers and students to think in-depth about content, while it presents the opportunity to think about the functioning of the lessons and their planning after teaching (Schön, 1983). Reflective thinking is regarded as an emotion, which distances teachers from their biases, allows them to be criticized, and helps them to be more competent in their works (Roskos, Vukelich,

and Risko, 2001). Teachers' reflective thinking skills vary according to their branches, gender, and school type they work (Dilekli and Orakçı, 2019).

Different tools are used to assess reflective thinking. Thinking out loud, having group discussions, and reflection diaries are considered to be some of these tools. Reflective thinking has a great impact on the development of a student's problem-solving skills. Therefore, reflective thinking skill becomes evident the best in the problem-solving processes (Kızılkaya and Aşkar, 2009). An individual's evaluating the alternatives he/she has developed throughout life and selecting and implementing one of these is defined as the problem-solving process as well (Philips, Paziienza and Ferrin, 1984). Dewey (1933) has stated that the problem-solving stages are extremely important and have ordered them as follows: defining and analyzing the problem, determining a criterion for a solution, suggesting solutions, evaluating the solutions, selecting the solution, and implementing the solution. Reflective thinking toward problem-solving involved three sub-dimensions: questioning, evaluation, and reasoning. Questioning is the process of seeking answers to the questions that an individual poses or asked to her/him. Evaluation is to look at the person's actions; analyze then and later determine the right and wrong parts of the action.

The reasoning is expressed as an examination of cause-effect relationships and, as a result, to examine these relationships in the context of cause-effect.

Previous studies have suggested that STEM education positively affects students' achievement in the areas of science and mathematics (Ceylan, 2014; McClain, 2015; Olivarez, 2012; Ricks, 2006; Vollstedt, Robinson & Wang, 2007; Wade-Shepherd, 2016; Worker & Mahacek, 2013; Wosu, 2013; Yıldırım, 2016) and develops their critical thinking (Şahin, Ayar & Adıgüzel, 2014; Wosu, 2013), creative thinking (Ceylan, 2014), and problem-solving skills (Ceylan, 2014; Pekbay, 2017; Saleh, 2016; Wosu, 2013).

The importance given to STEM education will allow all individuals to be knowledgeable in STEM areas, develop their problem-solving skills, and having a career that involves STEM subjects (Aydagül and Terzioğlu, 2014). The inclusion of STEM education will also encourage students' curiosity, doing research, learning by doing (Tuğluk and Öcal, 2017). Thus, students will be able to solve the problems they face in daily life (Bybee, 2010; Soylu, 2016).

In light of all these processes, what is expected from an individual is to determine methods and strategies related to a particular problem and arrive

for a conclusion rather than demonstrating a result (Savul, 2017). Therefore, it is considered concerning a problem students face in STEM disciplines that the 21st-century skills would have a significant impact on finding solutions to the problems. While developing solutions to these problems, it is stated by researchers that reflective thinking skill has an important impact. Because of this, the purpose of this study is to examine the relationship between middle-school students' STEM attitudes and reflective thinking skills in solving problems. The research questions that guide this research are as follows: Is there any difference in the students' level of problem-solving skills in terms of gender and grade level variables?

1. Is there any difference in the students' STEM attitudes in terms of gender and grade level variables?
2. Is there a relationship between the students' STEM attitudes and their reflective thinking skills in solving problems?
3. Are the students' reflective thinking skills in solving problems a predictor of their STEM attitude scores?

Method

The Model of the Study

In this study, the survey model which is a descriptive model was used. Survey models are a research approach that aims at describing the existing situation as it is. These are studies in which the participants' views, attitudes, and skills about a subject or event are determined. Survey studies are defined as studies which make it possible to give answers to questions such as “*at which phase, at which level, when*” and determine in general the characteristics of large masses (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, and Demirel, 2017).

Data Collection Tools

In this study, the “STEM Attitude Scale” and the “Reflective Thinking Skill on Problem Solving Scale” were used as the data collection tools. To measure the students' attitude towards STEM disciplines, the STEM attitude scale was used. The scale was developed by Faber et al. (2012). The adaptation of the scale into Turkish and its validity and reliability processes were carried out

by Yıldırım and Selvi (2015). The scale consisted of a total of 37 items and four sub-dimensions including mathematics, science, engineering and technology, and 21st-century skills. The scale is used in the 5 points Likert type, including "I totally agree; I agree; Undecided; I don't agree and I don't agree." The Cronbach alpha value for the whole scale was determined as .94. It was found to be .89 for mathematics dimension, .86 for the science dimension, .86 for the engineering and technology dimensions, and .89 for the 21st-century skills. In this study, the Cronbach Alpha value for the whole scale was determined as .88. It was found to be .84 for the mathematics dimension, .87 for the science dimension, .85 for the engineering and technology dimensions, and .88 for the 21st-century skills.

The Reflective Thinking Skill on Problem Solving Scale was developed by Kızılkaya and Aşkar (2009). The scale is a 5 point Likert type and consists of 14 items and 3 sub-dimensions including questioning, evaluation, and reasoning. The Cronbach alpha value for the whole scale was .83. It was found to be .73 for the questioning dimension, .71 for the reasoning dimension, and .69 for the evaluation dimension. In this study, the Cronbach Alpha value for the whole scale was calculated as .88, while .82 for the questioning dimension, .84 for the reasoning dimension and .84 for the evaluation dimension.

Results

Before the analysis of the data obtained, the normality distribution assumption was checked. For the normality test, a Kolmogorov-Smirnov test was conducted and the skewness and kurtosis values were examined. As a result, it was determined that it displayed a normal distribution and the analyses were carried out accordingly.

Participants

The participants of the study were middle-school students who enrolled in the Alanya district of the city of Antalya province of the Republic of Turkey during the 2017-2018 academic year. A total of 576 fifth, sixth, seventh and eighth-grade students participated voluntarily in the study. Of the 576 students, 300 were female and 276 were male. 140 of them were 5th grade, 140 were 6th grade, 160 were 7th grade and 136 were 8th-grade students. While

involving the students in the study, the convenience sampling method which is one of the purposeful sampling methods was used. According to Gürbüz and Şahin (2018), a study group of 576 individuals represents a population of 4250 people with a .01 margin of error. Therefore, it is considered that this study group will represent the population. The demographic information related to the participants is given in Table 1.

Table 1. Demographic Information Of The Participants

Grade level	Male	Female	Total
5	65	75	140
6	65	75	140
7	79	81	160
8	67	69	136
Total	276	300	576

The Effect of Gender on Reflective Thinking Skill on Problem Solving

To find out the effect of gender on students' reflective thinking skills on problem-solving, the unrelated samples t-test was conducted. The results of the t-test are given in Table 2.

Table 2. Gender Differences in Problem Solving Skill

Dimensions	Gender	N	\bar{x}	S	t	df	p
Questioning	Female	300	3.88	.72	2.248	574	.026
	Male	276	3.58	.85			
Evaluation	Female	300	3.82	.78	.835	574	.405
	Male	276	3.70	.89			
Reasoning	Female	300	3.93	.74	2.689	574	.008
	Male	276	3.56	.89			

According to the obtained results, a significant difference was found in the questioning dimension ($t(574)=2.248$, $p<.05$) and reasoning dimension ($t(574)=2.689$, $p<.05$) in terms of the gender variable. The results also show that this significant difference is in favor of female students.

The Effect of Grade Level on Reflective Thinking Skills on Problem Solving

To find out the effect of grade level on students' reflective thinking skills on problem-solving, the one way ANOVA was used. The results are given in Table 3.

Table 3. Grade Level Differences in Problem Solving Skill

Dimensions		Sum of squares	sd	Averages of squares	F	p	Significant difference
Questioning	Ingroup	10.967	3	3.656	6.299	.000	5th-7th grades 5th-8th grades
	Between groups	81.246	572	.580			
	Total	92.213	575				
Evaluation	Ingroup	19.501	3	6.500	11.201	.000	6th-7th grades
	Between groups	81.246	572	.580			
	Total	100.746	575				
Reasoning	Ingroup	3.137	3	1.046	1.504	.216	-
	Between groups	97.356	572	.695			
	Total	100.493	575				

It was analyzed whether the students’ reflective thinking skills on problem-solving changed according to the grade level variable or not. As a result of the analysis, a significant difference was found in the questioning [$F_{(3-572)}=6.299, p<.05$] and evaluation [$F_{(3-572)}=11.201, p<.05$] dimensions. In light of the Bonferonni test which was used to determine differences among groups, students’ average points ranged were found to be 5th-grade students ($\bar{x}=4.15$) and 7th-grade students ($\bar{x}=3.40$), and 5th-grade students ($\bar{x}=4.15$) and 8th-grade students ($\bar{x}=3.64$) in the questioning dimension. In the evaluation dimension, the average points were found to be for 6th-grade students ($\bar{x}=3.91$) and 7th grades ($\bar{x}=3.22$).

The Effect of Gender on STEM Attitude

To control whether the students’ STEM attitudes changed according to the gender variable, the unrelated samples t-test was run. The results are given in Table 4.

Table 4. Gender Differences in STEM Attitudes

Dimensions	Gender	N	\bar{x}	S	t	df	p
Mathematics	Female	300	3.37	1.01	.862	574	.390
	Male	276	3.23	.92			
Science	Female	300	3.64	.84	.470	574	.639
	Male	276	3.58	.75			
Engineering and Technology	Female	300	3.60	.67	3.082	574	.002
	Male	276	3.99	.86			
21st Century Skills	Female	300	4.15	.65	1.279	574	.203
	Male	276	4.00	.78			

As can be seen from Table 4, a significant difference was found for the dimension of engineering and technology ($t_{(574)}=3.082$, $p<.05$). This difference was in favor of males.

The Effect of Grade Level on STEM Attitude

One way ANOVA was used to determine whether grade level affects STEM attitudes. The results of this test are shown in Table 5.

Table 5. STEM Attitudes in terms of the Grade Level

Dimensions		Sum of squares	sd	Average of squares	F	p	Significant difference
Mathematics	Ingroup	14.540	3	4.847	5.631	.001	6th-7th grades 7th-8th grades
	Between groups	120.509	572	.861			
	Total	135.049	575				
Science	Ingroup	.924	3	.308	.472	.702	-
	Between groups	91.248	572	.652			
	Total	92.171	575				
Engineering and Technology	Ingroup	5.225	3	.308	2.865	.069	-
	Between groups	85.093	572	.652			
	Total	90.318	575				
21st Century Skills	Ingroup	6.423	3	2.141	4.385	.006	6th-7th grades 7th-8th grades
	Between groups	68.362	572	.488			
	Total	74.785	575				

Analyses show that there is a significant difference in the dimensions of mathematics [$F(3-572)= 5.631$, $p<.05$] and 21st-century skills [$F(3-572)= 4.385$, $p<.05$]. To determine differences among groups, the Bonferonni test was conducted. According to this test, the differences were between sixth grade ($\bar{x}=3.63$) and seventh grades ($\bar{x}=2.83$) and seventh grade ($\bar{x}=2.83$) and eight grade students ($\bar{x}=3.54$). In the dimension of 21st-century skills, these differences were between sixth grade($\bar{x}=4.19$) and seventh-grade students ($\bar{x}=3.74$) and seventh grade ($\bar{x}=3.74$) and eight grade students ($\bar{x}=4.25$).

The Relationship between Reflective Thinking Skill on Problem Solving and STEM Attitudes

To determine whether there is a relationship between students' STEM attitudes and their reflective thinking skills on problem-solving, a correlation analysis was run. The results are given in Table 6.

Table 6. Correlation Analysis of STEM Attitudes and Reflective Thinking Skills on Problem Solving

		Questioning	Evaluation	Reasoning
STEM Attitude	Pearson Correlation	.73	.69	.68

When Table 6 is analyzed, it can be noted that there is a linear, positive, and strong relationship between students’ STEM attitudes and their reflective thinking skills on problem-solving.

Regression Analysis

In the study, to determine whether students’ reflective thinking skills on problem-solving is a predictor for their STEM attitudes, a simple linear regression analysis was conducted. The results are given in Table 7.

Table 7. Regression Analysis on STEM Attitudes and the Reflective Thinking Skill on Problem Solving

Predictor Variable	R	R2	Estimated Standard Error	Corrected R2	B	F	β	p
STEM Attitude	.735	.540	.480	.539	.840	425.231	.735	.000

As can be seen from Table 7, it can be concluded that there is a significant relationship between attitudes toward STEM and reflective thinking skills on problem-solving scores. According to this finding, reflective thinking skill on problem-solving scores is a significant predictor of STEM attitude (R = .735, R² = .540, p<.05). The students’ reflective thinking skills in problem-solving explain 54% of their STEM attitudes. According to the results of the simple linear regression analysis, the regression equation is as follows:

STEM Attitude Score = (.840 × Reflective Thinking Skill on Problem Solving Score) + .650.

Results and Discussion

In the study, the relationship between middle-school students’ STEM attitudes and their reflective thinking skills on problem-solving was examined. In light of the obtained findings, the following results were reported. First, it was revealed that the students’ reflective thinking skills on problem-solving

show differences in terms of gender. In the questioning and reasoning dimensions, a significant difference was reported in favor of female students. According to grade levels, a difference was found in the questioning and evaluation dimensions. It was also found that female students were better compared to males in explaining a given situation presented to them. Although a significant difference was not found in the evaluation dimension, the average scores of females were higher compared to males. In light of these findings, it can be concluded that female students' reflective thinking skills on problem-solving were higher compared to males. When an analysis was conducted on grade levels, a significant decrease was found in students' average scores in questioning and devaluation dimensions as their grade level increase.

Besides, it was found that lower grade students had higher reflective thinking skills in terms of thinking about a problem. This result is similar to the findings of previous research. For example, Morrison (2006) reported that students' problem-solving skills had developed they faced problems developed in STEM education. Acar, Tertemiz, and Taşdemir (2018), in a study conducted on fourth-grade primary school students, they found that STEM education had a significant effect on developing students' problem-solving skills. In light of findings from previous research and our current study, it can be concluded that, as students' grade level increases, their focus on general exams may have led to the development of their problem-solving skills. Thus, when considering the dimensions of reflective thinking skills toward problem-solving, it can be noted that the process is more at the forefront than the result.

The results also revealed a significant difference in students' STEM attitudes in terms of gender. This difference in engineering and technology dimensions was in favor of male students. In the analysis related to the grade level variable, significant differences were found in mathematics and 21st-century skills. When the students' STEM attitude scores were analyzed, although a significant difference was not found except for the engineering and technology dimensions, female students' attitudes were higher than males. In addition to this finding, sixth and eighth-grade students' attitudes were higher in mathematics and 21st-century skills dimensions. When the students' scores in science and engineering and technology dimensions were analyzed, it was found that 5th and 8th-grade students had had higher attitudes. Besides students' 21st-century skill scores in all grade levels were much

higher than other dimensions. In a study by Güzey, Harwell, and Moore (2014), their findings revealed that students in STEM-focused schools had more positive attitudes toward STEM and STEM careers than students in non-STEM-focused schools. In this study, students' attitudes regarding 21st-century skills were found to be higher than the other three dimensions in the attitude scale. One possible reason for this result may stem from that 21st-century skills are perceived more generally and comprehensively than other dimensions in the scale.

Another result of this study is that students who have higher attitudes toward STEM pose high reflective thinking skills on problem-solving. In addition, as a result of the regression analysis, students' reflective thinking skills had a significant effect on their STEM attitude scores.

In light of the aforementioned results, we propose some implications for researchers and further studies. First, specific activities that can encourage students to develop reflective thinking skills may increase their attitudes towards STEM subjects. Hence, teachers and scholars should focus more on these activities that would help to develop their students' reflective thinking skills in their teaching. Second, the present study has focused on reflective thinking skills, problem-solving, and attitudes toward STEM education. Further studies should be conducted to examine the effect of other skills on students' attitudes toward STEM.

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