Sevgi, S., Macun, Y. & Işık, C. (2020). Investigating middle school students' metacognition and mathematical reasoning of problem-solving skills. *Bartın University Journal of Faculty of Education, 9*(3), 545-563

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buefad.bartin.edu.tr

Investigating Middle School Students' Metacognition and Mathematical Reasoning of Problem-Solving Skills

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Article Info

DOI: 10.14686/buefad.675770

Article History:
Received: 16.01.2020
Accepted: 21.09.2020
Published: 05.10.2020

Keywords:
Metacognition,
Problem-solving,
Middle school mathematics.

Article Type:
Research Article

Abstract

Described as being aware of and controlling one's own thinking processes and a benefit of consequences, metacognition is known to be related to both academic achievement and students' thinking. This study aimed to investigate the problem-solving and metacognition skills of middle school students with regard to gender, grade level, number of siblings, financial status of the family, and educational background of the parents. For this purpose, 280 middle school students were selected from a public middle school in Melikgazi, Kayseri by using convenience sampling method. As a result of the analysis based on the four factors of metacognition scale and problem-solving inventory, male participants were better than female not only at solving problems requiring mathematical reasoning but also at monitoring what they did, what they would do and, most importantly, their own thinking processes. Surprisingly, 5th grade students had higher predictive abilities than 8th graders. Although predictive skills were higher, 5th and 6th graders had lower level of problem-solving skills than upper-class levels. Also, students whose mothers have undergraduate and graduate degrees were better at solving problems than those whose mothers had never attended a school or who graduated from elementary school.

Ortaokul Öğrencilerinin Üstbiliş ve Problem Çözmede Kullandıkları Matematiksel Muhakeme Becerilerinin İncelenmesi

Makale Bilgisi

DOI: 10.14686/buefad.675770

Makale Geçmişi:
Geliş: 16.01.2020
Kabul: 21.09.2020
Yayın: 05.10.2020

Anahtar Kelimeler:
Üstbiliş,
Problem çözme,
Ortaokul öğrencileri.

Makale Türü:
Araştırma Makalesi

Öz

Kişinin kendi düşünme süreçlerinin farkında olması ve bu süreçleri kontrol etmesi olarak tanımlanan üstbilişin hem düşünce hem de akademik başarı ile ilişkili olduğu bilinmektedir. Bu çalışmada ortaokul öğrencilerinin cinsiyet, sınıf düzeyi, kardeş sayısı, ailenin mali durumu ve ebeveynlerin eğitim durumuna göre problem çözme ve üstbiliş becerilerinin incelenmesi amaçlanmıştır. Bu amaçla, Kayseri ili Melikgazi ilçesinde bulunan bir devlet ortaokulundan kolay örnekleme yöntemi ile 280 ortaokul öğrencisi seçilmiştir. Problem çözme envanteri ve üstbiliş ölçeğinin dört faktörüne dayanan analizler sonucunda, erkek öğrencilerin hem muhakeme gerektiren problemleri çözmede hem de kendi düşünme süreçlerini yönlendirmede daha iyi oldukları, 5. sınıf öğrencilerinin 8. sınıf öğrencilerine göre daha yüksek tahmin yeteneğine sahip oldukları, 5. ve 6. sınıf öğrencilerinin üst sınıflara kıyasla daha düşük problem çözme becerilerine sahip oldukları ve anneleri lisans ve/ya lisansüstü derecesine sahip olan öğrencilerin problem çözmede anneleri hiçbir okula gitmemiş veya ilkokul mezunu olanlardan daha iyi oldukları sonucuna ulaşılırken, kardeş sayısının iki ölçekten elde edilen puanlar üzerinde anlamlı bir etkisi bulunmamıştır.

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Introduction

For most middle school students, mathematics is seen as difficult to understand due to the fact that it involves complex mental processes. In order to make mathematics understandable, it is necessary to use cognitive, metacognitive, and self-regulation skills to overcome these complex mental processes (Kaplan & Duran, 2016). Metacognition is a concept linked to cognition and expressed as a benefit of consciousness. For a better understanding of metacognition, it is important to first know what cognition is (Erez & Peled, 2001). According to Fidan (1996), cognition is all the mental processes that the human mind does to understand the world and the events around it. Metacognition, on the other hand, means that one is aware of and can control his or her own thinking processes (Flavell, 1976, 1979) and involves an individual's ability to predict, plan, monitor and evaluate his or her mental activities (Brown, 1980; Swanson, 1990). Although cognition and metacognition are related, they are actually different. The function of cognition is to provide cognitive interventions to solve problems while the function of metacognition is to regulate or manage an individual's cognitive performance in problem solving (Akturk & Sahin, 2011). Metacognitive skill is a more advanced thinking ability that enables people to become successful in all areas of life and aids effective control of cognitive processes during learning. This awareness about the individuals' own thinking process has a significant relation with other mental activities and academic achievements (Deseote & Roeyers, 2002; Eggen & Kauchak, 2001; Victor, 2004).

According to Flavell (1976), individuals with metacognitive skills use metacognitive knowledge, a deeper point of view and knowledge of one's own cognitive abilities and outcomes, consisting of three components namely person variable, task variable, and strategy variable. Studies on how individuals' metacognitive skills and knowledge change in terms of these variables generally focus on four metacognitive skills which are orientation or prediction, planning, monitoring, and evaluation (Deseote, 2001; Lucangeli & Cornoldi, 1997; Schoenfeld, 1992). First of all, orientation skill requires thinking slowly and determining the appropriate learning environment, time, and characteristics. With this skill, children estimate the difficulty level of a task or mission and organize what needs to be done in their mind to accomplish (Winne, 1997). Secondly, planning skill enables children to think in advance of how, when, and why to take action to complete a particular task successfully. Thirdly, monitoring skill is connected self-regulating controls of cognitive strategies used with simultaneous verbal narratives during actual performance, to identify problems and change plans (Tobias & Everson, 1996). Lastly, evaluation skill is defined as reflective verbal statements in which children look at what strategies were used after the activity ended and whether they took it to the anticipated outcomes (Deseote, 2001).

The use of metacognition in mathematics is considered crucial by some researchers especially in problem solving (Borkowski, 1992; De Clercq, Desoete, & Roeyers, 2000; Schoenfeld, 1992). Not only in the first stage of mathematical problem-solving, students are involved in metacognition, while creating an appropriate representation of the problem, but also in the final stage of interpretation and checking the result of calculations (Verschaffel, 1999). Schoenfeld (1987) stated that the metacognition levels of the students can be improved with problem-solving in the best way. For this purpose, he organized courses that included problem-solving strategies and proposed a model for effective problem solving that emphasized the students' monitoring, organizing and evaluating their own studies. While there is such an important link between problem-solving and metacognition, it has been crucial to examine the relationships between these skills of middle school students and other factors affect middle school students' metacognition levels.

Method

This study is aimed to investigate the factors affecting middle school students' metacognitions and problem-solving skills requiring mathematical reasoning. The strategies used by middle grade students in problem solving process were also examined. For this purpose, the study aimed to answer the following research problem: "What are the factors affecting middle school students' metacognitions and problem-solving skills requiring mathematical reasoning?"

Research Design

In this study, quantitative techniques were used to realize the analyse of the research problem. Descriptive research methods were used to determine the metacognitive skill levels and the factors affecting these skills (Creswell, 2009). The descriptive method is a research approach based on collecting data over a certain period of time, aiming to describe a situation that exists in the past or present and compare the relationships between variables (Fraenkel & Wallen, 2010).

Population and Sample

The sample of the study which was selected using the convenience sampling method consisted of 135 male and 145 female students studying in a public middle school in Melikgazi, Kayseri, Turkey in 2019-2020 academic year. Convenience sampling, which is a frequently used method in educational studies, is appropriate compared to other methods and is commonly used when the researcher is not able to use other sampling methods (Creswell & Plano Clark, 2017). In addition, studying an acquainted sample can give practicality and speed to the study.

Table 1. Sample of the Study by Grade Level and Gender

Grade Level	f	%	Gender	f	%
5	57	20.4	Girl	29	50.9
			Boy	28	49.1
6	59	21.1	Girl	38	64.4
			Boy	21	35.6
7	72	25.7	Girl	32	44.4
			Boy	40	55.6
8	92	32.9	Girl	46	50
			Boy	46	50

Due to the structure of the sample, the number of 8^{th} grade students is slightly higher than the other grade levels. This would be beneficial in achieving better results for research rather than a disadvantage. The distribution percentage between grade levels are nearly close to each other. In Turkey, eighth graders are not volunteer to be participant in research projects so this could be advantage.

Data Collection Tools

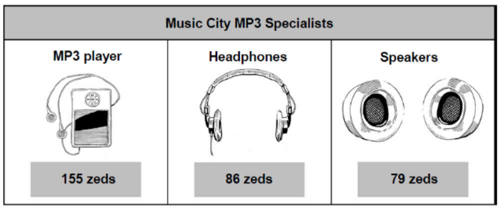
In the study, to determine metacognitive skills of middle school students, a personal information form was used together with the Metacognitive Scale (MS) developed by Yildiz, Akpinar, Tatar, and Ergin (2009), which consisted of 30 items and whose reliability coefficient was calculated as 0.96 by the researchers. There were 30 positive items in the Likert type in total. The options are “None (1), Sometimes (2), Frequently (3)” and “Always (4)”. There are two factors of the scale which are knowledge of cognition and knowledge of regulation according to the factor analysis. The knowledge of cognition has three components as declarative knowledge, procedural knowledge, and conditional knowledge while the knowledge of regulation has five components namely planning, self-control, cognitive strategies, self-evaluation, and self-monitoring. In parallel to the study of Yildiz et al. (2009), it was seen that the items in the metacognition scale were loaded under four factors namely prediction (3, 6, 15, 20, 21, 22, 23, 25, 28, 29, 30), planning (9, 13, 17, 19, 27), monitoring (4, 5, 11, 12, 16, 24, 26), and evaluation (1, 2, 7, 8, 10, 14, 18) as a result of the explanatory factor analysis (EFA) conducted with 50 iterations of the data collected from 280 middle school students. Costello and Osborne (2005) states that the final decision on the number of factors belongs to the researcher and the number of factors is determined not only by the data but also by the theoretical expectations. So, it was decided that the items of metacognition scale were loaded in four factors for the purpose of the research. According to the Tabachnick and Fidell (2015), there must be at least 0.10 differences between the highest values a substance is loaded in successive factors as a result of EFA. When the rotated components matrix is examined in Table 2, it is seen that this difference is greater than 0.10 in all substances. The sphericity test, which tested the general significance of all correlations within the Bartlett correlation matrix, was significant [$\chi2(435) = 2406.38$, $p = .000 < .001$] and showed that it was appropriate to use the factor analysis in this group of data. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy showed that the relationships between variables were extremely high (KMO = .914), so it was acceptable to continue the analysis (Field, 2005).

Table 2. Rotated Component Matrix Results

Items	**Factors**			
	Prediction	**Evaluation**	**Planning**	**Monitoring**
28	.577			
29	.619			
23	.572			
22	.550			
3	.549			
15	.485			
30	.470			
25	.461			
21	.420			
6	.338			
20	.300			
1		.681		
2		.650		
10		.563		
18		.518		
7		.472		
14		.457		
8		.448		
9			.670	
13			.561	
17			.508	
19			.435	
27			.390	
16				.587
24				.574
11				.492
26				.429
4				.427
12				.371
5				.359

In addition, in order to examine the strategies used by students to solve problems that require mathematical reasoning, the program inventory consisting of five items was selected by taking expert opinion from the Program for International Student Assessment (PISA) questions applied in 2012 was used in Figure 1 (OECD, 2012). The personal information form used with metacognition scale and problem-solving inventory consisted of the information about genders, grade levels, parents' educational backgrounds, number of siblings, and family financial status.

MP3 PLAYERS



Translation Note: The use of zeds is important to the unit, so please do not adapt "zed" into an existing currency.

Olivia added the prices for the MP3 player, the headphones and the speakers on her calculator.

The answer she got was 248.

Olivia's answer is incorrect. She made one of the following errors. Which error did she make?

A. She added one of the prices in twice.
B. She forgot to include one of the three prices.
C. She left off the last digit in one of the prices.
D. She subtracted one of the prices instead of adding it.

(Item 1)

WHICH CAR?

Chris has just received her car driving licence and wants to buy her first car.

This table below shows the details of four cars she finds at a local car dealer.

Model:	**Alpha**	**Bolte**	**Castel**	**Dezal**
Year	2003	2000	2001	1999
Advertised price (zeds)	4800	4450	4250	3990
Distance travelled (kilometres)	105 000	115 000	128 000	109 000
Engine capacity (litres)	1.79	1.796	1.82	1.783

Translation Note: Change the car's names to other more suitable fictional names if necessary – but keep the other numbers and values the same.

Translation Note: The use of zeds is important to the Unit, so please do not adapt "zed" into an existing currency.

Translation Note: Change to , instead of . for decimal points, if that is your standard usage, in EACH occurrence.

Chris wants a car that meets **all** of these conditions:

- The distance travelled is **not** higher than 120 000 kilometres.
- It was made in the year 2000 or a later year.
- The advertised price is **not** higher than 4500 zeds.

Which car meets Chris's conditions?

A. Alpha
B. Bolte
C. Castel
D. Dezal

(Item 2)

Which car's engine capacity is the smallest?

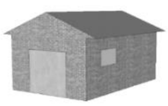
A. Alpha
B. Bolte
C. Castel
D. Dezal

(Item 3)

GARAGE

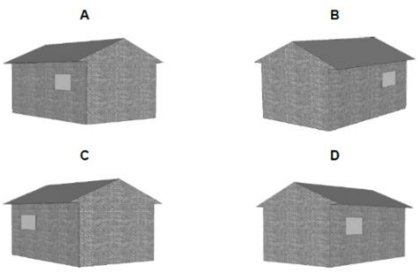
A garage manufacturer's "basic" range includes models with just one window and one door.

George chooses the following model from the "basic" range. The position of the window and the door are shown here.



The illustrations below show different "basic" models as viewed from the back. Only one of these illustrations matches the model above chosen by George.

Which model did George choose? Circle A, B, C or D.



(Item 4)

CLIMBING MOUNT FUJI

Mount Fuji is a famous dormant volcano in Japan.

Translation Note: Please do not change the names of locations or people in this unit: retain "Mount Fuji", "Gotemba" and "Toshi".

Mount Fuji is only open to the public for climbing from 1 July to 27 August each year. About 200 000 people climb Mount Fuji during this time.

On average, about how many people climb Mount Fuji each day?

A. 340
B. 710
C. 3400
D. 7100
E. 7400

(Item 5)

Figure 1. *Items of the Problem-Solving Inventory*

As shown in Figure 1, five items of the Problem-Solving Inventory were selected according to the cognitive levels and grade levels of the students since they should be at a level that can be answered by students at each grade.

Table 3. Reliability Coefficients of the Scales

Scales	Cronbach's Alpha	Number of Items
Metacognition	.910	30
Prediction	.803	11
Evaluation	.780	7
Planning	.699	5
Monitoring	.676	7
Problem-Solving Inventory	.457	5

Table 3 shows that metacognition scale has a high reliability value whereas problem-solving inventory has a low reliability value due to the small number of questions. If both the number of questions was more than five and the sample of the study was big enough, this value of the scale would be expected to be higher. Similar to the whole Metacognition Scale, the reliability results of the four factors are in the appropriate range as shown in Table 3.

Data Collection

MS and Problem-Solving Inventory were applied at the beginning of the 2019-2020 academic year in order to examine the metacognition and problem-solving skills of a public middle school in Kayseri with 280 students at different grade levels. In addition, students were asked to fill out a personal information form to obtain their demographic information at the same time.

Data Analysis

It is important whether the data obtained in the analysis of quantitative data show normal distribution (Buyukozturk, Cakmak, Akgun, Karadeniz, & Demirel, 2013). Tabachnick and Fidell (2015) state that in multivariate analyses, it is one of the first actions to see whether continuous variables have a normal distribution. The normal distribution of variables gives better results in the analysis. Therefore, it was tested firstly whether the data obtained with the scales showed normal distribution. Kolmogorov-Smirnov test was applied as the sample size was more than 50. In the Kolmogorov-Smirnov test, it is assumed that the data is normally distributed when $p > 0.05$. In addition, some studies indicate that skewness and kurtosis values are considered to be excellent in the ± 1 range for most psychometric purposes, but that ± 2 are considered sufficient criteria for normality in most cases (George & Mallery, 2010; Gravetter & Wallnau, 2014).

Table 4. Normality Tests of Data by Gender

Scales	Gender	df	p	Skewness	Kurtosis
Metacognition	Both	280	.200	-.076	-.471
	Girls	145	.200	.052	-.900
	Boys	135	.195	-.212	.165
Problem-Solving Inventory	Both	280	.000	.276	-.579
	Girls	145	.000	.128	-.624
	Boys	135	.000	.260	-.781

As shown in Table 4, metacognition scale and the problem-solving inventory showed a normal distribution not only as a whole but also by gender.

Table 5. Normality Tests of Data by Grade Levels

Scales	Grade Levels	df	p	Skewness	Kurtosis
	5th Grade	57	.000	-.059	-.843

Problem-Solving Inventory	6^{th} Grade	59	.000	-.087	-.771
	7^{th} Grade	72	.000	.219	-.813
	8^{th} Grade	92	.000	.053	-.813
Metacognition	5^{th} Grade	57	.020	.081	-.594
	6^{th} Grade	59	.191	-.364	-.222
	7^{th} Grade	72	.200	-.215	-.329
	8^{th} Grade	92	.200	.168	-.506

Similar to the normality test results by gender, metacognition scale and the problem-solving inventory showed a normal distribution by grade levels as given in Table 5. In addition to looking at the normality values of both scales as a whole, it would be useful to look at the normality results of the four factors that emerged as a result of factor analysis applied to the metacognition scale by the independent variables as gender, grade level, financial status of the family, number of siblings, and educational backgrounds of the parents to apply parametric tests.

Table 6. Normality Tests of the Factors of Metacognition Scale by Gender

Factors	Gender	df	p	Skewness	Kurtosis
Prediction	Female	145	.078	-.102	-.625
	Male	135	.023	-.170	-.345
Evaluation	Female	145	.000	-.157	-.921
	Male	135	.000	-.608	.220
Planning	Female	145	.003	.124	-.765
	Male	135	.000	-.286	-.345
Monitoring	Female	145	.001	-.556	-.066
	Male	135	.001	-.643	.367

As shown in Table 6, skewness and kurtosis values of four factors according to gender are within the limits accepted for normality.

Table 7. Normality Tests of the Factors of Metacognition Scale by Grade Levels

Metacognitive Factors	Grade Levels	df	p	Skewness	Kurtosis
Prediction	5^{th} Grade	57	.076	-.177	-.654
	6^{th} Grade	59	.071	-.428	-.114
	7^{th} Grade	72	.200	-.006	-.311
	8^{th} Grade	92	.200	.054	-.569
Evaluation	5^{th} Grade	57	.042	-.400	-.801
	6^{th} Grade	59	.011	-.255	-.843
	7^{th} Grade	72	.020	-.631	.047
	8^{th} Grade	92	.041	-.257	-.098
Planning	5^{th} Grade	57	.000	.252	-1.039
	6^{th} Grade	59	.200	-.223	-.482
	7^{th} Grade	72	.200	-.198	-.525
	8^{th} Grade	92	.133	.017	-.684
Monitoring	5^{th} Grade	57	.067	-.423	-.283
	6^{th} Grade	59	.008	-.626	-.148
	7^{th} Grade	72	.001	-.788	.144
	8^{th} Grade	92	.048	-.693	1.169

According to the normality test of the factors by grade levels, it is seen in Table 7 that all data are in the acceptable normal distribution range.

Table 8. Normality Tests of the Factors of Metacognition Scale by Parents' Educational Backgrounds

Metacognitive Factors	Educational Background	Parents	df	p	Skewness	Kurtosis
Prediction	Non or Elementary School	Mother	105	.200	-.172	-.041
		Father	64	.200	-.390	-.347
	Middle or High School	Mother	141	.031	-.083	-.700
		Father	153	.063	-.006	-.645
	Undergraduate or Graduate	Mother	34	.200	-.293	-.572
		Father	63	.200	-.140	-.341
Evaluation	Non or Elementary School	Mother	105	.005	-.443	-.186
		Father	64	.056	-.316	-.449
	Middle or High School	Mother	141	.031	-.315	-.378
		Father	153	.000	-.454	-.295
	Undergraduate or Graduate	Mother	34	.138	-.369	-1.072
		Father	63	.200	-.113	-.691
Planning	Non or Elementary School	Mother	105	.020	.050	-.764
		Father	64	.014	.077	-.698
	Middle or High School	Mother	141	.007	-.148	-.422
		Father	153	.002	-.127	-.596
	Undergraduate or Graduate	Mother	34	.200	-.203	-.992
		Father	63	.044	-.101	-.576
Monitoring	Non or Elementary School	Mother	105	.018	-.649	.680
		Father	64	.030	-.389	-.763
	Middle or High School	Mother	141	.000	-.664	.081
		Father	153	.000	-.875	1.033
	Undergraduate or Graduate	Mother	34	.136	-.657	-.277
		Father	63	.038	-.421	-.538

The normality values of the four factors of the metacognition scale according to the educational status of the mother and father are observed to be within the desired skewness and kurtosis ranges for normality in Table 8.

Table 9. Normality Tests of the Factors of Problem-Solving Inventory by Parents' Educational Backgrounds

Scale	Educational Background	Parents	df	p	Skewness	Kurtosis
Problem-Solving Inventory	Non or Elementary School	Mother	105	.000	.495	-.076
		Father	64	.000	.249	-.579
	Middle School or High School	Mother	141	.000	.180	-.733
		Father	153	.000	.275	-.575
	Undergraduate or Graduate	Mother	34	.036	-.058	-.563
		Father	63	.001	.163	-.759

It is seen in Table 9 that the problem-solving inventory shows a normal distribution by the educational backgrounds of the parents, similar to the results obtained from the normality test of the metacognition scale considering the skewness and kurtosis values in the appropriate range.

Table 10. Normality Tests of the Factors of Metacognition Scale by Number of Siblings

Metacognitive Factors	Number of Siblings	df	p	Skewness	Kurtosis
Prediction	1 or 2 siblings	68	.183	.215	-.560
	3 siblings	120	.048	-.264	-.469
	More than 3 siblings	92	.091	-.201	-.315
Evaluation	1 or 2 siblings	68	.200	-.058	-.504
	3 siblings	120	.005	-.385	-.357
	More than 3 siblings	92	.002	-.529	-.298
Planning	1 or 2 siblings	68	.177	-.114	-.607
	3 siblings	120	.005	.029	-.773
	More than 3 siblings	92	.047	-.082	-.674
Monitoring	1 or 2 siblings	68	.050	-1.007	1.684
	3 siblings	120	.001	-.566	-.137
	More than 3 siblings	92	.051	-.446	-.341

According to the number of siblings of the students, the data obtained from the metacognition scale shows normal distribution as shown in Table 10 since either the significance values are greater than .05 or the skewness and kurtosis values are between -1 and +1.

Table 11. Normality Tests of the Factors of Problem-Solving Inventory by Number of Siblings

Scale	Number of Siblings	df	p	Skewness	Kurtosis
Problem-Solving Inventory	1 or 2 siblings	68	.000	.664	-.227
	3 siblings	120	.000	.173	-.669
	More than 3 siblings	92	.000	.108	-.645

Similar to the results of metacognition scale, problem-solving inventory by number of siblings has a normal distribution with respect to the skewness and kurtosis values as shown in Table 11.

Table 12. Normality Tests of the Factors of Metacognition Scale by Financial Status of the Family

Metacognitive Factors	Financial Status of the Family	df	p	Skewness	Kurtosis
Prediction	Low	12	.200	.561	-1.428
	Medium	120	.003	-.337	-.308
	High	148	.026	.015	-.608
Evaluation	Low	12	.200	.080	-1.400
	Medium	120	.001	-.601	.070
	High	148	.005	-.227	-.740
Planning	Low	12	.200	.614	-.153
	Medium	120	.006	-.044	-.611
	High	148	.005	-.111	-.694
Monitoring	Low	12	.200	-.580	-.699
	Medium	120	.002	-.828	.758
	High	148	.000	-.375	-.607

Parallel to the other variables, it is seen that the data obtained from the metacognition scale shows a normal distribution according to the financial situation of the students' families in Table 12 with respect to either the significance values or the skewness and kurtosis values.

Table 13. Normality Tests of the Factors of Problem-Solving Inventory by Financial Status of the Family

Scale	Financial Status of the Family	df	p	Skewness	Kurtosis
Problem Solving Inventory	Low	12	.000	.664	-.227
	Medium	120	.000	.173	-.669
	High	148	.000	.108	-.645

Finally, whether the problem-solving inventory is distributed normally according to the family financial situation, skewness and kurtosis values are found to be within the desired ranges in Table 13. As a result of the normality test of the metacognition scale and problem-solving inventory by all independent variables, all the data appeared to meet the normality requirements. Therefore, according to Tabachnick and Fidell (2015), parametric tests can be used. Hence, metacognition scale and problem-solving inventory were analyzed with descriptive statistics, independent samples t-test, ANOVA, and Pearson Correlation by using IBM SPSS 25.0.

Findings

In this section, the total scores of the middle school students from metacognition scale and problem-solving inventory were analyzed in terms of gender, grade level, parents' educational status, number of siblings, and family financial status. Also, the relation between the total scores of metacognition scale and problem-solving inventory were inspected.

Gender Differences at Metacognition Scale and Problem-Solving Inventory

The total scores of the middle school students from metacognition scale and problem-solving inventory were analyzed in terms of gender with independent samples t test. Descriptive statistics and t test results were given at Table 14.

Table 14. Mean Scores of the Middle School Students with respect to the Gender

Scale		Gender	n	$\bar{X}$	SD	min	max	t	p
Problem-Solving Inventory		Male	145	1.88	1.181	0	5	-2.622	.009*
		Female	135	2.29	1.392	0	5		
Metacognition		Male	145	91.10	13.971	62	120	-1.312	.190
		Female	135	93.26	13.474	57	120		
	Prediction	Male	145	32.48	5.642	19	44	-.844	.399
		Female	135	33.06	5.787	18	44		
	Evaluation	Male	145	21.49	4.055	12	28	-.138	.890
		Female	135	21.56	3.903	9	28		
	Planning	Male	145	14.12	3.142	8	20	-1.600	.111
		Female	135	14.72	3.066	6	20		
	Monitoring	Male	145	23.01	3.497	12	28	-2.396	.017*
		Female	135	23.93	2.911	14	28		

* p < .05

As shown in the Table 14, as a result of independent samples t-test there are statistically significant mean differences between problem-solving inventory scores of female ($\bar{X}$=1.88) and male ($\bar{X}$=2.29) [$t_{(278)}$ = -2.622, p=.009<.000] and monitoring factor scores of metacognition scale between female ($\bar{X}$=3.497) and male ($\bar{X}$=2.911) [$t_{(278)}$ = -2.396, p=.017<.000]. Result shows that there are no significant mean differences between the scores of female and male of not only though the whole scale but also in the factors of the prediction, evaluation, and planning.

Grade Level Differences at Metacognition Scale and Problem-Solving Inventory

The total scores of the middle school students from metacognition scale including the factors and problem-solving inventory were analyzed in terms of grade level with ANOVA. Before applying the ANOVA test, it is necessary to show the homogeneity of the variances which is an important requirement of this test.

Table 15. Test of Homogeneity of Variances Results by Grade Levels

Scale		Levene Statistic	df (between groups)	df (within groups)	p
Problem-Solving Inventory		5.003	3	276	.002
Metacognition		.166	3	276	.919
	Prediction	.477	3	276	.698
	Evaluation	1.502	3	276	.214
	Planning	.428	3	276	.733
	Monitoring	2.014	3	276	.112

According to the test of homogeneity of variances, it is seen in Table 15 that metacognition scale provides homogeneity of variances both as a whole and sub-factors separately whereas problem-solving inventory does not. In cases where the assumption of homogeneity of variances is not provided in ANOVA, the Welch test, which does not require this assumption and has a high statistical power, can be performed (Field, 2005).

Table 16. Welch Test of Problem-Solving Inventory for Homogeneity of Variances

Scale	Statistic	df_1	df_2	p
Problem-Solving Inventory	12.260	3	148.892	.000

According to Welch test in Table 16, it is seen that problem-solving inventory does not provide homogeneity of variances (p=.000). This means that if there is a significant difference between the means of problem-solving inventory by grade level, then the tests to be performed in case of the lack of homogeneity of variances from post hoc tests are applied.

Table 17. Metacognition Scale and Problem-Solving Inventory by the Grade Levels (ANOVA)

Scales		Sum of Squares	df	Mean Square	F	p
Problem-Solving Inventory	Between Groups	45.181	3	15.060	9.733	.000*
	Within Groups	427.090	276	1.547		
Metacognition	Between Groups	673.336	3	224.445	1.189	.314
	Within Groups	52086.949	276	188.721		
Prediction	Between Groups	285.509	3	95.170	2.982	.032*
	Within Groups	8809.459	276	31.918		
Evaluation	Between Groups	32.753	3	10.918	.688	.560
	Within Groups	4377.118	276	15.859		
Planning	Between Groups	23.002	3	7.667	.789	.501
	Within Groups	2682.766	276	9.720		
Monitoring	Between Groups	11.343	3	3.781	.354	.786
	Within Groups	2943.957	276	10.667		

* $p < .05$

In Table 17, it was given that there were significant mean differences between the scores of the middle school students by grade levels in the Problem-Solving Inventory [$F(3, 276) = 9.733$, $p = .000 < .05$] and prediction factor of the Metacognition Scale [$F(3, 276) = 2.982$, $p = .032 < .05$]. On the other hand, there was no significant mean difference between the metacognition scale and the other factors except the prediction factor and the whole metacognition scale in terms of grade levels.

To find out the source of this significant mean difference in the prediction factor of Metacognition Scale and Problem-Solving Inventory, Tukey HSD and Tamhane tests from Post Hoc tests were applied.

Table 18. Tukey HSD Results of Metacognition Scale by Grade Levels

Scale	Grade Levels		M.D.	S.E.	p
Metacognition	5th Grade	6th Grade	-.074	2.551	1.000
		7th Grade	1.988	2.436	.847
		8th Grade	3.557	2.316	.417
	6th Grade	7th Grade	2.062	2.412	.828
		8th Grade	3.631	2.291	.389
	7th Grade	8th Grade	1.569	2.162	.887
Prediction	5th Grade	6th Grade	.289	1.049	.993
		7th Grade	1.577	1.002	.395
		8th Grade	2.459*	.952	.050
	6th Grade	7th Grade	1.287	.992	.565
		8th Grade	2.170	.942	.100
	7th Grade	8th Grade	.882	.889	.754
Evaluation	5th Grade	6th Grade	.580	.740	.862
		7th Grade	.564	.706	.855
		8th Grade	.964	.671	.478
	6th Grade	7th Grade	-.016	.699	1.000
		8th Grade	.384	.664	.939
	7th Grade	8th Grade	.400	.627	.919
Planning	5th Grade	6th Grade	-.321	.579	.945
		7th Grade	.124	.553	.996
		8th Grade	.461	.526	.817
	6th Grade	7th Grade	.445	.547	.849
		8th Grade	.782	.520	.436
	7th Grade	8th Grade	.338	.491	.902
Monitoring	5th Grade	6th Grade	-.622	.607	.734
		7th Grade	-.276	.579	.964
		8th Grade	-.327	.551	.934
	6th Grade	7th Grade	.346	.574	.931
		8th Grade	.295	.545	.949
	7th Grade	8th Grade	-.051	.514	1.000

*p < .05

As a result of Tukey HSD test, it was seen in the Table 18 that only the mean of prediction factor of Metacognition Scale made a significant mean difference between 5th grade middle school students ($\bar{X}$=34.04) and 8th grade middle school students ($\bar{X}$=31.58) in favor of 5th graders.

Table 19. Tamhane Results of Problem-Solving Inventory by Grade Levels

Scale	Grade Levels		M.D.	S.E.	p
Problem-Solving Inventory	5th Grade	6th Grade	-.529	.231	.103
		7th Grade	-.777*	.221	.003*
		8th Grade	-1.107*	.210	.000**
	6th Grade	7th Grade	-.248	.218	.667
		8th Grade	-.579*	.207	.029*
	7th Grade	8th Grade	-.330	.196	.332

*p<.05; **p<.01

According to the results obtained from the Tamhane test, in Table 19, Problem-Solving Inventory by the grade levels had significant mean differences between 5th ($\bar{X}$=1.40) and 7th ($\bar{X}$=2.18) graders, between 5th ($\bar{X}$=1.40) and 8th ($\bar{X}$=2.51) graders, and between 6th ($\bar{X}$=1.93) and 8th ($\bar{X}$=2.51) graders.

Parents' Educational Backgrounds Differences at Metacognition Scale and Problem-Solving Inventory

In order to see whether the means of the scores of the two scales have significant differences with respect to parents' educational backgrounds, ANOVA is applied. For this purpose, data was recoded into three groups for each variable as "Non or Elementary School", "Middle School or High School", and "Undergraduate or Graduate". According to the ANOVA results, it is clearly seen after providing the homogeneity of variances that the educational backgrounds of the parents has a significant mean difference among the groups for both two scales.

Table 20. Test of Homogeneity of Variances Results by Parents' Educational Backgrounds

Variable	Scale	Levene Statistic	df (between groups)	df (within groups)	p
Mothers' Educational Status	Problem-Solving Inventory	.869	2	277	.421
	Metacognition	1.726	2	277	.180
	Prediction	.678	2	277	.508
	Evaluation	3.129	2	277	.045
	Planning	1.604	2	277	.203
	Monitoring	.290	2	277	.748
Fathers' Educational Status	Problem-Solving Inventory	1.607	2	277	.202
	Metacognition	.392	2	277	.676
	Prediction	.152	2	277	.859
	Evaluation	1.161	2	277	.315
	Planning	.053	2	277	.948
	Monitoring	.766	2	277	.466

According to the test of homogeneity of variances by educational backgrounds of parents, it is seen in Table 20 that both problem-solving inventory and metacognition scale provides homogeneity of variances except "evaluation" factor of Metacognition Scale by mothers' educational backgrounds.

Table 21. Welch Test of the Evaluation factor of Metacognition Scale by Mothers' Educational Backgrounds for Homogeneity of Variances

Factor	Statistic	df_1	df_2	p
Evaluation	.738	2	88.338	.481

According to Welch test in Table 21, it is seen that evaluation factor of the Metacognition Scale by mothers' educational backgrounds provides homogeneity of variances (p=.481). Thus, in case of significant mean differences, Tukey HSD test can be applied for all data.

Table 22. Metacognition and Problem-Solving Inventory Scales by the Educational Backgrounds of the Parents (ANOVA)

Variable	Scale			Sum of Squares	df	Mean Square	F	p
Mothers' Educational Background	Problem-Solving Inventory		Between Groups	11.040	2	5.520	3.315	.038*
			Within Groups	461.231	277	1.665		
	Metacognition		Between Groups	186.293	2	93.146	.491	.613
			Within Groups	52573.993	277	189.798		
		Prediction	Between Groups	46.429	2	23.215	.711	.492
			Within Groups	9048.539	277	32.666		
		Evaluation	Between Groups	24.577	2	12.288	.776	.461
			Within Groups	4385.295	277	15.831		
		Planning	Between Groups	3.449	2	1.725	.177	.838
			Within Groups	2702.319	277	9.756		
		Monitoring	Between Groups	1.534	2	.767	.072	.931
			Within Groups	2953.766	277	10.663		
Fathers' Educational Background	Problem-Solving Inventory		Between Groups	5.212	2	2.606	1.546	.215
			Within Groups	467.059	277	1.686		
	Metacognition		Between Groups	168.517	2	84.259	.444	.642
			Within Groups	52591.768	277	189.862		
		Prediction	Between Groups	15.860	2	7.930	.242	.785
			Within Groups	9079.107	277	32.777		
		Evaluation	Between Groups	44.665	2	22.333	1.417	.244
			Within Groups	4365.206	277	15.759		
		Planning	Between Groups	16.963	2	8.481	.874	.419
			Within Groups	2688.805	277	9.707		
		Monitoring	Between Groups	.450	2	.225	.021	.979
			Within Groups	2954.850	277	10.667		

* $p < .05$

According to the ANOVA results in Table 22, there were significant mean differences between the scores of the middle school students by educational backgrounds of parents in the Problem-Solving Inventory whereas there was no significant mean difference in the metacognition scale both as a whole and factor by factor.

Table 23. Tukey HSD results of Problem-Solving Inventory by Mothers' Educational Status

Scale	Mothers' Educational Status		M.D.	S.E.	p
Problem-Solving Inventory	Non or Elementary School	Middle School or High School	-.187	.166	.498
		Undergraduate or Graduate	-.654*	.255	.029
	Middle School or High School	Undergraduate or Graduate	-.467	.247	.143

* $p < .05$

According to the results obtained from the Tukey HSD test in Table 23, Problem-Solving Inventory by the mothers' educational backgrounds had significant mean differences between "Non or Elementary School" ($\overline{X}$=1.90) and "Undergraduate or Graduate" ($\overline{X}$=2.56) in favor of "Undergraduate or Graduate".

Family Financial Status Differences at Metacognition and Problem-Solving Inventory

In order to examine whether there are significant mean differences of the scores of problem-solving inventory and metacognition scale ANOVA test was used. But first, the data of the middle school students about financial status of their families recoded into three groups as “low”, “medium”, and “high”. Then, homogeneity of variance was tested.

Table 24. Test of Homogeneity of Variances Results by Family Financial Status

Scale	Levene Statistic	df (between groups)	df (within groups)	p
Problem-Solving Inventory	1.532	2	277	.218
Metacognition	.776	2	277	.461
Prediction	1.299	2	277	.274
Evaluation	.210	2	277	.811
Planning	.406	2	277	.667
Monitoring	3.685	2	277	.026

In Table 24, it is seen that both problem-solving inventory and metacognition scale provides homogeneity of variances except the monitoring factor of metacognition scale. For this factor, Welch test is applied to get strong statistic power.

Table 25. Welch Test of the Monitoring factor of Metacognition Scale by Family Financial Status for Homogeneity of Variances

Factor	Statistic	df_1	df_2	p
Monitoring	.213	2	29.033	.809

As seen in the Welch test from Table 25, homogeneity of variance of monitoring factor of metacognition scale by family financial status is provided since p=.809>.000.

Table 26. Metacognition and Problem-Solving Inventory Scales by Family Financial Status (ANOVA)

Scale		Sum of Squares	df	Mean Square	F	p
Problem-Solving Inventory	Between Groups	1.908	2	.954	.562	.571
	Within Groups	470.363	277	1.698		
Metacognition	Between Groups	347.822	2	173.911	.919	.400
	Within Groups	52412.464	277	189.215		
Prediction	Between Groups	77.993	2	38.996	1.198	.303
	Within Groups	9016.975	277	32.552		
Evaluation	Between Groups	22.557	2	11.278	.712	.492
	Within Groups	4387.315	277	15.839		
Planning	Between Groups	15.212	2	7.606	.783	.458
	Within Groups	2690.556	277	9.713		
Monitoring	Between Groups	8.710	2	4.355	.409	.664
	Within Groups	2946.590	277	10.638		

According to the ANOVA results of the problem-solving inventory and metacognition scale by family financial status, there are no significant mean differences of the scores of middle school students as shown in Table 26.

Correlation between Metacognition Scale and Problem-Solving Inventory

The relation between the total scores of metacognition scale and problem-solving inventory were examined with Pearson correlation coefficient. Based on the analyze results of Pearson correlation, relationship between the means of metacognition scores and problem inventory scores is not remarkable [*r* (280) = .064, *p* = .288].

Table 27. Pearson Correlation Results of Metacognition Scale and Problem-Solving Inventory

Scales	Metacognition Scale	Prediction	Evaluation	Planning	Monitoring
Problem-Solving Inventory	.064	-.029	.027	.130*	.163**
Metacognition Scale		.902**	.869**	.841**	.776**
Prediction			.680**	.702**	.557**
Evaluation				.657**	.629**
Planning					.560**

*p<.05; **p<.01

Although there is no significant relationship between problem-solving inventory and metacognition scale as a whole, the relationships between problem-solving inventory and the two factors, monitoring [r (280) = .163, p = .006] and planning [r (280) = .130, p = .030], are significant as shown in Table 27.

Discussion and Conclusion

In this section, the findings from metacognition scale and problem-solving inventory which were analyzed with respect to gender, grade level, parents' educational backgrounds, family financial status, and number of siblings are discussed in order to investigate the factors affecting middle school students' metacognition and problem-solving skills requiring mathematical reasoning. First of all, the mean scores from the metacognition scale and problem-solving inventory of middle school students were analyzed by gender. The results show that the means of problem-solving inventory has a significant mean difference in favor of male. Also, as a result of examining the metacognition scale and its factors according to gender, it was seen that only the monitoring factor made a significant mean difference in favor of male in parallel with the result of previous studies (Lemieux Collin, & Watier, 2019; Peclak & Pecjak, 2002; Yildiz, Baltaci, &, Kuzu, 2018). At monitoring stage of metacognition, individuals follow their mental activities and processes in the learning process and think about what they should do to achieve better results (Garofalo & Lester, 1985). Secondly, problem-solving inventory and metacognition scale were analyzed according to grade levels and the results of these two scales were almost opposite. On behalf of metacognition scale, only the prediction factor of metacognition scale has a significant mean difference between 5th and 8th grade middle school students in favor of 5th graders (Sevgi & Caglikose, 2020). It means that as students' grade levels increase, there is a decrease in their predictive skills in metacognition. In other words, students who are just starting middle school level are better at metacognitive prediction than students who are about to graduate from middle school (Sevgi & Orman, 2020). In the problem-solving inventory, on the other hand, the mean of the 8th grade middle school students' total scores are significantly higher than the means of 5th and 6th graders' scores. Also, the mean of the 7th grade middle school students' total scores are significantly higher than the mean of 5th graders. This result is similar to Lutfiyya's (1998) study about determining the effects of the grade level and student's gender on the mathematical thinking of high school students in Nebraska. He found that the mean scores of the higher-grade level students from mathematical thinking instrument developed by himself of were significantly higher than lower graders excepting the mean difference between 11th and 12th grade high school students. Thirdly, the data from metacognition scale and problem-solving inventory have been analyzed with respect to parents' educational status. Results showed that father's and mother's educational levels do not make any significant mean differences in students' metacognition scores which were obtained from whole scale also in factors of metacognition as predicting, evaluation, monitoring and planning. On the contrary, mothers' educational backgrounds had significant mean differences in favor of "Undergraduate or Graduate" compared with "Non or Elementary School" (Sevgi & Caglikose, 2020). This means that mothers' educational status has a significant effect on students' problem solving and reasoning abilities. This situation may be influenced by the fact that students' relationships with their mothers are stronger than their fathers. Next, when the effects of the financial situation of the families on the problem-solving and metacognitive abilities of middle school students were examined, no significant mean difference was found between the scores obtained from both metacognition scale and problem-solving inventory. In other words, it was seen that the economic opportunities provided to children in families or the financial situation of the family did not cause significant differences in problem-solving, reasoning and metacognitive abilities. Finally, it would be beneficial to examine the relationship between the two scales as well as the variables affecting the mean scores of middle school students obtained from the problem-solving inventory and metacognition scale. As a result of the Pearson Correlation, there are statistically significant but weak relationship between the mean scores of problem-solving inventory and both monitoring and planning factors of metacognition scale. This means that students who have good skills in planning and monitoring are also good at solving the problems requiring advanced mathematical reasoning and vice versa.

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