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The Mediating Role of Metacognitive Strategies in the Relationship between Gender and Mathematical Reasoning Performance

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Abstract

The purpose of this study was to investigate the mediating effect of metacognitive strategies in the relationship between gender and mathematical reasoning skills. 350 eighth-grade students participated in the research. Data were obtained using the mathematical power scale and the metacognitive strategies scale. Reasoning and metacognitive strategies were compared based on gender by applying independent groups t-test. The mediating effect of metacognitive strategies was investigated using SPSS Process Macro model 4. The results showed that the mathematical reasoning skills of female students were higher than male students. In addition, female students used more metacognitive strategies in mathematics lessons. Metacognitive strategies partially mediated the gender difference in mathematical reasoning skills. By enabling male students to learn and use metacognitive strategies effectively, gender differences in mathematical reasoning skills can be reduced.

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INTRODUCTION

The importance of individual differences in education has been known for a long time. Today, education systems are considered successful to the extent that they are sensitive to differences between individuals. Individual differences have a significant impact on students' academic performance (Farsides & Woodfield, 2003; Humphreys & Revelle, 1984; Şanlı, 2020). Individual differences come to the fore, especially in acquiring mathematical skills (Adams, 2007; Agrillo et al., 2013; Dulaney et al., 2015). Gender is one of the individual differences that affect mathematical skills (Gallagher & Kaufman, 2005; Lindberg et al., 2008). Mathematical reasoning skills, spatial skills, and mathematical problem-solving skills of females and males may differ (Mills et al., 1993; Tzuriel & Egozi, 2010; Zhu, 2007). According to the results of a meta-analysis study, it was stated that the mathematics achievement of females in the eighth grade is higher than that of males (Li et al., 2018). It is crucial to determine the factors that may mediate the gender difference to reduce gender-based differences in mathematics achievement. This study examined the mediating role of metacognitive strategies in the relationship between gender and mathematical reasoning skills. The results may advance helpful information for suggestions to reduce gender differences in mathematical skills.

GENDER DIFFERENCES IN MATHEMATICAL REASONING

Mathematics is a branch of science that requires reasoning. Mathematical reasoning is the process of acquiring new knowledge with mathematical tools (symbols, definitions, relations, etc.) and ways of thinking (inductive, deductive, comparison, generalizing, etc.). According to the National Council of Teachers of Mathematics (2000), reasoning is a fundamental part of mathematics and is among the basic standards. Reasoning is a mathematical force that should be developed for all students. Indicators of mathematical reasoning ability are a) preparing arguments, b) predicting results, c) explaining models by relating them to facts, d) using mathematical induction, e) developing assumptions, f) inferring and checking assumptions, g) using patterns and relationships h) making logical conclusions (Sumarmo, 2006). The secondary school mathematics curriculum aims to equip students with these indicators (MoNE, 2013). There are individual differences in mathematical reasoning. It is essential to consider individual differences for effective teaching of reasoning skills.

There are studies in the literature indicating that mathematical reasoning differs by gender. In a study of grades 2-6, males performed better on a mathematical reasoning test than females. It has been stated that males outperform females in tasks that require the application of algebraic rules or algorithms and in tasks that require understanding mathematical concepts and number relations (Mills et al., 1993). Sumpter (2016) aimed to determine which types of mathematical reasoning are used more by male and female students. It has been found that male students tend to use algorithmic reasoning, and female students have a higher tendency to use familiar algorithmic reasoning methods. Triyadi (2013), on the other hand, revealed that females outperform males in mathematical communication, mathematical connection, mathematical reasoning, and mathematical solving. Rosdiana et al. (2019) examined the reasoning styles used by male and female students in understanding mathematical problems and checking the accuracy of results. It was found that the answers given by the male students at the stage of understanding the problem were more detailed than the answers of the female students. In checking the results' accuracy, male and female students used similar reasoning techniques. Subekti et al. (2021) noted that female students had a higher rate of making correct assumptions about the patterns. Male students' explanations of the patterns are more superficial. It has been observed that male students have a higher tendency to misunderstand the patterns and accordingly draw wrong conclusions. Studies indicated that reasoning skills, which are very important for success in mathematics, differ according to gender.

Some research conducted in Turkey compares general mathematical reasoning skills by gender (Erdem & Soylu, 2017; Kocaman, 2017; Pay, 2018), while some research compares mathematical reasoning skills related to probability, fraction, and ratio-proportion by gender (Karaduman, 2018;

Kayhan, 2005; Sarıbaş, 2019). Sarıbaş (2019) examined the probabilistic reasoning skill levels of the sixth, seventh, and eighth-grade mathematics students. In the “sample space” dimension of the reasoning, a result in favor of the girls emerged. It has been stated that female students have a higher level of probabilistic reasoning skills on “sample space.” Kocaman (2017) concluded that the logical thinking scores of eleventh-grade female students are better than male students. Kayhan (2005) emphasized that sixth and seventh-grade female students are more successful in choosing and using the right strategies in the reasoning process. Erdem and Soylu (2017) emphasized that mathematical reasoning improved as age increased in secondary and high school students (8th, 9th and 10th grade). In addition, male students performed better than female students in mathematical reasoning. Karaduman (2018) stated that female sixth, seventh, and eighth-grade students had higher proportional reasoning performances. Pay (2018), who worked with preschool students, reported that mathematical reasoning skills did not differ according to gender. Studies have shown that mathematical reasoning skills differ according to gender during middle and high school years. There is a need to investigate the reasons behind the observed gender difference in mathematical reasoning.

METACOGNITION AND ITS MEDIATING ROLE

Metacognition is the core of cognitive activities. Metacognition is thinking to think (Blakey & Spence, 1990) and means that the individual is aware of his cognitive processes and controls these processes (Jager et al., 2005). The concepts of cognition, self-control, and self-control are the most used concepts to explain metacognition (Flavell, 1979). Students with high self-control can control their minds and learning processes by effectively using cognitive strategies.

Knowledge and regulation are the two essential components of metacognition. Metacognitive knowledge includes information about the learner’s learning style, information about the factors that will affect their performance, learning strategies, and which strategies should be used and when (Kuhn & Dean, 2004). A student with high metacognitive knowledge knows what skills and level of knowledge they have in mathematics and what methods and techniques they should use in the problem-solving process. Metacognitive regulation consists of planning, monitoring, and evaluation activities (Schraw et al., 2006). Metacognitive regulation includes focusing on a task, making predictions, planning, reviewing the whole process, evaluating, and making corrections. Thanks to metacognitive regulation, individuals provide active control over their cognitive processes (Eilam & Aharon, 2003).

According to some researchers, metacognitive skills are general skills, not specific to a particular field. Due to this feature, it has been stated that metacognition can be used in different fields and transferred from one field to another (Frost et al., 2015; Mccurdy et al., 2013). It was found that the planning, monitoring, and evaluation components of metacognition can be successfully adapted to different tasks (Schraw et al., 1995). For example, metacognitive strategies are used effectively in the problem-solving process orientation, organization, execution, and verification stages. (Pugalee, 2010). Metacognition supports mathematical performance (Garofalo & Lester, 1985), and metacognitive strategies strengthen mathematical reasoning skills (Lestari, 2018). In this respect, it can be argued that students with low metacognitive strategies will have difficulties in mathematical reasoning.

Studies have shown that there is a relationship between metacognition and academic achievement. It has been stated that students with high metacognitive skills have high academic achievement, too. A low level of metacognitive skills weakens the possibility of having high academic achievement (Holton & Clarke, 2015; Kleitman & Gibson, 2011). Students with low metacognitive skills cannot correctly operate cognitive processes such as planning, evaluation, and monitoring learning processes. In this regard, even if these students have high intelligence and motivation, they are less likely to have high academic achievement (Kazuhiro & Tetsuya, 2018; Hong et al., 2020). Mathematical metacognition is a particular form of metacognition based on metacognition knowledge. Students with a high level of mathematical metacognition can evaluate, control and regulate cognitive processes in mathematics (Shen & Chen, 2014). Studies have shown that students’ mathematical metacognition levels positively affect their mathematics achievement (Fernie et al., 2018; Kahramanoğlu & Deniz, 2017; Xue et al., 2021). Having mathematical metacognitive skills can increase the likelihood of success in mathematics.

THE PRESENT STUDY

Many studies have been conducted in the literature examining gender differences in mathematical reasoning skills (Erdem & Soylu, 2017; Karaduman, 2018; Kayhan, 2005; Kocaman, 2017; Mills et al., 1993; Rosdiana et al., 2019; Sarıbaş, 2019; Sumpter, 2016; Triyadi, 2013). However, limited studies examine the variables that moderate the relationship between gender and mathematical reasoning skills (Kadarisma et al., 2019). There is no study in the literature concerning the mediating effect of metacognitive strategies on the relationship between gender and mathematical reasoning skills. The present research fills a gap in the literature by examining the mediating role of metacognition in the relationship between gender and mathematical reasoning. The research results are believed to help better understand the mechanisms behind the link between gender and mathematical reasoning. Secondary school years are critical for developing mathematical skills (Reynolds, 1991). Thanks to the suggestions provided, mathematics teaching can be more efficient for secondary school students. In Turkey, students take the exam held within the scope of the High School Entrance System (LGS) in the eighth grade to attend some high schools (MoNE, 2022). In the eighth grade, students study more intensively for lessons and exams. Students are more familiar with tests such as mathematical reasoning and problem-solving during this period, and eighth-grade students were included in the current study. In line with the purpose of the research, answers to the following research questions were sought;

1- Do mathematical reasoning skills and metacognitive strategies differ significantly by gender?

2- Do metacognitive strategies have a mediating role in the relationship between gender and mathematical reasoning skills?

METHOD

RESEARCH DESIGN

This research was carried out according to the correlational research design. A correlational study examines the relationships between two or more variables without intervention (Karasar, 2000). The obtained correlation coefficients provide evidence to predict some outcomes. For this purpose, the predictive relationships between gender, mathematical reasoning, and metacognition were investigated in the present study.

SAMPLING AND PARTICIPANTS

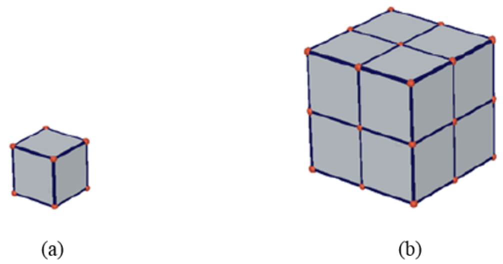
350 eighth-grade students selected by convenient sampling method participated in the study. 40.7% (n = 142) of the students were females, and 59.3% (n = 208) were males. The ages of the students were between 13 to 15. The participants were randomly selected from different state schools located in a city center with different socioeconomic backgrounds. Before data collection, approval from the research ethics committee was received, and all participants gave informed consent.

MEASURING TOOLS

Mathematical Power Scale: It was developed by Yeşildere (2006) for eighth-grade students. In the development of the scale, the basic structure for the mathematical power determined by the NAEP (National Assessment of Educational Progress) was taken into account. There are ten open-ended questions on the scale (Appendix 1). A question in the scale is shown in Figure 1.

Figure 1. *Open-Ended Mathematical Reasoning Question*

Zeynep is trying to get bigger cubes by combining the small cubes in her hand. First, she puts one small cube (a). She then places two small cubes side by side and places the other small cubes so that the object is a larger cube (b).



Zeynep wants to calculate how many cubes are needed for the whole larger cube that she started by putting five small cubes side by side, without adding the cubes one by one. How can Zeynep do this? Please explain with details.

The application time of the test is approximately 40 minutes. The responses given to the questions in the test are scored in values varying between 0 and 4 using a rubric developed by Yeşildere (2006). Two mathematics teachers performed the scoring. There was almost perfect agreement (kappa = 0.85) between the scorer. The consensus was fully achieved by reviewing the results where there was no agreement between the scorer. The lowest 0 and the highest 40 points can be obtained from the test (Table 1). High scores indicate high mathematical reasoning skills. The test paper of a student who gets 29 points from the test is shown in Appendix 2. The Cronbach's alpha coefficient calculated for the test in the present study was 0.78.

Table 1. *The Scoring Rubric*

Criterion	Score
There are answers that express the way of solving the problem and its explanation correctly, express their thoughts with correct mathematical notation and symbols, express their reasoning clearly, and indicate that they are in a complete understanding.	4
There are answers that are correct except for a few minor errors or ambiguities in the way of solving the problem and the explanation, expressing their thoughts with proper mathematical notation and symbols, expressing the way of reasoning, and stating that they are in full understanding.	3
Although the way of solving the problem and its explanation shows that the problem is understood a little, there are answers that indicate that he has insufficient knowledge in some aspects of the explanations for the solution.	2
There are answers that show that he has limited knowledge about the way and explanation of solving the problem.	1
There are answers that solve the problem incorrectly or that are left unanswered.	0

Motivated Strategies for Learning Questionnaire (MSLQ): The questionnaire developed by Pintrich et al. (1993) and adapted into Turkish by Karadeniz et al. (2008) was used to determine the level of metacognitive strategies used by students in mathematics lessons. The measuring tool has a multidimensional structure. The scale is a 7-point Likert type (1=Absolutely wrong for me, 7=Absolutely true for me). In this study, the metacognitive strategies sub-dimension of the scale consisting of 11 items was used. One of the expressions on the scale is as follows; "When reading resources related to mathematics, I ask myself questions to help me focus on the subject." The lowest score that can be obtained from the metacognitive strategies scale is 11, and the highest score is 77. Higher scores indicate greater use of metacognitive strategies in mathematics. The Cronbach's alpha coefficient calculated for the metacognitive strategies scale in the present study was 0.85.

DATA ANALYSIS

The distribution of mathematical reasoning skills and metacognitive strategies scores was analyzed based on skewness and kurtosis coefficients. The skewness and kurtosis coefficients in the range of ±1 indicate that the scores have a normal distribution (Tabachnick & Fidell, 2013). The skewness and kurtosis coefficients were within the specified range (Table 2). This result indicated that the scores showed univariate normal distributions.

Relationships between gender, mathematical reasoning skills, and metacognitive strategies scores were examined using Pearson Correlation coefficients. The correlation coefficient takes values in the range of ±1. Coefficients between 0 and ±0.30 indicate low, coefficients between ±0.30 and ±0.70 indicate moderate, and coefficients between ±0.70 and ±1 indicate high-level relationships (Ratner, 2009).

Table 2. *The Skewness and Kurtosis Coefficients*

Variables	Skewness		Kurtosis	
	z	SE	z	SE
Mathematical reasoning	0.71	0.15	-0.15	0.31
Metacognitive strategies	-0.19	0.15	0.01	0.31

SPSS Process Macro Model 4 (Version 4.0) was used to test the mediating role of metacognitive strategies in the effect of gender on mathematical reasoning skills (Hayes, 2017). Hayes Macro performs the basic analysis of the bootstrap method. This method determines whether the direct and indirect effects are significantly based on the confidence interval (Shrout & Bolger, 2002). Cook distance values (<1) showed no multivariate outliers in the data set. VIF>10 values indicate multicollinearity between the variables (Menard, 2002). The calculated VIF value was calculated as 1.15. The value showed that there was no multicollinearity between the variables. SPSS 25.0 statistical package program was used for the analysis.

RESULTS

The mathematical reasoning skills and metacognitive strategies mean scores of male and female students are shown in Table 3. Female students' reasoning skills (M=14.84, SD=7.50) score was significantly higher than the mean (M=9.40, SD=6.23) score of male students (t(249)=6.26, p <0.001). Female students' metacognitive strategies mean (M=54.98, SD=11.34) score was significantly higher than male students' mean (M=45.87, SD=11.72) score (t(249)=6.13, p<0.001).

Table 3. *Means and Standard Deviations of the Variables by Gender*

Variables	Female (n=142)		Male (n=208)		All (n=350)			
	M	SD	M	SD	M	SD	Min.	Max.
Mathematical reasoning	14.84	7.50	9.40	6.23	11.61	7.27	1.00	30.00
Metacognitive strategies	54.98	11.34	45.87	11.72	49.57	12.38	16.00	77.00

Relationships between gender, mathematical reasoning skills, and metacognitive strategies scores were examined by calculating Pearson Correlation coefficients. Calculated correlation coefficients are given in Table 4.

Table 4. *Pearson correlation with Gender, Mathematical Reasoning, and Metacognitive Strategies*

	Variables	1.	2.	3.
1.	Gender [a]	1		
2.	Mathematical reasoning	-0.37**	1	
3.	Metacognitive strategies	-0.36**	0.39**	1

**p<0.01, N=350, [a]0 = Female, 1 = Male.

Table 4 shows that gender was negatively correlated with mathematical reasoning skills (r=-0.37, p<0.01) and metacognitive strategies (r=-0.36, p<0.01). Mathematical reasoning skill was positively correlated with metacognitive strategies (r=0.39, p<0.01).

SPSS Process Hayes (2017) Macro Model 4 (Version 4.0) was used to test the mediating role of metacognitive strategies in the effect of gender on mathematical reasoning skills. In the model, gender was the independent variable, mathematical reasoning was the dependent variable, and metacognitive strategies were included as the moderator variable (Figure 2). Path coefficients for direct and indirect effects are displayed in Table 5.

Figure 2. *Direct And Indirect Effect of Gender on Mathematical Reasoning, ***p<0.001, c^1= Indirect Effect*

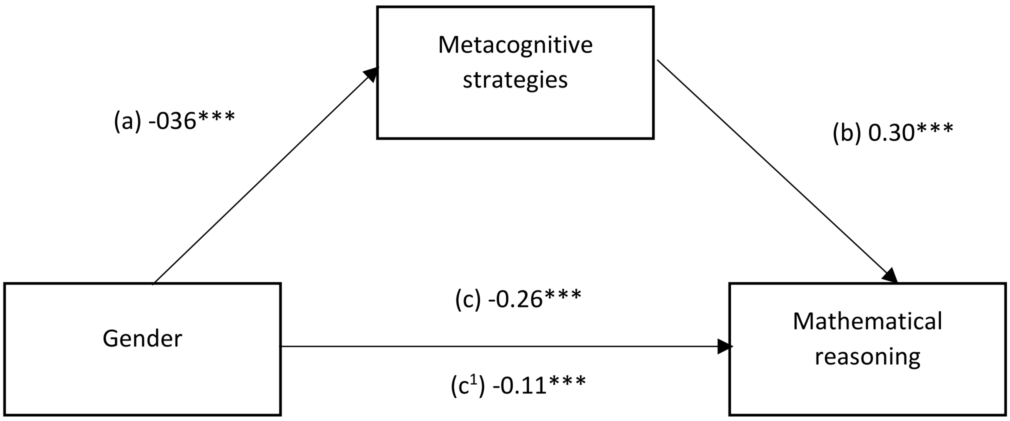


Table 5. *Direct And Indirect Effect of Gender on Mathematical Reasoning*

	Model			B	β	SE	t	p	LLCI	ULCI
	Model 1									
Gender	---->		MR	-3.71	-0.37	0.87	-6.27	0.00***	-0.47	-0.26
	Model 2									
Gender	---->		MS	-9.12	-0.36	0.06	-6.14	0.00***	-0.47	-0.25
	Model 3									
Gender	---->		MR	-3.87	-0.26	0.06	-4.34	0.00***	-0.39	-0.14
MS	---->		MR	0.17	0.30	0.06	4.90	0.00***	0.17	0.42
	Model 4									
Gender ---->	MS	---->	MR	-1.58	-0.11	0.03		0.00***	-0.17	-0.06

***p<0.001, MR= Mathematical Reasoning, MS= Metacognitive Strategies, LLCI= Lower limit of the Confidence interval, ULCI= Upper limit of the Confidence interval

When Table 5 is examined, the effect of gender on mathematical reasoning was examined in model 1 ($F(1,249)=39.16$, $R=0.37$, $p<0.01$). The fact that the confidence interval (95% CI= -0.47, -0.26) did not contain a zero-value showed that the observed effect was significant (Shrout & Bolger, 2002). Gender had a negative and significant effect on mathematical reasoning skills ($\beta=-0.37$, $p<0.001$). Thus, the negative coefficient of the direct effect of gender on mathematical reasoning indicated that female students, on average, scored -0.37 standard deviations higher mathematical reasoning scores than male students.

In Model 2, the effect of gender on metacognitive strategies was examined ($F(1,249)=37.60$, $R=0.36$, $p<0.010$). The fact that the confidence interval (95% CI= 0.47, -0.25) did not contain a zero-value showed that the observed effect was significant (Shrout & Bolger, 2002). Gender had a negative and significant effect on metacognitive strategies ($\beta=-0.36$, $p<0.001$). Thus, the negative coefficient of the direct effect of gender on metacognitive strategies indicated that female students, on average, scored -0.36 standard deviations higher mathematical reasoning scores than male students.

In Model 3, the effects of gender and metacognitive strategies on mathematical reasoning skills were examined ($F(2,248)=33.31$, $R=0.46$, $p<0.01$). Confidence intervals calculated for gender (95% CI= -0.39, -0.14) and metacognitive strategies (95% CI= 0.17, 0.42) did not contain zero values, indicating that the observed effects were statistically significant (Shrout and Bolger, 2002). Gender ($\beta =-0.26$, $p<0.001$) and metacognitive strategies ($\beta=0.30$, $p<0.001$) had a significant effect on mathematical reasoning.

In Model 4, the indirect effect of gender on mathematical reasoning skills was examined. The indirect effect ($\beta = -0.11$, $p<0.001$) was statistically significant as the confidence interval (95% CI= -0.17, -0.06) did not contain a zero value (Shrout & Bolger, 2002). The significant indirect effect showed that cognitive strategies had a mediating role in the relationship between gender and mathematical reasoning skills. The fact that only a part of the total effect was realized through the mediating variable indicates that metacognitive strategies were partial mediators.

DISCUSSION, CONCLUSION, AND IMPLICATIONS

This study compared the mathematical reasoning and metacognitive strategies of eighth-grade secondary school students by gender. Additionally, the relationships between gender, metacognitive strategies, and mathematical reasoning were examined. It was investigated whether metacognitive strategies mediated the gender difference in mathematical reasoning.

The present research showed that female students had higher mathematical reasoning performance than male students. Gender plays a crucial role in mathematics learning and may lead to differences in the mathematics achievement of male and female students (Xue et al., 2021). There are studies indicating that men (Erdem & Soylu, 2017; Mills, Ablard & Stumpf, 1993; Rosdiana et al., 2019) or women (Gherasim et al., 2012; Robinson & Lubinski, 2011) are more successful in mathematics. However, some researchers suggested that there is no gender-related difference in math (Sarouphim & Chartouny, 2017). There are studies that attribute the cause of gender difference in mathematics to cultural factors (Devine et al., 2012; Else-Quest, Hyde & Linn, 2010; Sarouphim & Chartouny, 2017). For example, Tsui (2007) noted that the perception that males are better at mathematics is transmitted to students by parents and teachers, and this is reflected in students' mathematics achievement. These observations may be valid in countries where gender-related cultural factors predominate. It may not be enough to explain the gender difference with cultural factors alone. Mathematics is a discipline that requires cognitive ability. There are also studies showing that cognitive abilities are the basis of individual differences in mathematics (Efklides et al., 1997; Erdem & Soylu, 2017; Karaduman, 2018; Kayhan, 2005; Kocaman, 2017; Rohde & Thompson, 2007; Rosdiana et al., 2019; Sarıbaş, 2019; Subekti et al., 2021). For example, Kayhan (2005) emphasized that female students are more successful in choosing and using the right strategies in the mathematical reasoning process. Subekti et al. (2021)

stated that female students had a higher rate of making correct assumptions about mathematical patterns. Male students' explanations of the patterns are more superficial and tend to misunderstand the patterns and accordingly draw wrong conclusions. Sumpter (2016) found that female students tend to use familiar algorithmic reasoning methods. Rosdiana et al. (2019) examined the reasoning styles used by male and female students in understanding mathematical problems and checking the accuracy of results. It was noted that the answers given by the male students at the stage of understanding the problem were more detailed than the answers of the female students. Previous research has revealed that the cognitive approaches of females and males to mathematical reasoning differ. Unlike the literature studies, the present research argues that this difference may be of metacognitive origin.

One of the findings obtained in the research is that female students use metacognitive strategies more than male students. These results are consistent with the researchers whom that indicated females had better knowledge of metacognitive strategies (Liliana & Lavinia, 2011; Kolic´-Vehovec & Bajšanski, 2006; Sheorey & Mokhtari, 2001; Topçu & Yılmaz-Tüzün, 2009; Wu, 2014; Zimmerman & Martinez-Pons, 1990). Topçu and Yılmaz-Tüzün (2009) emphasized that in 4th to 8th grades, being a girl was positively correlated with knowledge of cognition and regulation of cognition. Liliana and Lavinia (2011) stated that 8th-grade male students use prior knowledge in problem-solving, planning, various learning strategies, and monitoring the learning process. Also, female students have more knowledge about their intellectual strengths and weaknesses. Zimmerman & Martinez-Pons (1990) noted that among self-regulation skills, females mostly used record keeping and monitoring, environmental structuring, goal setting, and planning than males. While planning the mathematics teaching process, it should be considered that female students may be superior in using metacognitive strategies.

Another significant result of the present research is that metacognitive strategies partially mediate the gender difference in mathematical reasoning. Cornoldi (1997) stated that metacognition is one of the most critical cognitive skills required for learning. A low level of metacognitive skills weakens the possibility of having high academic achievement (Holton & Clarke, 2015; Kleitman & Gibson, 2011). Students with low metacognitive skills cannot correctly operate cognitive processes such as planning, evaluation, and monitoring learning processes. In this regard, even if these students have high intelligence and motivation, they are less likely to have high academic achievement (Kazuhiro & Tetsuya, 2018; Hong et al., 2020). Shen and Chen (2014) emphasized that mathematical metacognition is a particular form of metacognition based on metacognition knowledge. Students with a high level of mathematical metacognition can evaluate, control and regulate cognitive processes in mathematics. Pugalee (2010) stated that metacognition is effectively used in the orientation, organization, execution, and verification stages of problem-solving. Lestari (2018) noted that using metacognitive strategies strengthens mathematical reasoning skills. In this respect, students who use metacognitive strategies effectively are more likely to solve mathematical problems. The present research supports studies that emphasize metacognition's importance in mathematics skills. It was observed that females who used mathematical strategies more effectively had higher mathematical reasoning performance than males. The present research has provided quantitative evidence that the observed gender differences in mathematical skills are of metacognitive origin.

In conclusion, the present research showed that metacognitive strategies mediated gender differences in mathematical reasoning ability. To reduce the gender difference in mathematical reasoning, male students can be taught to learn metacognitive strategies and use these strategies effectively. Teachers' inclusion of applications that support metacognitive strategies while teaching mathematics may prevent the emergence of gender differences in mathematical reasoning. Conducting this research with only eighth-grade students limits the results' generalizability. The mediating role of metacognitive strategies in different cultures and age groups can be studied with further research. These studies may help clarify and generalize the relationships between gender, reasoning, and metacognition. In addition, it can be investigated whether metacognitive strategies mediate gender differences observed in other mathematical skills.

AUTHOR CONTRIBUTION

I, the author of the article titled "The Mediating Role of Metacognitive Strategies in The Relationship Between Gender and Mathematical Reasoning Performance," participated in every step of the conception, design, analysis, and discussion of the data as well as the writing of the manuscript and I take public responsibility for its publication.

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Appendix 1

Mathematical Power Scale

1. You have to fill the inside of a sphere with colored liquid. Since you cannot move the sphere, you must fill it with one of the cylinder, cone, square pyramid or square prism shaped glasses you have.

    - ✓ All glasses and globes are of equal height.
    - ✓ Radius lengths of the cylinder, cone, sphere, the length of one side of the square pyramid and the length of one side of the square prism are equal to each other.

    Choose such a glass that it can fill the sphere with the least number of moves. Explain in detail how you made this choice.

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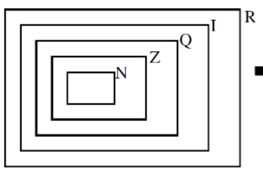
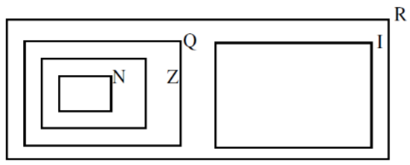
2. 2. The teacher asked Sema and Yasemin to show the numbers they have learned so far as diagrams. These number sets are Natural Numbers (N), Integers (Z), Rational Numbers (Q), Irrational numbers (I) and Real numbers (R).

    - Sema and Yasemin's answers are given below.



➡ Semas's answer



➡ Yasemin's answer

    - Which student's drawing is correct? Explain with reason.

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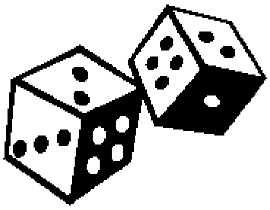
3. Below are the views of a pair of dice from two different angles. These dice are exactly "cube" shaped and the numbers are placed on the dice in the same order.

According to this information,

- Which number is on the reverse side of the face with 3 on it?
- What is the probability that the face that comes after the face with 4 is the number 6?



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4. The following dialogue takes place between Sertap, Sibel and Orhan:

Sertap: The object formed by rotating any triangle about one side 360° is called a right cone.
Sibel: But when it rotates around its different sides, other objects form, some of which are bent, some of which are not. Then why is it called a "vertical" cone?
Orhan: No, all cones are upright anyway. A cone that is not perpendicular cannot be drawn.
Is there any information given incorrectly or incompletely by the students here?
Write a statement for each student highlighting where they are wrong or right.

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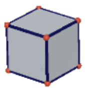
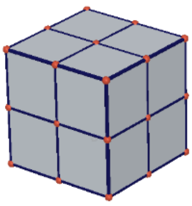
5. Zeynep is trying to get biggest cubes by combining the small cubes in her hand. First, she puts one small cube (a). She then places two small cubes side by side and places the other small cubes so that the object is a larger cube (b).


(a)


(b)

Zeynep wants to calculate how many cubes are needed for the whole larger cubes that she started by putting five small cubes side by side, without adding the cubes one by one. How can Zeynep do this? Please explain with details.

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6. Fatma's teacher asked her to put her hand in a bag that she could not see, and to understand what the regular geometric object was in it without seeing -just by touching-. Fatma took the following notes in her notebook about the geometric object she could feel by touching:
    - It has a total of 5 corners.
    - Its lateral faces are triangular and its base is not triangular.
    - The opposite sides of the base are equal in length.

    According to this information;

    a) Predict what this geometric object might be. Explain in detail why you made this prediction.
    b) What is the probability that it is a cylinder? Explain with reasons.
    c) What is the probability that it is a prism? Explain with reasons.
    d) What is the probability that it is a square pyramid? Explain with reasons.

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7. The following dialogue takes place between the teacher and Canan and Ayşe:

    Teacher: What is the intersection of a sphere with a rectangular plane?
    Canan: I think it's rectangular. A portion of the plane's size intersects the sphere.
    Ayşe: I think it is a flat. Since the plane is an infinitely expanding region, its intersection will be a circle.

    Is there any incorrect or incomplete information given by the students here? Write a letter to each student highlighting where they were wrong or right.

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8. Salesman, Mehmet Bey, frequently travels between cities due to his job and markets 1000 liters of goods per week in a nearby city. Mehmet Bey wants to buy the vehicle that consumes the most fuel, which will make the least trips. Evaluate the suitability of each car in terms of these criteria. According to the information given below, which car would meet Mehmet Bey's wishes? Why? Express your way of thinking clearly.

RENAULT	
Motor Hacmi (cc)	1598
Son Hız (km/s)	181
0-100 km/s Hızlanma (sn)	12.4
Şehir İçinde (litre)	8.6
Şehir dışı (litre)	5.8
Bagaj Hacmi (litre)	485

PEUGEOT	
Motor Hacmi (cc)	1587
Son Hız (km/s)	190
0-100 km/s Hızlanma (sn)	10.7
Şehir içi (litre)	9.5
Şehir dışı (litre)	5
Bagaj Hacmi (litre)	420

OPEL	
Motor Hacmi (cc)	1199
Son Hız (km/s)	180
0-100 km/s Hızlanma (sn)	14.0
Şehir İçinde (litre)	7.3
Şehir dışı (litre)	4.8
Bagaj Hacmi (litre)	260

VOLKSWAGEN	
Motor Hacmi (cc)	1896
Son Hız (km/s)	180
0-100 km/s Hızlanma (sn)	12.6
Şehir içi (litre)	6.5
Şehir dışı (litre)	4.1
Bagaj Hacmi (litre)	330

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9. How many triangles are there in the figure below? List the triangles you find by lettering.

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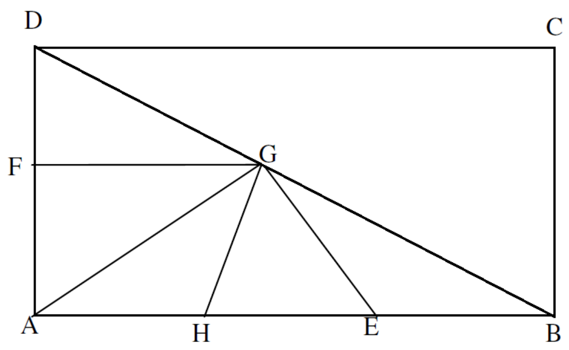
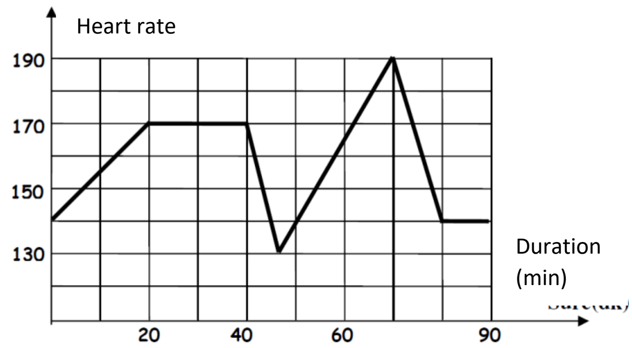


10. The rate of our heartbeat is the basic function of our life. For the continuation of our life in a healthy way, our heart rate should beat in the ranges given below:



If our heart beats within the ranges found by this formula, our heart health is in place.

On the side, the heart rate graph of 25-year-old football player Serhat during a match is given. Using the safe heart rate calculation given above, interpret whether the player's heart beats regularly during the match by associating with the graph.

Safe heart rate = 220-human age) Minimum safe heart rate = safe heart rate x 60% Maximum safe heart rate = safe heart rate x 90%

- Serhat's heart during the first 20 minutes,

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- Between 20 minutes and 40 minutes, Serhat's heart,

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- Between 45 and 70 minutes, Serhat's heart,

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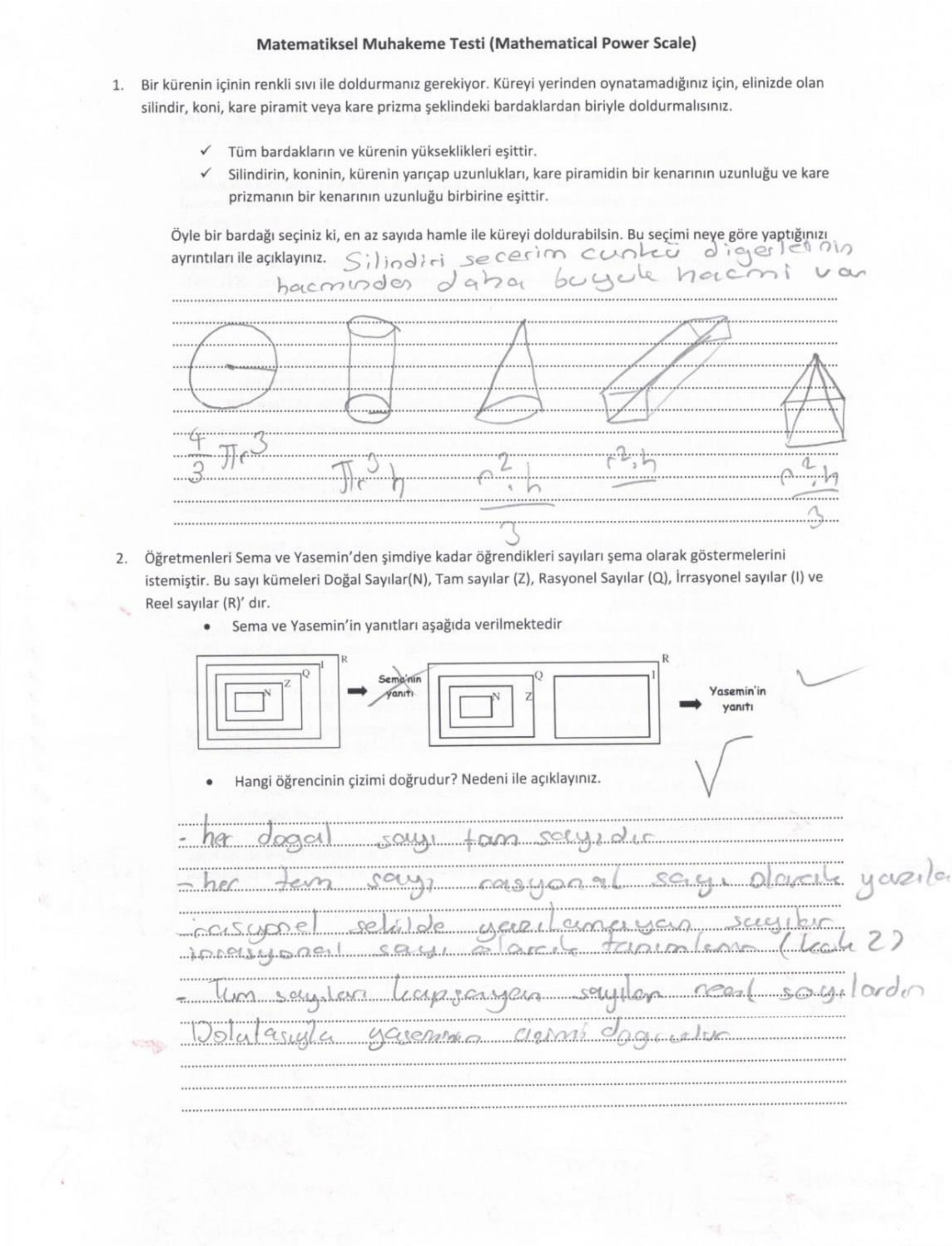
Appendix 2 (Turkish Version, Sample)



Matematiksel Muhakeme Testi (Mathematical Power Scale)

1. Bir kürenin içinin renkli sıvı ile doldurmanız gerekiyor. Küreyi yerinden oynatamadığınız için, elinizde olan silindir, koni, kare piramit veya kare prizma şeklindeki bardaklardan biriyle doldurmalısınız.

   ✓ Tüm bardakların ve kürenin yükseklikleri eşittir.
   ✓ Silindirin, koninin, kürenin yarıçap uzunlukları, kare piramidin bir kenarının uzunluğu ve kare prizmanın bir kenarının uzunluğu birbirine eşittir.

   Öyle bir bardağı seçiniz ki, en az sayıda hamle ile küreyi doldurabilsin. Bu seçimi neye göre yaptığınızı ayrıntıları ile açıklayınız. Silindiri seçerim çünkü diğerlerinin hacminden daha büyük hacmi var

   $\frac{4}{3}\pi r^3$ $\pi r^3 h$ $\frac{r^2 \cdot h}{3}$ $r^2 \cdot h$ $\frac{r^2 \cdot h}{3}$

2. Öğretmenleri Sema ve Yasemin'den şimdiye kadar öğrendikleri sayıları şema olarak göstermelerini istemiştir. Bu sayı kümeleri Doğal Sayılar(N), Tam sayılar (Z), Rasyonel Sayılar (Q), İrrasyonel sayılar (I) ve Reel sayılar (R)' dır.

   - Sema ve Yasemin'in yanıtları aşağıda verilmektedir

   Sema'nın yanıtı ➡ Yasemin'in yanıtı

   - Hangi öğrencinin çizimi doğrudur? Nedeni ile açıklayınız.

   - her doğal sayı tam sayıdır
   - her tam sayı rasyonel sayı olarak yazıla
   rasyonel şekilde yazılamayan sayılar irrasyonel sayı olarak tanımlanır (kök 2)
   - Tüm sayıları kapsayan sayılar reel sayılardır
   Dolayısıyla yasemin çizimi doğrudur

3. Aşağıda bir çift zarın farklı iki açıdan görünüşleri verilmektedir. Bu zarlar tam "küp" şeklindedir ve rakamlar zarların üzerlerine aynı sırayla yerleştirilmiştir.

Buna göre,

- Üzerinde 3 yazan yüzün tam arka yüzünde hangi rakam vardır?
- Dört yazan yüzün arkasına gelen yüzün 6 olma olasılığı nedir?

Birinci küpü sağa doğru çevirdiğimizde ikinci şekildeki küp elde edilir. Sağa çevirdiğimizde üç noktalı yüz kaybolmakta ve bir noktalı yüz belirmektedir. 3 noktalı yüzün karşısında bir noktalı yüz bulunur.

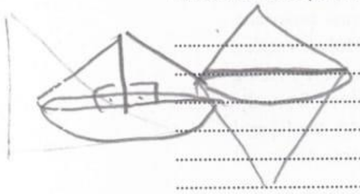
4. Aşağıdaki diyalog Sertap, Sibel ve Orhan arasında geçmektedir:

Sertap: Herhangi bir üçgenin, bir kenarı etrafında 360° döndürülmesiyle oluşan cisme dik koni denir.

Sibel: Ama farklı kenarları etrafında döndüğünde başka cisimler oluşuyor bazıları eğik duruyor, bazıları eğik durmuyor. Madem o zaman neden "dik" koni denilsin ki?

Orhan: Hayır, zaten bütün koniler diktir. Dik olmayan koni çizilemez.

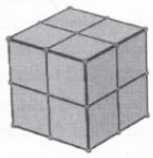
Buradaki öğrenciler tarafından hatalı veya eksik olarak verilen bilgi var mıdır? Her bir öğrenciye, nerede hatalı veya nerede haklı olduklarını vurgulayan bir mektup yazınız.



herhangi bir üçgen değilde dik üçgenin dik kenarı etrafında döndürülürse dik oluşur. Yani Sibelin söyledikleri doğru çıkıyor

5. Zeynep elindeki küçük küpleri bir araya getirerek daha büyük küpler elde etmeye çalışıyor. İlk önce bir tane küçük küp koyuyor (Şekil 1). Daha sonra iki tane küçük küpü yan yana koyuyor ve diğer küçük küpleri de cisim daha büyük bir küp olacak şekilde yerleştiriyor (Şekil 2).

Şekil 1



Şekil 2

Zeynep beş tane küçük küp yan yana koyarak başladığı daha büyük küpün tamamı için kaç küp gerektiğini tek tek küpleri koymadan hesaplamak istiyor. Zeynep bunu nasıl yapabilir? Ayrıntıları ile açıklayınız.

Şekil 1. 1 küp $= 1^3 = 1$ her bir adımda şekil numaraları küpü kadar küp kullanılmaktadır

Şekil 2. 8 küp $= 2^3 = 8$

Şekil 3. 27 küp $= 3^3 = 27$

⋮ ⋮

6. Fatma'dan öğretmeni, içini göremediği bir torbaya elini sokmasını ve içinde olan düzgün geometrik cismin ne olduğunu görmeden -sadece dokunarak- anlamasını istemiştir. Fatma dokunarak hissedebildiği geometrik cisme ilişkin, defterine aşağıdaki notları almıştır:
    - Toplam 5 tane köşesi var.
    - Yan yüzleri üçgensel bölge, tabanı üçgensel bölge değil.
    - Tabanın karşılıklı olan kenar uzunlukları eşit.

    Bu bilgilere göre;

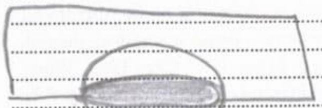
    a) Bu geometrik cismin ne olabileceğini tahmin ediniz. Neden bu tahmini yaptığınızı ayrıntılarıyla açıklayınız.
    b) Silindir olma olasılığı nedir? Nedenleri ile açıklayınız.
    c) Prizma olma olasılığı nedir? Nedenleri ile açıklayınız.
    d) Kare piramit olma olasılığı nedir? Nedenleri ile açıklayınız.

b) Silindirin köşesi yok

a-) 
→ üçgensel bölge c-) Prizma olmaz prizmanın yan
→ tabanı kenar yüzü diktörtgensel olmalı
d) piramit olabilir
→ kenar Çünkü 5 tane köşesi var, yan yüzü üçgensel bölge karşılıklı kenar uzunlukları eşit

7. Aşağıdaki diyalog öğretmen ile Canan ve Ayşe arasında geçmektedir:
Öğretmen: Bir kürenin bir dikdörtgensel düzlem ile arakesiti nedir?
Canan: Bence dikdörtgendir. Düzlemin büyüklüğü kadarlık bölümü küre ile kesişir.
Ayşe: Bence dairedir. Düzlem sınırsız genişleyen bir bölge olduğundan kesişimi daire olacaktır.

Buradaki öğrenciler tarafından verilen hatalı veya eksik bilgi var mıdır? Her bir öğrenciye, nerede hatalı veya nerede haklı olduklarını vurgulayan bir mektup yazınız.


Ayşeye katılıyorum Kürenin herhangi cisme buluştuğu ortak alan kadar olacaktır bu ortak alan da daire olmaktadır

8. Pazarlamacı Mehmet Bey, işi gereği sıklıkla şehirlerarası yolculuk yapmakta ve haftada 1000 litrelik malları yakın bir şehirde pazarlamaktadır. Mehmet Bey en az seferi yapacağı en ekonomik yakıt tüketen aracı satın almak istiyor. Bu kriterler açısından her bir arabanın uygunluğunu değerlendirin. Aşağıda verilen bilgilere göre hangi arabayı alması Mehmet Bey'in isteklerini karşılar? Neden? Düşünce biçiminizi açıkça ifade ediniz.

RENAULT	
Motor Hacmi (cc)	1598
Son Hız (km/s)	181
0-100 km/s Hızlanma (sn)	12.4
Şehir İçinde (litre)	8.6
Şehir dışı (litre)	5.8
Bagaj Hacmi (litre)	485

PEUGEOT	
Motor Hacmi (cc)	1587
Son Hız (km/s)	190
0-100 km/s Hızlanma (sn)	10.7
Şehir içi (litre)	9.5
Şehir dışı (litre)	5
Bagaj Hacmi (litre)	420

OPEL	
Motor Hacmi (cc)	1199
Son Hız (km/s)	180
0-100 km/s Hızlanma (sn)	14.0
Şehir İçinde (litre)	7.3
Şehir dışı (litre)	4.8
Bagaj Hacmi (litre)	260

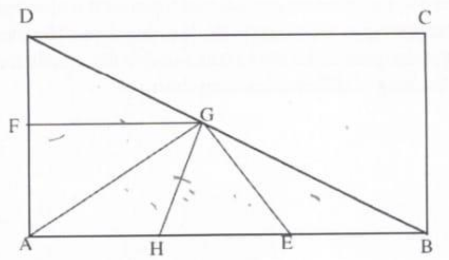
VOLKSWAGEN	
Motor Hacmi (cc)	1896
Son Hız (km/s)	180
0-100 km/s Hızlanma (sn)	12.6
Şehir içi (litre)	6.5
Şehir dışı (litre)	4.1
Bagaj Hacmi (litre)	330

Renault 1000/485=3 sefer 5,8 lt
Peugeot 1000/420=3 sefer 9,8 lt
Opel 1000/260=4 sefer 5,8 lt
Volkswagen 1000/330=4 sefer 4,1 lt

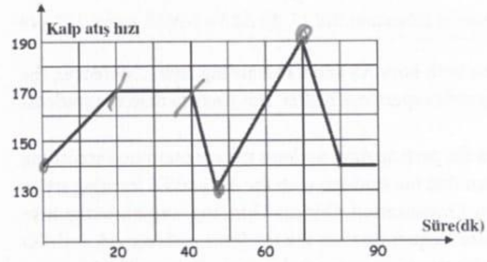
Pego markasını tercih etsin daha az sefer yapar
Az yakıt tüketir
Vol ... wasvagen tercih etmeli

9. Aşağıdaki şekilde kaç tane üçgen bulunmaktadır? Bulduğunuz üçgenleri harflendirerek listeleyiniz.

DGF, FGA, DGA, AGH, HEG, AGE
GEB, AGB, DCB, DAB



10. Kalp atışlarımızın hızı, yaşamımızın temel fonksiyonudur. Yaşamımızın sağlıklı olarak devamı için, kalp atış hızımız aşağıda formülü verilen aralıklarda atmalıdır:



Kalbimiz, bu formülle bulunan aralıklarda atarsa, kalp sağlığımız yerindedir. Yan tarafta 25 yaşındaki Fenerbahçeli futbolcu Serhat'ın bir maç boyunca kalp atış hızı grafiği verilmiştir. Yukarıda verilen güvenli kalp atış hızı hesabından yararlanarak, maç boyunca futbolcunun kalbinin düzenli atıp atmadığını grafikle ilişkilendirerek yorumlayınız.

Güvenli kalp atışı hızı= 220-insanın yaşı)

Asgari (en az) güvenli kalp atış hızı = güvenli kalp atışı x %60

Azami (en çok) güvenli kalp atış hızı = güvenli kalp atışı x %90

220 - 25 = 195

$195 \cdot \frac{60}{100} = 117$

$195 \cdot \frac{90}{100} = 175,5$

- İlk 20 dakika boyunca Serhat'ın kalbi

220-25 eşittir 195 güvenli kalp atış hızı bu aralıktaki Serhat'ın kalbi 190 ile 170 arasındaki kanı güvenli aralıkta

- 20 dakika ile 40 dakika arasında Serhat'ın kalbi,

Bu aralıkta kalp atış hızı 170 te sabit Güvenli kalp atış hızı aralığı ve sınırları güvenli kalp atış hızının üzerindedir

- 45 ile 70 dakika arasında Serhat'ın kalbi

Bu aralıkta kalp atış hızı 130 ile 190 arasında değişmektedir. Bu aralık asgari güvenli kalp atış hızının üzerindedir azami (175,5 güvenli kalp atış hızının ise üzerindedir Serhat'ın hayati tehlikesi bulunmaktadır