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Research Article

Investigation of the Relationship Between the Eighth Grade Students' Spatial Abilities and Their Geometry Achievements*

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Abstract

The main goal of this study is to determine the relationship between the eighth-grade students' spatial abilities and their geometry achievement considering the variables of gender, preschool education and type of school. This research study was carried out by applying correlational survey model. 400 eighth-grade students receiving education at different types of middle schools in Göksun, Kahramanmaraş participated in the study. Demographic information form, Transformational Geometry and Geometric Objects Achievement Test developed by the authors of this study and Spatial Ability Practice Test developed by Newton and Bristoll (2011) and adapted to Turkish by the authors were used as data collection instruments in the study. The data were analysed via SPSS 17.0 package software by using descriptive statistics, independent samples t-test, one way ANOVA and Pearson correlation coefficient. According to the findings of the research, it was determined that there was positively significant and moderate correlation between students' spatial ability and their geometry achievement scores. In respect to the students' spatial abilities, a significant difference was determined in favor of girls, the students receiving education in day school and the students who received preschool education.

Sekizinci Sınıf Öğrencilerinin Uzamsal Yetenekleri ile Geometri Başarıları Arasındaki İlişkinin İncelenmesi

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Anahtar Kelimeler
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Cinsiyet, Okul türü,
Okul öncesi eğitim.

Öz

Bu çalışmanın temel amacı, sekizinci sınıf öğrencilerinin uzamsal yetenekleri ile geometri başarıları arasındaki ilişkiyi cinsiyet, okul öncesi eğitim alma durumu ve okul türü değişkenlerini dikkate alarak belirlemektir. Bu araştırma ilişkisel tarama modeli uygulanarak gerçekleştirilmiştir. Kahramanmaraş ili Göksun ilçesinde farklı ortaokul türlerinde öğrenim gören 400 sekizinci sınıf öğrencisi katılmıştır. Araştırmada veri toplama aracı olarak demografik bilgi formu, çalışmanın yazarları tarafından geliştirilen Dönüşümsel Geometri ve Geometrik Cisimler Başarı Testi ile Newton ve Bristoll (2011) tarafından geliştirilen ve bu çalışmanın yazarları tarafından Türkçeye uyarlanan Uzamsal Yetenek Uygulama Testi kullanılmıştır. Veriler SPSS 17.0 paket programı ile betimsel istatistikler, bağımsız örneklemler için t-testi, tek yönlü ANOVA ve Pearson korelasyon katsayısı kullanılarak analiz edilmiştir. Araştırma bulgularına göre; öğrencilerin uzamsal yetenekleri ile geometri başarı puanları arasında pozitif yönde anlamlı ve orta düzeyde bir ilişki olduğu tespit edilmiştir. Öğrencilerin uzamsal yetenekleri açısından; kız öğrenciler, gündüzlü okullarda eğitim alan öğrenciler ve okul öncesi eğitim alan öğrenciler lehine anlamlı bir farklılık tespit edilmiştir.

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Introduction

Mathematics, as an important discipline, has been developing in accordance with human needs and the exploration of the nature. In conjunction with the improvements in mathematics, certain learning domains have arisen to work through mathematics. Geometry is one of those learning domains gaining a seat in mathematics. This learning domain has started to make progress via the development of individuals' sense of sight, and the individuals have been trying to learn and teach geometry both theoretically and practically in the educational environments (Ministry of National Education [MoNE], 2013). Geometry includes the acquisitions that make it possible for students to examine 2-d and 3-d objects, to identify spatial relations, to practice the transformations and to use spatial abilities and geometric modelling in problem solving process (National Council of Teachers of Mathematics [NCTM], 2000). Geometry also allows of gaining an understanding that students can be aware of the nature and the beauty of mathematics and it assists students in practicing geometric thoughts and relations on different fields such as science, architecture and daily life situations (MoNE, 2013). Schattschneider (2010) gives some thought to arts in order to observe the concrete usage of the subjects of geometry, so especially attaches importance to Escher's artistic works and examines his works. It is observed in the works that transformational geometry is blended uncommonly with art. Similarly, the architectural and artistic practices of geometric objects occur in many artists' and scientists' works. Certain geometric objects such as sphere and regular octahedron can be seen in Kepler's model trying to explain his theorem of interplanetary distance. The production of a regular icosahedron was given in the work designed by Luca Pacioli as a friend of Leonardo da Vinci in 1509 (Stillwell, 2010). The subjects of transformational geometry and geometric objects come into prominence as applied components of geometry learning domain. Solids and their properties and three-dimensional space are concerned with geometric objects. Transformational geometry can be explained as bijective function including reflection, translation and rotation that conserves distance and property in plane geometry (Hollebrands, 2003). O'Brien (1989), mentioned about the importance of relational network that individuals organize between images, visuals and patterns during mathematical thinking process. Similarly; Coxford (1995) propounded the geometrical thinking abilities as a subcomponent of mathematical associations including visual/imaginary thinking and representations. Learning geometry enables learners to recognize the characteristics of geometric objects in plane and three-dimensional space, to find out the spatial relations among them, to identify the geometric locus and to explain the transformations and geometric propositions via spatial perception and sense. Learners are supposed to notice the relations and different positions between concrete objects at early ages. Classification of 2-d and 3-d objects, realizing the motion of the objects, rotation of geometric objects with a certain angle, translating the objects to different directions and understanding length, area and volume concepts are some of the essential skills that the students are supposed to learn in the later years during geometry education (Baki, 2015). Many researchers assert that developing students' spatial abilities with the help of certain representations and three-dimensional figures is among the main goals of geometry education (Battista, 2007; Ben-Chaim, Lappan, and Houang, 1989). Thus; it can be expressed that spatial thinking and ability play an important role in geometry learning process.

Theoretical Framework

The study published by National Research Council (2006) propounds that spatial thinking is the set of cognitive abilities including usage of reasoning processes and representation tools and the knowledge of spatial content and concepts. Spatial thinking evaluated independently of mathematical thinking in the study draws attention in the field of education (Jo, Hong, and Verma, 2016). Spatial abilities requiring the utilization of spatial thinking that people encounter in daily life situations, interaction with the environment and mental processing stand out with different definitions (Kösa, 2016). Based on the definitions; it can be stated that spatial ability is a notion including the skills of rotation, manipulation, visualization, open-close, association, looking from different directions of two and three dimensional objects through the reasoning processes created in mind. Also, spatial ability interested in the usage of space and geometric form is the ability of imagining and moving the objects consisting of one or more parts and their components mentally in three dimensional spaces (Lohman, 1996; Olkun and Altun, 2003; Turğut and Yılmaz, 2012). There are differences among researchers about the definition of spatial ability. Similarly, the researchers do not agree about which subcomponents the spatial ability comprised of. Spatial ability having positive correlation with many disciplines, particularly geometry and mathematics is not unidimensional and consists of sub-skills related to each other (Shamsuddin and Din, 2016). Considering the studies about subcomponents of spatial ability, spatial visualization (Burnett and Lane, 1980; Elliot and Smith, 1983; McGee, 1979; Pellegrino, Alderton and Shutle, 1984), spatial rotation (Kurt, 2002; Maier, 1996; Tartre, 1990), spatial relations (Carroll, 1993; Colom, Contreras, Botella, and Santacreu, 2001; Del Grande, 1990) subcomponents arementioned often while describing spatial ability. Spatial visualization including the skills of rotating, moving, manipulating, folding the objects mentally requires high level thinking skills and complex operations in mind rather than processing speed (McGee, 1979). Depending upon the position of a person, understanding the order between interior parts of the model constituted as two or three dimensional and comprehending the positional relationship of the model with the others address to spatial orientation subcomponent. Spatial orientation involves accepting the objects as a whole and imagining the position and view of the shapes or objects from different perspectives and evaluating this process in mind (Kurt, 2002). Spatial orientation has an important role in daily life such as direction finding, usage of navigation tools and address description (Mazman and Altun, 2013). Spatial relations subcomponent involves the skills of turning over 2-d or 3-d objects completely using different directions snappily and correctly. The situations corresponding to spatial relations have less complexity in processing compared to the ones related to spatial visualization. Also, rotation of the cube forms as a whole mentally is linked to spatial relations sub-skill (Colom et al., 2001). It can be expressed that spatial abilities contribute to mathematics and especially geometry education addressing to problem solving, reasoning and representation skills both practically and theoretically.

Importance and Purpose of the Research

Spatial ability has been discussed in several studies including different variables, scientific methods and models. Turğut (2007) cares researches about spatial ability because of the fact that there is significantly positive correlation between spatial ability and positive sciences, also geometry and mathematics achievement and activities enable people living in the environment surrounded by three dimensional objects to comprehend and perceive the transposition and reconstruction of the objects effectively. It is known that students in our country get low scores in the large scaled central exams and assessment tests such as PISA and TIMSS in mathematics, particularly in geometry (Berberoğlu, 2007). When the acquisitions in the geometry section of the exams considered, it is observed that they are associated with spatial thinking and ability, so it is important to make studies on the spatial ability and geometry achievement (Berberoğlu, 2007). Also, the acquisitions in the international exams mentioned above are mostly related to the eighth-grade students' mathematics curriculum in middle school. Allocated time for the acquisitions of transformational geometry and geometric objects constitutes 18 percent of overall time assigned for the acquisitions in the eighth-grade students' mathematics curriculum (MoNE, 2013). Thus; it is important to take middle school eighth-grade students into consideration as a sample group in the study. Many research studies regarding the correlation between spatial ability and geometry and mathematics achievement reveal that positively significant correlation is authenticated amongst them (Boulter, 1992; Hannafin, Truxaw, Vermillion, and Liu, 2008; Kösa and Kalay, 2018; Turğut andYılmaz, 2012). Thus, it is important to take the geometry achievement into consideration in the study in order to determine the presence and the degree of the correlation with spatial ability. It is important to examine whether there are differences depending on the gender variable in scientific researches. Gender variable is also ranked in numerous studies concerning spatial ability. Considering the related studies, it is stated that most of the researches reveal the results in favor of male students regarding spatial ability levels (Kaufman, 2007; Postma, Jager, Kessels, Koppeschaar, and van Honk, 2004; Yenilmez and Kakmaci, 2015). On the other hand, some of the researches about spatial ability bring out that there is no significant difference with regard to gender variable (İrioğlu and Ertekin, 2012). Also, some of the studies discussing spatial ability emphasize higher level spatial ability scores of female students over male contrary to much of the researches resulted in males' favor in the literature (Toptaş, Çelik, and Karaca, 2012). Considering the conflicting results about gender variable in the studies related to spatial ability, it is worth to include gender variable in the study to observe whether there is a significant difference or not. Preschool education has an important place on the physical and educational development of a child. Learning process in preschool education is known as learning by experience and entertaining with play via providing children with activity and material support. Early childhood experiences are also regarded as valuable in terms of attributing to development of spatial abilities (Lehmann and Jansen, 2019). Much of the researches about spatial ability including preschool education variable in the literature reveals that spatial ability levels of students differentiate significantly on behalf of those received preschool education (İrioğlu and Ertekin, 2012; Turğut and Yılmaz, 2012). Educational environments including opportunities and different type of students in terms of their settlement, socioeconomic status, parents' level of education and etc. have become an issue in the studies. The types of schools providing individuals with practices, activities or opportunities enable the individuals to develop their spatial thinking skills (Ogunkola and Knight, 2019). Some of the researches related to spatial ability exhibited that the findings were significantly differentiated with respect to type of schools (Chao and Liu, 2017; Guzel and Sener, 2009). Differently from this, Kayhan (2005) found out in her study that there was no significant difference among students' spatial ability levels depending upon the type of schools. Hence, it is important to debate the type of school as a variable in the study to observe the results.

In the view of such information; the goal of this research study is to determine the eighth-grade students' spatial abilities and geometry achievement levels. By taking the gender, preschool education and type of school variables into consideration, this study aspires to examine the existence and level of the correlation between eighth-grade students' spatial abilities and their geometry achievements. In order to achieve these goals, answers to the following problems are looked for:

1. What is the level of eighth-grade students' spatial ability and geometry achievement?
2. Is there a statistically significant difference between eighth-grade students' spatial abilities and gender, preschool education, and type of school variables?
3. Is there a statistically significant correlation between eighth-grade students' spatial abilities and their geometry achievements?

Method

Design of the Study

Based upon the aim of this research study; it can be stated that the study is convenient to correlational survey model that targets to describe the issue, situation or subject through appropriate data collection tools without any intervention. Correlational survey model requires collecting data in order to investigate the presence and the degree of relationship between two or more measurable variables. Also, the high correlation achieved in the research study allows making predictive inferences among variables (Gay and Mills, 2014). Thus; this study was planned in correlational survey model depending on obtaining and analyzing the quantitative data.

Population and Sample

The population of the research included the eighth-grade students receiving education at different schools in Göksun, Kahramanmaraş. Participants of the study consisted of 400 eighth-grade students receiving education in central schools randomly selected from Göksun, Kahramanmaraş.

Table 1. Distribution of the sample by gender and type of school.

Gender	Day School	TransportationCenter School	Boarding School	N	%
Female	118	35	31	184	46.0
Male	113	58	45	216	54.0
Total	231	93	76	400	100.0

Day school is a type of school where students only attend during class hours and then return home using their own means of transportation. Transportation center school is a type of school where students who have problems with access to school owing to different reasons, and transported with state resources on a daily basis to have education (Çavuşoğlu and Dönmez, 2018). Boarding school is a type of school where students live separately from their families to receive education, and their educational needs and need for shelter and food are met by the state (Arı, 2003).

Data Collection Instruments

In the study; demographic information form regarding gender, preschool education (yes/no) and type of school variables (day/transportation center/boarding school) was prepared by getting expert opinion.

Topics and acquisitions discussed within the scope of geometry achievement test developed by the researchers of this study were selected as part of transformational geometry and geometric objects sub-learning domain addressing spatial abilities by considering middle school mathematics curriculum, particularly eighth-grades. Items to be included in the geometry achievement test were chosen from the items in the national exams covering the years 1998-2016 addressing to the acquisitions of geometric transformations and solids. The items were approved as convenient to students' level and valid in accordance with the opinions of three mathematics education specialists and four mathematics teachers since the items took part in the national exams. With the advice and arrangements, the test consisting of 48 multiple-choice type items became ready for the pilot study. In consideration of the data collected in the pilot study, geometry achievement test was examined statistically for item analysis and reliability. The internal consistency reliability value was calculated as (KR-20= .82); so the test was reliable. On the other hand, some of the items were determined as unsuitable with the frame of the values obtained from item analysis. Hence; 23 items were decided to be removed from the geometry achievement test, and the test took its final form with 25 items (KR-20= .79) to be applied in the research study (see Appendix for sample items). Also, table of specifications for the geometry achievement test was prepared for the content validity.

Another instrument to collect data is spatial ability practice test 1 developed by Newton and Bristoll (2011) in order to utilize in certain disciplines such as architecture, arts, design, mapping and particularly mathematics addressing spatial reasoning abilities.

Table 2. The classification of the items within the frame of spatial ability sub-skills.

Sub-skills	Related abilities	Item
Spatial Relations	2-D thinking abilities, reflection, translation and rotation in 2-D plane, moving the shapes in mind practically, rotation of the cube forms as a whole	I1,I2,I3,I4,I5,I6,I7,I8,I9,I10, I11,I12,I13,I14,I15,I16,I17,I18, I19,I20,I21,I22,I23,I24,I25,I26, I27,I28,I29,I30
Spatial Visualization	Tangram, rotating, manipulating, associating and moving the objects mentally in 2-D and 3-D with higher order and complex thinking skills, folding paper	I31,I32,I33,I34,I35,I36,I37,I38, I39,I40,I41,I42
Spatial Orientation	Comprehending the positional relationship of the model, map, navigation skills, direction finding, address description	I43,I44,I45

Spatial ability practice test includes 45 items (see Appendix for sample items); the first part of the test consisting of 25 items requires matching of the two dimensional shapes each other with respect to geometric transformations. As the rest of the test, 20 items comprise of multiple-choice type questions. Spatial ability practice test was examined by three specialists of mathematics education and four mathematics teachers for availability in the research study, and the items were evaluated as clear and convenient to the students' level. Considering the opinions, the test was adapted to Turkish by the researchers without changing its integrity and structure. The last version of the test was desired to be checked by domain expert, mathematics teacher, science of translation expert and English philology expert. In line with the views and offers, statements in the items were revised and the test was applied to 10 eighth-grade students out of the sample with different success levels for solving in order to determine the suitability, clarity and comprehensibility of the items. As a result of the procedure, the test was regarded as valid by the specialists. The final form of the test was approved for the reliability analysis; so internal consistency value was statistically calculated as (KR-20= .75), and the test was reliable.

Data Collection Procedure and Analysis

The scales taking their final forms about to be used in the research study were copied out sufficiently and clearly. By obtaining the necessary permissions, the scales were applied to 400 eighth-grade students by assigning 40 minutes for both geometry achievement test and spatial ability test in Göksun, Kahramanmaraş. The data and scores obtained from the scales were transferred to computer and analyzed with SPSS 17.0 packaged software program. Kolmogorov-Smirnov (One-Sample K-S) test was applied to analyze whether geometry achievement test and spatial ability test scores show normal distribution. The test scores, spatial ability test (KS-Z= 2.088, $p>.05$) and geometry achievement test (KS-Z= 2.076, $p>.05$) were determined as having normal distribution according to the result of the analysis, so the parametric tests including descriptive statistics, independent samples t-test, Pearson correlation coefficient, variance analysis (ANOVA) and Scheffe test were used for the analysis of the data (Büyüköztürk, 2002). Statistically significance level was considered as ($p<.05$) in line with the findings to comment on.

Findings

The goal of this research study is to determine the relationship between eighth-grade students' spatial abilities and their geometry achievements by considering the variables; gender, type of school and preschool education. According to the findings obtained from the data analysis, a total of 400 eighth-grade students were assessed on the spatial ability test and geometry achievement test and the descriptive statistics were given in the tables below.

Table 3. Descriptive statistics for the spatial ability test scores.

Gender	N	$\bar{x}$	SD	Min	Max
Female	184	30.85	5.27	2.00	42.00
Male	216	29.16	6.37	5.00	42.00
Total	400	29.94	5.94	2.00	42.00

The items in spatial ability practice test were graded as 1 for every correct answer and 0 for every wrong or unanswered ones. The mean scores of eight-grade students for spatial ability test was determined as 29.94 as seen in Table 3, so it can be stated that the average success level of eighth-grade students for spatial ability test is found 66% and medium.

Table 4. Descriptive statistics for geometry achievement test scores.

Gender	N	$\bar{x}$	SD	Min	Max
Female	184	15.03	4.40	5.00	25.00
Male	216	13.57	4.51	3.00	24.00
Total	400	14.24	4.51	3.00	25.00

The items in geometry achievement test were graded as 1 for every correct answer and 0 for every wrong or unanswered question. Also, the mean scores of eighth-grade students for geometry achievement test was determined as 14.24 as seen in Table 4, so it is stated that the success level of eighth-grade students for geometry achievement test is found 57% and medium.

To determine whether the findings about eighth-grade students' spatial ability test scores show statistically significant difference in regard to the gender and preschool education variables, independent samples t-test analysis was applied and the results were given in the tables below.

Table 5. Analysis of t-test for eighth-grade students' spatial ability scores x gender.

Scale	*Gender*	*N*	$\bar{x}$	*SD*	*df*	*t*	*p*
SpatialAbility Practice Test	*Female*	*184*	*30.85*	*5.27*	*398*	*2.854*	*.005*
	Male	*216*	*29.16*	*6.37*			

As shown in the Table 5; according to the findings of independent samples t-test, it was identified that there is statistically significant difference between female ($\bar{x}$ =30.85, SD=5.27) and male students ($\bar{x}$ =29.16, SD=6.37) in regard to their spatial ability test scores [t(398)=2.854, p<.01). Thus, it can be stated that eighth-grade students' spatial ability scores significantly differentiate in favor of girls.

Table 6. Analysis of t-test for students' spatial ability scores x preschool education.

Scale	*Preschool Education*	*N*	$\bar{x}$	*SD*	*df*	*t*	*p*
Spatial Ability Practice Test	*yes*	*209*	*30.61*	*5.86*	*398*	*2.372*	*.018*
	no	191	29.20	5.96			

Based upon the Table 6; independent sample's t-test was run to determine whether eighth-grade students' spatial ability scores show statistically significant difference with respect to preschool education, so eighth-grade students' spatial ability scores significantly differentiate between the ones received preschool education ($\bar{x}$ =30.61, SS=5.86) and the others ($\bar{x}$ =29.20, SS=5.96). Thus, it can be expressed that the students' spatial ability scores show significantly difference on the side of the ones received preschool education [t(398)= 2.372, p<.05].

To establish statistically whether eighth-grade students' spatial ability scores differentiate significantly in the context of type of school variable, ANOVA analysis was applied, and the results are shown in the tables below.

Table 7. ANOVA analysis for students' spatial ability scores x type of school.

Variable	*Source of Variance*	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Spatial Ability	*Between Groups*	*882.752*	*2*	*441.376*	*13.264*	*.000*
	Within Groups	*13210.925*	*397*	*33.277*		
	Total	*14093.678*	*399*			

As seen in the Table 7; it was put forward that eighth-grade students' spatial ability scores show statistically significant difference with respect to type of school variable as a result of ANOVA analysis [F(2-397)= 13.264, p<.01]. To establish the homogeneity of variances regarding the dependent variable of groups, Levene test was run (p>.05) (Büyüköztürk, 2002). Within the frame of this research study, variances of the scores regarding the dependent variable were determined homogeneous for spatial ability test [F(2-397)= .992, p>.05]. Additionally, the usage of appropriate multiple comparison tests (post-hoc test) is necessary to determine which groups are statistically differentiated depending upon the type of school variable. In case of equality of variances; if the sample size of the groups is different from each other, Scheffe test is utilized since it is one of the flexible multiple comparison tests and it can control the alpha error that may occur between groups (Kayri, 2009). Thus, Scheffe test was run to statistically investigate the difference between groups depending upon the type of school for eighth-grade students' spatial ability scores and the findings are given in the table below.

Table 8. Scheffe test analysis.

Variable	*(I) Type of School*	*(J) Type of School*	*Mean Difference (I-J)*	*Std. Error*	*p*
Spatial Ability	*Day School*	*Transportation Center School*	*2.92**	*.71*	*.000*
	Day School	*Boarding School*	*3.11**	*.76*	*.000*
	Transportation Center School	*Boarding School*	*.19*	*.89*	*.979*

** p<.05*

Based upon the Scheffe test analysis as seen in the Table 8; eighth-grade students taking education in day school ($\bar{x}$ =31.21, SD=5.33) are more successful than the ones taking education in transportation center school ($\bar{x}$ =28.29, SD=6.18) and the ones taking education in boarding school ($\bar{x}$ =28.10, SD=6.47). Also, the difference was determined as statistically significant (p<.05). It can be identified that students receiving education in day school have high spatial ability levels in comparison with the others. In addition to this, it was established that the difference between the spatial ability points of students taking education in transportation center school and boarding school was not statistically significant (p>.05).

In an attempt to specify the presence and the degree of correlation between eighth-grade students' spatial ability and their geometry achievement, Pearson correlation analysis was applied, and the findings were shown below.

Table 9. Pearson correlation analysis.

Scale		*Geometry Achievement Test*
Spatial Ability Test	*r*	*.630***
	p	*.000*

***p<.01*

Considering the Table 9, it was statistically determined that there is positively meaningful and moderate correlation between eighth-grade students' spatial abilities and their geometry achievements [r=.630, p<.01] according to Pearson correlation analysis. When determination coefficient (r^2=.3969) considered, 40% of total variances of spatial ability test values arise from the values of geometry achievement test.

Discussion

In this research study, the correlation between eighth-grade students' spatial abilities and their geometry achievements was investigated. Also, it was determined whether eighth-grade students' spatial ability scores statistically differentiate in regard to gender, preschool education and type of school variables.

As a result of the analysis of the data acquired from the sample, it was revealed that eighth-grade students' spatial ability level is medium. When the related studies were examined in the literature, Turğut and Yılmaz (2012) and Gül and Karataş (2015) indicated that the spatial ability level for the sample of their research study was lower than the finding obtained in this study. A possible reason for the discrepancy in the findings could arise from the characteristic of sample or the item styles of spatial ability practice test. The average student success level was determined as 80% for the matching section of spatial ability test; on the other hand, it was calculated as 49% for the section including multiple-choice type of questions of spatial ability test. Thus, it could be expressed that the items in the matching section of the test seemed to be easy to be answered by students correctly and the high success level contributed to the overall test. Similarly, eighth-grade students' geometry achievement level was established as medium according to the analysis of data in the present study, but the students' achievement could be improvable and be more satisfactory. On the other hand; there are some research studies revealing students' geometry achievement to be low and unsatisfactory results about their success level (Büyüköztürk, Çakan, Tan, and Atar, 2014; Polat, Gönen, Parlak, Yıldırım, and Özgürlük, 2016).

Another remarkable result acquired from analysis of the data in present study is that spatial abilities of eighth-grade students showed statistically significant difference on the side of female students. This finding is similar to the result of the scientific research done by Toptaş et al. (2012). On the other hand; overall, there is strong case that male students preponderate over females on spatial ability tests on an average (Hacıömeroğlu and Hacıömeroğlu, 2017; Kaufman, 2007; Postma et al., 2004; Voyer, Voyer, and Saint-Aubin, 2017; Yang and Chen, 2010; Yenilmez and Kakmaci, 2015). Some of the studies in the literature also revealed that there was no advantage depending upon gender on spatial ability tests (İrioğlu and Ertekin, 2012; Turğut and Yılmaz, 2012). In consideration of the research studies in the literature, it could be inferred that there is no generalizable result for spatial abilities based on gender variable. Certain studies investigating the gender factor on spatial abilities asserted that the difference about spatial ability or success between male and female students could be originating from biological or sociocultural factors consisting of genes, hormones, opportunities, material or toy preferences, early childhood experiences, artistic activities, environmental effects and educational activities (Carnoldi and Vecchi, 2003; Yılmaz, 2009).

The result revealing the advantage of taking preschool education on spatial ability in the current study was supported by the previous studies (İrioğlu and Ertekin, 2012; Turğut and Yılmaz, 2012) highlighting the significant difference favoring the students who received preschool education on spatial ability tests. This finding features the importance of taking preschool education in terms of early childhood experiences, concrete material usage, development of visuo-spatial abilities and learning environments promoting the capabilities such as reasoning and representation. Çilingir Altıner (2018) revealed that students who received preschool education obtained better and statistically significant results on the spatial ability, spatial visualization and puzzle tests. In addition, it was asserted in her study that developing students' spatial language use during preschool education by means of play and interaction enables them to improve geometrical and spatial thinking skills. On the other hand, it was determined in certain research studies that students' spatial ability scores did not significantly differentiate with respect to the variable of taking preschool education (Abay, Tertemiz, and Gökbulut, 2018; Yılmaz, 2017). This result canstem from the fact that, activities and studies planned to improve students' spatial ability are limited in preschool education program. Preschool teachers' preferences in choosing toys, equipmentor plays intended for development of spatial ability in educational setting can be considered as an important factor.

It was also determined based upon the analysis of the data that eighth-grade students' spatial ability scores significantly differentiated with respect to type of school variable, so the students taking education in day school outperformed in spatial ability test in comparison to the others. Also, there was no statistically significant difference between the students taking education in transportation center and boarding schools with respect to their spatial ability test scores. This finding is similar to the results of the researches in the literature (Chao and Liu, 2017; Guzel and Sener, 2009). As the result of the analysis in the current study, it was realized that the students in the boarding school underperformed on the spatial ability test. In general, the characteristic of the students taking education in boarding schools has been known as having low socio-economic status, and they have been receiving education away from home by meeting their own needs mostly (Arı, 2003). It could be stated that those students have been exposed to stimuli or experiences less than the others. In the research done by Verdine, Irwin, Golinkoff, and Hirsh-Pasek (2014), this result is supported and it was suggested that the students having low socio-economic status underperformed on the spatial ability test. It has been thought attaching importance to supporting the students' learning environments with activities, materials, tools and toys contributes to visuo-spatial intelligent and abilities. On the other hand, Kayhan (2005) and Ogunkola and Knight (2019) implied in the studies that there was no significant difference between students' spatial abilities and the type of school.It can be thought that various spatial ability tests used in the studies and the characteristics of the sample in terms of spatial thinking and reasoning may cause getting the different results. Besides, educational authorities can consider necessary actions in order to provide equality of opportunity among the school types, especially for transportation center and boarding schoolsin terms of spatial experiences students have.

When the results depending on the correlational analysis were examined, it was statistically determined that there is positively meaningful and moderate correlation between eighth-grade students' spatial abilities and their geometry achievements. This result shows similarity with numerous research studies related to spatial ability (Karaman and Toğrol, 2009; Kösa and Kalay, 2018; Panaoura, Gagatsis, and Lemonides, 2007; Pittalis, Mousoulides, and Christou, 2007; Turğut and Yılmaz, 2012; Ünlü and Ertekin, 2017) and the research studies assisted the finding in this research study. It could be said that as the spatial skills of the students increase, their geometry achievement levels will increase.

Conclusion

Research has shown positively significant and moderate relationship between eighth-grade students' spatial abilities and their geometry achievements. Also, in consideration of the findings obtained from the analysis of the data, it was revealed that with respect to the students' spatial abilities, statistically significant difference is determined in favor of female students, the students who received preschool education and the ones taking education in day school. The current study reflects the result obtained from eighth-grade students, so further research involving different grade level of students and types of schools are necessary to perform in order to reach more generalizable results. The present study also demonstrates the results obtained from a certain and restricted sample, so the issue could be discussed in large scaled sample chosen from different regions of the country. Spatial ability has been known as improvable ability, so there is a need for further examination into the effects of individual instructional strategies, tools, materials and technology-supported methods used by educators or teachers to improve the spatial ability of students. It is important to allow for experimental research studies to evaluate the effects of different factors and variables. Besides, researchers could apply different data collection instruments about spatial ability and geometry achievement and prefer various scientific research methods in further research studies. It is proposed that educational stakeholders, teachers, school administrators and policymakers should consider early childhood experiences, the importance of preschool education, usage of educatory materials, tools and games, enriching the learning environments and gender-related factors. Additionally, it is essential to raise awareness about spatial ability that it has distinctive place in mathematics education.

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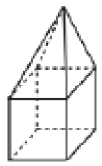
Appendix

Sample Items from the Geometry Achievement Test

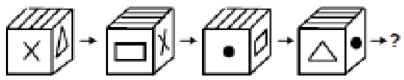
6.



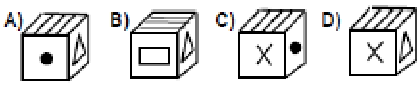
Yukarıda verilen çokyüzlü yapının yüz, köşe ve ayrıt sayıları sırasıyla aşağıdakilerden hangisidir?

A) 9 - 10 - 16 B) 9 - 9 - 20
C) 10 - 10 - 20 D) 9 - 9 - 16

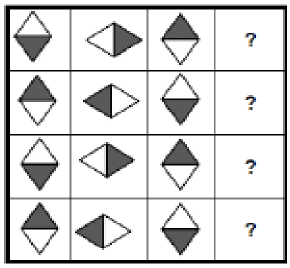
7.



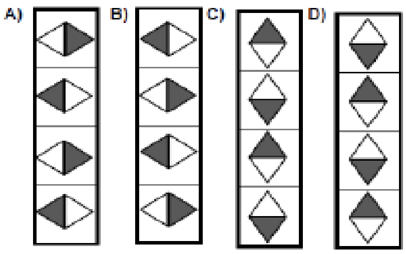
Yukarıdaki şekiller belli bir ilişkiye göre dizilmiştir. Buna göre, soru işaretinin yerine aşağıdakilerden hangisi gelmelidir?



9.

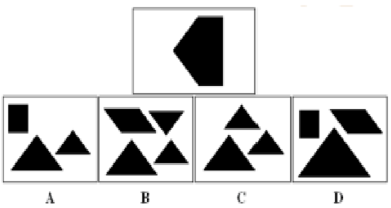


Yukarıdaki şekiller satır ve sütunlarda belli bir ilişkiye göre dizilmiştir.
Buna göre, soru işaretlerinin yerine aşağıdakilerden hangisi gelmelidir?

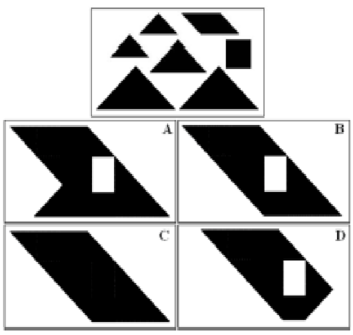


Sample Items from the Spatial Ability Practice Test

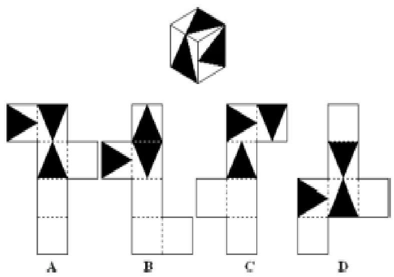
33. Üsteki şekli elde etmek için hangi şekil grubu birleştirilmeli?



34. Üsteki şekil grubunu birleştirdiğimizde hangi şekil elde edilir?



36. Verilen açılımlardan hangisi katlandığında üstteki küp elde edilir?



37. Verilen açılımlardan hangisi katlandığında üstteki küp elde edilir?