EFFECT OF USING DIFFERENT INSTRUCTIONAL METHODS TO TEACH GEOMETRY TOPICS ON FIFTH GRADE STUDENTS' SPATIAL ABILITY AND GEOMETRY ACHIEVEMENT

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ABSTRACT

EFFECT OF USING DIFFERENT INSTRUCTIONAL METHODS TO TEACH GEOMETRY TOPICS ON FIFTH GRADE STUDENTS' SPATIAL ABILITY AND GEOMETRY ACHIEVEMENT

The aim of this study is to investigate the effects of different instructional methods (technology-based, hands-on and blended instruction) to teach geometry topics on fifth grade students' spatial ability and geometry achievement. The study was conducted by using quasi-experimental pretest-posttest design. The participants of this study consisted of 57 fifth grade students from three classes in a private middle school in Istanbul. Each class received one of the following methods for twenty class hours: technology-based (n=20), hands-on (n=20) and blended (n=17) instruction. In technology-based instruction, students used various geometry applications from computers and computer tablets whereas students in hands-on instruction used concrete manipulatives. The blended instruction group used both technological and hands-on materials equally during the study. The Purdue Visualization of Rotations (ROT) Test and Differential Aptitude Test: Space Relations (DAT:SR) were used to evaluate students' spatial ability. In order to measure students' geometry achievement, Geometry Achievement Test (GAT) was developed by the researcher. The data collected from each pretest and posttest was analyzed by the nonparametric Kruskal-Wallis Test. The result of the ROT indicated a statistically significant difference in students' spatial ability among the groups. Three of the instructional methods improved students' spatial ability. However, technology-based instruction and blended instruction had significantly more effect when compared to hands-on instruction. Furthermore, students improved their geometry achievement significantly in each group after the treatment.

ÖZET

GEOMETRİ KONULARINI ÖĞRETMEDE FARKLI ÖĞRETİM YÖNTEMLERİNİN 5. SINIF ÖĞRENCİLERİNİN UZAMSAL YETENEKLERİ VE GEOMETRİ BAŞARISI ÜZERİNDEKİ ETKİSİ

Bu çalışmanın amacı, geometri konularını öğretmede farklı öğretim yöntemlerinin (teknoloji tabanlı, uygulamalı ve harmanlanmış öğretim) beşinci sınıf öğrencilerinin uzamsal yetenek ve geometri başarısı üzerindeki etkisini araştırmaktır. Çalışmada yarı deneysel ön test-son test deseni kullanılmıştır. Araştırmanın katılımcıları İstanbul'daki özel bir ortaokulda üç farklı sınıfta bulunan 57 beşinci sınıf öğrencisinden oluşmaktadır. Her sınıfa yirmi ders saati olmak üzere üç öğretim yönteminden biri uygulanmıştır: teknoloji-temelli ($n = 20$), uygulamalı ($n = 20$) ve harmanlanmış ($n = 17$) öğretim. Teknoloji tabanlı öğretimde öğrenciler bilgisayar ve tablet bilgisayarlardan çeşitli geometri uygulamalarını kullanırken, uygulamalı öğretimdeki öğrenciler somut manipülatifler kullanmışlardır. Harmanlanmış öğretim grubu, çalışma sırasında hem teknolojik hem de uygulamalı materyalleri eşit olarak kullanmıştır. Öğrencilerin uzamsal yeteneklerini ölçmek amacıyla Purdue Uzamsal Görselleştirme Testi (Görselleştirmeler) ve Diferansiyel Yetenek Testi: Uzay İlişkileri kullanılmıştır. Öğrencilerin geometri başarısını ölçmek için araştırmacı tarafından Geometri Başarı Testi geliştirilmiştir. Her gruptan toplanan ön test ve son test verileri parametrik olmayan Kruskal-Wallis testi ile analiz edilmiştir. Purdue Uzamsal Görselleştirme Testi sonucu öğrencilerin uzamsal yeteneklerinde gruplar arasında anlamlı bir fark olduğunu göstermiştir. Öğretim yöntemlerinin üçü de öğrencilerin uzamsal becerilerini geliştirmiştir. Ancak teknoloji tabanlı öğretim ve harmanlanmış öğretim, uygulamalı öğretim ile karşılaştırıldığında anlamlı ölçüde daha fazla etkiye sahiptir. Ayrıca, uygulamadan sonra her grupta bulunan öğrencilerin geometri başarısı anlamlı olarak artmıştır.

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LIST OF ACRONYMS/ABBREVIATIONS

DAT: SR	Differential Aptitude Test: Space Relations
GAT	Geometry Achievement Test
Gp-H	Hands-on Group
Gp-B	Blended Group
Gp-T	Technology-based Group
IEA	International Association for the Evaluation of Educational Achievement
MoNE	Ministry of National Education
NCTM	National Council of Teachers of Mathematics
OECD	Organization for Economic Co-operation and Development
PISA	Program for International Student Assessment
PreDAT	Differential Aptitude Pretest
PreGAT	Geometry Achievement Pretest
PreROT	Purdue Visualization of Rotations Pretest
PostDAT	Differential Aptitude Posttest
PostGAT	Geometry Achievement Posttest
PostROT	Purdue Visualization of Rotations Posttest
ROT	Purdue Visualization of Rotations Test
TIMSS	Trends in International Mathematics and Science Study

1. INTRODUCTION

Geometry is a significant and essential area of mathematics which helps us comprehend our environment. According to National Council of Teachers of Mathematics (2000), geometry is considered as a basic skill. Features and relationships of geometric shapes promotes to different areas of mathematics such as algebra and measurement. In addition, geometry has various areas of application such as; architecture, arts, engineering, design and navigation. Everyday situations such as moving objects in the house, estimating the space while parking the car or using the map of a city requires basic geometric and spatial abilities.

In middle school, the Ministry of National Education (MoNE) mathematics curriculum expects students to; define, draw, calculate the area and volume of basic geometrical shapes in respective grade levels (MoNE, 2018). The new curriculum offers various applications of geometry within the explanation of the objectives. However, most of the studies have indicated challenges in learning and teaching mathematics especially in geometry (Akuysal, 2007). Students usually have difficulties in visualizing the geometrical shapes, using geometrical reasoning and problem-solving skills (Battista, 1999; Idris, 2006). In this sense, using technology applications such as dynamic geometry softwares and hands-on activities such as drawing, folding, concrete manipulatives and geoboard exercises can be suggested. The results of both Trends in International Mathematics and Science Study (TIMSS, 2015) and the Program for International Student Assessment (PISA, 2015) demonstrated that Turkey has a poor performance in geometry and mathematics. Underachieved topics in TIMSS (2015) include geometric shape and measurements (IEA, 2016). Therefore, exploring spatial sense and geometric reasoning is important for understanding geometry.

Spatial ability can be regarded as a major component of geometry. Comprehending different aspects of our environment requires spatial abilities. Spatial ability is related to various fields such as; mathematics, technology, arts and design, science, engineering and geometry in particular. Olkun (2003) described spatial ability as "the mental manipulation of objects and their parts in 2D and 3D space" (p.8). Researches have shown that spatial abilities and geometry achievement have a positive correlation (Clements and Battista, 1992, Erbilgin, 2003; Unal, Jakubowski and Corey, 2009). Principles and Standards for School Mathematics offers spatial understanding, visualization and geometrical modelling as essentials for solving problems (NCTM, 2000). Significance of spatial ability is further pointed out in the elementary mathematics curriculum (MoNE, 2018). Furthermore, spatial ability underpins most of the questions in TIMSS and PISA (Yılmaz, 2009).

An important area to study is methods to improve students' geometry achievement. Geometry lessons may be an opportunity to mention spatial abilities which may lead to increase in geometry achievement (Arıcı and Tutak, 2015; Battista, 1990; Battista, Talsma and Wheatley, 1982). Lesson plans can be designed in accordance with developing students' spatial abilities. Spatial ability is claimed to be improved with various spatial trainings (Uttal et al. and Newcombe, 2013). Studies show that technological (Kaufmann, 2017; Kurtuluş and Uygan, 2010; Wolford and De Lisi, 2002) and concrete (hands-on) manipulatives (Arıcı and Tutak, 2015; Cheng and Mix, 2014; Mohler and Miller, 2009; Olkun, 2003) aids development in spatial abilities within school lessons. Furthermore, according to several studies, spatial activities may be used exchangeable (Alias, 2002; Sorby and Baartmans, 1996a; Kurtuluş and Yolcu, 2013; Olkun, 2003).

Considering the studies on improving spatial ability and geometry achievement with technological and concrete (hands-on) activities, more research studies are needed. The previous studies (Kaufmann, 2017; Kurtuluş and Uygan, 2010; Mohler and Miller, 2009; Olkun, 2003; Wolford and De Lisi, 2002) suggests using manipulatives such as origami, drawing and sketching activities, modeling and applications of dynamic computer softwares. The implementation process for these manipulatives mostly require extra lesson hours in addition to regular instruction. However, the present study may assist geometry instructors in implementing the existing curriculum by reconstructing the lesson plans according to an effective method of instruction. Therefore, the current study aimed to investigate the effects of different instructional methods for improving

5^{th} grade students' spatial ability and geometry achievement.

2. LITERATURE REVIEW

2.1. Geometry and Geometry Education

Geometry is one of the words that its meaning is best hidden inside. In the word of *geometry, geo* refers to the earth or land, and *metry*, to measure. The emergence of geometry has arisen from humankind's desire to recognize and locate themselves in earth. Geometry occupies an essential part of mathematics by providing an opportunity to interpret and interfere our environment. Geometry is the subject area of mathematics that takes the elements of points, lines, shapes and space into consideration. As a branch of mathematics, geometry studies the position of two-dimensional and three-dimensional figures besides their size and shape.

As a significant constituent of daily life application of mathematics, geometry is characterized as a basic skill and classifying geometric shapes and understanding its properties are remarked as a contributor for different fields of mathematics (algebra, rational numbers and calculation) and solving problems about real life (NCTM, 2000). Assuming the importance of learning geometry and its contributions to real life, geometry takes place in the school curriculum. The learning objectives in geometry mainly refer to students' ability to use geometry in, recognizing the environment, explaining and understanding the physical world and problem-solving process (Baki, 2001). Students' ability for imagining geometrical relations are expected to advance as they sort, build, draw, model, trace, measure and construct. In this sense, students are expected to; recognize, explain, classify and compare geometric shapes; develop a concept of space, investigate the transformations between the geometric shapes; recognize and explain three-dimensional objects and classify three-dimensional objects according to their properties (MoNE, 2018). The study of geometry in middle school requires thinking and doing. In the fifth-grade mathematics curriculum, students are expected to draw and design three-dimensional objects. The curriculum targets covering basic concepts such as, lines, line segments, and rays, two-dimensional forms such as triangles, quadrilaterals and polygons, and three-dimensional shapes such as rectangular prisms and cubes (MoNE, 2018).

According to NCTM (2000), children between kindergarten and twelfth class need to have the skill of defining spatial relations in the context of geometry. Studies have indicated that spatial ability is strongly connected with geometry, mathematics and science achievement (Clements and Battista, 1992; Wheatley & Reynolds, 1999). Furthermore, students' use of visual-spatial abilities in the process of solving geometry problems would affect the permanence of teaching (NCTM, 2000). However, students frequently have challenges in visualization, problem-solving skills and geometric reasoning (Battista, 1999; Idris, 2006).

The studies have indicated the difficulties in learning and teaching mathematics particularly in geometry (Akuysal, 2007). These difficulties might be due to disregarding geometric notions in favor of computational skills (Idris, 2006) such as; algebra, measurement, numbers and operations which might be an important reason for low achievement in geometry in middle school. According to the results of PISA (2015), students in Turkey do not have a good score in mathematical literacy (OECD, 2018). The scores revealed that Turkey ranked 50 out of 72 country in 2015 (OECD, 2018). The inferences driven from TIMSS (2015) showed that the performance of Turkey was also low in geometry. According to the results of TIMSS (2015), 4^{th} grade students' average score in geometric shape and measurement was 448 in 2011 and 475 in 2015. The average score of 8th grade students in geometry was 454 in 2011 and 463 in 2015 (IEA, 2016). Although the average score of both 4^{th} and 8^{th} grade constantly increased since 2011, they are still below the average.

Instructional methods play an important role in geometry education and achievement. Therefore, studies have investigated the effects of instructional methods on improving students' understanding of geometry (Bayram, 2004; Dimakos and Zaranis, 2010; Erbaş and Yenmez, 2011; Güven, 2012; Karakuş and Peker, 2013; Olkun, 2003). The reasons for low performance in geometry could be traditional instruction that consists of deductive teaching and due to focusing on test achievements which promotes memorizing.

Approaches which place students in center of learning and learning by experience should be considered in geometry instruction (Erdoğan, 2009). In this sense, instructional methods for geometry should be reconstructed as enabling the use of concrete and technological manipulatives and materials. In the study of Erbaş and Yenmez (2011), effect of using computer-based geometry application on students' geometry achievement in sixth grade was examined. The experimental group received computer aided instruction and control group received traditional instruction. They found that computer aided geometry instruction improved students understanding of geometry in the context of polygons. In addition, students in the experimental group became more interested in geometry lesson through the study. Similarly, Güven (2012) determined that using dynamic geometry software to teach geometry topics improved students' achievement academically. Dimakos and Zaranis (2010) investigated how computer-based explorations of geometry effect students' academic achievement in the subject area. They concluded that using such technological applications is crucial in order to develop students' geometry achievement.

On the other hand, activities to be used during the instruction should be consist of various hands-on implications such as folding paper, modelling and sketching according to Bishop (1986). Furthermore, students should be active while learning geometry topics which especially includes spatial concepts. The instruction should be designed to enable students to become interactive learners by measuring, drawing and manipulating the objects. The study of Bayram (2004) investigated the effect of teaching geometry by using concrete manipulatives on 8^{th} grade students' achievement in geometry. The researcher stated that there was an important development in academic success of students who received instruction by using concrete manipulatives in the context of geometry lesson. Olkun (2003) also claimed that concrete manipulatives improved 4^{th} grade students' achievement in two-dimensional geometry. Similarly, Karakuş and Peker (2013) found that pre-service teachers improved their geometric thinking level and spatial ability significantly after using physical manipulatives. Therefore, a greater emphasis should be given to geometry instruction.

In addition to geometry introduction, curriculum plays an important role in education and achievement of geometry. An emphasis is given on geometry in each grade level in the mathematics curriculum (MoNE, 2018). Geometric shapes and spatial relations take places in grade from 1 to 4 as sub learning areas of geometry. In middle school, geometric shapes are given in grade 5,6 and 8. Grade 7 includes shapes' views from different directions and grade 8 includes transformational geometry (MoNE, 2018). However, considering the modifications in the new teaching program (MoNE, 2018), a required level of importance was not given to implications of geometry and spatial ability as it was expected.

2.2. Spatial Ability

Although spatial ability is an area that researchers made a consensus due its importance, there is not a complete description for spatial ability. Linn and Petersen (1985) defined it as "a skill in representing, transforming, generating, and recalling symbolic, non-linguistic information" (p.1482). Olkun (2003), defined spatial ability as "the mental manipulation of objects and their parts in 2D and 3D space? (p.8). Newcombe (2013) stated that "spatial thinking concerns the locations of objects, their shapes, their relations to each other, and the paths they take as they move" (p.28). In the description of Lohman (1993), spatial ability is "the ability to generate, retain, retrieve, and transform well-structured visual images" (p.3).

Through the literature spatial ability has been divided into different sub-skills such as spatial visualization, spatial orientation, spatial relations, spatial perception and mental rotation (Clements, 1998; Contero, 2005; Lohman, 1979; Linn and Petersen, 1985; McGee, 2005). McGee (1979) stated that spatial ability has two of principal factors; spatial visualization and spatial orientation. Spatial visualization is defined as "the ability to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects" (p. 909). Spatial orientation is defined as "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations in which a spatial configuration may be presented, the ability to determine spatial orientation with respect to one's body" (p.

909).

Linn and Petersen (1985) defined spatial ability in three subcategories: spatial perception, spatial visualization and mental rotation. Spatial perception was defined as "the ability to determine spatial relationships with respect to the orientation of their own bodies, in spite of distracting information" (p.1482). The definition of spatial visualization included "complicated, multistep manipulations of spatially presented information" (p.1484). Mental rotation was defined as "the ability to rotate, in imagination, quickly and accurately two- or three-dimensional figures" (p. 1483).

After analyzing over 140 data sets, Carroll (1993) defined spatial ability under five major factors. These factors were spatial visualization, spatial relations, closure speed, flexibility of closure and perceptual speed. The factors defined by Carroll (1993) are shown in Figure 2.1.

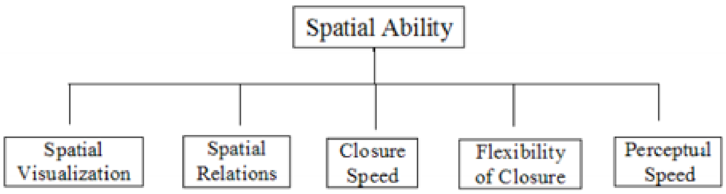


Figure 2.1. Major factors of spatial ability based on Carroll's (1993) analysis.

Maier (1996) also defined spatial ability as combination of five factors: spatial visualization, spatial relations, spatial perception, mental orientation and spatial rotation. In the meta-analytic study, according to Lohman (1979), spatial ability is separable in two main subfactors which are spatial relations and spatial visualization (Pellegrino, Alderton and Shute, 1984).

After the review of the related literature, it can be concluded that majority of the studies accepted spatial visualization and spatial relations as an essential part of spatial ability (Alderton, Pellegrino and Shute, 1984; Burnet and Lane, 1980; Clements and Battista, 1992; Clements, 1998; Contero, 2005; McGee, 1979; Olkun, 2003; Petersen, 1985). Among these different approaches, the classification of spatial ability by Marti'n-Dorta and Contero (2008), limited by the authors (Alderton, Pellegrino and Shute, 1984; Burnet and Lane, 1980; Clements and Battista, 1992; McGee, 1979; Olkun, 2003) was considered in this study. Therefore, main focus of current study is to measure the subcategories of spatial ability given as follows:

- Spatial Relations: the capability for envisioning rotations of 2D and 3D shapes as a complete mass (encompasses mental rotation and spatial perception).
- Spatial Visualization: the capability for envisioning rotations of shapes and their sections in 3-D spatial via folding and unfolding.

2.3. The Importance of Spatial Ability

Researches have shown that spatial ability is necessary for many areas such as mathematics, engineering, architecture, visual arts and design. According to Diezmann and Watters (2000), spatial ability is also valuable in careers such as aviation, engineering or technical drawing since interpreting spatial information is needed in these work areas. There is a wide range of academic works published that aim to prove the importance of spatial ability and its relevance to other disciplines such as mathematics (Hegarty and Kozhevnikov, 1999; Schmidt, 2001), geometry (Battista, 1990), science (Newcombe, 2010) and future career goals. With respect to the focused area and main objective of the study, literature review regarding the significance of spatial ability mainly consists of the works related to mathematics and geometry.

Development in visualizing two-dimensional and three-dimensional objects, as a component of spatial ability, is naturally provided through the middle school curriculum by the study of geometry (Boakes, 2009). Using visualization, spatial reasoning and geometric modeling to solve problems are given as a standard within geometry in the Principles and Standards for School Mathematics (NCTM, 2000). Moreover, NCTM (2010) suggested to include spatial reasoning into the elementary curriculum (Cheng and Mix, 2014). Elementary mathematics curriculum (MoNE, 2018) in Turkey also outlines the importance of spatial thinking under mathematical competence. Furthermore, spatial ability forms a basis for many questions asked in TIMSS and PISA (Yılmaz, 2009).

In order to investigate the significance of spatial visualization and cognitive development for geometry learning, Battista, Talsma and Wheatley (1982) observed 82 preservice teachers enrolled in the geometry course. One of the questions posed in the study focused on the improvement of spatial ability with the given geometry instruction. Results revealed that, at the end of the semester, the students who attended geometry class have significantly higher spatial visualization scores than the beginning of the semester as evaluated by the Purdue Spatial Visualization Test. Unal, Jakubowski and Corey (2009) conducted a study to investigate presser vice mathematics teachers' geometric understanding with respect to their spatial ability. The results revealed that participants who have poor spatial ability are also low geometry achievers. In addition, students van Hiele levels varied in each spatial ability level (low, mid, high) after the treatment. However, participants determined as mid-range in spatial ability demonstrated the the maximum increase.

Supporting the same view, spatial ability is straightly in relation with accomplishment in geometry, problem solving, and mathematics in general (Guay and McDaniel, 1977; Battista, 1982, 1990; Moses, 1980; Fennema and Sherman, 1977). In 1964, Smith found that spatial ability has a positive correlation with high-profile mathematical conceptualization. As he stated, people that have greater spatial ability are also more able to deal with high-level mathematical questions compared to people who have lower spatial ability. Guay and McDaniel (1977) researched about the connection between elementary school mathematics success and spatial ability. As a result, significant positive correlations observed. According to the findings, elementary school children with high mathematics achievement have greater spatial ability than the students with low mathematics achievement.

Fennema and Sherman (1977) investigated mathematics achievement of 9th-12th grade students enrolled in mathematics courses from four schools. The study indicated that spatial visualization was strongly in a positive relation with mathematics success considerably as correlated as verbal ability. The results additionally showed that there was a coherence between the significance of spatial visualization and mathematics learning in general (Fennema, 1975; Sherman, 1967).

The longitudinal study performed by Fennema and Tartre (1985), investigated how boys and girls used spatial visualization abilities in fraction problems and word problems. These students differed in their spatial ability and verbal skill performances and they were interviewed each year from grade 6 to grade 8. The study indicated that, in the comparison of students' usage of spatial abilities, students who have better spatial visualization abilities tend to apply their spatial abilities in problem-solving process.

Another research to investigate the importance of spatial ability and problem-solving abilities related to mathematics was conducted by Alias, Black and Gray (2003). The study aimed to investigate the effect of activities based on spatial visualization on engineering students' problem-solving abilities. They found that spatial visualization ability improves problem solving because it supported the understanding of structural behavior.

A research conducted by Booth and Thomas (1999), investigated the mathematical problem-solving skills of students who differed with respect to visuo-spatial abilities. The students were divided into two groups and there was no difference between their mathematical achievement. However, one of the groups were better in visuo-spatial abilities. During the study, participants were given arithmetic word problems in various representations. These representations were verbally, with a diagram and with an image. Findings of the study indicated that students with stronger visuo-spatial ability also had a higher performance on the given problems compared to the students with weaker spatial ability.

Kayhan (2005) investigated if spatial ability logical thinking skills and succeeding in mathematics have a relevance in her research. Research was implemented with 251 ninth grade students in three different high schools. Results show that spatial ability have significant positive relationships with mathematics achievement and logical thinking ability.

A case study conducted by Erbilgin (2003), focused on how 8^{th} grade students' spatial visualization and achievement effects their multiple representations usage in the case of linear equations and function problems. Students were purposefully chosen with respect to their degree of achievement and spatial ability. The results showed that students with stronger spatial ability performed higher in finding patterns, linear equations and representations. Therefore, spatial ability of visualization and achievement have influence on students' use of multiple representations.

2.4. The Improvement of Spatial Ability

Due to its strongly positive correlation with mathematics, technology, science and engineering, improving spatial ability have theoretical and practical importance. In this sense, researchers have done various studies to improve spatial ability. The meta-analysis of Uttal and Newcombe (2013) has been a significant evidence for improving spatial ability. Researchers analyzed 206 spatial training studies over a 25-year period and concluded that people of different ages demonstrated development in spatial abilities by various spatial trainings; video games, spatial task and course.

Considering the approaches to best enhance spatial ability, using different types of spatial activities are suggested (Alias, 2002; Sorby and Baartmans, 1996a; Olkun, 2003). As Bishop (1973) and Sundberg (1994) mentioned, providing concrete manipulatives during instructing enhances middle school students' spatial ability. Moreover, both computer and concrete manipulatives can be used to learn certain geometry topics in primary mathematics classroom (Olkun, 2003). Therefore, majority of the approaches in this part include improving spatial ability with technological and concrete manipulatives.

2.4.1. Improving Spatial Ability with Technological Manipulatives

A study conducted by Kurtuluş and Uygan (2010) investigated the effects of geometry activities and projects prepared with a 3D dynamic sketching software on preservice mathematics instructors' spatial visualization skills. Google SketchUp which is generally a helpful tool to create 3D building models was used for this purpose and implemented to geometry lesson. Research was a quasi-experimental design with pre-and posttest including a control group. According to the results, development in spatial abilities differed significantly. Therefore, Google SketchUp may be a useful tool to develop spatial ability.

In the quasi-experimental study by Ayub, Saha and Tarmizi (2010), with a nonequivalent control group posttest only design, examined the effects of using GeoGebra to learn coordinate geometry. Students were categorized according to their level of spatial ability. The research demonstrated that, students who were better in spatial abilities showed a higher improvement in Geogebra instruction and traditional instruction compared to students who had poor spatial ability. Therefore, it was stated that GeoGebra fosters students' performance in learning Coordinate Geometry.

In the qualitative study of Kaufmann (2017), Construct3D as geometric tool is used to develop spatial abilities. The results of the study revealed that Construct3D is user-friendly, promotes the practice of geometric structures and develops spatial ability. Similarly, Güven and Kosa (2008) determined how three-dimensional computer-supported activities created with Dynamic Geometry Software, Cabri 3D effects preservice mathematics teachers' spatial ability. Purdue Spatial Visualization test was implemented to 40 participants and activities with Cabri 3D software was implemented for 8 weeks. The findings of the study showed that there was a significant difference between students' pretests and posttests. Therefore, computer supported activities were stated to provide development in participants' spatial abilities.

Wolford and De Lisi (2002) examined the development of spatial ability by investigating the relation between mental rotation and computer game-playing. Forty-seven children from third grade participated 11 different computer game performance and completed a two-dimensional pre- and post-tests of Mental Rotation. Results showed that, the students in the experimental group performed significantly higher than the students in the control group on the post-test, but not on the pre-test. In addition, children who played computer games improved their mental rotation abilities. The findings suggested that activities which are designed based on computer might be helpful in developing students' spatial ability (Wolford and De Lisi, 2002).

An experimental research carried out by Çelik, Karaca and Toptaş (2012), investigated the effect of three-dimensional modeling application on 8^{th} grade students' spatial ability. Study was conducted with 82 students. During the six weeks, the experimental group (n=42) had computer-based instruction whereas the control group (n=40) had traditional instruction without a computer experience. The participants responded differential aptitude, mental rotation and spatial visualization tests before and after treatment. The findings revealed a difference between the pre- and post-tests which was significant. In addition, the modeling program influenced students' spatial progression positively and it may improve spatial ability (Çelik, Karaca and Toptaş, 2012).

The study conducted by Rafi (2005) investigated whether a group of pre-service teachers improved their spatial abilities using Web-based Virtual Environments (WbVE). 98 pre-service teachers who initially experienced a course of Computer Aided-Design (CAD) attended the research. The participants were administered tests about mental rotation and spatial visualization before and after a five-week spatial training. At the end of the instructional treatment with WbVE, findings revealed a significant difference in pre-service teachers' final test scores. In addition, WbVE was more powerful in learning compared to the traditional classroom practices. In addition, findings also indicate that experiencing 3D virtual objects have a considerable aid to comprehend spatial shapes.

2.4.2. Improving Spatial Ability with Concrete Manipulatives

Cheng and Mix (2014) examined a study about spatial ability and mathematics achievement. They investigated the development in math performance due to mental rotation training in children aged between 6 and 8. Fifty-eight children were administered two spatial tests and one math test before and after the 40-minute training. Children practiced mental rotation in the spatial training session which included object completion task. The study showed that even a short amount of spatial training could improve children's math performance, significantly on calculation problems (Cheng and Mix, 2014).

Olkun (2003), aimed to provide engineering drawing applications in order to improve middle school students' spatial abilities. One reason for choosing engineering applications was because it has practical implications in real life. Secondly, concrete experience with geometrical objects and freehand sketching were proved to improve students' spatial visualization abilities. The conclusion of the research indicated the significance of spatial ability and improvement could be possible with engineering drawing activities (Olkun, 2003).

Mohler and Miller (2009) investigated the effectiveness of mentored sketching for improving engineering students' sketching and spatial abilities. Researchers claimed that freehand sketch is one of the main approaches for advancing technical sketching and visualization abilities. As a result of the study, mentored sketching emerged as an important approach for enhancing sketching skills and spatial ability.

Similarly, Alias, Black and Gray (2002) conducted a pre- and post-test quasi-experimental design to examine how activities based on manipulating and sketching effect visualization skills of engineering students. Participants in the treatment group manipulated objects and studied sketching by observing and imaging in structural design class. Meanwhile, the participants in the control group continued their regular structural design class. The treatment group performed statistically higher than the control group. It was stated that concrete and practical such like spatial activities improve students' spatial ability (Alias, 2002).

Another study investigated how geometry instruction based on origami effected tenth-grade students' geometry performance, geometric thinking and spatial visualization (Arıcı and Tutak, 2015). Study was a pre- and post-test quasi-experimental design where control group received traditional instruction and experimental group received origami-based instruction for 4 weeks. Students' spatial visualization ability was measured with spatial ability tests and geometry performance was measured with a geometry achievement test developed by the researcher. According to the Spatial Visualization test, significant difference between students' spatial ability was detected in favor of the experimental group. Similarly, experimental group performed significantly higher in geometry achievement and geometry reasoning post-tests.

In a blended method research design, Kurtuluş and Yolcu (2013) aimed to improve sixth-grade Turkish students' spatial visualization ability. The implication consists of concrete manipulatives, computer practicing and paper representations. In order to assess the achievement in spatial ability, researchers designed Block of Cubes Test according to the Turkish primary education mathematics curriculum regarding; visualizing different view images of 3D forms made from unit cubes, interpreting two dimensional pictorial representations of 3D shapes and finding faces of the cube. In addition, clinical interviews were done to understand students' mistakes concerning spatial reasoning while solving problems. According to the findings emerged from the data collected through pre-and post-test, students improved their spatial ability and understood three-dimensional structures more easily with the approaches used in the study. (Kurtuluş and Yolcu, 2013).

In the study of Baki, Kosa and Güven (2011) about spatial ability, technological and concrete manipulatives were compared. Authors investigated the effects of geometry program on computer and concrete manipulatives on pre-service math teachers' skills of spatial visualization. One of the experimental groups received an instruction with Dynamic Geometry Software (DSG) while the other group used concrete manipulatives. The students in the control group received traditional instruction. All three treatment groups were administered the Purdue Spatial Visualization Test for a pre- and post-test. According to the results of the study, effect of concrete manipulatives and DSG-based types of instruction on improving spatial visualization skills were significant compared to the traditional instruction. Moreover, the group who received geometry software instruction showed a higher improvement compared to the group who used concrete manipulative in the views section of the Purdue Spatial Visualization Test.

There are also studies that investigated the effectiveness of both concrete and technological manipulatives on improving spatial ability in the literature (Furner and Marinas, 2006; Olkun, 2003; Yurt and Sümbül, 2012). Yurt and Sümbül (2012) investigated spatial ability and mental rotation skills by examining concrete objects and modeling based activities using virtual environments. The research was designed as a pretest and posttest experimental design on eighty-seven 6th grade students. The duration of the experiment was 9 weeks and several different models were developed to be used. Experimental Group 1 used to link cubes as concrete manipulatives and Experimental Group 2 used Cubix Editor for virtual environment. According to the results of the study, improvement in spatial thinking skills of Experimental Group 1 was significantly higher than Experimental Group 2 and the Control group. However, mental rotation skills improved significantly higher in Experimental Group 2 compared to the rest of the groups. Therefore, the researchers suggested that it was better to use both virtual environments and concrete manipulatives for improving spatial abilities (Yurt and Sümbül, 2012).

Another study conducted by Olkun (2003), compared computer and concrete objects to learn 2D geometry. Ninety-three students from 4^{th} and 5^{th} grade participated in the pretest, treatment and posttest experimental design study. In order for students to discover the relationship between 2D geometric figures, Tangram activity designed by the researcher was used. During the treatment, one of the three groups worked with Tangrams based on computer whereas the other group worked with Tangrams made from wood. Control group did not have an intervention. According to the results of the study, computer and concrete groups had significant improvement in their spatial abilities. However, students who received computer instruction improved relatively more than the students who received concrete instruction. In addition, fourth graders took more advantage of the concrete materials whereas fifth graders gained more from the computer manipulatives.

Furner and Marinas (2006), used a sketching program for teaching geometrical notions to elementary students. The researchers developed resources involving hands-on and technological applications that are easy to use. During the study, elementary students were more active in learning while using geometry software and they also took advantage of hands-on manipulatives for configuring their geometrical thinking. It can be said that, sketching software can be helpful for young children to transform their concrete understanding of mathematics to more abstract ideas.

3. SIGNIFICANCE OF THE STUDY

Geometry is an important necessity of understanding mathematics and our environment. However, it is well known that students have difficulties in understanding and interpreting geometry. Studies have indicated the importance of spatial ability and its positive relevance to mathematics and geometry (Battista, 1982 & 1990; Guay and McDaniel, 1977; Fennema and Sherman, 1977; Mix and Cheng, 2012; Moses, 1980; Schmidt, 2002). Therefore, the improvement in spatial ability becomes an important part of geometry achievement.

Due to the strong relationship between geometry and spatial ability, various in-class activities needed to be designed to develop these abilities of students (Clements and Battista, 1992). The activities used in the study are designed to meet the needs of three of the instruction groups and according to the objectives in the 5^{th} grade mathematics curriculum. The study consists of three different instructional methods (technology-based, hands-on and blended instruction) to teach geometry topics. Therefore, it is aimed to investigate the effect of using technological, hands-on and both type of manipulatives on students' spatial ability and geometry achievement.

4. STATEMENT OF THE PROBLEM

The present study questions the effect of using different instructional methods (technology-based instruction, hands-on instruction and blended instruction) to teach geometry topics on fifth grade students' spatial ability and geometry achievement.

4.1. Variables and Operational Definitions

4.1.1. Variables

The independent variable of this study is the method of instruction. The dependent variables of the study are students' spatial ability and geometry achievement.

4.1.2. Operational Definitions

The following operational definitions should be clarified in order to understand the research questions of the study:

Technology-based Instruction: Technology-based instruction refers to the set of geometry lessons which desktop and tablet computers are used to teach geometry concepts. The fifth-grade geometry topics include polygons, quadrilaterals, triangles and rectangular prisms.

Hands-on Instruction: The hands-on instruction in this study refers to the set of geometry lessons which concrete materials are used to teach geometry concepts. Polygons, quadrilaterals, triangles and rectangular prisms are included as the fifth-grade geometry topics.

Blended Instruction: The blended instruction in this study refers to an equal combination of the technology-based and hands-on instruction. Computers, tablet computers and concrete materials are used during the blended instruction. The same topics *with previous two instructions were covered in this method.*

Spatial Ability: Spatial ability was investigated under two sub skills according to the definition of Marti'n-Dorta, Saori'n, and Contero (2008) where they defined spatial ability as;

(i) *Spatial Relations: the capability for envisioning rotations of 2D and 3D shapes as a complete mass (encompasses mental rotation and spatial perception).*
(ii) *Spatial Visualization: the capability for envisioning rotations of shapes and their sections in 3-D spatial via folding and unfolding.*

Geometry Achievement: In the present study, geometry achievement score of a student referred to the score obtained from the Geometry Achievement Test (GAT) on angles, polygons, quadrilaterals, triangles and rectangular prisms which was prepared by the researcher.

4.2. Research Questions

The following research questions were investigated in this study:

(i) Is there any significant difference in spatial ability between fifth-grade students who participate in technology-based instruction, students who participate in hands-on instruction and students who participate in blended instruction as measured by,

- Purdue Visualization of Rotations (ROT) test?
- Differential Aptitude Test: Space Relations (DAT:SR)?

(ii) Is there any significant difference in geometry achievement concerning 5^{th} grade geometry topics measured by Geometry Achievement Test (GAT), between fifth-grade students who participate in technology-based instruction, students who participate in hands-on instruction and students who participate in blended instruction.

4.3. Statements of the Research Hypotheses

This study hypothesized that there would be significant differences in terms of spatial ability and geometry achievement concerning polygons, quadrilaterals, triangles and rectangular prisms among the groups of fifth-grade students who received technology-based instruction, hands-on instruction and blended instruction. Specifically, the hypotheses are given for the corresponding research questions as the following:

- There is a significant difference in spatial ability measured by the Purdue Visualization of Rotations (ROT) test between fifth-grade students who participate in technology-based instruction, students who participate in hands-on instruction and students who participate in blended instruction.
- There is a significant difference in spatial ability measured by the Differential Aptitude Test: Space Relations (DAT:SR) between fifth-grade students who participate in technology-based instruction, students who participate in hands-on instruction and students who participate in blended instruction.
- There is a significant difference in geometry achievement concerning 5^{th} grade geometry topics measured by Geometry Achievement Test (GAT) between fifth-grade students who participate in technology-based instruction, students who participate in hands-on instruction and students who participate in blended instruction.

5. METHODOLOGY

5.1. Design

In the study, pretest-treatment-posttest quasi experimental design was used. Three classes attended the study. First group got instruction with technology-based activities, whereas the second group with hands-on activities and the third group with blended activities which was an equal distribution of the technological and hands-on activities. The study was implemented in seven weeks including the administration of pretests and posttests. All the groups received twenty hours of instruction in total. The weekly hours of instruction were four hours. However, sometimes it varied among three groups due to unscheduled events in the school. The researcher recovered any unscheduled lesson loss during the implementation of the study. A lesson hour accounts for 40 minutes. The procedure of the research is described in Table 5.1.

Table 5.1. Research design of the study.

Pre-Treatment Measuring Instruments	**Treatment**	**After Treatment Measuring Instruments**
The Purdue Spatial Visualization Test: Rotations (ROT)	Hands-on instruction with Group 1 Technology-based instruction with Group 2 Blended instruction with Group 3	The Purdue Spatial Visualization Test: Rotations (ROT)
Differential Aptitude Test: Space Relations (DAT:SR)		Differential Aptitude Test: Space Relations (DAT:SR)
Geometry Achievement Pretest (PreGAT)		Geometry Achievement Posttest (PostGAT)

5.2. Participants

The student sample for this investigation was drawn from the fifth-grade population of a private middle school in Ümraniye town of Istanbul city, in Turkey. The sample of the study consisted of 57 students. Table 5.1 illustrates the demographic profile of the sample.

The students were generally similar on their socioeconomic backgrounds. Most of the parents were white-collar workers and had an education at the university level. They had a high level of income because the annual tuition of the school was above the average compared to the other private schools in Istanbul.

The school provides computers, tablet computers and various technological devices as well as course-related concrete materials, as educational equipments for all courses. In this sense, school have several computer laboratories and a mathematics room designed with concrete mathematics and geometry materials. Therefore, students were familiar with using technology and hands-on manipulatives during mathematics lessons as well as in other courses.

In total, there were six classes at the fifth-grade level however, three of them were chosen as the sample. The researcher was also the instructor of the mathematics classes. The three 5^{th} grade classes were administered to the instructor at beginning of the school year. Students were placed in the classes by the school administration according to their choice of secondary language lesson. In addition, students' academic success and behavioral orientation to school were also considered during the distribution of the classes in order to create homogenous groups. The instructional methods were randomly assigned to the classes as technology-based, hands-on and blended instruction.

Table 5.2. Demographic characteristics of the sample.

Groups	Females	Males	Total
Group 1	8	12	20
Group 2	8	12	20
Group 3	7	10	17
Total	23	34	57

5.3. Instruments

5.3.1. The Purdue Spatial Visualization Test: Rotations (ROT)

Guay (1977) generated a test named as "The Purdue Spatial Visualization Test: Rotations (ROT)" that evaluates how well the attendants are able to imagine rotational changes of three-dimensional objects (see Appendix A). The test was employed to evaluate imagination capability of examinees in this study. The test initially starts with a sample question describing the steps necessary to solve the questions. The directions simply explain participants the way object at the first row for the problem was rotated and imagine how the object in the problem seems like after rotated completely in an identical way. Thereafter, participants are asked to select the right drawing for the shape out of five given alternatives. This part of the test was explained by the researcher to the students in the beginning of the lesson considering their age level. The 20-item version of the test was used by the researcher. Item 2 from 20-item ROT test is shown in Figure 5.1. The duration of the test was 40 minutes and graded with the key generated by the author.

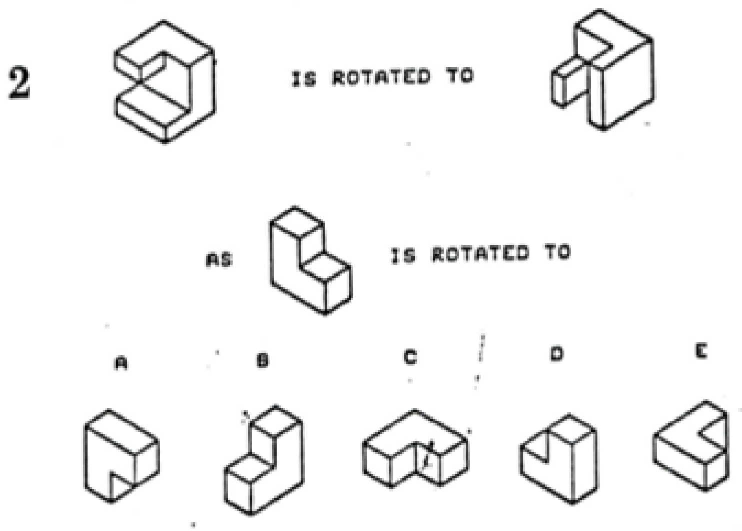


Figure 5.1. A sample Question from The Purdue Spatial Visualization Test: Rotations (ROT).

5.3.2. Differential Aptitude Test: Space Relations (DAT:SR)

The Differential Aptitude Test: Space Relations (DAT:SR) is generated to evaluate the skills for envisioning a three-dimensional object that refers to a two-dimensional pattern (see Appendix A). It measures the ability of an individual to accurately imagine the given two-dimensional pattern in three-dimensional space. Despite essentially including 60-items, only first 20 items were implemented by the researcher. The test is consisted up of 20 patterns that are able to be folded into shapes. There are four figures given at the right-hand side of all patterns. The participants are asked to choose the right figure that may possibly be reached via the given pattern. The test starts with two example questions including their reasonings for the correct answers. Although all four of the figures may have the right form, just one of them is possible to be reached from the given pattern. The duration of the test was 40 minutes and graded with the key generated by the author. Item 9 from the DAT:SR is shown in Figure 5.2.

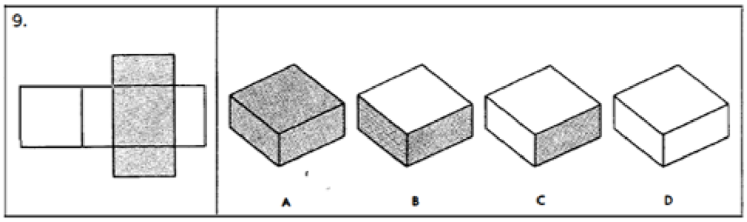


Figure 5.2. A sample Question from The Differential Aptitude Test: Space Relations (DAT:SR).

5.3.3. Geometry Achievement Test (GAT)

The Geometry Achievement Test (GAT) was employed for gathering data on geometry achievement about polygons, quadrilaterals, triangles and rectangular prisms of fifth grade students (see Appendix B). For content validity, the questions were prepared according to the advices of experts in mathematics education and covered objectives determined from the fifth-grade mathematics curriculum of the 2017-2018 school period. The objectives are mainly about the elements; angles, and perimeter of triangles and quadrilaterals, area of rectangle, elements and surface area of rectangular prisms. Similar questions parallel to the objectives of GAT were used as pretest and posttest. PreGAT (Geometry Achievement Pretest) and PostGAT (Geometry Achievement Posttest) involves 14 items. Some items include two or three sub-questions. The GAT consists of mostly open-ended questions where explanations, calculations and drawings were required. However, one of the sub-questions of the two items are multiple choice. In addition to the objectives covered during the treatment, the objectives M.5.2.1.4. and M.5.2.1.4. were included in the GAT. These objectives were added by the researcher due to their strong relation with the content. Objectives covered in the GAT are shown in Table 5.3. The GAT was developed and piloted by the researcher. The pilot study was implemented in one of the fifth-grade classes that did not involve in the study with the permission of that classes' mathematics teacher. After the pilot study, the duration for GAT was determined as 50 minutes and students' misunderstandings during the exam were noted by researcher. Important parts of the questions were rewritten in bold and extra space was given for the questions 5, 10 and 14.

A rubric was prepared by the researcher and approved by an expert in mathematics education (see Appendix B for the rubrics of the tests). The score of each item differs in terms of its content. First the steps to solve each question were determined, and then the points were assigned accordingly. The minimum point for any correct answer was determined as 1 to prevent scores with decimals. The possible maximum score for preGAT was 85 and for postGAT it was 90. In order to make comparison between the scores of preGAT and postGAT, the results of the both tests were recalculated as out of 100 points.

Table 5.3. Objectives covered in the Geometry Achievement Test (GAT)

Objectives
M.5.2.1.4. Constructs acute, right and obtuse angles based on an angle of 90°.
M.5.2.1.6. Constructs line segments that are parallel to a given line segment , interprets whether the drawn line segments are parallel or not.
M.5.2.2.1. Names polygons, constructs and introduces its basic elements.
M.5.2.2.2. Constructs and classifies triangles according to their angles and sides.
M.5.2.2.3. Defines and draws basic elements of a rectangle, parallelogram, rhombus and trapezoid.
M.5.2.2.4. Defines interior angles of a triangle and quadrilateral and finds the missing angle.
M.5.2.3.2. Calculates perimeter of triangles and quadrilaterals, constructs different shapes with given perimeters.
M.5.2.4.1. Calculates area of the rectangle by using centimeter square and meter square.
M.5.2.4.2. Estimates a given area by using centimeter square and meter square.
M.5.2.4.3. Constructs different rectangles with a given area.
M.5.2.4.4. Solves problems that require calculating the area of a rectangle.
M.5.2.5.1. Introduces rectangular prism and determines its basic elements.
M.5.2.5.2. Draws net of rectangular prisms and decides if a given net belongs to a rectangular prism.
M.5.2.5.3. Solves problems that require calculating the surface area of the rectangular prism.

5.4. Procedure

The study was conducted in seven weeks including pretest and posttest periods. Before the treatment, all participants received pretests. Initially, spatial visualization tests (DAT:SR, ROT) were administered. Then, GAT was administered respectively. Participants were informed about directions and purpose of the tests. The researcher explained that information gathered would remain confidential. Students were informed as the gathered data will be beneficial for educational studies in the future in mathematics, yet the test scores will not affect their school grades. The time schedule for the study is presented in Figure 5.3.

Table 5.4. Time schedule for the study.

Time	**Administration**
16 - 20 April 2018	Administration of Pretests
23 - 27 April 2018	Instruction on elements of polygons, classification and constructing triangles according to their side and angles
30 April - 4 May-18	Instruction on elements of quadrilaterals, drawing quadrilaterals, sum of interior angles of triangles and quadrilaterals
7-Nov May-18	Instruction on finding the perimeter of triangles and quadrilaterals as well as constructing these shapes with a specified perimeter, area of a rectangle and estimating a specified rectangular area
14 - 18 May-18	Instruction on constructing different rectangles with a given area, solving area of rectangle problems and elements of rectangular prisms
21 - 25 May-18	Instruction on drawing the nets of rectangular prisms as well as determining the closed shapes of given nets, solving area of rectangular prism problems
28 May ? 1 June	Administration of Posttests

The treatment began after the pretests were completed. The researcher instructed one class with technology-based activities, one class with hands-on activities and one class with blended activities. All groups used their mathematics booklets and mathematics books in addition to their activities to make sure that each class follows the 5^{th} grade mathematics curriculum and the time table determined by the mathematics teachers in the school. In order to be consistent with the mathematics curriculum

(MoNE, 2018), the objectives of the fifth-grade mathematics curriculum were taken into consideration in designing the instructions in all three groups. The technology-based instruction group used the computers in the laboratory and their tablet computers during the treatment. The hands-on group used geoboards, unit cubes, solid rectangular prisms, concrete 2D polygons and other materials needed during the treatment such as ruler, scissors, dice, squared and dot paper.

The treatment lasted seven weeks. All the groups received instruction with their own type of activities for twenty hours in total. However, blended group received ten hours of technology-based and ten hours of hands-on instruction. The activities were blended in the sequence of one technology-based and one hands-on. In addition, when there were more than one similar type of activity, the blended instruction done one type of each. For instance, the treatment includes four different geoboard activity, therefore blended instruction group used two hours of concrete and two hours of online geoboards. After completing the lessons, posttest data were collected by administering postGAT and re-administering spatial ability tests (DAT:SR, ROT).

5.5. Treatment

Twelve objectives were covered during the treatment. Each group received four lesson hours of weekly instruction for five weeks. The activities were prepared based on alignment with the objectives of fifth grade mathematics curriculum for all the groups. The topics that must be covered in the chosen time interval according to MoNE were integrated with the activities. Objectives covered in each week are shown in Table 5.5. During the study, no additional teaching was done other than the objectives of MoNE, however, the manipulatives were differentiated according to the type of instruction among the groups. As a part of the study, the researcher prepared online and hard-copy versions of the worksheets for technology-based and hands-on instruction.

Students in the hands-on instruction group used manipulatives such as, concrete 2D geometric shapes, sticks (toothpick, straw), geoboards, unit squares, unit cubes, concrete prisms and tools such as dice, ruler and scissors. Students used geoboards to,

Table 5.5. Objectives covered in each week.

Week	Objectives
1	**M.5.2.2.1.** Names polygons, constructs and introduces its basic elements. **M.5.2.2.2.** Constructs and classifies triangles according to their angles and sides.
2	**M.5.2.2.3.** Defines and draws the basic elements of rectangle, parallelogram, rhombus and trapezoid. **M.5.2.2.4.** Defines the interior angles of triangle and quadrilateral and finds the missing angle.
3	**M.5.2.3.2.** Calculates the perimeter of triangles and quadrilaterals, constructs different shapes with given perimeters. **M.5.2.4.1.** Calculates the area of the rectangle by using centimeter square and meter square. **M.5.2.4.2.** Estimates a given area by using centimeter square and meter square.
4	**M.5.2.4.3.** Constructs different rectangles with a given area. **M.5.2.4.4.** Solves the problems that require calculating the area of rectangle. **M.5.2.5.1.** Introduces the rectangular prism and determines its basic elements.
5	**M.5.2.5.2.** Draws the net of rectangular prisms and decides if a given net belongs to a rectangular prism. **M.5.2.5.3.** Solves the problems that require calculating the surface area of the rectangular prism.

construct triangles, quadrilaterals, polygons and found the perimeter and the area of geometric shapes. They cut and drew shapes using dot/squared paper. Unit squares and unit cubes are used to construct 2D and 3D shapes. Students observed concrete prisms' properties, nets and surface area in the activities. They constructed the net and the closed shape of a rectangular prism. During the implementation, the researcher used the mathematics room in the school which motivated the students as they spent time in a different environment. Appendix C can be seen for a sample lesson description of hands-on instruction.

Technology-based instruction consisted of various manipulatives available on computers and tablet computers. These manipulatives included online geoboard, GeoGebra geometry application, educational computer games and Google Classroom for communication and online documentary tools. Students in the technology-based instruction constructed triangles, quadrilaterals and found their perimeter and area by using online geoboards. A dynamic geometry software, GeoGebra, enabled students to observe the animations of geometric shapes and draw 2D and 3D shapes by using squared and isometric backgrounds. The computer laboratory and tablet computers were used during the activities. Therefore, in order to ensure that each student have their technological device ready-to-use every day, the researcher mostly preferred to use the computer laboratory in the school. Appendix C can be seen for a sample lesson description of technology-based instruction.

The blended instruction group used the technological devices such as computers in the laboratory, tablet computers and concrete manipulatives in the mathematics room during the study. The technological and hands-on activities were equally distributed in the blended instruction. For instance, the activities were mostly arranged as one technology-based and one hands-on so that students used both the online and the concrete geoboards equally. The types of instruction chosen for each objective in blended group is shown in Table 5.7-Table 5.11.

5.5.1. Instructional Activities

Instructional activities were designed equivalent with respect to their quality of instruction for both technology-based and hands-on instruction groups. The researcher prepared the activities and the related worksheets (both hardcopy and softcopy) according to the advices of experts in mathematics education. Description of an activity example for hands-on instruction and technology-based instruction is given in Table 5.6. Worksheets were designed as hardcopy and softcopy for the groups. Students used their Gmail accounts to send their products, Google Classroom when links of the applications and announcements were needed to be shared and online document tools of Gmail for worksheets of the activities. Details of the activities chosen for each instruction group for five weeks are shown in Table 5.7-Table 5.11.

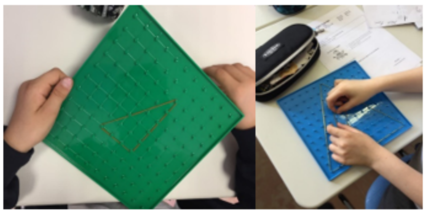
Learning Objective	**Descriptions of the activities**	
	(Hands-on Instruction)	**(Technology-based instruction)**
M.5.2.2.2. Constructs and classifies triangles according to their angles and sides.	*Construct Your Own Triangle(H)* Students constructed triangles by their sides and angles with geoboards. In the first lesson, they worked as a pair and shared their ideas on the properties of different types of triangles. They tried to make equilateral, isosceles and scalene triangle by using geoboards and elastic bands. In the following lesson, students constructed triangles according to their angle properties. Students shared ideas about the types of triangles by their angles and made acute, right and obtuse angled triangle. Sample triangles were checked out by the instructor during the lesson and students shared their examples with each other. The pictures of the process are given below. 	*Construct Your Own Triangle(T)* Students used the online geoboard application in their tablet computers to construct triangles according to their side and angle properties. First, they discussed the properties of equilateral, isosceles and scalene triangle as pairs and constructed an example of each triangle. Then, they constructed triangles according to their angles. Therefore, students made acute, right and obtuse triangle with their online geoboards and shared their drawings with the class. The process is shown below. 

Figure 5.3. Description of the “Construct Your Own Triangle” activity.

Table 5.6. Activities used in the first week for each instruction group.

	Learning Objectives	Activities used for each instruction group		
		Hands-on Instruction	**Technology-based Instruction**	**Blended Instruction**
wEEK1	M.5.2.2.1. Names polygons, constructs and introduces its basic elements.	*Find My Place! (H)* Concrete triangles, quadrilaterals and pentagons made from Eva paper were used to; classify and group similar shapes and name the shapes according to their forms and sides. In addition, students used toothpicks to construct polygons.	*Find My Place! (T)* Students used applications of GeoGebra to classify and construct polygons by manipulating the number of sides. The links of the applications are given below. https://www.geogebra.org/m/wHnByPks#material/psymRJDy https://www.geogebra.org/m/wHnByPks#material/VKhdFjdp https://www.geogebra.org/m/k4dJHaSy	*Find My Place! (H)*
	M.5.2.2.2. Constructs and classifies triangles according to their angles and sides.	*Let's Classify Triangles(H)* Students used different kinds of concrete triangles to classify by their angle and length properties.	*Let's Classify Triangles(T)* Students played the triangle splat game on their computers to detect obtuse, acute, right, equilateral, isosceles, scalene triangles. The link of the educational game is given below. http://www.sheppardsoftware.com/mathgames/geometry/shapeshoot/triangles_shoot.htm	*Let's Classify Triangles(H)*
		Construct Your Own Triangle(H) Students constructed equilateral, isosceles, scalene, acute, right-angled and obtuse triangle by using geoboards and elastic bands.	*Construct Your Own Triangle(T)* Students used an online geoboard application from their computers to construct triangles according to their angles and sides. The link of the application is given below. https://apps.mathlearningcenter.org/geoboard/	*Construct Your Own Triangle(T)*

Table 5.7. Activities used in the second week for each instruction group.

		Activities used for each instruction group		
	Learning Objectives	**Hands-on Instruction**	**Technology-based Instruction**	**Blended Instruction**
WEEK-2	**M.5.2.2.3.** Defines and draws the basic elements of rectangle, parallelogram, rhombus and trapezoid.	*What Makes Me Special? (H)* Students cut the quadrilaterals in their activity sheet. Then, classified the shapes according to their side and angle properties.	What Makes Me Special? (T) Students classified the quadrilaterals according to their side and angle properties in the online geometry game with their computers. The link of the game is given below. http://www.sheppardsoftware.com/mathgames/geometry/shapeshoot/QuadShapesShoot.htm	*What Makes Me Special? (T)*
		Quadrilaterals on Geoboards(H) Students constructed rectangle, parallelogram, trapezoid and rhombus on geoboards using elastic bands and drew the quadrilaterals on the given dot paper. Then, they drew angles, vertices and diagonals of the related quadrilaterals.	*Quadrilaterals on Geoboards(T)* Online geoboard application is used to constructed rectangle, parallelogram, trapezoid and rhombus. Then, students drew these quadrilaterals, their vertices; angles and diagonals on GeoGebra application. The links of the applications are given below. https://apps.mathlearningcenter.org/geoboard/ https://www.geogebra.org/geometry	*Quadrilaterals on Geoboards(H)*
	M.5.2.2.4. Defines the interior angles of triangle and quadrilateral and finds the missing angle.	*Sum of Interior Angles: Triangles(H)* In order to investigate the angle sum of triangle, students used color pencils and a paper. They answered the questions about missing angles on the given worksheet.	*Sum of Interior Angles: Triangles(T)* Students were given two different interactive applications to see the angle sum of a triangle. They answered the questions about missing angles in the worksheet sent via Google Classroom. http://www.learnalberta.ca/content/mejhm/index.html?l=0&ID1=AB.MATH.JR.SHAP&ID2=AB.MATH.JR.SHAP.ANG&lesson=html/video_interactives/angles/anglesInteractive.html	*Sum of Interior Angles : Triangles(T)*
		Sum of Interior Angles: Quadrilaterals(H) Students used color pencils and paper to investigate the angle sum of a quadrilateral. Worksheet about missing angles was given to students.	*Sum of Interior Angles: Quadrilaterals(T)* Students used an interactive application from GeoGebra to investigate the angle sum of quadrilaterals. Worksheet about missing angles was sent via Google Classroom. The link of the interactive is given as follows. https://www.geogebra.org/m/xwbvZyhv	*Sum of Interior Angles:* Quadrilaterals(H)

Table 5.8. Activities used in the second week for each instruction group.

	Learning Objectives	Activities used for each instruction group		
		Hands-on Instruction	**Technology-based Instruction**	**Blended Instruction**
WEEK-3	M.5.2.3.2. Calculates the perimeter of triangles and quadrilaterals, constructs different shapes with given perimeters.	*Find the Perimeter(H)* Students calculated the perimeters of given concrete shapes by measuring its sides with rulers and used geoboards to construct different shapes with given perimeters.	*Find the Perimeter(T)* Student measured the perimeter of the given polygons in GeoGebra with an online ruler. Then, they constructed different shapes with the given perimeters by using online geoboards. The links of the applications are given below. https://www.geogebra.org/m/Vpv2rXuA https://apps.mathlearningcenter.org/geoboard/	*Find the Perimeter(T)*
	M.5.2.4.1. Calculates the area of the rectangle by using centimeter square and meter square.	*Find the Area(H)* Students measured the side lengths of four objects (desk, locker, mathematics book and smartboard) in the class by using rulers with different sizes. Then, they calculated the area of the objects and noted their measurements in their worksheets.	*Find the Area(T)* An interactive geometry application was used to find the side lengths of the given shapes. Students noted the area measurements in their online worksheet and sent to the instructor via e-mail. The link of the interactive is given as follows. https://mathsframe.co.uk/en/resources/playgame/99	*Find the Area(H)*
		Area Dice Game(H) Students used paper, pencil and dice to play the game. They constructed rectangles with different perimeters and calculated their area according to the rules of the game.	*Party Designer Game(T)* Students played the computer game to construct rectangles with the intended area and perimeter. The link of the educational game is given as follows. https://www.mathplayground.com/PartyDesigner/index.html	*Party Designer Game(T)*
	M.5.2.4.2. Estimates a given area by using centimeter square and meter square.	*Let's Estimate the Area(H)* Students compared the size of three cities drawn on a map and explained their method of comparison which includes drawing squares on the map, using their hands and rubbers to measure the approximate sizes. Then, they estimated the area of irregular shapes in the following questions.	*Let's Estimate the Area(T)* Students compared the size of three cities given on a map. Then, they explained their method of comparison which included using geometric shape tool in the online worksheet. Students estimated the area of irregular shapes in the following questions and e-mailed their work to the instructor.	*Let's Estimate the Area(H)*

Table 5.9. Activities used in the second week for each instruction group.

		Activities used for each instruction group		
	Learning Objectives	**Hands-on Instruction**	**Technology-based Instruction**	**Blended Instruction**
WEEK-4	**M.5.2.5.2.** Draws the net of rectangular prisms and decides if a given net belongs to a rectangular prism.	*Open the Box! (H)* Students used a rectangular box to observe and rotate. They imagined its open shape from a certain direction and drew its net on a squared paper. Then, students checked their drawings by unfolding the prism.	*Open the Box! (T)* Students were given a rectangular box from GeoGebra that enables rotation. They imagined its open shape and drew it in GeoGebra with a squared background. Students checked their drawings by unfolding the prism. The links of the applications are given below. https://www.geogebra.org/m/JhPNZV8J https://www.geogebra.org/geometry	*Open the Box! (T)*
		Nets of Prisms(H) Students were asked to decide if the given 24 nets made from paper belong to a cube.	*Nets of Prisms(T)* Students answered 24 questions to decide if the nets belong to a cube in an interactive game. The link of the educational game is given as follows. https://www.nctm.org/Classroom-Resources/Illuminations/Interactives/Cube-Nets/	*Nets of Prisms(H)*
	M.5.2.5.3. Solves the problems that require calculating the surface area of the rectangular prism.	Area of Rectangular Prisms(H) Students observed the concrete rectangular prisms and found their surface area. They measured and noted the edge lengths of each prism on their worksheet and showed their calculations for the area.	*Area of Rectangular Prisms(T)* Students found the surface area of rectangles in the online worksheet by using GeoGebra application where they were able to see both the net and the closed shape of the prisms. They showed their calculations for area on the online worksheet. The link of the GeoGebra application is given as below. https://www.geogebra.org/m/htF9BJek	*Area of Rectangular Prisms(T)*

Table 5.10. Activities used in the second week for each instruction group.

	Learning Objectives	**Activities used for each instruction group**		
		Hands-on Instruction	**Technology-based Instruction**	**Blended Instruction**
WEEK-5	**M.5.2.5.2.** Draws the net of rectangular prisms and decides if a given net belongs to a rectangular prism.	*Open the Box! (H)* Students used a rectangular box to observe and rotate. They imagined its open shape from a certain direction and drew its net on a squared paper. Then, students checked their drawings by unfolding the prism.	*Open the Box! (T)* Students were given a rectangular box from GeoGebra that enables rotation. They imagined its open shape and drew it in GeoGebra with a squared background. Students checked their drawings by unfolding the prism. The links of the applications are given below. https://www.geogebra.org/m/JhPNZV8J https://www.geogebra.org/geometry	*Open the Box! (T)*
		Nets of Prisms(H) Students were asked to decide if the given 24 nets made from paper belong to a cube.	*Nets of Prisms(T)* Students answered 24 questions to decide if the nets belong to a cube in an interactive game. The link of the educational game is given as follows. https://www.nctm.org/Classroom-Resources/Illuminations/Interactives/Cube-Nets/	*Nets of Prisms(H)*
	M.5.2.5.3. Solves the problems that require calculating the surface area of the rectangular prism.	Area of Rectangular Prisms(H) Students observed the concrete rectangular prisms and found their surface area. They measured and noted the edge lengths of each prism on their worksheet and showed their calculations for the area.	*Area of Rectangular Prisms(T)* Students found the surface area of rectangles in the online worksheet by using GeoGebra application where they were able to see both the net and the closed shape of the prisms. They showed their calculations for area on the online worksheet. The link of the GeoGebra application is given as below. https://www.geogebra.org/m/htF9BJek	*Area of Rectangular Prisms(T)*

5.5.2. Teacher's Observation

5.5.2.1. Technical Issues. Students in each instructional group were familiar with using technological and concrete materials within the context of school lessons. In this sense, the researcher did not spend extra time for students to become familiar with the materials used in the study. The reservations for computer laboratories and mathematics room were booked according to the classes' schedules by the instructor/researcher each week. Technical problems (students' forgotten passwords, broken computers, insufficient number of computer tablets) in the technology-based instruction and blended instruction group were fixed with the aid of computer teachers and information technologists in the school. Students in the hands-on instruction and blended instruction group were informed about the required materials before the lessons and most of the materials were provided from the school in order to avoid problems. As the researcher were familiar with students and informed about the physical conditions of the school before the study, technical problems were minimized or at least did not affect the procedure.

5.5.2.2. Student Engagement. Student engagement increased in each instruction group during the study. Students in the technology-based instruction group gave more attention to the lessons compared to the beginning of the year. Students mentioned that they enjoyed using computers and tablet computers within the lessons. Therefore, they became more active during the activities as they liked using technology. Students were also motivated when they were going to the computer lab because they were happy to have the lesson in a different place rather than their regular class. However, they tended to behave as they were going to play an educational game whenever they went to the computer laboratory or used their tablet computers in the first week. This perception of students changed as they got used to the setting of the lessons. At the end of the study, students comprehended that using technological devices can be part of the lessons, not only for playing games. Therefore, they became more serious to technology integrated lessons through the study.

Students in the hands-on instruction group was the most energetic group in three of the classes. They became more focused when they used hands-on materials in every lesson. The students who avoided activities that required to cut, paste, measure and draw became more active learners as they became familiar with using these skills. They learned how to focus in the lessons with the help of concrete manipulatives. In addition, students improved their communication skills in group activities. They became more friendly to each other. At the end of study, students' awareness to mathematics increased as a class and an improvement was seen in their GAT scores and common mathematics exam scores. Moreover, the class became more focused and calmer. Therefore, a better learning environment was achieved through the study.

Blended instruction group was highly motivated since they were using both hands-on activities and computers. They were also more active in mathematics lessons comparing to the beginning of the year and became better at using technology in the school context through the lessons. Moreover, they enjoyed using different places in the school such as the mathematics room and computer laboratory in addition to their regular class.

6. RESULTS

In this section of study, results are arranged to provide answers for each research question by comparing the three types of instruction with respect to participants' spatial ability and geometry achievement levels. A non-parametric Kruskal Wallis Test was applied for comparing the mean of the scores obtained from geometry achievement and each spatial ability test. Kruskal Wallis test was chosen due to the small size of the groups ($n<30$).

6.1. Results for Spatial Ability Tests Analyses

In order to determine the effect of instruction on participants' spatial ability, Purdue Visualization of Rotations (ROT) test and Differential Aptitude Test: Space Relations (DAT:SR) were administered before and after the instruction. The results of the analyses are presented as follows.

6.1.1. Results for the Purdue Visualization of Rotations (ROT) Test Analyses

The ROT was administered to measure how well the participants visualized the rotation of three-dimensional objects. ROT was conducted to determine the effect of instruction type on participants' spatial ability. The results related to the administration of the ROT before and after treatment were evaluated for technology-based, hands-on and blended groups. Scores were evaluated by obtaining the number of correct answers. The descriptive statistics were conducted to compare participants' mean scores in three of the instructional groups are represented in Figure 6.1. Descriptive statistics for preROT scores of the groups indicated that the mean scores of technology-based, hands-on and blended instruction groups were $M=7.85$, $M=6.25$ and $M=6.59$, respectively. The postROT mean scores of the groups were $M=10.30$, $M=8.35$ and $M=10.41$, again respectively.

Table 6.1. Descriptive statistics for the preROT and postROT scores

Groups	N	preROT Mean	SD	postROT Mean	SD
Technology-based	20	7.85	3.80	1.30	3.61
Hands-on	20	6.25	1.94	8.35	2.00
Blended	17	6.59	2.18	1.41	2.29

The mean scores of pretest, posttest and percent increase of the postROT for each group were summarized in the graph given in Figure 6.1. The percent increase of hands-on, blended and technology-based group were 33.60%, 57.97% and 31.21% respectively. The blended instruction group has the highest increase in ROT with 57.97%.

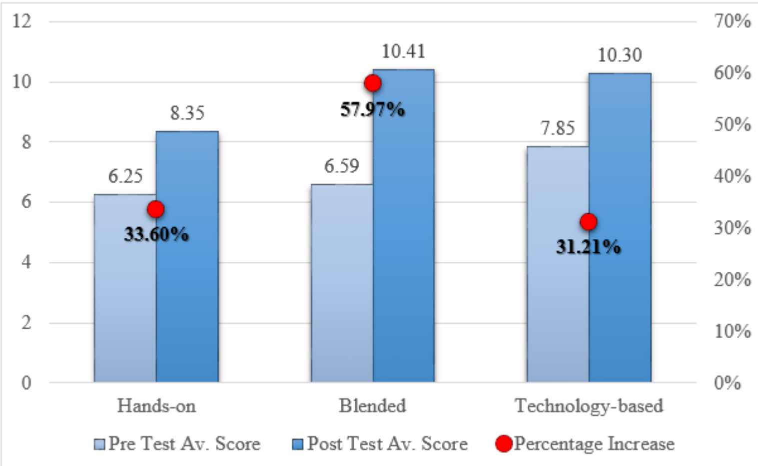


Figure 6.1. Percent increases in postROT scores.

A Kruskal-Wallis Test was conducted to determine whether there is a difference among the participants' preROT scores. Table 6.2 shows the results of Kruskal-Wallis Test for ROT. The analysis revealed statistically no significant difference ($p > 0.05$) in preROT scores of participants across three different instruction groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), $x^2(2, n = 57) = 1.759$, $p = 0.415$. Therefore, the groups were regarded as similar in terms of their spatial ability as measured by ROT before the treatment.

Table 6.2. Results of Kruskal-Wallis Test for preROT.

Groups	**N**	**Mean Rank**	**Chi-Square**	**df**	**Sig.**
Technology-based	20	32.58	1,759	2	0.41
Hands-on	20	25.70			
Blended	17	28.68			

Wilcoxon Signed Rank Test was conducted to determine the effect of instruction on spatial ability in each group by comparing the pretest and posttest scores of the ROT. The results of the test are represented in Table 6.3. Results revealed a statistically significant increase in scores of ROT statistics in technology-based instruction (z = -3.31, p < .001, r = 0.52), hands-on instruction (z = -3.20, p < .001, r = 0.50) and blended instruction (z = -3.63, p < .000, r = 0.62). In each group, the results indicate that the effect size was large (r > 0.5 for all the instructional methods) with respect Cohen (1988) criteria of 0.1 = small effect, 0.3 = medium effect, 0.5 = large effect.

Table 6.3. Wilcoxon Signed Rank Test for results of preROT and postROT.

Groups	**N**	**Z**	**Effect size**	**Sig.**
Technology-based	20	-3.31	0.52	0.01
Hands-on	20	-3.20	0.50	001
Blended	17	-3.63	0.62	0.00

In order to examine the effect of instructional methods on spatial ability among the groups, posttest scores of ROT were compared by using the Kruskal-Wallis Test. Table 6.4. shows the result of Kruskal-Wallis Test for ROT. The analysis showed a statistically significant difference (p < 0.05) in postROT scores among different instruction groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), $x^2(2, n = 57) = 8.017$ p = 0.018.

Table 6.4. Results of Kruskal-Wallis Test for postROT

Groups	N	Mean Rank	Chi-Square	df	Sig.
Technology-based	20	32.58	8,017	2	0.018
Hands-on	20	20.68			
Blended	17	34.59			

As shown in Table 6.4 postROT scores of technology-based, hands-on and blended group were found to be significantly different ($p < 0.05$). Mean ranks inspected that blended instruction group has the highest overall ranking. In order to determine which of the groups are statistically significantly different from one another in terms of ROT posttest scores, Mann-Whitney U tests between pairs of groups were conducted. Table 6.5. represents the analysis results of the posttest scores of the groups. Mann-Whitney U test for hands-on and blended groups revealed significant difference in ROT posttest scores, U = 79.00, z = -2.806, p = 0.05.

Table 6.5. Results of the Mann-Whitney U Test for the postROT scores.

Groups	N	Mean Rank	Z	U	Sig. (2-tailed)
Hands-on	20	14.45	-2,806	79.00	0.05
Blended	17	24.35			
Hands-on	20	16.73	-2,057	124.50	0.04
Technology-based	20	24.28			
Blended	17	19.24	-0.123	166.00	0.902
Technology-based	20	18.80			

Similarly, there was a significant difference in ROT posttest scores of hands-on and technology-based instruction groups according to the results shown in Table 6.5. U = 124.500, z = -2.057, p = 0.04. However, no significant difference between technology-based and blended instruction groups were found according to the Mann-Whitney U Test, U = 166.00, z = -0.123, p = 0.902. The results were summarized in Table 6.5.

The data analysis showed that technology-based instruction (p = 0.04) and blended instruction (p = 0.05) improved participants' spatial ability significantly more than the hands-on instruction measured by the ROT.

6.1.2. Results for the Differential Aptitude Test: Space Relations (DAT:SR) Analyses

The DAT:SR evaluated if a participant could visualize a two-dimensional pattern in three-dimensional space. DAT:SR was implemented to investigate the effect of instruction type on participants' spatial ability. The results for the pretest and posttest of DAT:SR were measured for technology-based, hands-on and blended instruction groups. Scores of the DAT:SR were measured according to the number of correct answers in the test. In order to compare participants' mean scores in three of the instruction groups, descriptive statistics were used. According to the descriptive statistics results, preDAT mean scores of technology-based, hands-on and blended groups were M=12.65, M=12.30 and M=13.06. The postDAT mean scores were M=15.30, M=14.85and M=16.35. The table 6.6. represents the detailed descriptive statistics of the DAT scores.

Table 6.6. Descriptive statistics for the preDAT and postDAT scores.

Groups	**N**	**preDAT Mean**	**SD**	**postDAT Mean**	**SD**
Technology-based	20	12.65	3.54	15.30	3.31
Hands-on	20	12.30	4.28	14.85	3.60
Blended	17	13.06	3.21	16.35	2.37

The pretest and posttest average scores of DAT and the percent increase for each instruction group were shown in the graph given in the Figure 6.2. The percent increases of hands-on; blended and technology-based group were 20.73%, 25.19% and 20.95%. The blended instruction group has the highest percent of increase with 25.19%.

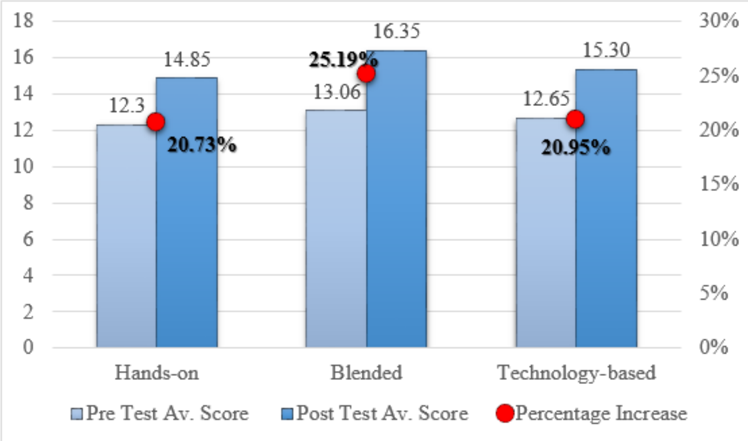


Figure 6.2. Percent increases in postDAT scores.

In order to determine whether there is a difference in participants' preDAT scores, Kruskal-Wallis Test was conducted. Table 6.7 shows the results of Kruskal-Wallis Test for DAT. The analysis revealed no statistically significant difference ($p > 0.05$) in preDAT scores of participants across three different instruction groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), $x^2(2, n = 57) = 0.365$, $p = 0.83$. Therefore, the groups were regarded as similar in terms of their spatial ability as measured by DAT before the treatment.

Table 6.7. Results of Kruskal-Wallis Test for preDAT.

Groups	**N**	**Mean Rank**	**Chi-Square**	**df**	**Sig.**
Technology-based	20	29.18	0.365	2	0.83
Hands-on	20	27.40			
Blended	17	30.68			

The effectiveness of the instruction on spatial ability in each group were examined by comparing the pretest and posttest scores of the DAT by using the Wilcoxon Signed Rank Test. As it is shown in Table 6.8. the results of the Wilcoxon Signed Rank Test revealed a statistically significant increase in DAT scores in technology-based instruction ($z = -3.86$, $p < .000$, $r = 0.61$), hands-on instruction ($z = ?3.78$, $p < .000$, $r = 0.59$) and blended instruction ($z = ?3.54$, $p < .000$, $r = 0.56$). In each group, the results indicate that the effect size was large (r > 0.5 for all the instructional methods) with respect Cohen (1988) criteria of 0.1 = small effect, 0.3 = medium effect, 0.5 = large effect.

Table 6.8. Wilcoxon Signed Rank Test for results for preDAT and postDAT

Groups	**N**	**Z**	**Effect size**	**Sig.**
Technology-based	20	-3.86	0.61	0.00
Hands-on	20	-3.78	0.59	0.00
Blended	17	-3.54	0.56	0.00

In order to examine the effect of instructional methods on spatial ability among the groups, posttest scores of DAT were compared by using the Kruskal-Wallis Test. The results are summarized in Table 6.9. As the analysis revealed no statistically significant difference (p> 0.05) were found among postDAT scores of the three groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), x^2 (2, n = 57) = 1.69 p = 0.428.

Table 6.9. Results of Kruskal-Wallis Test for postDAT.

Groups	**N**	**Mean Rank**	**Chi-Square**	**df**	**Sig.**
Technology-based	20	28.13	1.69	2	0.428
Hands-on	20	26.30			
Blended	17	33.21			

As shown in Table 6.9. no significant difference (p> 0.05) were found among postDAT scores of technology-based, hands-on and blended group. However, mean ranks inspected that blended instruction group has the highest overall ranking.

To summarize, the results obtained from both of the spatial ability tests indicated that, there was a significant difference in participants' spatial ability before and after treatment (pretest and posttest) in each instruction group. Furthermore, a significant difference among groups were found according to ROT. Participants who received technology-based instruction and blended instruction improved their spatial ability significantly higher than the students who received hands-on instruction measured by the ROT. However, DAT indicated no significant difference in participants' spatial abilities among groups. In addition, percent increase of the postROT and postDAT scores showed that participants who received blended instruction improved their scores more than the students who received technology-based instruction.

6.2. Results for Geometry Achievement Test (GAT) Analyses

Geometry Achievement Test (GAT) was conducted to evaluate participants'? geometry achievement levels about specific topics in fifth grade. The test was prepared by the researcher and covered objectives such as polygons, quadrilaterals, triangles and rectangular prisms. The GAT was used to determine the effect of instruction type on participants' geometry achievement. The scores of preGAT and postGAT were converted to be over 100 points for the data analysis. The results related to the administration of the GAT before and after treatment were evaluated for technology-based, hands-on and blended groups. The descriptive statistics were conducted to compare participants' mean scores in three of the instruction groups. Descriptive statistics for preGAT scores of the groups indicated that mean scores of technology-based, hands-on and blended groups were M=46.86, M=39.15 and M=44.84. The postGAT mean scores were M=74.00, M=68.35 and M=73.58. Table 6.10 represents the detailed descriptive statistics of the GAT scores.

Table 6.10. Descriptive statistics for the preGAT and postGAT scores.

Groups	**N**	**PreGAT Mean**	**SD**	**PostGAT Mean**	**SD**
Technology-based	20	46.86	Dec-91	74.00	16.96
Hands-on	20	39.15	15.53	68.35	21.9
Blended	17	44.84	9.50	73.58	14.71

The percent increases of hands-on, blended and technology-based group were 75.58%, 64.09% and 57.92%. The pretest and posttest average scores of GAT and the percent increase for each instruction group were shown in the graph given in Figure 6.3. The hands-on instruction group has the highest percent of increase with 75.58%.

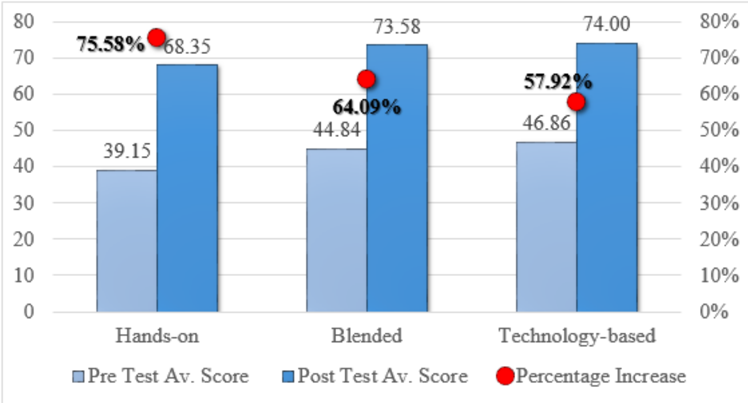


Figure 6.3. Percent increases in postGAT scores.

A Kruskal-Wallis test was conducted to examine whether there is a difference among the participants' preGAT scores. The Table 6.1 shows the results of Kruskal-Wallis Test for GAT. The analysis revealed statistically no significant difference ($p > 0.05$) in preGAT scores of participants across three different instruction groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), x^2 (2, n = 57) = 1.315, p = 0.52. Therefore, the groups were regarded as similar in terms of their geometry achievement as measured by ROT before the treatment.

Table 6.11. Results of Kruskal-Wallis Test for preGAT.

Groups	**N**	**Mean Rank**	**Chi-Square**	**df**	**Sig.**
Technology-based	20	31.33	1,315	2	0.52
Hands-on	20	25.63			
Blended	17	30.24			

Wilcoxon Signed Rank Test was conducted to determine the effect of instruction on geometry achievement in each group by comparing the pretest and posttest scores of the GAT. The results of the test are represented in Table 6.12. Results revealed a statistically significant increase in scores of GAT statistics in technology-based instruction (z = ?3.78, p < .00, r = 0.59), hands-on instruction (z = -3.72, p < .00, r =

0.58) and blended instruction (z = -3.62, $p < .00$, r = 0.57). In each group, the results indicate that the effect size was large ($r > 0.5$ for all the instructional methods) with respect Cohen (1988) criteria of 0.1 = small effect, 0.3 = medium effect, 0.5 = large effect.

Table 6.12. Wilcoxon Signed Rank Test for results for preGAT and postGAT.

Groups	**Z**	**Effect size**	**N**	**Sig.**
Technology-based	-3.78	0.59	20	0.00
Hands-on	-3.72	0.58	20	0.00
Blended	-3.62	0.57	17	0.00

In order to examine the effect of instructional methods on geometry achievement among the groups, posttest scores of GAT were compared by using the Kruskal-Wallis Test. The results of Kruskal-Wallis Test for GAT were represented in Table 6.13. The analysis revealed that there was not a statistically significant difference ($p > 0.05$) in postGAT scores among different instruction groups (Gp-T, n=20: technology-based, Gp-H, n= 20: hands-on, Gp-B, n=17: blended), $x^2(2, n = 57) = 0.372$, p = 0.83.

Table 6.13. Results of Kruskal-Wallis Test for postGAT.

Groups	**N**	**Mean Rank**	**Chi-Square**	**df**	**Sig.**
Technology-based	20	30.38	0.372	2	0.83
Hands-on	20	27.25			
Blended	17	29.44			

As shown in Table 6.13. no significant difference ($p > 0.05$) were found among postGAT scores of technology-based, hands-on and blended group. However, mean ranks inspected that technology-based instruction group has the highest overall ranking.

As a summary, the results of the Geometry Achievement Test (GAT) scores showed that there was a significant difference in participants' geometry achievement before and after treatment (pretest and posttest) in each instruction group. However, GAT revealed no significant difference in participants' geometry achievement among different instructional methods.

7. DISCUSSION AND CONCLUSION

The present study aimed to investigate the effects of using different instructional methods (technology-based instruction, hands-on instruction and blended instruction) to teach geometry topics on fifth grade students' spatial ability and geometry achievement. In order to obtain the effect of technology-based, hands-on and blended instruction on students' spatial ability and geometry achievement, three 5^{th} grade class participated in the study. Instructional methods were assigned randomly to the classes by the researcher. The researcher was also the instructor of the three classes. participants' spatial ability was measured by the Purdue Visualization of Rotations (ROT) test and the Differential Aptitude Test: Space Relations (DAT:SR). Geometry achievement of participants was evaluated by the Geometry Achievement Test (GAT). The Kruskal-Wallis Test was implemented to test the hypothesis related to spatial ability and geometry achievement. The pretest scores showed no significant difference among participants' spatial abilities and geometry achievements among the groups before the treatment. This result also supported the school administration's homogeneous distribution of students to classes according to their academic levels in beginning of each school year. During the study, hands-on group received instruction with concrete materials, technology-based group received instruction with computers and tablet computers and blended group received instruction with both concrete and technological materials.

7.1. Spatial Ability

ROT and DAT:SR were used to evaluate participants' spatial ability in the current study. The Kruskal-Wallis Test was administered to evaluate the effect of different instructional methods on spatial ability. The results of the Kruskal-Wallis Test revealed that there was no significant difference among participants preROT scores. Therefore, the groups were regarded as similar in terms of their spatial ability as measured by the ROT before the treatment.

The results respect to ROT revealed a significant difference in students' spatial ability before and after the treatment (pretest and posttest) in each instructional group (technology-based, hands-on and blended). It was found that, the blended instruction group (69.26 %) increased their ROT scores the highest while technology-based instruction (44.77%) and hands-on instruction (41.39%) group increased slightly less. Therefore, it can be said that three of the instructional methods could improve participants' spatial ability according to ROT. Moreover, the postROT scores revealed a significant difference on participants' spatial ability (Arıcı and Tutak, 2015; Battista, Talsma and Wheatley, 1982; Furner and Marinas, 2006; Kaufmann, 2017; Olkun, 2003) among the groups. According to this result, participants who received technology-based instruction and blended instruction scored significantly higher than the participants who received hands-on instruction in ROT after the treatment. Therefore, technology-based instruction and blended instruction had significantly more effect on improving s participants' spatial ability (Furner and Marinas, 2006; Kaufmann, 2017; Olkun, 2003). In other words, all the instructional methods improved participants' spatial ability, however, technology-based instruction and blended instruction had significantly more effect compared to hands-on instruction. Reason for the results occurred in favor of technology-based instruction might be due to fact that, participants engage more when they use technological manipulatives, so they become active learners (Furner and Marinas, 2006). Moreover, the studies (Alias, 2002; Sorby and Baartmans, 1996a; Furner and Marinas, 2006; Kurtuluş and Yolcu, 2013; Yurt and Sümbül, 2012) which suggested to use both technological and concrete manipulatives for improving spatial ability during instruction also supported the results in the study in favor of blended instruction. Participants' developed focusing skills during hands-on activities and high interest in technology might also be an important issue.

The result regarded to the Differential Aptitude Test: Space Relations (DAT:SR) measured by the Kruskal-Wallis Test revealed no significant difference among participants preDAT scores. Therefore, the groups were regarded as similar in terms of their spatial ability with respect to participants' DAT scores before the treatment. The results with respect to the Differential Aptitude Test: Space Relations (DAT:SR) revealed a significant difference in participants' spatial ability before and after treatment (pretest and posttest) in each instruction group. The percent increases of hands-on; blended and technology-based group were 20.73%, 25.19% and 20.95%. The blended instruction group has the highest percent of increase with 25.19%. It can be said that three of the instructional methods (Arıcı and Tutak, 2015; Furner and Marinas, 2006; Kaufmann, 2017; Olkun, 2003) could improve participants' spatial ability according to the DAT. However, the postDAT scores revealed no significant difference on participants' spatial ability among the groups. According to this result, the effectiveness of the instructional methods (technology-based, hands-on and blended) did not differ on improving participants' spatial ability as measured by the DAT. A reason for this might be due to the fact that, the questions asked in the DAT were mostly similar to the objective "M.5.2.5.2. Draws net of rectangular prisms and decides if a given net belongs to a rectangular prism?. Therefore, as part of the curriculum, in all three instruction groups, participants were taught questions similar to DAT in the lessons. As a result, all the groups improved their spatial ability significantly concerning the DAT scores. However, none of them were significantly more effective than the other with respect to DAT.

On the other hand, ROT revealed a significant difference among the groups. A reason for this result might be because, questions similar to the ROT were not included in the 5^{th} grade mathematics curriculum. Therefore, participants were unfamiliar to the types of questions in the ROT. In other words, it can be summarized as, DAT:SR did not make a difference among groups due to its familiar types of questions as in the geometry lessons. However, ROT determined a difference among the groups because participants were not familiar to those kind of rotation questions in test before and after treatment, so technology-based and blended instruction improved their rotation skills the most.

7.2. Geometry Achievement

The Geometry Achievement Test (GAT) was used to collect data on geometry achievement about polygons, quadrilaterals, triangles and rectangular prisms of fifth grade students. As it was mentioned in the results section, the scores of preGAT and postGAT were converted to be over 100 points for the data analysis. The result regarded to the Geometry Achievement Test (GAT) measured by the Kruskal-Wallis Test revealed no significant difference among participants' preGAT scores. Therefore, the groups were regarded as similar in terms of their geometry achievement with respect to participants' GAT scores before the treatment.

The results respect to the GAT revealed a significant difference in participants' geometry achievement before and after treatment (pretest and posttest) in each instruction group (technology-based, hands-on and blended). The percent increase of the technology-based, hands-on and blended instruction were 57.92%, 75.58% and 64.09% respectively. Therefore, all the instructional methods could improve participants' geometry achievement according to GAT (Arıcı and Tutak, 2015; Ayub, Saha and Tarmizi, 2010; Battitsta, 1990; Battista and Clements, 1996;1991, Battista, Wheatley and Talsma, 1982). However, the postGAT scores revealed no significant difference on participants' geometry achievement among the groups.

On the other hand, the hands-on instruction group has the highest percent of increase with 75.58% which have an important difference especially with the increase in technology-based instruction group (57.92%). According to the observations of the researcher, reason for this result might be due to participants' focusing skills which developed during the study. Participants in the hands-on instructional group learned to listen, focus and engage in the lesson while they interacted with concrete manipulatives and hands-on activities throughout the research study. Therefore, their geometry achievement resulted as the highest of all three groups.

In conclusion, the effectiveness of the instructional methods (technology-based, hands-on and blended) did not differ on improving participants' geometry achievement as measured by GAT. Thus, all the instructional methods improved participants' geometry achievement, however, none of them were significantly more effective than the other.

7.3. Limitations of the Study

The current study has several limitations which prevents the study to be generalizable. One of the limitations is the small sample size, namely 57. Due to the fact that the aim of the study was to investigate the effects of different instructional methods for improving 5^{th} grade students' spatial ability and geometry achievement, purposive sampling was implemented. The school was not selected randomly because the researcher was currently working in the school as an instructor. Three 5^{th} grade classes were already assigned to the instructor at the beginning of the school year. However, the instructional method (technology-based, hands-on and blended) for each class was assigned randomly. Due to the fact that the current school was a private school, the study does not reveal sufficient conclusions for all the school types. Therefore, in order to make broader generalizations about the results, the current study could be replicated with a larger and randomly selected sample including participants from both private and state schools.

Another limitation may be that mathematics and science lessons were held in English. This fact might have a negative effect on geometry achievement and improvement in spatial ability of the participants who were low achievers in English. In addition, participants were not familiar with the type of spatial ability tests implemented in the study. Therefore, it took some time for participants to understand what they needed to do.

There are studies which supports that spatial ability can be improved in a short amount of time (Cheng and Mix, 2014), however, a longer period of instruction might be more effective on improving participants' spatial ability since abilities develop over a long period of time (Ben-Chaim, Lappan and Houang, 1988; Fennema and Tartre, 1985). In addition, a pilot study could not be conducted before implementing the current study.

7.4. Implications and Suggestions for Further Research

There are studies to support the benefits of spatial ability for achievement in geometry (Ayub, Saha and Tarmizi, 2010; Battista, Talsma and Wheatley, 1982; Battista, 1990). The majority of the suggested activities to improve spatial ability require extra lesson hours and implementations in addition to planned schedule. The current study provided an opportunity to investigate the effects of different instructional methods that on the spatial ability and geometry achievement of students within the existing curriculum.

The results of the current study can be beneficial for curriculum designers and mathematics educators. Mathematics curriculum can be reorganized by considering the importance of improving students' spatial ability. Technology-based and hands-on activities can be increased in middle school curriculum, especially in geometry units. Geometry educators may be informed about planning and preparing lessons that supports improving spatial ability since mathematics/geometry achievement and spatial ability have strong positive correlation. Therefore, the current study can be helpful in assisting geometry instructors in designing lessons by using the most effective instructional method. In addition, implementation of the study to larger samples may be helpful for reaching higher scores compared to the previous PISA (2015) and TIMSS (2015) scores of Turkey.

According to the results, both technological and hands-on manipulatives could improve students' spatial abilities and geometry achievement. Therefore, the study can be replicated after enriching the number of technological and hands-on activities for both instructional methods. However, geometry achievement was seen to be improved with hands-on instruction the most. Thus, mathematics teachers can give greater emphasis on teaching geometry units with hands-on activities for providing more effective understanding of geometry for 5^{th} grade students.

This study was implemented to 5^{th}h grade students, however, geometry takes place in each grade level from 1 to 8 in the middle school mathematics curriculum

(MoNE, 2018). Therefore, the current study may be conducted to lower and higher grades by redesigning the activities appropriate to the related grade levels. In order to make broader generalizations about the results, the current study can be replicated with a larger and randomly selected sample including participants from both private and state schools. Furthermore, a longitudinal study could give more sufficient results, by implementing the study to the same sample in 6th, 7th and 8^{th} grade to see the retention of students' spatial ability and geometry achievement.

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APPENDIX A: SPATIAL ABILITY TESTS THE PURDUE (ROT)

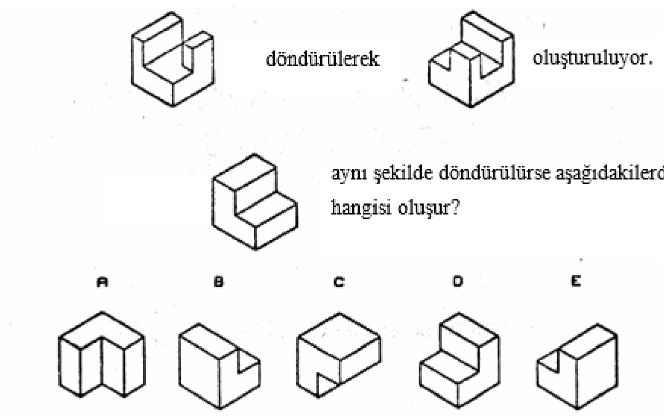
THE PURDUE VISUALIZATION OF ROTATIONS TEST (ROT)

Bu kitapçığa herhangi bir işaretleme yapmayınız.

Cevaplarınızı cevap anahtarlarına işaretleyiniz.

YÖNERGELER

20 sorudan oluşan bu test 3 boyutlu nesnelerin döndürülmesini ne kadar iyi canlandırdığınızı ölçmek üzere hazırlanmıştır. Bu testte bulunan soruların bir örneği aşağıda verilmiştir.



Verilen her soru için aşağıdaki aşağıda verilen aşamaları takip etmelisiniz.

1) En üstte verilen nesnenin nasıl döndürüldüğünü inceleyiniz.
2) Orta sırada verilen nesnenin üst sıradaki nesneyle tamamen aynı şekilde döndürüldüğünü zihninizden canlandırınız.
3) En alt sırada verilen beş çizim arasından (A, B, C, D, E) doğru şekilde döndürülmüş olanı seçiniz.

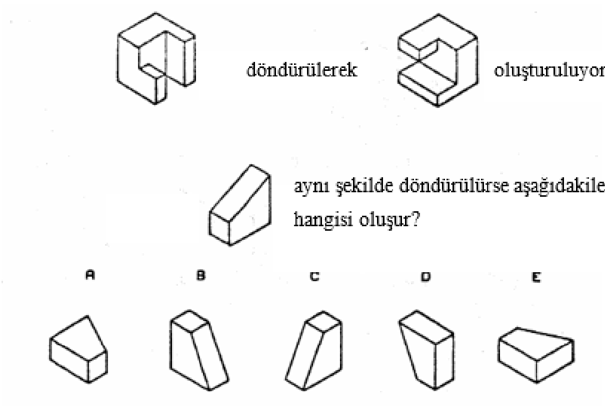
Yukarıda verilen örnek sorunun cevabı nedir?

Figure A.1. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 1.

A, B, C ve E şıklarında verilen cevaplar yanlış. Sadece D şıkkında verilen çizim döndürme işlemi sonucu elde edilecek nesneyi verir.

Her sorunun sadece bir cevabı vardır!

Şimdi de aşağıda verilen örneğe bakınız ve örnekte verilen döndürme işlemi orta sırada verilen şekle uygulayınız.



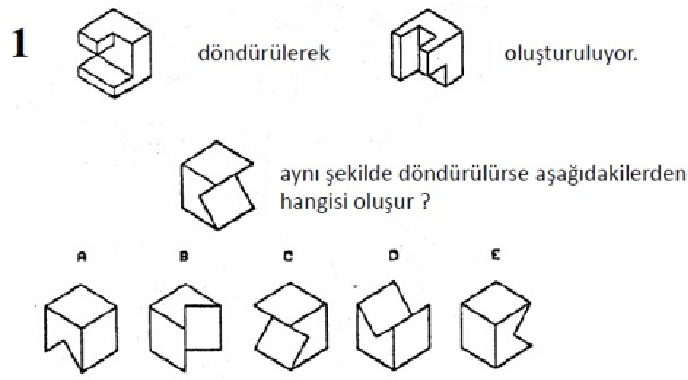
Bu örnekteki döndürme işleminin daha harmanlanmışşık olduğuna dikkat edin. Bu örneğin doğru cevabı B şıkkıdır.

Bu kitapçığa herhangi bir işaretleme yapmayınız.
Cevaplarınızı cevap anahtarlarına işaretleyiniz.

Bu çalışmaya tüm katılımcılar aynı anda başlayacaktır.

Bu çalışma 40 dakika sürecektir.

Figure A.2. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 2.



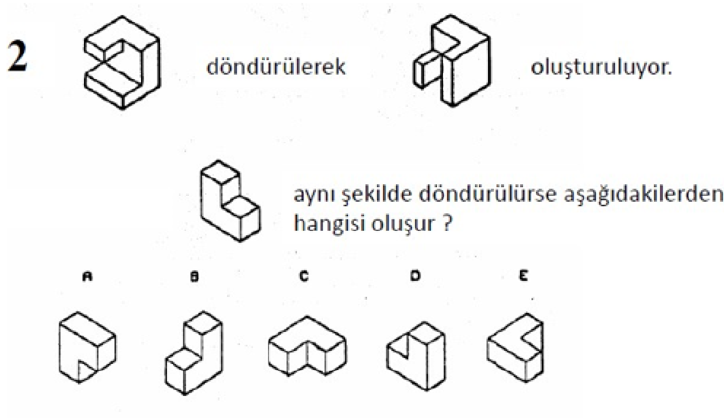
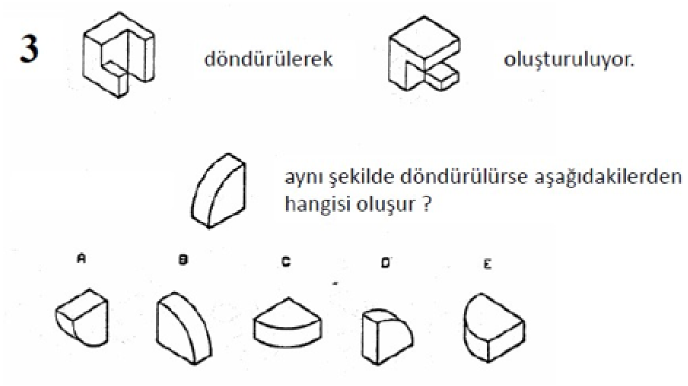


Figure A.3. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 3.



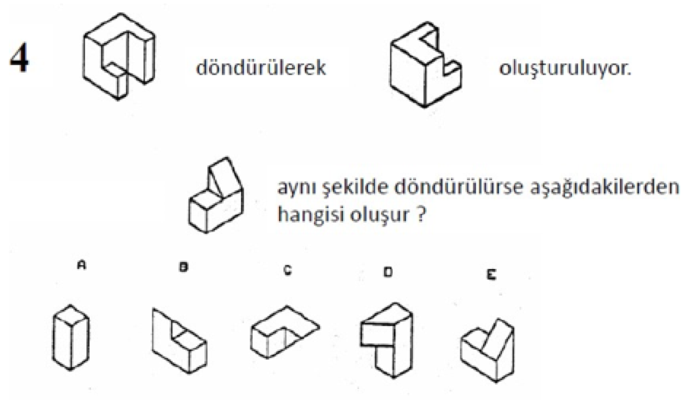


Figure A.4. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 4.

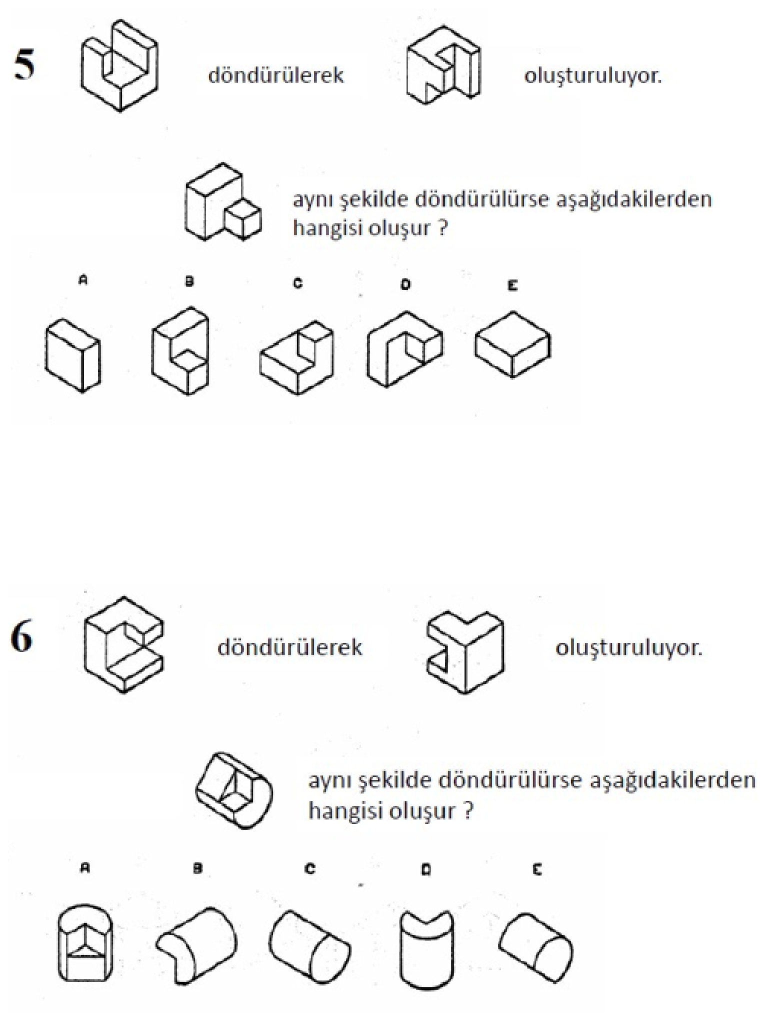
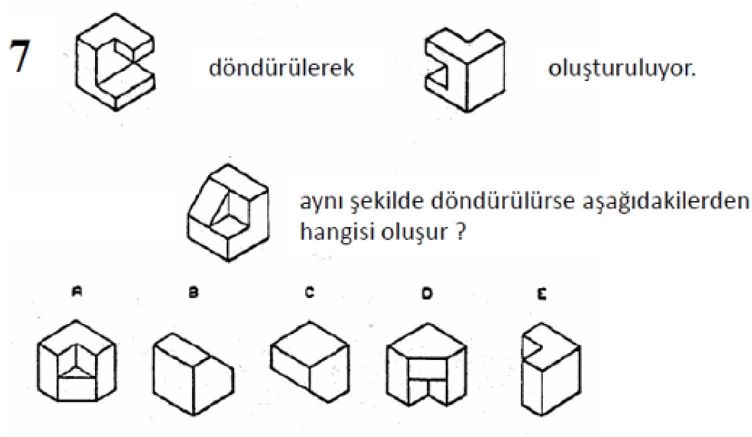


Figure A.5. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 5.



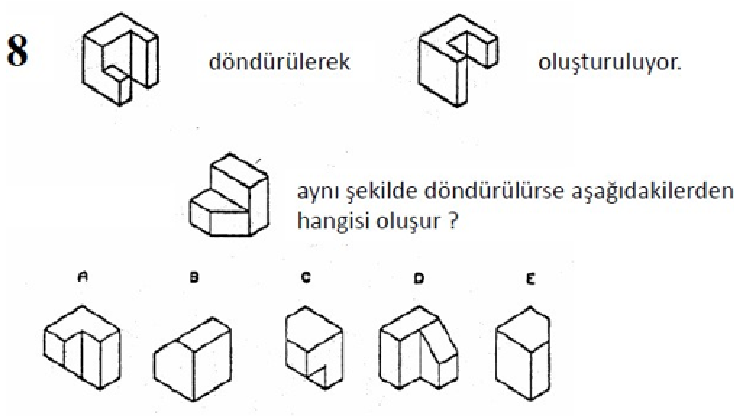


Figure A.6. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 6.

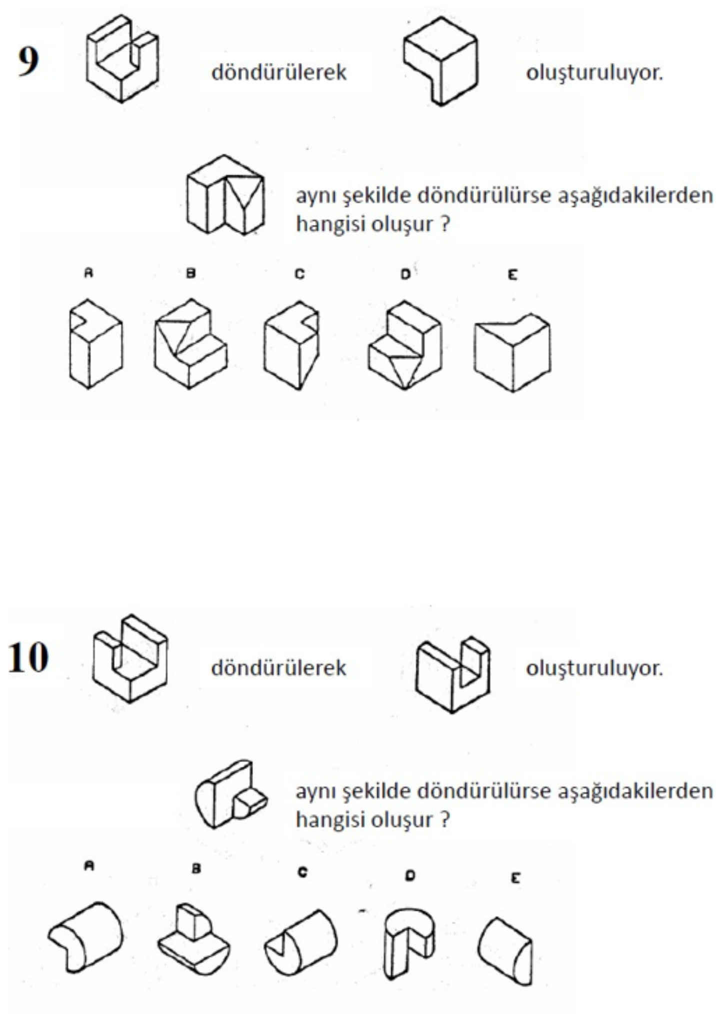
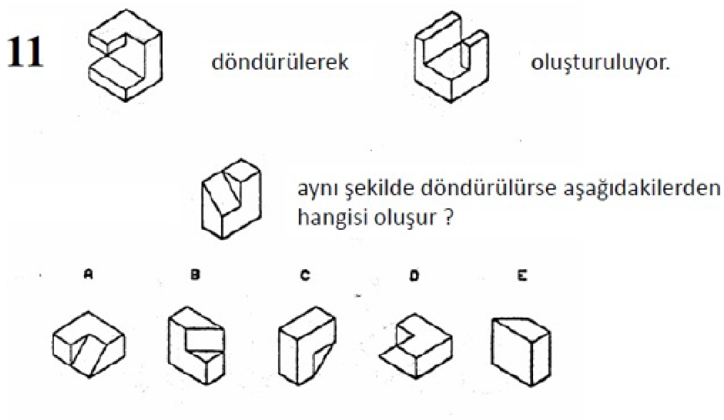


Figure A.7. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 7.



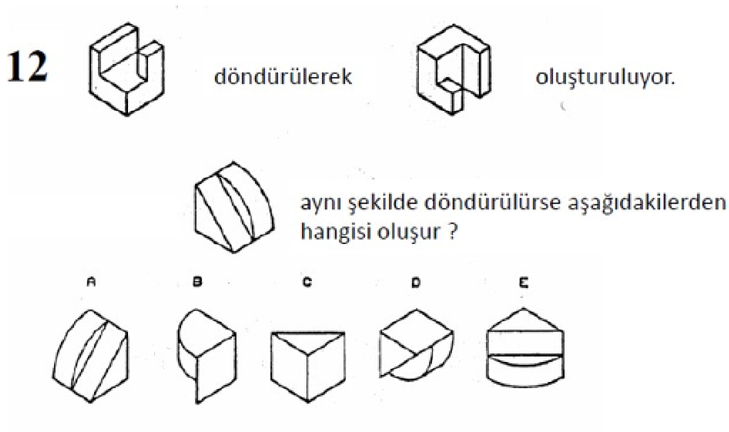
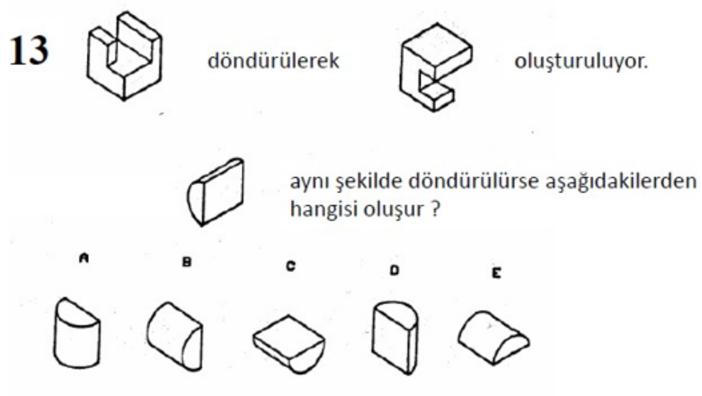


Figure A.8. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 8.



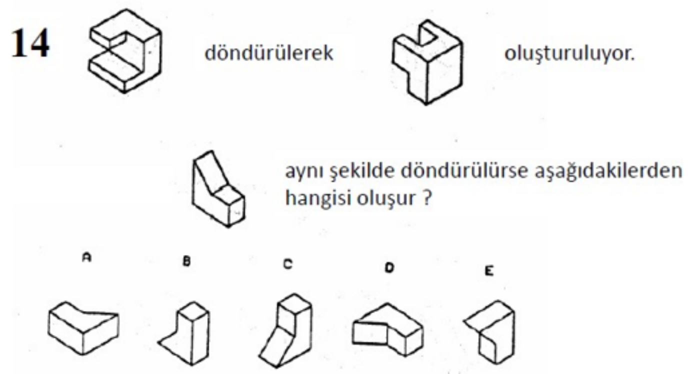
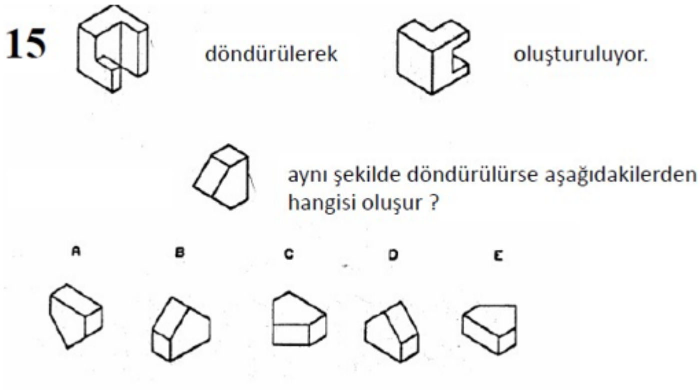


Figure A.9. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 9.



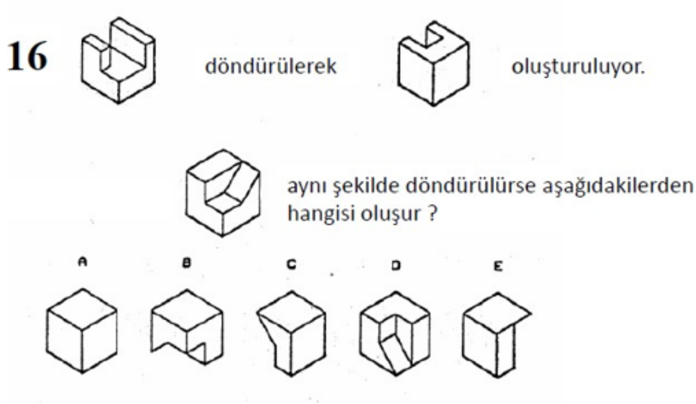
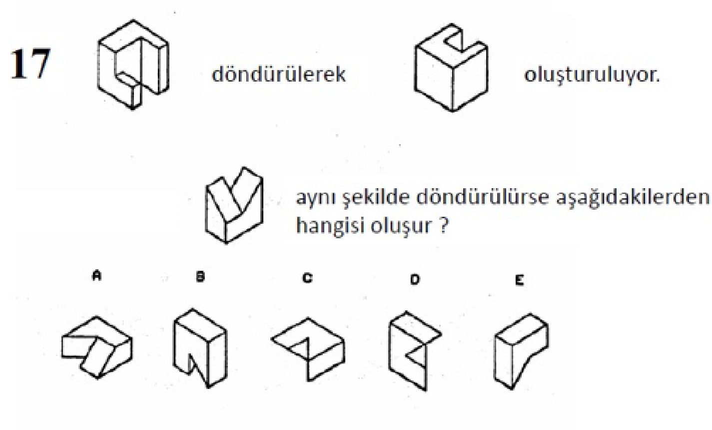


Figure A.10. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 10.



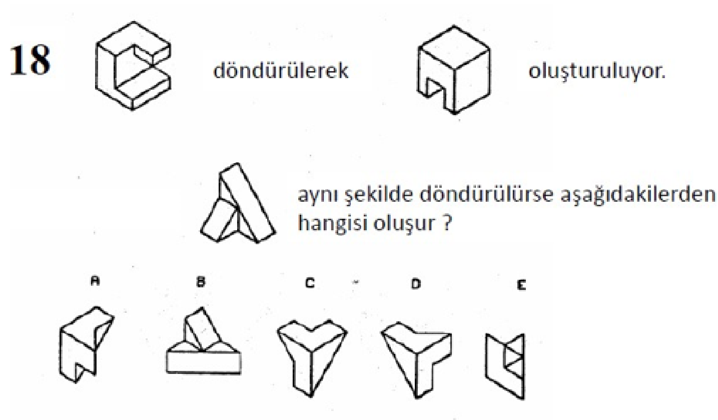


Figure A.11. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 11.

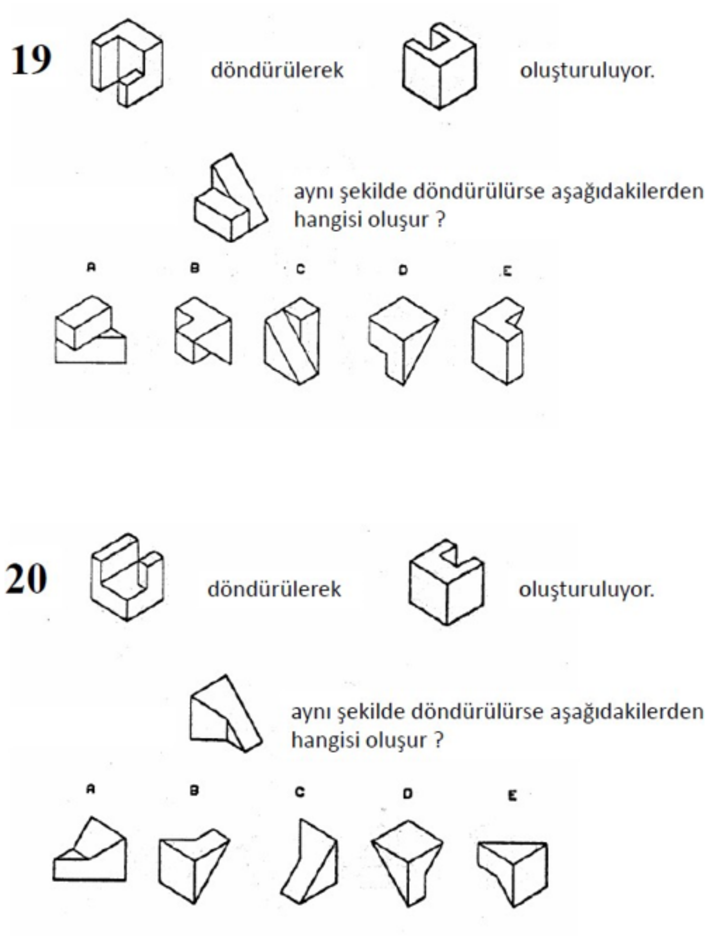


Figure A.12. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 12.

DIFFERENTIAL APPTITUDE TEST: SPACE RELATIONS (DAT: SR)

UZAMSAL YETENEK TESTİ

UZAMSAL İLİŞKİLER

KİTAPÇIK ÜZERİNE İŞARETLEME YAPMAYINIZ!

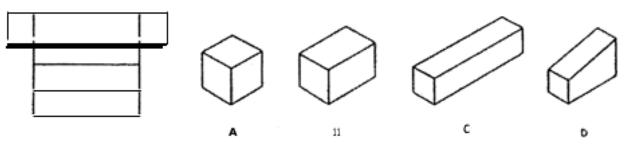
BÜTÜN İŞARETLEMELERİNİZİ YANIT ANAHTAR! ÜZERİNE YAPINIZ!

1. Kurşun kalem kullanınız.
2. İşaretlemenizi belirgin bir şekilde yapınız.
3. Unutmayınız, her soruda yalnızca bir şık doğrudur.

YÖNERGE:

Bu test 3 boyutlu cisimlerin açınımlarını içeren 20 sorudan oluşmaktadır. Her bir sorudaki kare içinde verilen açınım katlandığında şıklardakilerden hangi cismin oluşacağı sorulmaktadır. Verilen açınım daima cismin dıştan görüntüsüne aittir.

ÖRNEK X.

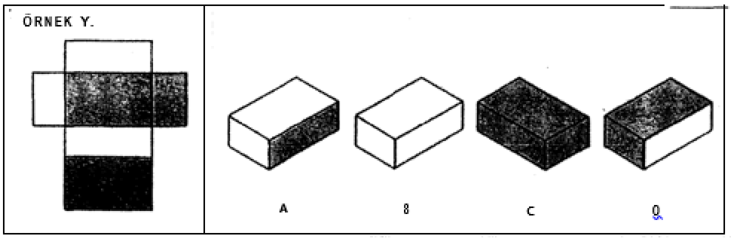


X örneğinde solda verilen açınım katlandığında A, B, C, D şıklarında verilen cisimlerden hangisi oluşur? A ve B kesinlikle olamaz. D için de aynı şeyi söyleyebiliriz. Doğru yanıt C olmalıdır.

Unutmayınız: Bu testte bütün sorularda, solda verilmiş bir açınım ve bunun sağında verilmiş 4 seçenek vardır. Bu seçeneklerden yalnızca biri doğrudur.

Figure A.13. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 13.

Şimdi de Y örneğine bakalım.



Y örneğinde bütün şıklar şeklen doğrudur fakat bunlardan yalnızca birisi verilen açınımdan yapılabilir. Dikkat ederseniz açınım katlandığında oluşacak cismin 3 yüzeyinin gri olması gerekir. Bunlardan birisi taban diğeri tavan olmak üzere 2 yüzey en geniş olan yüzeylerdir. Diğer gri yüzey ise kutunun herhangi bir ucunda bulunabilecek en küçük yüzeylerden biridir.

Şimdi verilen 4 şekle bakalım:
A şıkkı yanlıştır. Uzun ve dar yüzey açınımda gri değildir. En geniş yüzey ise gri olmalıdır.

B şıkkı yanlıştır. Gri yüzey arkada olabilir ancak en geniş yüzey gri olmalıdır.

C şıkkı yanlıştır. Gri tavan ve gri uç doğru yerinde fakat açınımda dar ve uzun gri yüzey yoktur.

D şıkkı doğrudur. Geniş gri yüzey tavan olarak görünmekte, diğer gri yüzey ise bir uçta bulunmaktadır.

Görüldüğü gibi şeklen 4 şık da doğru olmasına rağmen yalnızca D şıkkı gri yüzeyleri doğru yerlerinde göstermektedir.

Bu testi tamamlamak için 40 dakikanız vardır. Soruları hızlı ve doğru yanıtlamaya çalışınız. Yanıttan emin değil iseniz en iyi tahmininizi işaretleyiniz.

Figure A.14. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 14.

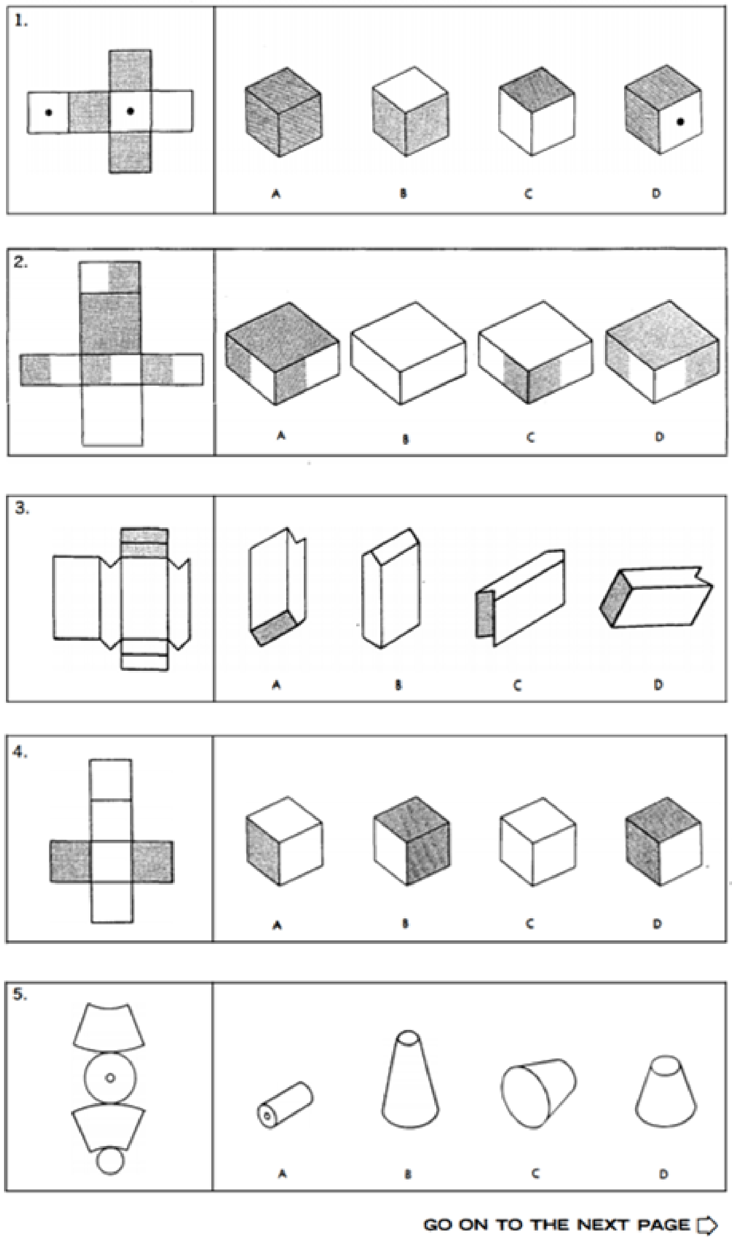


Figure A.15. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 15.

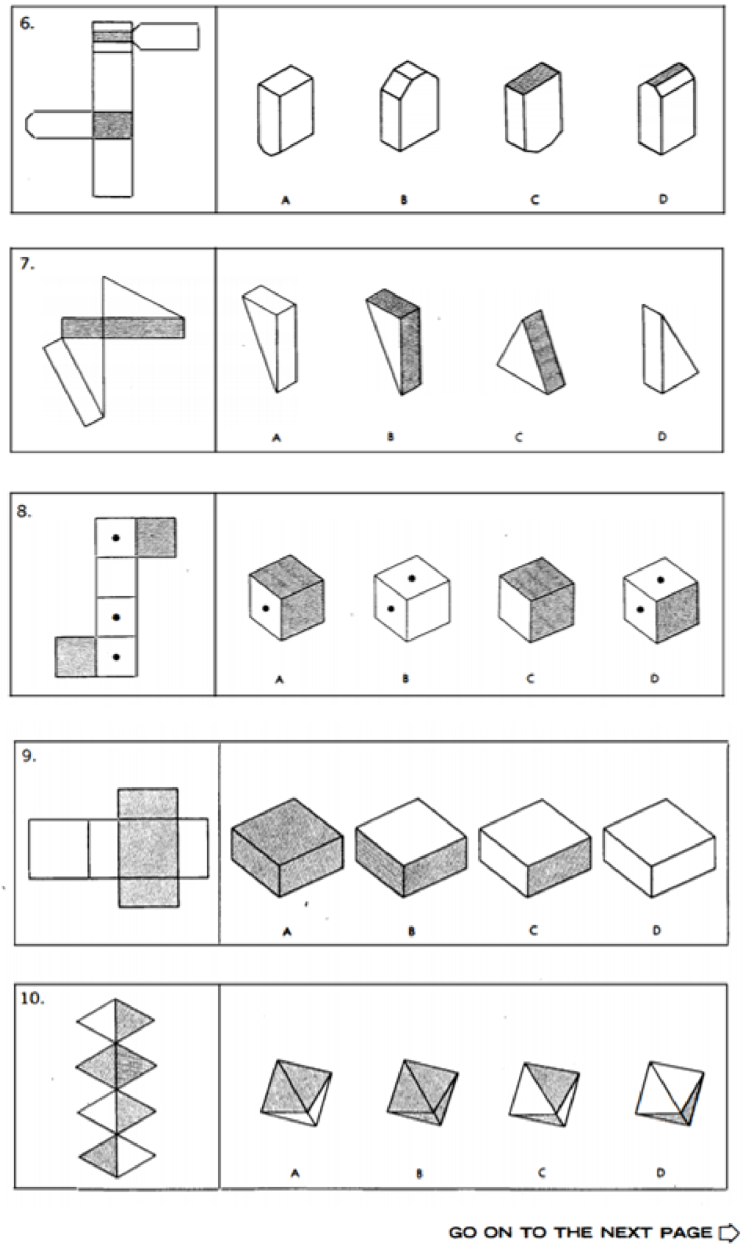


Figure A.16. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 16.

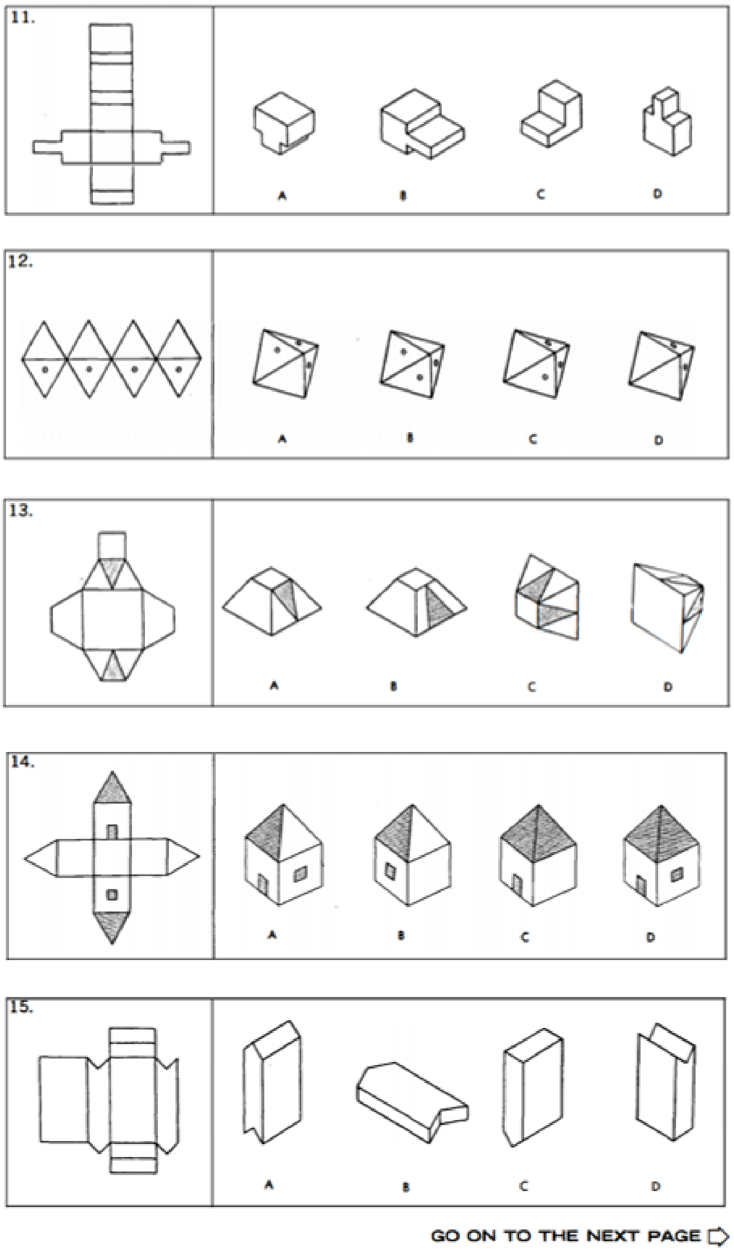


Figure A.17. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 17.

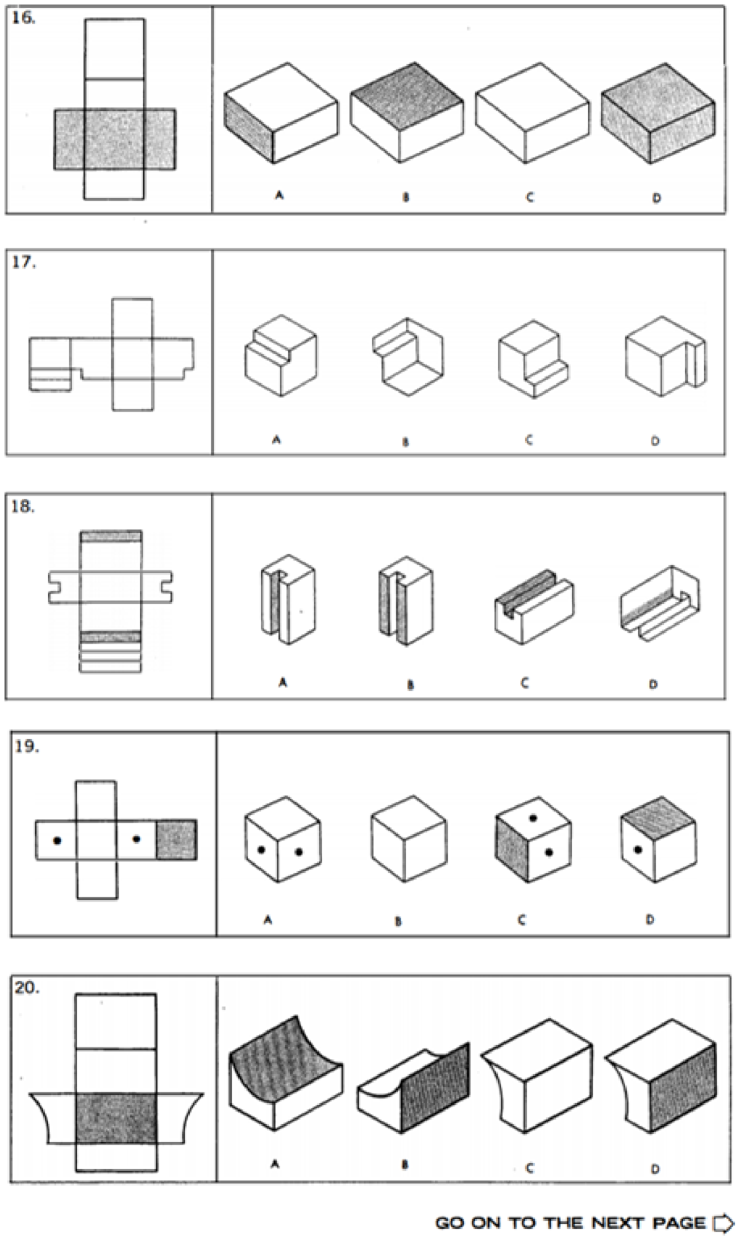


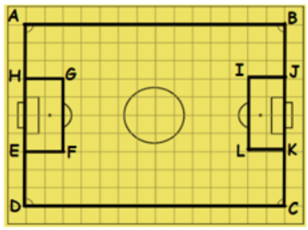
Figure A.18. Spatial Ability Tests the Purdue Visualization of Rotations Test (ROT) 18.

APPENDIX B: GEOMETRY ACHIEVEMENT TESTS AND RUBRICS

GEOMETRY ACHIEVEMENT PRETEST (preGAT)

İsim/Name: ________________________ **Sınıf/Class:** ______________

1. Aşağıdaki kareli kâğıtta verilen futbol sahası modelinde paralel ve eşit uzunlukta olan doğru parçalarına üçer tane örnek veriniz. Bu doğru parçalarını isimlendirerek tabloyu doldurunuz. *(Give three examples to the parallel line segments and congruent line segments from the model of the soccer field given below. Name the line segments and fill in the table.)*



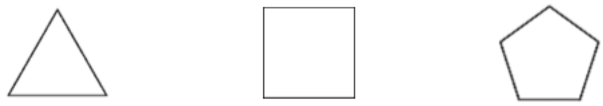
Paralel doğru parçaları *(Parallel line segments)*	Eşit uzunluktaki doğru parçaları *(Congruent line segments)*
.... ve	.... ve ....
.... ve	.... ve ....
.... ve	.... ve ....

2. Aşağıdaki saatlerde gösterilen açıların çeşitlerini (dar, dik, geniş) **altlarına yazınız**. *(**Write down** the types of the angles (acute, right, obtuse) shown by the clocks.)*

______________ ______________ ______________

Figure B.1. Geometry Achievement Tests and Rubrics 1.

3. Aşağıdaki çokgenlerin **isimlerini** altlarına yazınız. **Köşe, kenar, açı** ve **köşegen sayısını** belirtiniz. (*Write down the **names** of the polygons given below. Specify the number of **corners, sides, angles, and diagonals**.*)



Çokgenin ismi: (*Name of the polygon*):	**Çokgenin ismi:** (*Name of the polygon*):	**Çokgenin ismi:** (*Name of the polygon*):
Köşe sayısı: (*Number of the vertices*):	**Köşe sayısı**: (*Number of the vertices*):	**Köşe sayısı:** (*Number of the vertices*):
Kenar sayısı: (*Number of sides*):	**Kenar sayısı:** (*Number of sides*):	**Kenar sayısı:** (*Number of sides*):
Köşegen sayısı: (*Number of diagonals*):	**Köşegen sayısı:** (*Number of diagonals*):	**Köşegen sayısı:** (*Number of diagonals*):

4. a) Aşağıdaki üçgenlerin altına açı özelliklerine göre çeşitlerini **yazınız.**
(***Write down** the types of the triangles according to their angles*).

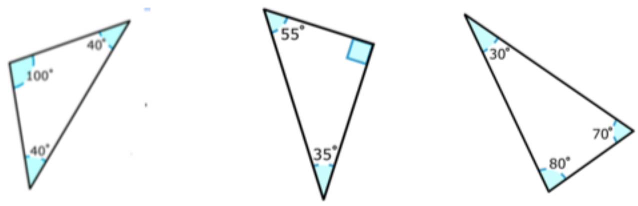
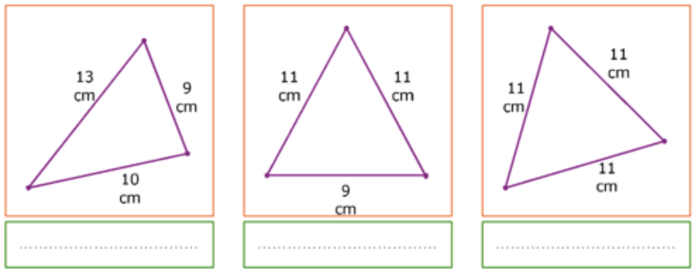


Figure B.2. Geometry Achievement Tests and Rubrics 2.

b) Aşağıdaki üçgenlerin altına kenar uzunluklarına göre çeşitlerini **yazınız.**
*(**Write down** the types of the triangles according to their side lengths).*



c) Aşağıdaki kareli alana bir **dik üçgen** çiziniz.
(Draw a right triangle on the squared area given below).

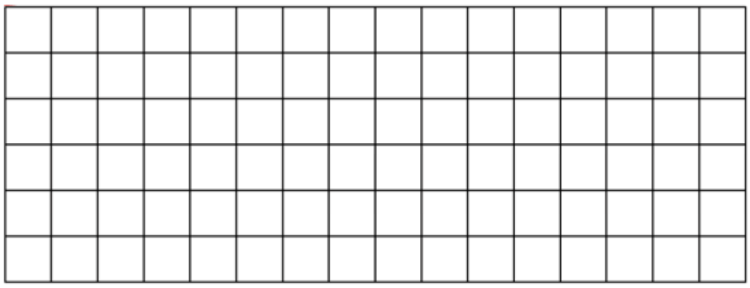
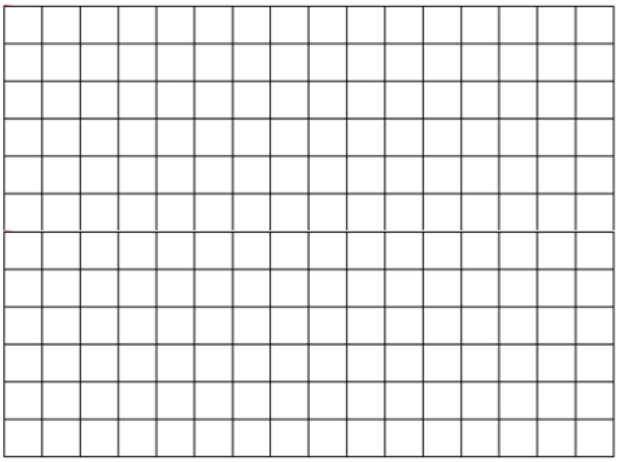


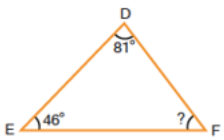
Figure B.3. Geometry Achievement Tests and Rubrics 3.

5. Aşağıdaki kareli alana **dikdörtgen**, **paralelkenar, eşkenar dörtgen** ve **yamuk** çiziniz.
Daha sonra **açılarını** ve **köşegenlerini** şekil üzerinde gösteriniz.
*(Draw a **rectangle, parallelogram, rhombus** and **trapezoid** on the squared area given below. Then show the angles and diagonals on the shapes).*

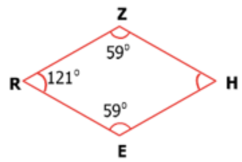


6. Verilmeyen açıları bulunuz. *(Find the missing angles.)*

a)



b)

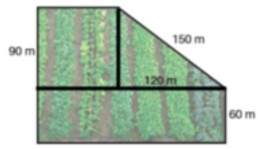


F açısı ....derecedir.
Angle F is .... degrees.

H açısı ....derecedir.
Angle H is .... degrees.

Figure B.4. Geometry Achievement Tests and Rubrics 4.

7. Ayşe öğretmen bahçesini aşağıdaki gibi 3 kısma ayırmıştır. Kare şeklindeki bölüme domates, dikdörtgen şeklindeki bölüme salatalık ve üçgen şeklindeki bölüme marul ekmiştir. Buna göre, *(Ayşe teacher has divided her garden into 3 parts as follows. She planted tomato in the square area, cucumber in the rectangular area, and lettuce in the triangular area. According to this,)*

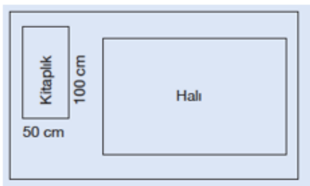


a. Domates ekili olan kısmın çevresini bulunuz.
(Find the planted area of the tomato).

b. Marul ekili olan kısmın çevresini bulunuz.
(Find the planted area of the lettuce).

c. Salatalık ekili olan kısmın çevresini bulunuz.
(Find the planted area of the cucumber).

8. Deniz yeni okul yılı için kısa kenarı 13 cm, uzun kenarı 19 cm olan matematik defterinin **ön yüzünü** farklı renkte bir kağıtla kaplamak istiyor. Buna göre, Deniz'in kaplayacağı alanın kaç **cm²** olduğunu bulunuz.
*(Deniz wants to cover the **front page** of the mathematics book with 13 cm and 19 cm side lengths with a colored paper. How many* **cm²** *will be covered?)*



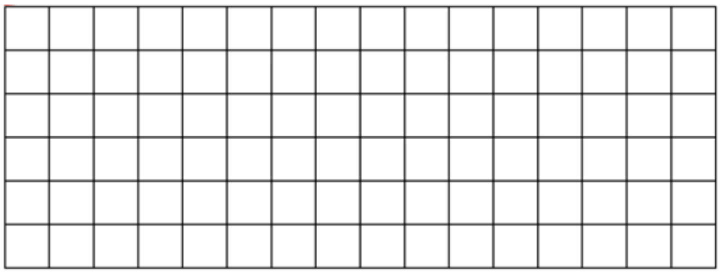
9. Yanda bir odanın zemininde, kitaplık ve halının kapladığı yer verilmiştir.
(The area of the bookcase and a carpet are given on the right side.)

a) Kitaplık için verilen uzunluklara göre, halının alanı tahminen kaç cm²'dir?
(According to the lengths given for the bookcase, how many **cm²** *is the area of the carpet?)*

b) Tahmin yaparken nasıl bir yöntem izlediğinizi açıklayınız. *(Explain the method of your estimation.)*

Figure B.5. Geometry Achievement Tests and Rubrics 5.

10. Aşağıdaki kareli kâğıt üzerine alanı 24 birim kare ve kenar uzunlukları farklı olan **iki dikdörtgen** çiziniz. *(Draw two rectangles with 24 unit squares and different side lengths on the following squared paper.)*



11. Bir iş kulesinin ön cephesi uzun kenarı 4 m, kısa kenarı uzun kenarının yarısı olan dikdörtgen şeklindeki cam paneller ile kaplanacaktır. Buna göre, henüz 150 cam panel takan işçiler kaç **m²**'lik alanı kaplamıştır? *(The front face of a tower will be covered with rectangular glass panels. Long side of the rectangular panels are 4 m and short side is the half of the long side. According to this, if the workers placed 150 panels, how many* **m²** *is covered?)*

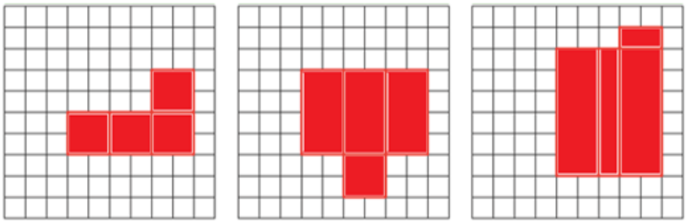
12. a) Aşağıdaki şekillerden hangisi/ hangileri dikdörtgenler prizmasıdır? Altındaki kutuyu **işaretleyiniz.** *(Which of the followings are rectangular prism?* ***Mark*** *the box below it.)*

b) Dikdörtgenler prizması ile ilgili 3 **özellik** yazınız. *(Write 3 properties of the rectangular prism.)*

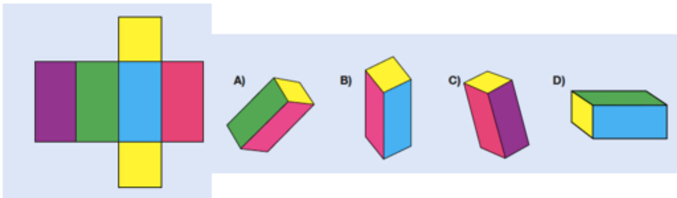
1. ______________________________
2. ______________________________
3. ______________________________

Figure B.6. Geometry Achievement Tests and Rubrics 6.

13. a) Aşağıdaki prizmaların yüzey açınımlarının çizimlerini tamamlayınız. *(Complete the drawings of the nets of the following prisms.)*



b) Aşağıdakilerden hangisi açık hali verilen prizmanın kapalı hali **olamaz**?
*(Which of the following **cannot be** the closed shape of the net of the prism given below?)*



14. Yanda verilen hediye kutusunun yüzeyi el işi kağıdı ile kaplanmak isteniyor. Buna göre, tüm yüzeyin kaplanması için kaç cm2 el işi kâğıdı gerektiğini bulunuz.
(The surface of the gift box will be covered with handcraft paper. Find the area of the paper that is needed to cover the entire surface of the box.)

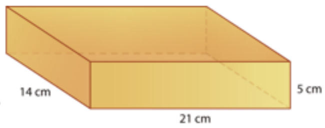


Figure B.7. Geometry Achievement Tests and Rubrics 7.

RUBRIC OF GEOMETRY ACHIEVEMENT PRETEST

Question: 1	
Score	**Description**
6	Student response includes the following 6 elements (or equivalent correct answers). **Each correct pair equals 1 point.** Parallel line segments: IABI and IDCI IGFI and IJCI IHEI and IBCI Equal line segments: IJKI and IGFI IADI and IBCI IHGI and IEFI
5	Student response includes 5 of the 6 elements.
4	Student response includes 4 of the 6 elements.
3	Student response includes 3 of the 6 elements.
2	Student response includes 2 of the 6 elements.
1	Student response includes 1 of the 6 elements.
0	Student response is incorrect or irrelevant.

Question: 2	
Score	**Description**
3	Student response includes the following 3 elements respectively. Obtuse angle Acute angle Right angle
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

Figure B.8. Geometry Achievement Tests and Rubrics 8.

Question: 3	
Part a	
Score	**Description**
3	Student response includes the following 3 elements. Name of the polygon: triangle Number of the vertices and sides: 3 Number of diagonals: none
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part b	
3	Student response includes the following 3 elements. Name of the polygon: quadrilateral / square Number of the vertices and sides: 4 Number of diagonals: 2
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part c	
3	Student response includes the following 3 elements. Name of the polygon: pentagon Number of the vertices and sides: 5 Number of diagonals: 5
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

Figure B.9. Geometry Achievement Tests and Rubrics 9.

Question: 4	
Part a	
Score	**Description**
3	Student response includes the following 3 elements respectively. Obtuse angle triangle Acute angle triangle Right angle triangle
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part b	
3	Student response includes the following 3 elements respectively. Scalene triangle Isosceles triangle Equilateral triangle
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part c	
2	Student draws a complete right triangle.
1	Student draws a triangle other than right angled.
0	Student response is incorrect or irrelevant.

Figure B.10. Geometry Achievement Tests and Rubrics 10.

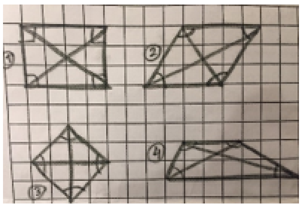
Question: 5	
Score	**Description**
8	Student response includes the following 8 elements. Drawings of the quadrilaterals (each correct drawn shape equals 1 point) Angle and diagonal drawing of each quadrilateral (each correct shown angle and diagonal equals 1 point) Sample Student Response: 
7	Student response includes 7 of the 8 elements.
6	Student response includes 6 of the 8 elements.
5	Student response includes 5 of the 8 elements.
4	Student response includes 4 of the 8 elements.
3	Student response includes 3 of the 8 elements.
2	Student response includes 2 of the 8 elements.
1	Student response includes 1 of the 8 elements.
0	Student response is incorrect or irrelevant.

Figure B.11. Geometry Achievement Tests and Rubrics 11.

Question: 6	
Part a	
Score	**Description**
4	Student response includes the following 4 elements. • **Method component = 2 points** Adding the given angles, 46 + 81 Subtracting the sum of given angles from 180 degrees, 180 – 127 • **Computation component = 2 points** Correct sum,127 Correct subtrahend, 53 Note: A student can also receive a score of 4 by finding 53 without showing the calculations.
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.
Part b	
4	Student response includes the following 4 elements. • **Method component = 2 points** Adding the given angles, 121 + 59 + 59 Subtracting the sum of given angles from 360 degrees, 360 – 239 • **Computation component = 2 points** Correct sum, 239 Correct subtrahend, 121 Note: A student can also receive a score of 4 by finding 121 without showing the calculations.
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.

Figure B.12. Geometry Achievement Tests and Rubrics 12.

Question: 7	
Part a	
Score	**Description**
2	Student response includes the following 2 elements. • **Method component = 1 point** 90 + 90 + 90 + 90 or 90 x 4 • **Computation component = 1 point** Correct result, 360
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.
Part b	
2	Student response includes the following 2 elements. • **Method component = 1 point** 90 + 120 + 150 • **Computation component = 1 point** Correct result, 360
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.
Part c	
3	Student response includes the following 3 elements. • **Method component = 2 points** Adding the lengths 2 x (90+ 120 + 60) or 90 + 120 + 60 + 90 + 120 + 60 • **Computation component = 1 point** Correct result, 540
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

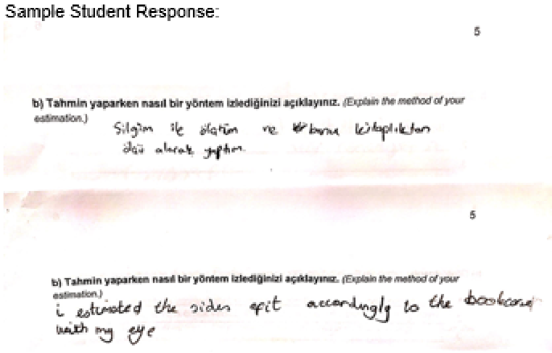
Figure B.13. Geometry Achievement Tests and Rubrics 13.

Question: 8	
Score	**Description**
2	Student response includes the following 2 elements. • **Method component = 1 point** 13 x 19 • **Computation component = 1 point** Correct product, 247
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.

Question: 9	
Part a	
Score	**Description**
4	Student response includes the following 4 elements. • **Method component = 2 points** Area of the bookcase, 50 x 100 Area of the carpet, 5000 x 6 (estimated value) • **Computation component = 2 points** Correct product for the area of the bookcase, 5000 Correct product for the area of the bookcase, 30000 Note: Student also gets 2 points if the perimeter of the shape is found instead of the area with a valid explanation
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.
Part b	

Figure B.14. Geometry Achievement Tests and Rubrics 14.

<table>
<tr><td>1</td><td>Student gives a valid explanation of how to find the area of the carpet.

Sample Student Response:

</td></tr>
<tr><td>0</td><td>Student response is incorrect or irrelevant.</td></tr>
</table>

Question: 10	
Score	**Description**
3	Student draws two different rectangles with the area of 24 unit square.
2	Student draws one rectangle with the area of 24 unit square.
1	Student draws two rectangles different areas.
0	Student response is incorrect or irrelevant.

Figure B.15. Geometry Achievement Tests and Rubrics 15.

Question: 11	
Score	**Description**
6	Student response includes the following 6 elements. • **Method component = 3 points** Width of the rectangular panels, 4: 2 Area of the rectangular panels, 4 x 2 Area of the total place, 150 x 8 • **Computation component = 3 points** Correct quotient, 2 Correct product 4 x 2, 8 Correct product 150 x 8, 1200
5	Student response includes 5 of the 6 elements.
4	Student response includes 4 of the 6 elements.
3	Student response includes 3 of the 6 elements.
2	Student response includes 2 of the 6 elements.
1	Student response includes 1 of the 6 elements.
0	Student response is incorrect or irrelevant.

Figure B.16. Geometry Achievement Tests and Rubrics 16.

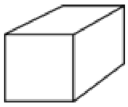
Question: 12	
Part a	
Score	**Description**
1	Student response includes the correct choice from the multiple answers. 
0	Student response is incorrect or left blank.
Part b	
3	Student response includes the following 3 elements. **Each correct answer equals 1 point.** Sample Student Response: Consist of 6 rectangular face, Has 4 lateral surface, Has 8 vertices.
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

Figure B.17. Geometry Achievement Tests and Rubrics 17.

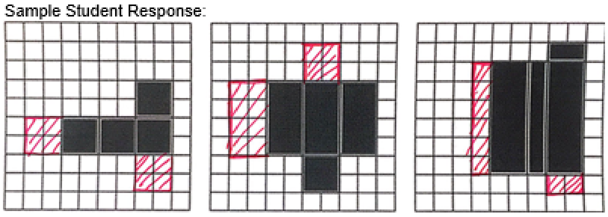
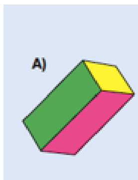
Question: 13	
Part a	
Score	**Description**
6	Student response includes the following 6 elements. Student completes all the drawings of nets correct. **Each correct rectangle equals 1 point.** Sample Student Response:  Note: Student gets no points if more than 2 rectangles are drawn for each prism even if they include the correct rectangles.
5	Student response includes 5 of the 6 elements.
4	Student response includes 4 of the 6 elements.
3	Student response includes 3 of the 6 elements.
2	Student response includes 2 of the 6 elements.
1	Student response includes 1 of the 6 elements.
0	Student response is incorrect or left blank.
Part b	
1	Student response includes the correct choice from the multiple answers. 
0	Student response is incorrect or left blank.

Figure B.18. Geometry Achievement Tests and Rubrics 18.

Question: 14	
Score	**Description**
9	Student response includes the following 9 elements. • **Method component = 5 points** Finding the area of the sides: 21 x 5, 14 x 5, 21 x 14 (1 point each) Finding the total surface area: 2 x (105 + 70 + 294) (2 points) • **Computation component = 4 points** Correct product of area of sides, 21 x 5 = 105, 14 x 5 = 70, 21 x 14 = 294 (1 point each) Correct product of the total surface area: 2 x 469 = 938 (1 point)
8	Student response includes 8 of the 9 elements.
7	Student response includes 7 of the 9 elements.
6	Student response includes 6 of the 9 elements.
5	Student response includes 5 of the 9 elements.
4	Student response includes 4 of the 9 elements.
3	Student response includes 3 of the 9 elements.
2	Student response includes 2 of the 9 elements.
1	Student response includes 1 of the 9 elements.
0	Student response is incorrect or irrelevant.

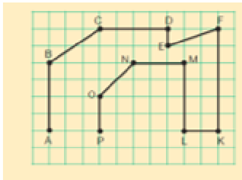
Figure B.19. Geometry Achievement Tests and Rubrics 19.

GEOMETRY ACHIEVEMENT POSTTEST (postGAT)

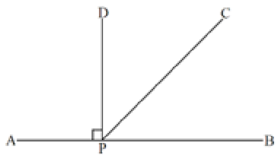
İsim/Name: ________________________ **Sınıf/Class:** ______________

1. Aşağıdaki kareli kâğıtta bulunan doğru parçalarına göre verilen ifadelerin yanına "Doğru (D)" ya da "Yanlış (Y)" yazınız. *(Write "true(T)" or "false (F)" next to the expressions below according to the given line segments on the squared paper.)*

……… EF=BC
……… OP// ML
……… LK=NO
……… KF// AB
……… BA=CD
……… DE// KF



2. Aşağıda verilen şekilden yararlanarak **dar, dik** ve **geniş** açıya bir örnek veriniz.
*(Give one example for **acute, right** and **obtuse** angle from the shape given below.)*



……… dik açıdır *(is a right angle)*

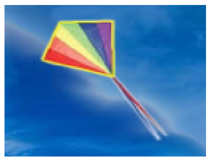
……… dar açıdır *(is an acute angle)*

……… geniş açıdır *(is an obtuse angle)*

3. Aşağıdaki çokgenlerin **isimlerini** altlarına yazınız. **Köşe, kenar, açı** ve **köşegen sayısını** belirtiniz. (*Write down the names of the polygons given below. Specify the number of corners, sides, angles, and diagonals.)*

Çokgenin ismi:
(Name of the polygon):
Köşe sayısı:
(Number of the vertices):
Kenar sayısı:
(Number of sides):
Köşegen sayısı:
(Number of the diagonals):

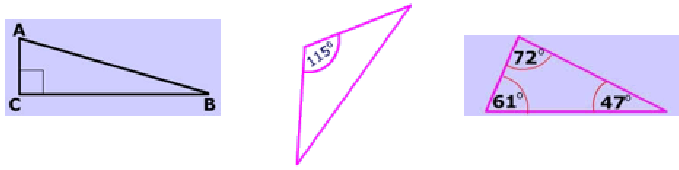
Çokgenin ismi:
(Name of the polygon):
Köşe sayısı:
(Number of the vertices):
Kenar sayısı:
(Number of sides):
Köşegen sayısı:
(Number of the diagonals):



Çokgenin ismi:
(Name of the polygon):
Köşe sayısı:
(Number of the vertices):
Kenar sayısı:
(Number of sides):
Köşegen sayısı:
(Number of the diagonals):

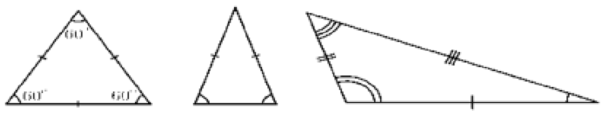
Figure B.20. Geometry Achievement Tests and Rubrics 20.

4. a) Aşağıdaki üçgenlerin altına açı özelliklerine göre çeşitlerini yazınız.
(Write down the types of the triangles according to their angles.)



______________ ______________ ______________

b) Aşağıdaki üçgenlerin altına kenar uzunluklarına göre çeşitlerini yazınız.
(Write down the types of the triangles according to their side lengths).



______________ ______________ ______________

c) Aşağıdaki kareli alana bir **ikizkenar üçgen** çiziniz.
*(Draw an **isosceles** triangle in the squared area given below.)*

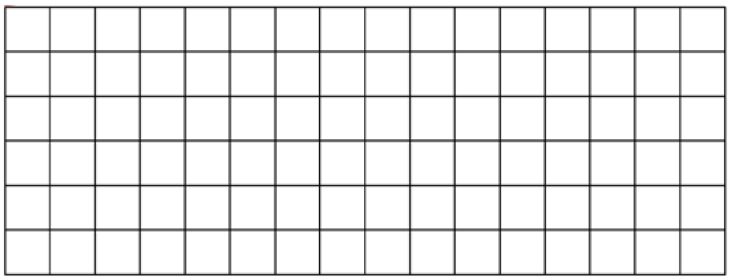
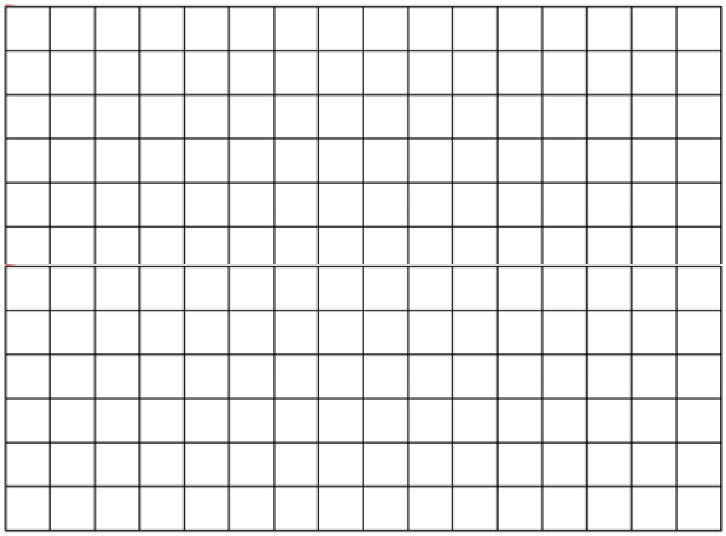


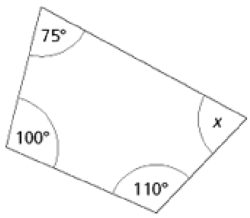
Figure B.21. Geometry Achievement Tests and Rubrics 21.

5. Aşağıdaki kareli kâğıda **dikdörtgen**, **paralelkenar**, **eşkenar dörtgen** ve **yamuk** çiziniz. Daha sonra **açılarını** ve **köşegenlerini** şekil üzerinde gösteriniz.
(Draw a rectangle, parallelogram, rhombus and trapezoid on the following squared paper. Then show the angles and diagonals on the shapes.)

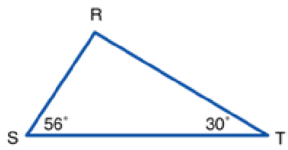


6. Verilmeyen açıları bulunuz. *(Find the missing angles.)*

a)



b)

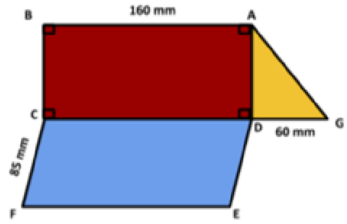


x ....derecedir.
x is .... degrees.

R açısı ....derecedir.
Angle R is .... degrees.

Figure B.22. Geometry Achievement Tests and Rubrics 22.

7.



Aycan'ın Tangram parçaları ile oluşturduğu şekilde IBAI= 160 mm, IFCI = 85mm ve IDGI= 60 mm'dir. **ABCD dikdörtgeninin uzun kenarı kısa kenarının 2 katı olduğuna göre,**

(Aycan made the following shape from the Tangram pieces. IBAI= 160 mm, IFCI = 85 mm, IDGI= 60 mm and ***the length of the ABCD rectangle is 2 times its width.****)*

a. ABCD dikdörtgeninin çevresini bulunuz. *(Find the perimeter of the ABCD rectangle.)*

b. CDEF paralelkenarının çevresini bulunuz. *(Find the perimeter of the CDEF parallelogram.)*

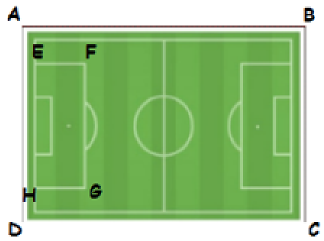
c. ADG üçgeninin çevresi 240 mm olduğuna göre, AG kenarının uzunluğunu bulunuz. *(If the perimeter of ADG triangle is 240 mm, find the length of AG.)*

8. Bir boya ustası birinci gün uzun kenarı 8 m, kısa kenarı 2 m olan dikdörtgen şeklindeki bir duvarı, ikinci gün ise bir kenarı 4 m olan kare şeklindeki bir duvarı boyayacaktır. Usta, işi bittiğinde toplamda kaç m2'lik bir alanı boyamış olur? *(A foreman will paint a rectangle wall with side lengths of 3 m and 8 m in the first day and a square wall with side lengths of 4 m in the second day. Find how much area will be painted at the end of the second day.)*

Figure B.23. Geometry Achievement Tests and Rubrics 23.

9. Yanda bir futbol stadının üstten görünümü verilmiştir. *(The top view of a soccer field is given on the right side.)*

a) Şekilde ceza sahasının (EFGH dikdörtgeni) kapladığı alan 640 m² ise, futbol sahasının alanı tahminen kaç m²'dir? Işlemlerinizi gösteriniz.
(If the penalty area (EFGH rectangle) is 640 m^2*, find the area of the soccer field (ABCD rectangle) in* m^2 *and show your work.)*



b) Tahmin yaparken nasıl bir yöntem izlediğinizi açıklayınız. *(Explain the method of your estimation.)*

10. Aşağıdaki kareli kağıt üzerine alanı **36** birim kare olan **bir kare** ve **bir dikdörtgen** çiziniz.
(Draw one rectangle and one square with the area of 36 unit squares on the following squared paper.)

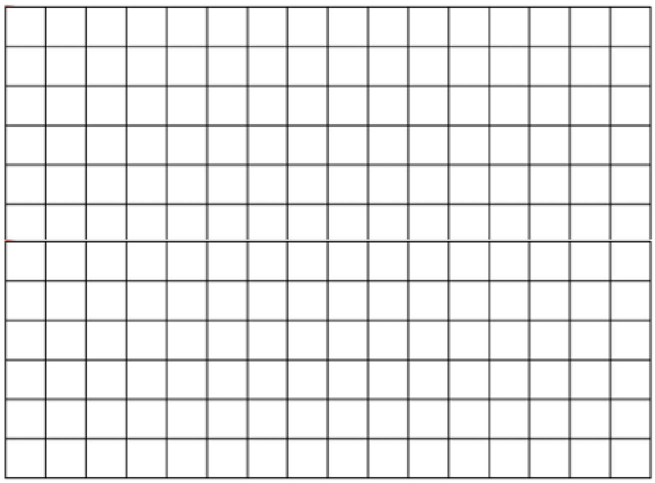
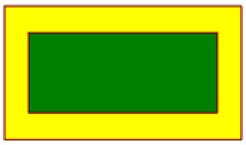


Figure B.24. Geometry Achievement Tests and Rubrics 24.

11. Yanda dikdörtgen şeklindeki bir parkın planı verilmiştir. Parkın ağaçlık bölgesi yeşil ile, yürüyüş parkuru ise sarı ile gösterilmiştir. **Ağaçlık bölgeyi** oluşturan dikdörtgenin kısa kenarı **8 m** ve çevresi **46 m**' dir. **Parkın alanı 450 m²** olduğuna göre **<u>yürüyüş parkurunun alanını bulunuz.</u>**
(Plan of a park is given on the right. The area where the trees are located is shown in green color and the walkway in yellow. The length of the green rectangle is 8 m and its perimeter is 46 m. ***If the area of the park is 450 m², find the area of the walkway.)***



12. Aşağıda dikdörtgenler prizması ile ilgili verilen cümlelerin yanlarına "Doğru (D)" veya "Yanlış (Y)" yazınız. *(Write "true(T)" or "false (F)" next to the given sentences about rectangular prism.)*

(.......) En, boy ve yükseklik olmak üzere 3 boyutu vardır. *(Has 3 dimensions; width, length and height.)*
(.......) Karşılıklı yüzleri birbirinden farklı dikdörtgenlerden oluşur. *(Opposite faces are different rectangles.)*
(.......) 6 yüzeyi, 8 köşesi ve 12 ayrıtı vardır. *(Has 6 faces, 8 vertices and 12 edge.)*
(.......) Karşılıklı yüzeylerinin alanları birbirine eşittir. *(Opposite faces have the same area.)*
(.......) Tüm ayrıtlarının uzunluğu birbirine eşittir. *(All the edges have equal length.)*

13. a) Aşağıda verilen kareli kağıda bir dikdörtgenler prizmasının yüzey açınımını çiziniz. *(Draw a net of a rectangular prism.)*

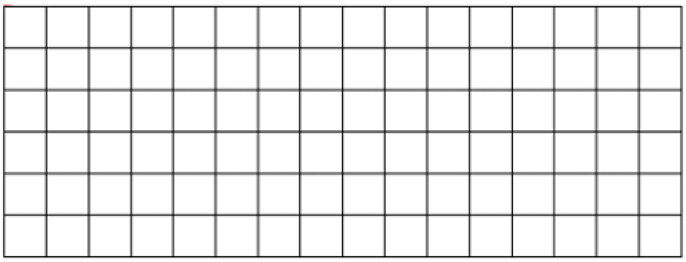
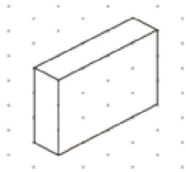
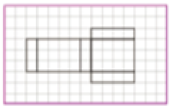


Figure B.25. Geometry Achievement Tests and Rubrics 25.

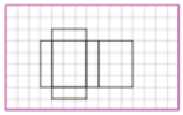
b) İzometrik kağıt üzerine çizilen dikdörtgenler prizmasının açınımı aşağıdakilerden hangisidir? *(Which of the following is the net of rectangular prism given on the isometric paper?)*



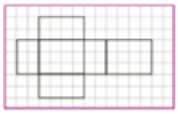
a.



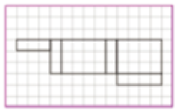
b.



c.



d.



14. Yanda verilen hediye kutusunun yüzeyi el işi kağıdı ile kaplanmak isteniyor. Buna göre, tüm yüzeyin kaplanması için kaç cm2 el işi kağıdı gerektiğini bulunuz.
(The surface of the gift box will be covered with handcraft paper. Find the area of the paper that is needed to cover the entire surface of the box.)

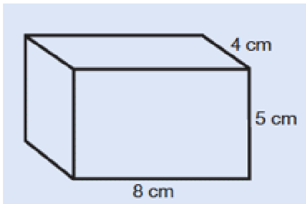


Figure B.26. Geometry Achievement Tests and Rubrics 26.

RUBRIC OF GEOMETRY ACHIEVEMENT POSTTEST

RUBRIC OF GEOMETRY ACHIEVEMENT POSTTEST

Question: 1	
Score	**Description**
6	Student response includes the following 6 elements respectively. **Each correct answer equals 1 point.** False IEFI = IBCI True IOPI // IMLI False ILKI = INOI True IKFI // IABI True IBAI = ICDI True IDEI // IKFI
5	Student response includes 5 of the 6 elements.
4	Student response includes 4 of the 6 elements.
3	Student response includes 3 of the 6 elements.
2	Student response includes 2 of the 6 elements.
1	Student response includes 1 of the 6 elements.
0	Student response is incorrect or irrelevant.

Question: 2	
Score	**Description**
3	Student response includes the following 3 elements respectively. APD or DPB BPC or DPC APC
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

Figure B.27. Geometry Achievement Tests and Rubrics 27.

Question: 3	
Part a	
Score	**Description**
3	Student response includes the following 3 elements. Name of the polygon: pentagon Number of the vertices and sides: 5 Number of diagonals: 5
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part b	
3	Student response includes the following 3 elements. Name of the polygon: triangle Number of the vertices and sides: 3 Number of diagonals: none
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part c	
3	Student response includes the following 3 elements. Name of the polygon: quadrilateral / square Number of the vertices and sides: 4 Number of diagonals: 2
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.

Figure B.28. Geometry Achievement Tests and Rubrics 28.

Question: 4	
Part a	
Score	**Description**
3	Student response includes the following 3 elements respectively. Right angle triangle Obtuse angle triangle Acute angle triangle
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part b	
3	Student response includes the following 3 elements respectively. Equilateral triangle Isosceles triangle Scalene triangle
2	Student response includes 2 of the 3 elements.
1	Student response includes 1 of the 3 elements.
0	Student response is incorrect or irrelevant.
Part c	
2	Student draws a complete isosceles triangle.
1	Student draws a triangle other than isosceles.
0	Student response is incorrect or irrelevant.

Figure B.29. Geometry Achievement Tests and Rubrics 29.

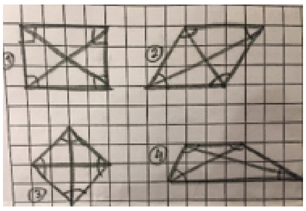
Question: 5	
Score	**Description**
8	Student response includes the following 8 elements. Drawings of the quadrilaterals (each correct drawn shape equals 1 point) Angle and diagonal drawing of each quadrilateral (each correct shown angle and diagonal equals 1 point) Sample Student Response: 
7	Student response includes 7 of the 8 elements.
6	Student response includes 6 of the 8 elements.
5	Student response includes 5 of the 8 elements.
4	Student response includes 4 of the 8 elements.
3	Student response includes 3 of the 8 elements.
2	Student response includes 2 of the 8 elements.
1	Student response includes 1 of the 8 elements.
0	Student response is incorrect or irrelevant.

Figure B.30. Geometry Achievement Tests and Rubrics 30.

Question: 6	
Part a	
Score	**Description**
4	Student response includes the following 4 elements. • **Method component = 2 points** Adding the given angles, 110 + 100 + 75 Subtracting the sum of given angles from 360 degrees, 360 – 285 • **Computation component = 2 points** Correct sum, 285 Correct subtrahend, 75
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.
Part b	
4	Student response includes the following 4 elements. • **Method component = 2 points** Adding the given angles, 56 + 30 Subtracting the sum of given angles from 180 degrees, 180 – 86 • **Computation component = 2 points** Correct sum, 86 Correct subtrahend, 94
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.

Figure B.31. Geometry Achievement Tests and Rubrics 31.

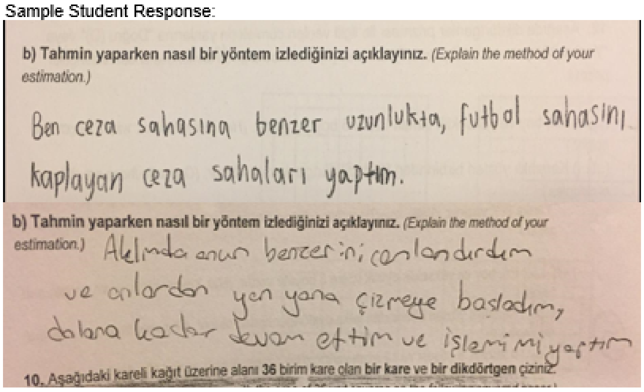
Question: 7	
Part a	
Score	**Description**
4	Student response includes the following 4 elements. • **Method component = 2 points** 160: 2 160 + 160 + 80 + 80 or 2 x (160 + 80) • **Computation component = 2 points** Correct result of the division, 80 Correct result of the addition or multiplication, 480
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.
Part b	
2	Student response includes the following 2 elements. • **Method component = 1 point** 85 + 85 + 160 + 160 or 2 x (160 + 85) • **Computation component = 1 point** Correct result, 490
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.
Part c	
4	Student response includes the following 4 elements. • **Method component = 2 points** 60 + 80

Figure B.32. Geometry Achievement Tests and Rubrics 32.

	240 – 140 • **Computation component = 2 points** Correct result of the addition, 140 Correct result of the subtraction, 100
3	Student response includes 3 of the 4 elements.
2	Student response includes 2 of the 4 elements.
1	Student response includes 1 of the 4 elements.
0	Student response is incorrect or irrelevant.

Question: 8	
Score	**Description**
6	Student response includes the following 6 elements. • **Method component = 3 points** 8 x 3 4 x 4 24 + 16 • **Computation component = 3 points** Correct products, 24 and 16 Correct sum, 40
5	Student response includes 5 of the 6 elements.
4	Student response includes 4 of the 6 elements.
3	Student response includes 3 of the 6 elements.
2	Student response includes 2 of the 6 elements.
1	Student response includes 1 of the 6 elements.
0	Student response is incorrect or irrelevant.

Figure B.33. Geometry Achievement Tests and Rubrics 33.

Question: 9	
Part a	
Score	**Description**
2	Student response includes the following 2 elements. • **Method component = 1 point** Area of the soccer field 640 x 6 (estimated value) • **Computation component = 1 point** Correct product, 3840
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.
Part b	
1	Student gives a valid explanation of how to find the area of the soccer field. Sample Student Response: 
0	Student response is incorrect or irrelevant.

b) Tahmin yaparken nasıl bir yöntem izlediğinizi açıklayınız. *(Explain the method of your estimation.)*

Ben ceza sahasına benzer uzunlukta, futbol sahasını kaplayan ceza sahaları yaptım.

b) Tahmin yaparken nasıl bir yöntem izlediğinizi açıklayınız. *(Explain the method of your estimation.)*

Aklımda onun benzerini canlandırdım ve onlardan yan yana çizmeye başladım, dolana kadar devam ettim ve işlemimi yaptım

Figure B.34. Geometry Achievement Tests and Rubrics 34.

Question: 10	
Score	**Description**
2	Student response includes the following 2 elements. A rectangle with the area of 24 unit square. A square with the area of 24 unit square.
1	Student response includes 1 of the 2 elements.
0	Student response is incorrect or irrelevant.

Question: 11	
Score	**Description**
10	Student response includes the following 10 elements. • **Method component = 5 points** 8 x 2 46 - 16 30: 2 15 x 8 450 - 120 • **Computation component = 5 points** Correct product,16 Correct subtrahend, 30 Correct quotient, 15 Correct product, 120 Correct subtrahend, 330
9	Student response includes 9 of the 10 elements
8	Student response includes 8 of the 10 elements
7	Student response includes 7 of the 10 elements
6	Student response includes 6 of the 10 elements
5	Student response includes 5 of the 10 elements
4	Student response includes 4 of the 10 elements
3	Student response includes 3 of the 10 elements
2	Student response includes 2 of the 10 elements
1	Student response includes 1 of the 10 elements.
0	Student response is incorrect or irrelevant.

Figure B.35. Geometry Achievement Tests and Rubrics 35.

Question: 12	
Score	**Description**
5	Student response includes the following 5 elements relatively. True False True True False
4	Student response includes 4 of the 5 elements.
3	Student response includes 3 of the 5 elements.
2	Student response includes 2 of the 5 elements.
1	Student response includes 1 of the 5 elements.
0	Student response is incorrect or irrelevant.

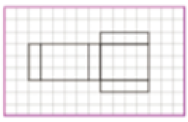
Question: 13	
Part a	
Score	**Description**
3	Student draws a complete net of a rectangular prism.
2	Student draws a rectangular prism with 1 or 2 missing parts.
1	Student draws a correct net of a prism other than rectangular prism.
0	Student response is incorrect or left blank.
Part b	
1	Student response includes the correct choice from the multiple answers. **a)** 
0	Student response is incorrect or left blank.

Figure B.36. Geometry Achievement Tests and Rubrics 36.

Question: 14	
Score	Description
9	Student response includes the following 9 elements. • **Method component = 5 points** Finding the area of the sides: 8 x 5, 4 x 5, 8 x 4 (1 point each) Finding the total surface area: 2 x (40 + 20 + 32) (2 points) • **Computation component = 4 points** Correct product of area of sides, 8 x 5 = 40, 4 x 5 = 20, 8 x 4= 32 (1 point each) Correct product of the total surface area: 2 x 92 = 184 (1 point)
8	Student response includes 8 of the 9 elements.
7	Student response includes 7 of the 9 elements.
6	Student response includes 6 of the 9 elements.
5	Student response includes 5 of the 9 elements.
4	Student response includes 4 of the 9 elements.
3	Student response includes 3 of the 9 elements.
2	Student response includes 2 of the 9 elements.
1	Student response includes 1 of the 9 elements.
0	Student response is incorrect or irrelevant.

Figure B.37. Geometry Achievement Tests and Rubrics 37.

APPENDIX C: SAMPLE LESSON DESCRIPTIONS

SAMPLE LESSON DESCRIPTION FOR TECHNOLOGY-BASED INSTRUCTION

Activity 3: Construct Your Own Triangle

Aim: The aim of the activity is to construct triangles according to their angles and sides.

Duration: 80 min

Method: Pair work

Materials: Activity sheet, geoboards, elastic bands

Description: Students constructed triangles by their sides and angles. In the first lesson, they worked as a pair and shared their ideas on the properties of equilateral, isosceles and scalene triangle. They tried to make equilateral, isosceles and scalene triangle by using geoboards and elastic bands. Then, they prepared two different triangles of each triangle type. In the following lesson, students constructed triangles according to their angle properties. They shared ideas about the types of triangles by their angles and made acute, right and obtuse angled triangle. Students' samples were checked out by the teacher and they shared their examples with each other. The pictures of the process are given below.

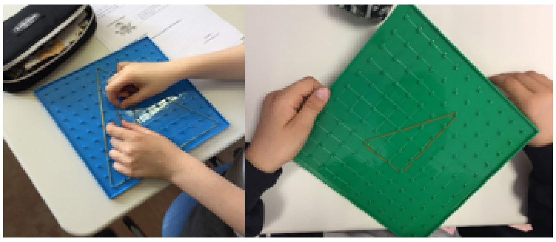


Figure C.1. Students using geoboards to construct triangles.

SAMPLE LESSON DESCRIPTION FOR HANDS-ON INSTRUCTION

Activity 3: Construct Your Own Triangle

Aim: The aim of the activity is to construct triangles according to their angles and sides.

Duration: 80 min

Method: Pair work

Materials: Activity sheet, tablet computer, online geoboard application, ruler

Description: Students used the geoboard application from their tablet computers to construct triangles according to their side and angle properties. They worked as a pair and shared their ideas on the properties of equilateral, isosceles and scalene triangle in the first part of the lesson. They prepared two different triangles of each and used rulers where needed. Some of their examples were shown in the class and students' samples were checked out by the teacher. In the next session, students made acute, right and obtuse triangle with their online geoboards and used protractor when needed. Pictures of the process are given below.

Figure C.2. Students using online geoboards from tablet computers to construct triangles.