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A DESCRIPTIVE INVESTIGATION OF TURKISH HIGH SCHOOL STUDENTS' SPATIAL VISUALIZATION ABILITY

A MASTER'S THESIS

BY

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THE PROGRAM OF CURRICULUM AND INSTRUCTION
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To my father with love…

A Descriptive Investigation of Turkish High School Students'

Spatial Visualization Ability

The Graduate School of Education

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by

Dilara Toplu

In Partial Fulfilment of the Requirements for the Degree of

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June 2020

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

Assoc. Prof. Dr. Erdat Çataloğlu (Supervisor)

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ABSTRACT

A Descriptive Investigation of Turkish High School Students'

Spatial Visualization Ability

Dilara Toplu

M.A. in Curriculum and Instruction
Supervisor: Assoc. Prof. Dr. Erdat Çataloğlu

June 2020

The purpose of this study was to investigate Turkish high school students' spatial visualization ability. Gender, school type, and grade were used as independent variables to describe spatial visualization ability as it pertains to the respective dimensions. Descriptive research was used, and the sample consisted of 555 students from private and state high schools. The study was carried out in Çankaya, Ankara. The "Purdue Spatial Visualization Test - PSVT" developed by Roland Guay in 1976, adapted into Turkish by Sevimli (2009) was used to measure students' spatial visualization abilities. The data collection took place during the fall semester of the 2018-2019 academic year. The data analyses were conducted by considering students' total scores of PSVT. Descriptive statistical analyses were conducted to determine students' spatial visualization levels based on the variables: gender, school type, and grade. An independent samples t-test was conducted to determine whether the mean difference between gender and school types were statistically significant. Welch's ANOVA test was conducted to determine whether the mean difference between grades was statistically significant. Moreover, Pearson correlation coefficients were computed to find out if there were relationships between the students' PSVT total scores and their mathematics course grades, also for their socioeconomic status. Analyses revealed that students' spatial visualization levels were dependent on their gender and school type. It was found that there was not a statistically significant difference between the PSVT mean scores of grades. There was a significant, positive correlation between students' spatial visualization levels and mathematics grades and socioeconomic status.

Keywords: Spatial visualization ability, mathematics achievement, gender

ÖZET

Ankara’nın Çankaya İlçesindeki Lise Öğrencilerinin Görsel Uzamsal Becerileri Üzerine Nicel Bir Çalışma

Dilara Toplu

Yüksek Lisans, Eğitim Programları ve Öğretim

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Bu çalışmanın amacı, Türk lise öğrencilerinin uzamsal görselleştirme becerilerini araştırmaktır. Bu çalışmada cinsiyet, okul türü ve sınıf seviyeleri değişkenleri kullanılmıştır. Çalışmada betimleyici araştırma yöntemi kullanılmıştır ve örneklem bir özel okul ve iki devlet lisesinden 555 lise öğrencisinden oluşmaktadır. Çalışma Ankara'nın Çankaya ilçesinde gerçekleştirildi. Kullanılan enstrüman Sevimli (2009) tarafından “Purdue Uzamsal Görselleştirme Testi- PUGT” nin orijinal İngilizce versiyonu kullanılarak Türkçe’ ye uyarlanmıştır. PUGT, öğrencilerin uzamsal görselleştirme becerilerini ölçmek için 1976 yılında Roland Guay tarafından geliştirilmiştir. PUGT 36 çoktan seçmeli, tek doğru cevaplı soru içermektedir. Veri toplama 2018-2019 akademik yılının sonbahar döneminde gerçekleşmiştir. Verilerin analizleri, öğrencilerin PUGT toplam puanları dikkate alınarak yapılmıştır. Öğrencilerin cinsiyet, okul türü ve sınıf seviyeleri değişkenlerine göre uzamsal görselleştirme beceri seviyelerini belirlemek için betimleyici istatistiksel analiz yapılmıştır. Cinsiyet ve okul türünün kendi içindeki gruplarının ortalama skorları arasında belirleyici bir fark olup olmadığını ortaya koymak için bağımsız örneklemler t-testi kullanılmıştır. Sınıf seviyelerinin ortalama skorları arasında belirleyici bir fark olup olmadığını belirlemek için tek yönlü varyans analizi yapılmıştır. Ayrıca, öğrencilerin PUGT toplam puanı ile matematik dönem sonu ders notları arasında ve sosyoekonomik durumları arasında ilişki olup olmadığını öğrenmek için Pearson korelasyon katsayıları hesaplanmıştır. Analizler öğrencilerin uzamsal görselleştirme seviyelerinin cinsiyet ve okul türlerine bağımlı olduğunu ortaya koymuştur. Ayrıca, PUGT ortalama puanları ile sınıf seviyeleri arasında istatistiksel olarak anlamlı bir fark olmadığı bulunmuştur. Öğrencilerin uzamsal görselleştirme seviyeleri ile matematik notları ve sosyoekonomik durumları arasında anlamlı ve pozitif bir korelasyon bulunmuştur.

Anahtar kelimeler: Uzamsal görselleştirme becerisi, cinsiyet, matematik başarısı

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CHAPTER 1: INTRODUCTION

Introduction

In this chapter, the researcher explains the background, problem, purpose, significance of this study, and concludes with the definition of key terms.

Spatial ability is required to perceive, interpret, and adapt to changes in the environment. Having a good spatial ability skill means having a mental ability to perceive, imagine, and rotate objects mentally. Spatial ability skills make humans function efficiently and safely in the environment. Therefore, there's no surprise that it has an important role in both daily life and education.; mathematics, especially geometry, science, engineering, etc. For instance, when someone describes an item's location, the person draws mental maps of the object while providing the information. We also use it in the manoeuvres we make while parking our car, trying to find a different place, using two-dimensional maps, arranging the furniture in our room and arranging the objects around us according to each other or to ourselves (down-up, front-back, right-left, high-low, far-close, internal-external). Clearly, spatial ability skills have an important place in daily life.

The importance of spatial ability places a mathematical subcategory of geometry because it focuses on shapes and objects, which helps students understand the world they live in, recognize its importance, and explore the world of shapes. In order for an individual to perform the specified mental thinking activities, that is to have good geometric thinking, s/he needs a strong spatial visualization ability as a component of spatial ability. A spatial visualization ability can be defined as an ability to perceive shapes from different perspectives, to understand the relations between two- and three-dimensional shapes, to create mentally different views, and to visualise nets of the objects. Spatial skills are also needed in order to imagine and draw the views of three-dimensional shapes in two-dimensions. Secondly, it helps to view a three-dimensional shape when drawn in a two-dimensional space. For example, when architects draw the blueprints for a building, they may use spatial ability skills to show a three-dimensional terrain on a two-dimensional map. In many studies, it has been stated that disciplines such as engineering, architecture, science, and art are related to spatial ability skills (Rafi, Anuar, Samad, Hayati, & Mahadzir, 2005).

Even though, a good number of studies conducted separately for the variables gender, grade, school type, mathematics course grades, and socioeconomic status, this study aimed to analyse the variables within one study. Also, some of the studies were conducted with elementary, middle school and college students. This study specifically aimed to describe the variables for the high school students.

There are several tests that measure spatial thinking skills. While some tests measure the spatial orientation level, some tests are concentrated on spatial relations. Among the tests, we chose the Purdue Spatial Visualization test developed by Guay in 1976. This test specifically measures the spatial visualization ability level. In addition, the test has three different sections that measure different constructs. This helped us identify areas where participants are strong, need to be improved, and/or weak.

Moreover, a Turkish version of the test was already available, speeding up the process of the research.

In summary, this study investigated Turkish students' spatial visualization abilities as defined by Guay (1976). The study also examines variables such as gender, grade, school type, mathematics course grades, and socioeconomic status that are related to students' spatial visualization ability.

Background

Spatial ability is a topic that many researchers have investigated in their studies. Furthermore, many educators advocate for the development of students' spatial abilities during students' school years. There is a great interest in the topic of spatial ability because this ability is needed to be successful in disciplines such as art, architecture, engineering, geometry, and science (Wai, Lubinski, & Benbow, 2009). In the literature review of their paper, Mclurg, Lee, Shavalier and Jacobsen (1997) identify a variety of studies to illustrate the role of spatial ability in various professions. They gave examples of studies as achievement in art, achievement in physics, and achievement in mathematics. Notably, many studies highlight the importance of spatial ability for mathematics, some studies have found a statistically significant positive relationship between spatial ability and mathematics achievement (Battista, Wheatley, & Talsma, 1989; Seng & Chan, 2000; Weckbacher & Okamoto, 2014).

Although there are many studies on spatial ability, researchers have not been able to come up with a common definition for the terminology. Hence, different researchers have studied spatial ability using a variety of words and explanations; consequently, in the literature, there are many different terms to describe spatial ability. Among these terms, spatial skills, spatial perception, spatial reasoning and spatial sense are the terms that define similar processes and commonly used in literature (Clements & Battista, 1992; NCTM, 2000).

Mohler (2009) notes that these varying explanations for spatial ability can be traced as far back as Sir Francis Galton when he discussed mental imagery and innate intelligence. Since then, many researchers started to define spatial ability in several ways (Mohler, 2009). The following are just a few of the different ways to describe spatial ability. French (1951) described spatial ability as the ability to manipulate objects that are in a three-dimensional space, and to imagine those objects in their mind (as cited in McGee, 1979). Lord (1985) explains spatial ability as a need of changing and using images that are created in the mind. Another definition is by Linn and Petersen (1985) who present spatial ability as presenting, creating, rotating, and renaming symbolic nonverbal information. Also, Clements and Battista (1992) define spatial thinking ability as imagining and understanding the movements of objects in two- and three-dimensional space. Lohman (1993) expresses the spatial skill as the ability to visualize, reorganize and transform a form into another form.

The spatial ability is defined as the relationship between a person and his environment or between objects outside of him by Stockdale and Possin (1998). Olkun (2003) describes spatial ability as a visualization, rotation, and interpretation of two-dimensional and three-dimensional parts of objects in one’s mind. The other definition that using for spatial ability is visually manipulating, rearranging or explaining the expression of relations of objects (Kayhan, 2005). Turgut (2007) expressed it as the ability of movement or interpretation of the objects and their components in three-dimensional space in the mind. According to Yıldız (2009), it is a set of the abilities to be visualized in the mind, to be recognized from different angles, or to move as a whole or to move objects parts separately in space. Spatial ability is also explained as to estimate the appearance of the object from different angles when it is rotated and to construct the open or closed form of an 3D object in the mind by Kösa (2011).

Since there are differences in the definition of spatial ability, there are also differences in explaining the components of the spatial ability. Different researchers have stated spatial ability as comprising two components, the others have stated as comprising three components. For example, McGee (1979), Clements (1998) and Kayhan (2005) define spatial ability as two different components: spatial visualization and spatial orientation. Turgut (2007) also classified spatial ability into two components: spatial visualization and spatial relations. However, Linn and Petersen (1985) and Kösa (2011) categorize spatial ability in three components: spatial perception, mental rotation, and spatial visualization. Since the component of the test used in the present study was a spatial visualization ability, the focus will be on spatial visualization. In this sense, McGee (1979) defines spatial visualization as the ability to visualize the state of the object after the movement of the parts, folding and unfolding a 3D object, reshaping objects in different ways in space, and image manipulation of an object in mind. In this study, the researcher focused on spatial visualization ability as a component of spatial ability.

Considering that the definitions of these researchers basically share a similar meaning, for the current study the spatial ability is defined as the ability to create visuals in the mind and being able to manipulate these visuals. Generally, spatial ability relates to the mind functions that involve rotation of objects, estimation of views from different angles, imagination of the object according to the location of the individual and studying patterns of 3D objects.

All of these aspects of spatial ability have an important place in the mathematical thinking process. The effect of spatial ability on mathematics, geometry and physics course achievement, and mathematical problem-solving performance have been generally investigated. In the literature, there has been a variety of studies examining the relationship between spatial ability and academic achievement. Since spatial ability have been considered to be a critical factor in mathematical learning, many studies have been conducted to investigate the relationship between spatial ability, mathematics achievement and mathematical problem-solving skills (Clements, 1998; Kayhan, 2005; Lord & Rupert, 1995; Tartre, 1990; Yurt & Sünbül, 2012). For instance, Yenilmez and Kakmacı (2015) found 6th-grade students with higher cumulative mathematics grades performed better in the spatial visualization test than those with lower grades. Kayhan (2005) in her study in which she investigated the spatial ability of high school students revealed a positive and significant correlation between mathematical achievements. Clements (1998) examined the knowledge of young children about geometry and space and their ideas about certain concepts in this field. For the development of students' ideas about geometry and space, he made activities that enable children to discover shapes like square, triangle, circle, and so on by touching them, drawing shapes and viewing from different perspectives. Later, he stated that geometry and space perception should take a larger place in the education field and research. The following paragraphs go further to explain how these skills are important to be in mathematics education.

The National Council of Teachers of Mathematics (NCTM, 2000), in the USA, emphasizes the importance of having one-, two-, and three- dimensions study in geometry in different settings in order to help students to develop spatial ability thinking processes. This provides learners with the knowledge to manipulate geometric objects that are studied in the mathematics curriculum. Likewise, NCTM (2000) reports that the high school curricula should include mathematical problems on three-dimensional objects and their relationship with the spatial ability that is integrated into the lesson. Since spatial thinking ability requires the movement of 2D and 3D objects as it is an important part of geometric thinking, it needs to be considered in more detail. Also, including the construction of these objects in the mind and the ability to imagine these objects from different angles are the expected outcomes for geometry classes. In this respect, spatial thinking, especially visualization, is vital for geometry; this ability is a building block for comprehending abstract geometric concepts.

Problem

Spatial ability is important; it is particularly valuable for mathematics (e.g. geometry) because learners need to visualize the abstract objects in their mind. The spatial visualization of objects is a challenging skill for many students. Not only do students struggle manipulating objects in the mind, they rarely think about relating their manipulation of two- and three-dimensional objects to the real world. One of the reasons why students have difficulties in spatial visualization is that their spatial thinking ability is not well developed; they lack the ability to construct concrete meanings of spatial operations in their mind. In other words, they are challenged to manipulate abstract and concrete objects and observe their features "in space" mentally.

There has been a variety of studies that have attempted to unveil spatial visualization and its relationship with mathematics achievement, gender, age, school type and socioeconomic status. In PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) reports, it is observed that the desired success in terms of geometric problem solving and spatial ability skills cannot be achieved (OECD, 2016). The findings of these investigations have helped somewhat educators to understand the complex phenomenon of spatial ability. Unfortunately, there have been limited studies in Turkey that have tried to understand the meaning of spatial ability, and how it relates to some other variables such as mathematics course grades, gender age, school type and socioeconomic status. Therefore, there is a need for more research that measures and examines Turkish students' spatial visualization ability levels.

Purpose

The purpose of this study was to investigate Turkish high school students' spatial visualization ability level. As the secondary purpose, students' gender, grade and school type were used as independent variables to describe spatial visualization ability level. Also, this study aimed to look for a relation between students' spatial visualization scores both for students' mathematics course scores and socioeconomic status.

Research questions

The main research questions of this study were as follows:

1. What are the students' spatial visualization ability levels as measured by Purdue Spatial Visualization test?
2. Do male and female high school students have significantly different levels of spatial visualization ability and its constructs?
3. Do the students' spatial visualization ability levels and the constructs of the test vary with respect to school type?
4. Do the students' spatial visualization ability levels and the constructs of the test change with respect to grade?
5. Do the students' spatial visualization ability levels and the constructs of the test relate to their mathematics course grades?
6. Do the students' spatial visualization ability levels and the constructs of the test relate to their socioeconomic status?

Significance

This study is a combination of some factors such as gender, age, socioeconomic factor and school types that influence the development of spatial visualization ability. The identification of the ability level in the high school may help to improve students' spatial ability further. Likewise, if the students' ability is determined earlier it may be useful for their future life in terms of their profession.

It is thought that identification of the factors related to spatial visualization ability can be useful in terms of organizing and planning of the teaching and learning environments in order to address the development of spatial abilities of academicians, educators and practitioners working in this field. It is important for students and teachers to know that spatial visualization ability as a component of spatial ability can be developed. The study may provide resources to the curriculum, curriculum developers and teachers. In this sense, when it comes to spatial ability, we can take a step closer to determining the effectiveness of the mathematics education system.

Definition of key terms

Gender: Refers to the gender of students either male or female.

Purdue Spatial Visualization Test: This instrument was devised to measure students 'spatial visualization skills. PSVT was developed by Roland Guay in 1976. The test was adapted to Turkish by Sevimli (2009) using the original English version.

Spatial ability: The ability to create images in the mind of the individual and to manipulate these images in his mind. In general, spatial ability needs to involve the rotation of an object, estimation of views from different angles, different image of the object according to the location of the individual, visualization of the extended form of an object, or formation of the extended form of an object in the open form can be created in the mind (McGee, 1979).

Spatial visualization ability: Spatial visualization is the ability to visualize the state of the object after the movement of the parts, net of the 3D object, reshaping the objects in different ways in space, and imagine manipulation of an object in mind.

Mathematics achievement: Refers to the mathematics Grade Point Average (GPA) scores of the students at the end of the first term of 9th, 10th,11th and 12th grade and the scores are given on the scale of hundred.

School types: Refers to the two different types of high schools: Private school and state school.

Socioeconomic status (SES): Refers to the gathered information by asking questions about students' parents' educational background, second language, monthly income; students' own study room, number of siblings.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

The background and the problem of this study presented briefly in the first chapter. The purpose of this study was to investigate Turkish high school students' level of spatial visualization ability. The study used gender, grade and school types as independent variables and described how spatial visualization relates to mathematics course grades and socioeconomic status of the students. This second chapter consists of the literature review to explore the theoretical framework that was used to answer the research questions for the study. This chapter aimed to investigate the main concepts and frameworks of this research which were:

- The studies conducted with Purdue Spatial Visualization Test (PSVT)
- Studies investigating possible relations of spatial ability to gender-differences
- Spatial ability as it relates to grade level and/or age
- Spatial ability as it relates to mathematics achievement
- Spatial ability as it relates to socioeconomic status

One important concept related to the learning and teaching of mathematics is the concept of spatial ability. Moreover, according to the NCTM spatial ability is a basic skill for students to be learned. No surprise then, that research in this area dates back and is still lively. Spatial ability studies have been a study field that has been investigated by many researchers since Sir Francis Galton (1880) discussed mental imagery and innate intelligence (Mohler, 2009). Since then, different efforts have been made on what skills spatial ability consists of and what specific skills are expected to be displayed in these areas.

Spatial ability appears in the literature with numerous names and definitions. Considering the definitions of many researchers described in the first chapter, around the same axis, spatial ability can be defined as the ability of the individual to create images in her/his mind and to manipulate these images in the mind. However, in general, spatial skills, rotating an object, estimating their appearance from different angles, changing the image of the object according to the position, being able to visualize the nets of an object or vice versa. It can be said that it includes the ability to organize. It is clear that these skills, regardless of their definition or content, have an important place in human thought and learning (Höffler, 2010).

Many researchers have studied this ability with the combination of external sub-components thought to be a possible factor. What follows is an exploration of these studies.

The studies conducted with Purdue Spatial Visualization Test (PSVT)

PSVT is an international psychometric test used in the literature to determine spatial ability. This section explored some of the studies that were conducted with PSVT. Baki, Kosa, and Guven (2011) conducted an experimental study with pre-service first-year mathematics teachers. For the pre-test and post-test, the PSVT was used as an instrument. They, however, found no statistically significant differences between students' spatial visualization abilities in the experimental and control groups before training. Students' PSVT total mean scores were found to be nearly 18 (SD = 5.43) before treatment. And, developments, rotations, and views mean scores were found to be 7 (SD = 2.16), 6.5 (SD = 2.09), 4.5 (SD = 2.59) respectively. In other words, subjects of the studies performed better in development constructs than the other constructs. These results were valid after the treatment for all constructs. So, the subjects of their studies showed better performance in the development construct than the other two constructs.

Turgut, Yenilmez, and Balbağ (2017) looked for possible effects of gender and academic performance on the spatial thinking abilities of mathematics and science prospective teachers. As an instrument, the researcher used PSVT. For PSVT, the number of correctly marked questions was calculated in each section, and scores were collected from the developments and rotations construct counted for spatial visualization ability, and the score obtained from the views construct was directly included in the analysis as a measurement of spatial orientation level. In addition, by calculating the total score of PSVT; the PSVT scores of the students were taken as dependent variables and analysed by gender, department and academic performance a three-way between-subjects analysis of variance. General results showed that prospective teachers had low-level of spatial visualization ability. Also, gender and academic performance had significant effects on spatial visualization ability.

Yazıcı (2014) conducted a study on 447 preservice teachers from different teaching programs in order to determine their spatial visualization ability level through the PSVT. The test is variable and reliable itself, also in his study, the alpha reliability coefficient was calculated to be 0.79. The dependent variables of his study were teachers' total scores of developments, rotations, and views and one of the independent variables was teachers' gender. He reached that spatial visualization scores differ between males and females. Male students outperformed female students for each construct (developments, rotations, and views).

Dündar (2014) conducted his correlational study with 96 prospective right-handed Primary Mathematics Education Department students. He categorized the sample based on gender (54 female and 42 male). He investigated if there were any statistical differences on each construct; developments, rotations, and views. The Purdue Spatial Visualization Ability Test was used to examine the spatial ability of prospective teachers. In general, students' maximum score was at 10 and 18 based on two different groups (field dependent and field independent) of his study. Besides, students performed better in development construct than the rotations and views construct. In his study, he also found that male teachers outperformed female ones in the spatial visualization ability test.

Studies investigating possible relations of spatial ability to gender-differences

Gender as a factor has been a major concern in studies related to spatial ability. The existence of possible gender differences in cognitive skills regarding spatial ability is a controversial topic. Some of the studies widely acknowledge that there is a gender-related difference, some other studies acknowledge that there are no or very small gender-related differences. For example, Reilly, Neumann, and Andrews (2017) reported that even though males perform better than females in tests that measure visual-spatial ability on average there is more variability within males and females. (p. 528). Based on his research Feingold (1988) suggested that the gender differences in visual-spatial ability is gradually decreasing. Researchers differ in their perspectives on the origins of gender differences including the relative factors such as, maturation rate, culture, and birth order (Fairweather, 1976). Therefore, research on this issue has switched its focus on addressing the gender difference in terms of magnitude, and the other factors that affect gender differences such as environmental, age factors, school types, instructions different types of spatial ability, etc.

Yang and Chen (2010) hypothesized that digital games help to improve students' spatial skills equally for both genders. They also indicated that spatial skill is a crucial skill in geometry learning. Hence, this study addressed how students' performances were affected by factors such as gender difference and spatial skills through the development of a digital pentominoes game. The empirical study was conducted quantitatively, and 34 fifth-grade students were selected as participants. The statistical results indicated that students' spatial abilities were significantly improved after they took the digital pentominoes game. Moreover, it was also demonstrated that digital games can sensibly decrease the spatial ability level differences between boys and girls. Furthermore, the greatest mean differences between gender were found within mental rotation among the other three types of spatial ability. Lastly, Yang and Chen (2010) used the findings of the study to develop a framework that might be employed to help the understanding of gender differences and spatial skills in digital games.

Studies in favour of males

Research on gender differences in spatial ability affected by environmental factors dates back to the 1970s. Fennema (1974) stated when a significant difference in performance spatial ability tasks are found, they usually indicate males' superiority. However, he also noted that such differences were often fairly small in magnitude.

The reason behind obtaining controversial results in terms of gender differences and spatial ability skills lies in the very nature of the studies conducted on this issue. Studies were conducted at different age levels and most of them with different visualizing probing instruments. For example, a meta-analysis of Linn and Petersen (1985) aimed to determine the extent of gender differences in spatial ability, which aspects of spatial ability exist, and the age at which gender differences in spatial ability first appeared. Students had different results according to the components of spatial abilities. They stated that gender differences occur "large only for mental rotation, medium for spatial perception and small for spatial visualization" (p.1491). Also, the effect of gender on spatial ability emerged at the age of 8 years and that male students performed better in the mental rotation than female students.

Some researchers have focused on gender difference issues in terms of age while some of them have changed their focus to instructional and environmental factors. For example, there are gender differences that are not biologically based but are influenced by experience and environment where boys are more exposed to the physical environment than girls (Ferguson, Ball, McDaniel, & Anderson, 2008).

Gold et al. (2018) in their studies with undergraduate students, found significant differences in spatial skills that are, male students, did better than female students particularly in the area where mental rotation was required. However, the existence of gender differences was determined after examining various academic factors and their interaction with constructive-based toys, video games or playing sports. In their studies, this indicated existing gender differences were not biological, it developed spatial skills, where differences depended on educational opportunities and students' interaction with toys affecting spatial ability development. With these results, it was concluded both formal academic education and extracurricular activities enable students to develop spatial abilities throughout their lives.

A meta-analysis study by Maeda and Yoon (2013) was carried out to predict the magnitude of gender differences in three-dimensional rotation ability. The study found out gender differences influenced by test administration conditions. However, the effect occurred because of test conditions such as length of the test, time limitation, administration mode, biological, experimental and so on. Thus, the results revealed that males outperform females only when time-limit was introduced.

Ben-Chaim, Lappan and Houang (1985) examined the spatial visualization ability of fifth to eighth-grade students. It was argued that spatial visualization was a well-documented feature of gender-related differences in favour of the male. However, after certain instruction, male and female students achieved equal benefits that reduced gender differences on spatial ability as a result of instruction. However, in another study, Smith and Litman (1979) investigated gender-related differences in spatial visualization ability. They focused on the girls and boys from sixth and seventh grades in early adolescence. Even though girls and boys were differentially affected by instruction, the boys showed improvement in this ability as a result of instruction. Scientific studies on gender differences have been stated that generally, males are more successful than females in terms of the stated variables. However, this difference has diminished as females have started to take advantage of educational opportunities more equally with males. Therefore, studies are finding that there is no longer any significant difference in terms of gender. Similarly, there are studies showing that there is no difference between males and females in terms of spatial abilities (Alias, Black,& Gray, 2002).

Studies that showed no difference

According to Monahan, Harke and Shelley (2008), in contrast to spatial perception and mental rotation, spatial visualization ability is the component with the small effect size and statistically non-significant results in gender differences. While Fennema (1975) specified that "on tasks measuring one kind of spatial ability, i.e., spatial visualization, data from a variety of sources indicate that males perform at a higher level than females starting about adolescence and continuing through high school and adulthood" (p. 34).

In their broad literature review, Maccoby and Jacklin (1974), stated that there were a "well-established" gender-related differences in spatial abilities in favour of males. Also, this difference was emerging in adolescence and continuing into adulthood. Whereas, Voyer (1996) explained that only considering spatial ability studies the magnitude of gender differences differs depending on the task and measurement utilized. A meta-analysis by Hyde (1981) investigated the magnitude of gender differences in the performances of female and male students in spatial ability reported by Maccoby and Jacklin (1974). He found the magnitude of gender differences was very small. He, thus, argued that gender had only a minimal effect on explaining students' spatial test scores.

Seng and Chan (2000), conducted a study with 127 elementary school students as participants. They aimed to find how gender influenced spatial ability, thus the participants consisted of 72 boys and 55 girls. Their study also investigated spatial ability, spatial orientation, spatial visualization and its relationship to mathematical achievement. Participants' spatial ability was measured by Spatial Relations-Orientation Test and the Spatial Visualization Test Results of the study demonstrated despite small gender difference in spatial ability between boys and girls, the boys were not found to be significantly better than the girls in the spatial tasks. Moreover, Seng and Chan (2000) highlighted that cultural factors, training sessions may have influenced spatial ability based on gender in the last ten years. Further results indicated that there was a significant positive relationship between spatial ability and mathematical performance.

Spatial abilities mature in the ages between 11 and 15 so that it is expected to not show any gender-differences or age-differences after age 15 (Fennema & Leder 1990). On the other hand, Johnson and Meade (1987) found that gender differences occurred from the age ten and the magnitude of advantage remains constant from 18 years on after they applied spatial ability tests at different cognitive development levels of children from ages 6 to 18. Oppositely, A meta-analysis of the three-component of spatial abilities dealt by Voyer, Voyer, and Bryden (1995), which obtained no significant gender differences for the participants younger than 18. Whereas, they found out significant gender differences for participants who were over 18 years old.

This section provided an overview of controversial issue of gender differences in spatial ability, as well as the different results of the research-related areas.

Spatial ability as it relates to grade level and/or age

Many researchers have suggested that as the grade level increases student's spatial ability performance also increases. Ben-Chaim et al. (1985) measured the spatial visualization abilities of students by making them counting cubes. To give an example, one of the items was "How many cubes are needed to build this rectangular solid?" by presenting the picture with a rectangle. The researcher's strategies were that students who missed the items were using the incorrect counting strategies. Some of the students completed two-dimensions rather than three, while others left the hidden part of the figure incomplete. As a result, the performances of the fifth, sixth, seventh and eighth grades were directly proportional to their level. Students' performances increased as the grade level increased.

To give an example for study on grade, the following study tested 107 fifth to eighth graders on spatial rotation multiple-choice items. The purpose was to check the relationship between age and gender in spatial ability. Michaelides (2002) conducted the study, firstly interviewing some of the students. They were required to describe their way of solving four of the items and problem-solving tasks. He identified visual and non-visual strategies that students utilized but noticed that students did not use the strategies consistently. He later added that older students performed better in three-dimensional manipulation. However, there were no any other age and gender differences in the use of strategy in spatial ability.

To give another example, Ben-Chaim, Lappan, and Houang (1988) investigated the effects of grade, gender and region variables on spatial visualization abilities and differences between 5th to 8th-grade students' spatial visualization abilities. Middle Grades Mathematics Project Spatial Visualization Test was applied as a pre-test and post-test to approximately 1000 students representing different socio-economic levels. For 3 weeks, students were engaged in concrete material activities such as the drawing and construction of cubes. At the end of the research, it was seen that spatial visualization scores of 5th, 6th, 7th, and 8th-grade students increased statistically, and the gains were close to each other after instruction for both male and female students.

Spatial ability as it relates to mathematics achievement

As mathematical concepts were introduced visually and geometrically, e.g. number lines and graphs, success in geometry may bring success in mathematics regarding the spatial ability.

Many scientists, including Voyer and Sullivan (2003), highlighted that spatial ability tests carried out with hands on activities such as drawing of tilted containers, revealed the males performed better; however, mathematics course grades showed the opposite. The researchers believed that this contradiction occurs for two reasons. The first reason was that the grades were measured in the classroom conditions, where many components of mathematical skills are measured frequently. The second reason was that the hands-on tasks used only a specific measurement that demonstrated a limited number of mathematical concepts such as three-dimensional, space, spatial concepts than concepts in mathematics objectives. Therefore, it would be better to investigate the final grade in a mathematics course which may reflect more accurate estimation of the relevant skills. In other words, rather than laboratory testing, high school grades in mathematics need to be considered. That is to say, Voyer and Sullivan (2003) investigated the analysis of mathematics course grades as an indicator of the relationship between mathematical performance, spatial skills and gender. In this research participants were equally divided by genders, 144 introductory psychology students. Also, their mean age was 18.6 years with a range from 17 to 28 years.

Research on mathematical achievement regarding spatial ability dates back 1970's. Fennema (1974) claimed that the relationship between mathematics and spatial ability is a "logically evident" (p.34). Regarding spatial representations used in mathematics, he explained that "not only are spatial visualization components an integral part of the structure of mathematics, spatial representations are being increasingly included in the teaching of mathematics most concrete and pictorial representations of arithmetical, geometrical and algebraic ideas appear to be heavily reliant on spatial attributes" (p. 36).

Weckbacher and Okamoto (2014) examined 113 high school students to analyze the relations between one of the spatial ability components and mathematics achievement. The study was conducted with a spatial ability test that required mentally rotating blocks. Significant relations emerged between spatial ability and both geometry grades and the standardized geometry measure. However, no significant relation emerged between spatial ability components and algebra grades. Also, Weckbacher and Okamoto (2014) emphasized how to improve spatial thinking by encouraging students' interests in mathematical and scientific careers were addressed. Their effort would modify educational curricula for spatially talented students who may help meet the growing demand of several fields such as science, technology, education and mathematics.

Turğut and Yılmaz (2012) investigated the relationship between 674 seventh and eighth grade Turkish students' spatial ability, gender, mathematics achievement and pre-school education in their descriptive studies. A spatial ability test and personal information form were used in their research. Frequency, mean, t-test and correlation analysis were used to interpret the data obtained for the level of spatial abilities of 7th and 8th grade students. The result showed that the spatial abilities of the students were quite low. According to descriptive statistical results of the study, seventh grade students' mean score of the test was found to be 12.39 (SD=4.49) and eight grade students' mean score was found to be 11.81 (SD=4.45) out of 23. While there were no significant relationships between spatial ability and gender, a moderate positive and significant relationship was found between spatial ability and mathematics achievement. Moreover, those who received pre-school education were more successful than those who did not. This finding might be another indication to the environmental factor described in the section studies investigating possible relations of spatial ability to gender-differences.

In their correlational study, Yenilmez and Kakmaci (2015) examined a possible relationship between sixth grade students' spatial visualization ability level regarding gender and mathematics achievement. They conducted a study with spatial abilities tests to investigate students' spatial visualization level and they had students' latest mathematics grades. T-test analysis revealed a significant difference in spatial visualization achievements in favour of male. From a variance analysis for spatial visualization achievements between mathematical achievement groups it was found that there were significant differences. Correspondingly, students with higher math grades have more success in the spatial visualization test than others.

Battista (1990) examined the relationship between spatial visualization, logical reasoning, geometrical problem-solving strategies, and gender in a study conducted with 75 male and 53 female high school students. An adapted version of the Purdue Spatial Visualization Test: Rotations was selected to measure students' ability for mental rotations of objects in space. As hypothesized by Battista (1990), spatial visualization and the discrepancy between spatial visualization and logical reasoning were attained to be related use of problem-solving strategies. Furthermore, the results revealed spatial visualization ability and logical reasoning were positively related in geometry achievement. Besides, the spatial visualization performance of male students was higher than female students.

Another study conducted by Battista, Wheatley and Talsma (1982) investigated the effect of spatial ability and cognitive development on the learning of geometry and the effect of geometry teaching on the development of spatial ability. The researchers conducted the study with 82 pre-primary teachers. He stated that in order to realize the thinking of individuals in concrete processes, pictorial representation is required, and therefore spatial visualization may be important for these individuals to learn mathematics. As a result of the study, it was concluded that geometry lessons improved spatial ability and spatial visualization and cognitive development.

Karaman and Toğrol (2009) investigated the understanding of plane geometry with the factors gender, spatial visualization, spatial orientation of 120 sixth grade students in a private school. Correlation analyses were applied for the variables. As a result of these analyses, a significant correlation among each factor except for gender was found. Also, multiple regression analyses were used for more clarification of the relationships among factors. As a result, there was a significant relationship between spatial visualization ability and the performances on plane geometry topics. Karaman and Toğrol concluded that the spatial abilities are the significant factor of the development of the concept of space.

Another study was conducted by Cheng and Mix (2014) to investigate the relationship between spatial ability and mathematics achievement. Studies were encouraging this relationship as they claimed that math learning is directly related to spatial development. For the study of Cheng and Mix, 58 children mostly from the middle class were selected as participants. Their age ranged from six to eight because these children are still in the period of developing fundamental arithmetic skills. Participants were divided into two groups. There were 17 boys in the spatial experimental group and 17 boys in the control group. The pre-test was applied first to all children. After there were 40 minutes training sessions followed by three post-tests which were called mental rotation test, spatial relations subtest (test of primary mental abilities), and Math test. The analysis indicated a significant difference favouring the spatial training group. However, there was no significant group difference in the Spatial Relations subtest, yet, indicating that our mental rotation training did not lead to a general improvement in spatial ability. On the other hand, even a single session of spatial training led to significant improvement on specific problems. That is to say, spatial cognition and mathematical reasoning are connected, there still need more studies to prove a more concrete link though.

Remarkably, many studies highlight the importance of spatial ability for mathematics, some studies have found a statistically significant positive relationship between spatial ability and mathematics achievement. Spatial ability is important ability because learners need to visualize the abstract objects in their mind.

Spatial ability as it relates to socioeconomic status

Aydin and Ubuz (2014), in their studies, use parents' educational attainment as the measure of SES. In the theoretical frameworks of their studies, they emphasized that parents' educational background, in general, affects the individual development of the students. Some characteristics specific to mothers and fathers can serve to construct the way their children think differently, and in turn, can develop or weaken different mathematical thinking aspects of children.

Levine, Vasilyeva, Lourenco, Newcombe and Huttenlocher (2005) inquired to find relationship between boys' spatial ability from diverse socioeconomic status. 547 students (271 girls, 276 boys) were the participants of this study. Boys and girls were roughly equally divided in each of the SES groups, but more participants represented in the middle level SES than other levels. The number of participants at each time changed because the children were often absent from school and because one low level SES school dropped out of the study after the first year. Also, based on parents' education level, the families' socioeconomic levels differed as middle to upper-middle class. This longitudinal study was conducted with the children who were asked to do two spatial tasks requiring mental transformations. The results revealed that the boys from middle and high-SES backgrounds outperformed the girls. On the other hand, the participants from a low-SES did not reveal any differences between these two genders.

Verdine, Irwin, Golinkoff and Hirsh-Pasek (2014), in their study of 22 boys and 22 girls with different socioeconomic status, aimed to investigate the effect of spatial ability on pre-school students' mathematics performances. The relationship between mathematics and pre-school students was evaluated within the framework of a spatial ability measurement, which included the ability to copy 2D and 3D structures. According to the findings, spatial abilities were found to be an important determinant of general mathematics performance. Also, it was stated that children with low socioeconomic status have low spatial abilities.

In summary, researchers and educators have been aware of the importance of spatial ability for years and have been progressing with spatial ability studies. As the literature review revealed that, research has yet to come to a common understanding of what exactly spatial ability entities since there has been no common definition of spatial ability. In addition, it has been seen that concepts such as spatial ability, spatial skill, spatial visualization, and spatial relationships have been used interchangeably. Whether this phenomenon is a non-gender biased rudimentary skill or an ability has been still discussed by psychologists and mathematics educators alike (Turgut, 2007).

Furthermore, this chapter examined studies on spatial ability and studies investigating possible relations of spatial ability to external factors. Research has shown a positive relationship between students' mathematics achievement and spatial abilities. It was also concluded that spatial ability was important not only in mathematics achievement but also in many business areas and even higher thinking skills. The results of the studies insisted that there was a strong relationship between students' spatial abilities and their logical thinking abilities. The following chapter will introduce the methodology conducted in this research.

CHAPTER 3: METHOD

Introduction

The main purpose of this study was to investigate Turkish high school students' spatial visualization ability level. As the secondary purpose, students' gender, grade and school type were used as independent variables to describe spatial visualization ability. This study aimed to look for a possible relation between students' spatial visualization scores and both for students' mathematics course scores and socioeconomic status (SES). In this chapter, the researcher explained the methodology used to conduct this study in general. Particularly, it consisted of an explanation of the research design, context, population and sample, the instrumentation, data collection procedures, and data analysis procedures. Table 1 presented the timetable that shows the summary of dates and the major steps of the research.

Table 1
Timetable of thesis

Steps	Year							
	2017-2018			2018-2019			2019-2020	
	Semester							
	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring
Literature Review	x	x		x	x		x	x
Meetings with Supervisor	x	x	x	x	x	x		x
Permission for the test			x					
Permission from MoNE				x				
Collecting data from schools				x				
Analysis of the data					x	x		
Interpreting the results						x		
Organizing the thesis						x	x	x
Submission of thesis								x

Research design

A quantitative research methodology was employed in order to conduct this research. Among the four possible quantitative research designs (i.e. experimental, quasi-experimental, correlational and descriptive), the descriptive research design was the appropriate structure that provided a sound fundamental blueprint in order to reach scientifically valid answers for the research questions. Descriptive research was used because the main purpose was to describe the characteristics of the population or phenomenon being researched. This particular research design did not describe what the direct causes were regarding the phenomenon studied. Two forms exist in descriptive research design; these are observational and survey type. Survey research is when you systematically gather information from respondents to try to understand and predict some behavioural aspects of the general population that you are interested in. Simply, it implies the information that has been gathered by type of a questionnaire. The researcher must be concerned with aspects such as sampling, questionnaire design, questionnaire administration, and finally data analysis (Jackson, 2015).

Also, Fox and Bayat (2008) stated descriptive research as "aimed at casting light on current issues or problems through a process of data collection that enables them to describe the situation more completely than was possible without employing this method" (p. 8). Since the purpose of the study was to investigate Turkish high school students' spatial visualization ability level, in other words, it was aimed to describe the characteristics of the population through the use of Purdue Spatial Visualization Test (PSVT), the descriptive design was deemed to be appropriate. This descriptive study answered the following research questions:

1. What are the students' spatial visualization ability levels and its constructs as measured by Purdue Spatial Visualization test?
2. Do male and female high school students have significantly different levels of spatial visualization ability and its constructs?
3. Do the students' spatial visualization ability levels and the constructs of the test vary with respect to school type?
4. Do the students' spatial visualization ability levels and the constructs of the test change with respect to grade?
5. Do the students' spatial visualization ability levels and the constructs of the test relate to their mathematics course grades?
6. Do the students' spatial visualization ability levels and the constructs of the test relate to their socioeconomic status?

In the following sections, context, sample, instrumentation, data collection, and the data analysis were explained. The context section provided information about where the study was conducted and included a description of the participant schools and students. In the sample section, the population definition, and the sampling strategy was explained with appropriate justification. The instrument that addressed the research questions, explanation of the instrument and reliability and validity of the instrument were stated in the instrumentation section. Data collection section provides an explanation on data collection and gives information regarding the procedures for ethical allowance. Data analysis was the last section, and it provided information regarding how data were analysed and reported in chapter four.

Context

The present study was carried out in Çankaya, a large and diverse district of Ankara. Ankara is the capital city located in the central Anatolia region of Turkey. The study took place during the fall semester of the 2018-2019 academic year. Students from both private and state schools took part in the study. A total of 555 high school students who were enrolled in mathematics courses took part in the study. Information about the schools and number of students from each school were given in Table 2 below. A detailed explanation follows regarding the sampling for this study. There were three schools and two of them were state and the other one was a private school.

Table 2
Schools and number of the participant students

Schools	School type	Number of students
School 1	State	129
School 2	State	215
School 3	Private	211

Sample

The population is defined as the whole set of individuals or values that the researcher is interested in. The sample can be defined as the set of individuals or values that were selected from the population. The sample is hypothesized as to represent the population (Dawson & Trapp, 2001). When proper probability sampling processes are employed, then the researcher has the opportunity to validly generalize the conclusion of the research outcome to the population.

Identifying the sample size is categorized as probability and non-probability sampling methodologies. Essentially, probability sampling allows every individual to set an equal chance of being selected. Systematic sampling, random sampling, and stratified sampling are commonly used procedures for probability sampling. On the other hand, non-probability sampling methods refer to the probability of a subject being selected is not equal. Some of the common use techniques for non-probability sampling are convenience sampling, purposeful sampling and quota sampling (Acharya, Prakash, Saxena, & Nigam, 2013).

This study took place in some of the high schools of Turkish Ministry of National Education (MoNE). In order to decide which schools to carry out the study, the researcher obtained a list of the high schools in Çankaya district for the year of 2019. There were 63 high schools which consist of Anatolian, vocational, general, science, and İmam Hatip high schools. Among these, there were 31 Anatolian high schools where all students had mathematics classes. Also, the researcher assumed the number of high school students in those schools as 10,000. Since it would be difficult to access such a high number of students, the researcher used a convenience sampling method. Sample size was determined by using the calculator available on Sample Size Calculator (Creative Research Systems, 2012). In the calculation, the population number was entered as 10,000, confidence level was set as 95% and the error percentage was set as 15%. Accordingly, the sample size was computed as 18 schools. For that reason, 10 private and 24 public schools in Çankaya district were included in the permission letter submitted to the MoNE, in Ankara. Due to several factors (i.e. time and financial limitations, not allowed to conduct the study by the school principal; being closed; not being able to arrange meeting a class) the data collection was carried out in three schools and these schools were randomly chosen. From these schools a total of 565 students participated in this study. Students were chosen conveniently from ninth, tenth, eleventh and twelfth grades. In these schools, the questionnaire was conducted with students in December 2018. Hence, the students selected for this study were high school students from three high schools in Çankaya, Ankara. The high school students were chosen based on the non-probability convenience sampling method as the researcher applied it to the school from her university region (Etikan, Musa, & Alkassim, 2016). Also, the sample was chosen without knowing the probability of any case being selected. The reason behind choosing participants through the convenience sampling method was limitations of time, money and labour force, the sample was selected from easily accessible and applicable units.

Firstly, 565 high school students from two state schools and one private school participated. However, because ten out of 565 students either did not complete fully the demographic form and/or had specific patterns in their answers on the PSVT answer sheet were excluded from the total data set. Hence, the statistical analysis continued with 555 students. In addition, all students in this study were older than 13 years of age. The PSVT test developer required that the participants must be at least 13 years of age. Moreover, all of the students had a geometry course, usually as a part integrated into mathematics courses throughout their middle school years.

Figure 1 shows the percentage distribution of female and male students participated in the study.

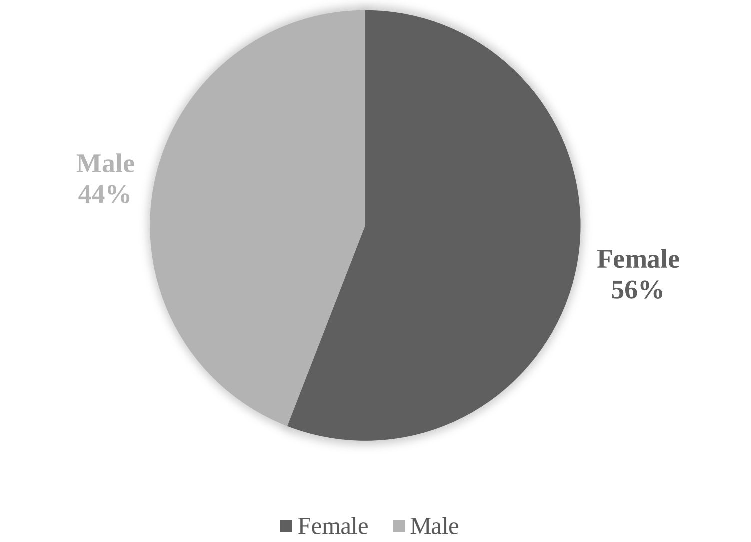

Figure 1. Percentage distribution of total participant students by gender

As shown in Figure 1, the percentage of female students in this study was 56% (*n*=310) and the percentage of male students was about 44% (*n*=245).

Figure 2 displays the percentage distribution of private and state school students participated in the study.

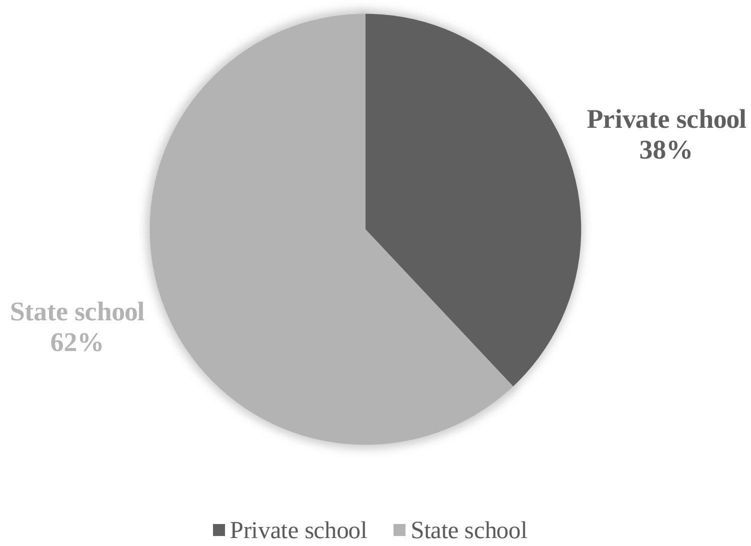

Figure 2. Percentage distribution of total participant students by school type

As shown in Figure 2, the percentage of private school students in the sample was 38% (*n*=211). Also, the percentage of state school students in the sample was 62% (*n*=344).

Figure 3 shows the distribution percentage of students for each grade level.

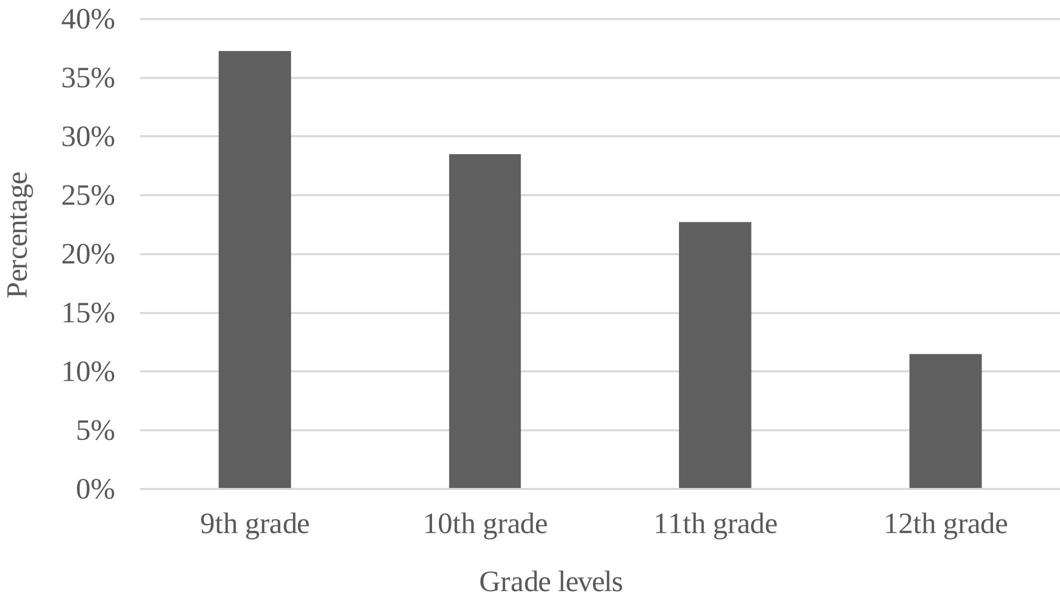

Figure 3. The percentage of total participant students by their grade levels

As shown in Figure 3, 37% (n=207) of students were from ninth grade, 28% (n=158) of students were from tenth grade, 23% (n=126) of students were eleventh-grade students and 12% (n=64) of students were twelfth-grade students.

Figure 4 shows the distribution percentage of students based on ages.

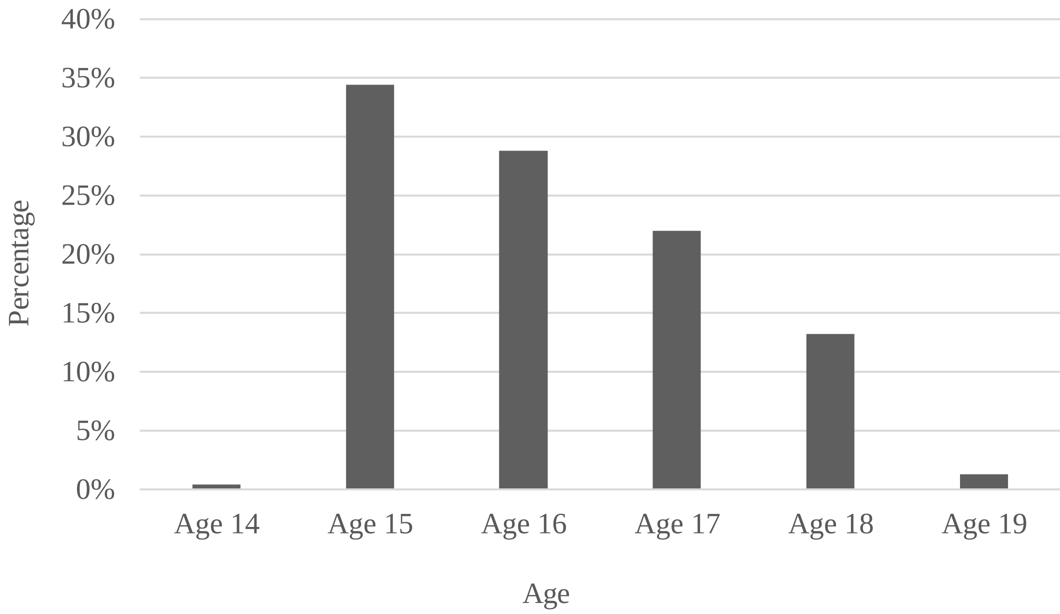

Figure 4. The percentage of total participant students by their age

As shown in Figure 4, the percentages of ages were 1% for age 14 (*n*=2), 34% for age 15 (*n* = 191), 29% for age 16 (*n*= 160), 22% for age 17 (*n*= 122), 13% for age 18 (*n* = 73), and 1% for age 19 (*n* =7).

Instrumentation

In this study, the data were obtained using the Purdue Spatial Visualization Test (PSVT). This instrument was devised to measure students 'spatial visualization skills. PSVT was developed by Roland Guay in 1976. The test was adapted to Turkish by Sevimli (2009) using the original English version. The Turkish version of the test was presented in Appendix A. To be able to use the Turkish version of the instrument, written permission was obtained from the person who adapted into Turkish (Appendix C).

In addition to PSVT, students were asked to complete a demographic form in order to identify important demographic information about each student. More specifically, students state their gender, age, grade level, mother's and father's education, language and income, and number of siblings. The demographic form was listed in Appendix B.

Purdue Spatial Visualization Test (PSVT)

In the literature, there are many different measurement tools listed to measure spatial ability. Among these tests, PSVT was determined as the most appropriate test regarding the theoretical framework of the study. Also, the tool was a free tool to use and it had been already translated and used in Turkey. The test has three sections (each measuring a specific construct) and each section has 12 items. So, the total number of items on the test was 36. These three constructs are *developments*, *rotations*, and *views*. All the items on the PSVT are multiple-choice type questions with only one correct answer and four distractors. For each construct the test items are sequenced from easy to difficult. At the beginning of each section on the PSVT, instructions are provided with two relevant sample questions as examples. The guidelines aim to explain the process for solving the questions.

Specifically, the common skills of spatial visualization ability explained in previous chapters highlight the ability as to find unfolded 3D object from its 2D representation, to rotate a 3D object in the mind, and to predict how a 3D object views from different perspectives through these geometrical objects it was aimed to measure this ability through the PSVT. Also, the objects in questions composed of circular cylinders, rectangular prisms, rotated hexagons and triangular prisms. It was expected from the students to integrate these abilities to those objects for all the sections. Table 3 represents each subsection of the test and question numbers that correspond to sections.

Table 3
PSVT constructs and corresponds items

Constructs	Developments	Rotations	Views
Question Numbers	Item 1-12	Item 13-24	Item 25-36

As it is seen in Table 3, each section has equal numbers of items. The constructs in the PSVT and sample questions for each section were given below.

PSVT's constructs and explanations of these constructs

Developments: First construct of PSVT. This is the first section of the PSVT. The 12 questions were designed to probe how students visualize three-dimensional objects through a cognitive process which required them to mentally fold-up 2D blueprints of various 3D objects. The question stem provided the 2D blueprint and five distracters provided assembled 3D images of objects. Students were asked to choose the correct 3D form of the object representing in the 2D form. Figure 5 shows an example question from developments construct.

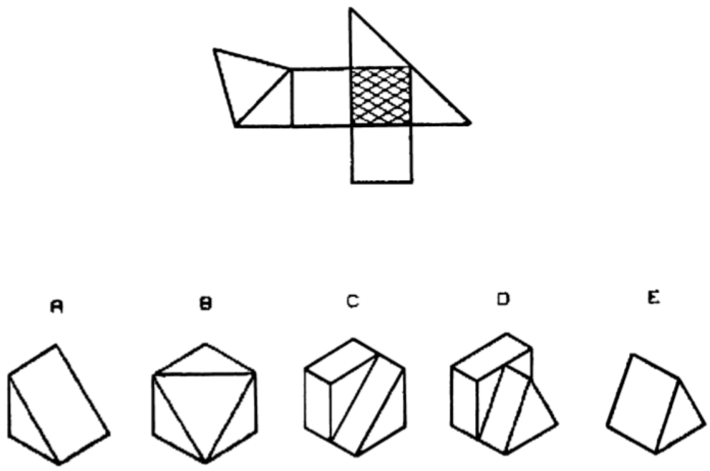

Figure 5. A sample question from the Purdue Spatial Visualization Test in developments construct

Rotations: Second construct of PSVT. Each item of PSVT in this section showed a 3D object at first and then at final position. The questions asked the students to figure out how the object was rotated, that is possible rotations around the Cartesian axes from its initial potions to its final position. Students were asked to select one of five options from the representation of the object that occurred when the student rotated by applying the same steps to the shape in the middle section. Figure 6 represents a question from the rotations construct.

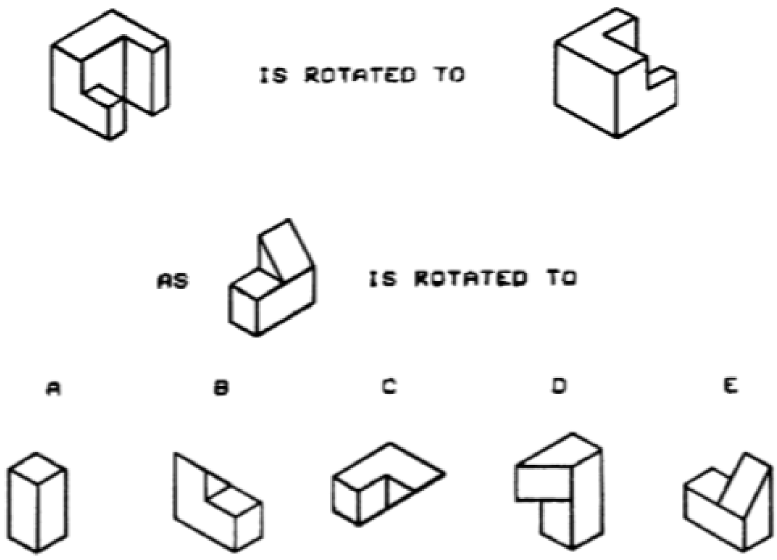

Figure 6. A sample question from the Purdue Spatial Visualization Test in rotations construct

Views: Last construct of PSVT. The last section of PSVT, the questions were designed to probe how students visualize three-dimensional objects from various viewing perspectives. The stem of the question shows an object placed in the center of a cube. At any of the corners of the cube a viewing point is designated. Then, the students were asked to find out how the object would possibly look like from that particular vantage point. Figure 7 shows a question from the views construct.

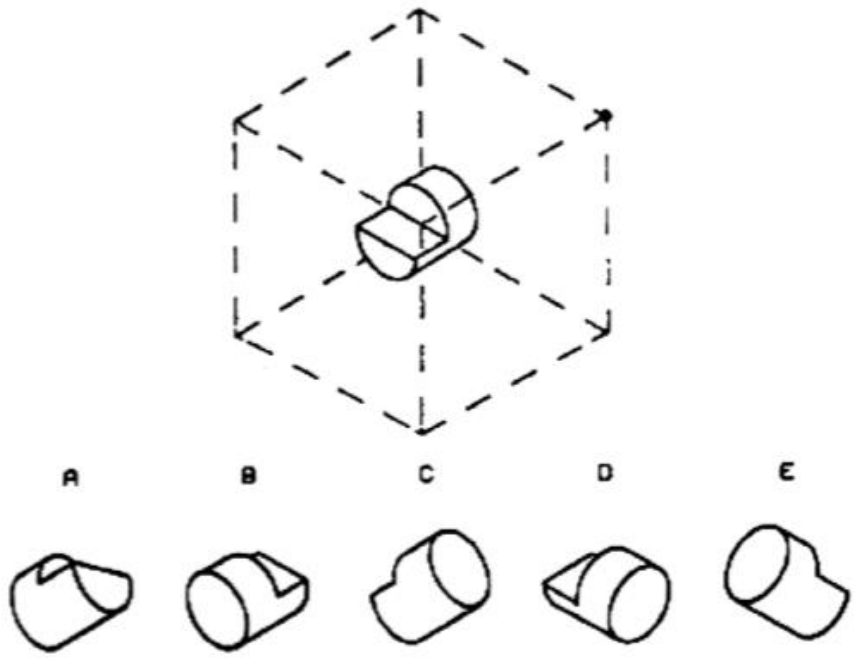

Figure 7. A sample question from the Purdue Spatial Visualization Test in views construct

The developer of the test reported the internal consistency coefficient KR-20 (Kuder-Richardson) of .87, .89, and .92 for the different groups of participants (Guay, 1980). Sevimli (2009), reported the reliability coefficient to be .88 of the Turkish version of the PSVT.

For the current research, the internal consistency of the test for this study was computed using Cronbach’s alpha test. Cronbach’s alpha is a special case of Kuder Richardson coefficient (Cronbach, 1951), known as “coefficient of internal consistency”. The Cronbach’s alpha test for the spatial visualization test was calculated as .79. The Cronbach’s alpha test result is presented in Table 4.

Table 4
Cronbach’s alpha test result for PSVT

Cronbach’s alpha	Cronbach’s alpha based on standardized items	Number of items
.790	.780	36

According to Guay, PSVT is a valid data collection tool for measuring an individual's spatial visualization ability (1980). The validity study of PSVT was obtained by comparing with Shepard Merler Rotation test and a correlation coefficient was found to be .61 (1976). Related studies have shown that the test has scope validity and gives parallel results with other spatial visualization tests (Guay, 1980; Sorby, 2001). Sevimli (2009), however, revealed a study with five experts' opinions in mathematics education and linguistics for the validity of appearance. Finally, the translated test was found to be clear and fluent.

Demographic form

The secondary instrument used was a simple form asking students about demographic variables (Appendix B). The students were asked about their educational information, gender, parents’ educational background, parents’ second language, family’s income, number of siblings, and having study rooms.

Parents’ educational background, parents’ second language, family’s income, number of siblings, and having study rooms was taken as a measure of SES. The education level of the parents was taken as one of the measures of the SES using the components as mother’s educational background and father’s educational background (1 = elementary school, 2 = middle school, 3 = high school, 4 = university, 5= masters’ degree, 6= PhD) (Aydin & Ubuz, 2014). The other measures were parents’ second language (1 = does not have, 2 = have), family’s income (1 = 1500 and below, 2 = 1500-4500, 3 =4501-9000, 4 = above 9000), number of siblings (1 = no sibling, one sibling, two siblings, 2 = three and above), and having study room (1 = no, 2 = yes). Each student had a total point for their SES level. The highest point was 16 and the lowest point was 5. This used to calculate the Pearson product-moment correlation coefficient between the students' spatial visualization ability and socioeconomic status.

Additionally, for the students' mathematics achievement, students' latest mathematics final grades (GPA) of the first semester of the 2018-2019 academic year were collected with the permission of the school administration. Grades for all students were on the scale of a hundred.

Method of data collection

After the researcher decided on the research method to be applied, she decided to use the appropriate data collection tool. The researcher chose an appropriate tool by considering its effectiveness, reliability and validity.

As indicated before, to be able to use the Turkish version of the instrument, written permission was obtained from the person who adapted into Turkish. In order to get legal permission by MoNE, the Turkish version of the proposal was sent to the relevant MoNE department during the summer semester of the 2018-2019 academic year. After the researcher got the approval of the MoNE (Appendix D) she started the data collection portion of the study during the fall term of the 2018-19 academic year. The first step after the approval was to get an appointment and meet school principals in person to confirm the MoNE permission and ask for possible date and times to carry out the study. This also helped the researcher to administer the study easily since the principals directed the researcher to school counsellors or vice principals who were in charge of school-wise research studies. Later, the instruments were administrated to 555 high school students. The researcher was present throughout the administration of the PSVT and she gave instructions and explanations regarding the demographic information form and the test. Those two instruments were completed in one lesson period of time. The researcher visited six schools during the fall semester. However, some schools did not allow to conduct the present study. Although permission was granted by MoNE the school principals and/or subject teachers has the right to refuse the administration of the test.

Method of data analysis

The study used Statistical Package for the Social Sciences (SPSS) 24.0, R 3.5.1, RStudio 1.1.463 and MS Excel to analyze the data and plot the graphs. Chapter 4 provides the descriptive statistical analyses. Before reporting those results the following measures were computed. The reliability coefficient of the PSVT, that is Cronbach's alpha, was computed to be 0.79. Moreover, the normality of the data was checked. It was observed that the skewness and kurtosis values were between 2 and -2. Thus, the variables in the study were assumed to have a normal distribution. Then, the average of PSVT total and PSVT's constructs scores were calculated. For the variables in demographic form, the frequency of the gender, school types, and grade level were calculated. Also, ten of the students' responses, were excluded from the analysis. Therefore, the analyses were conducted based on the 555 high school students out of the total of the 565.

Typical descriptive statistical analyses were conducted to compute the following statistics; mean, median, mode, range, standard deviation, skewness, kurtosis, and frequency. Then, the same descriptive statistical analyses were applied to data based on variables such as gender, school types, and grades. Moreover, the projection of population and sample probability density function over students' PSVT total scores histogram, and each constructs' histogram graphs were drawn. The reason for doing this was to investigate students' levels of spatial visualization ability. Then, all students' levels of spatial visualization ability were categorized as high, middle and low. The same method was applied to the data based on factors such as gender, school type (private and state schools), and grade levels. Furthermore, independent samples t-test was conducted to determine whether the difference between gender and school types were statistically significant. Welch's ANOVA test was conducted to determine whether the mean difference between grades was statistically significant. Pearson correlation coefficient was computed to find out if there were relationships between the PSVT total score of students and their mathematics course grades, also for their socioeconomic status. For independent samples t-test, the homogeneity of variance checked with Levene's test to see if the assumption was met. Results of independent-samples t-test were given accordingly. Also, the alpha level was set to .05 for all the analyses conducted and reported in Chapter 4.

CHAPTER 4: RESULTS

Introduction

The purpose of this study was to examine Turkish high school students' spatial visualization ability level. The secondary purpose was to investigate variables such as gender, age, school type, and socio-economic status as it related to students' spatial visualization ability. It further investigated a possible relationship between students' spatial visualization ability level and their mathematics achievement scores. It also investigated a possible relationship between students' spatial visualization ability and socioeconomic status.

In this section, results and interpretations based on the descriptive statistical analysis of the data were given in accordance with the research questions listed in chapter 3.

The descriptive result on students' PSVT scores

Firstly, the general result related to the outcomes of all students' PSVT scores were reported. This section gave information about the first research question which was "*what are the students' spatial visualization ability levels and its constructs as measured by Purdue Spatial Visualization test*". There were thirty-six items in the PSVT, and students were awarded one point for each correct answer. Additionally, no punishment points were deducted for the incorrect answers.

A total of 555 high school students answered the test. There were a total of 36 multiple-choice type items on the test and each item had four distractors and one correct answer. The test probed three constructs (see. p.39) and each construct was probed with 12 items. The highest possible score was 36 and the lowest possible score was 0. The general results of analyses were displayed in Table 5.

From the Table 5, one can see that the students' overall mean score of the PSVT was calculated to be 14.19 and median was calculated to be 14.00. The arithmetic difference between the mean and median score was observed to be small. The PSVT score distribution could be considered as symmetric. The skewness value was computed to be .497 indicating a slight positive skewness, kurtosis value of -0.15 showing the scores had only a few numbers of extreme outliers. All these results showed that the students score distribution did follow a pattern close to the normal distribution. When considering the standard deviation (*SD*=5.84) one can conclude that the majority of student scores were distributed between 8 and 20 points.

Table 5
Descriptive statistical results of all students' PSVT scores

Construct	Mean	Median	SD	Skewness	Kurtosis	Range	Min.	Max.
Developments	5.93	6	2.83	0.21	-0.75	12	0	12
Rotations	4.33	4	2.30	0.25	-0.65	10	0	10
Views	3.93	4	2.51	0.49	-0.38	10	0	10
Total	14.19	14	5.84	0.50	-0.15	29	2	31

Moreover, students' mean score for the three constructs (i.e. developments, rotations, and views) was calculated each to be 5.93, 4.33, and 3.93 respectively. Also, the value of the median was found to be 6, 4, and 4. As shown in Table 5, the mean and median scores of each construct were very close to each other, which indicated that the constructs also almost showed a normal distribution pattern. The overall range value of students' test scores was found to be 29 illustrating a relatively widespread of scores. On the other hand, the range value of students' test scores of three constructs were 12, 10, and 10 respectively.

Figure 8 shows the frequency distribution of all students' total scores. For example, the highest score was 31. The lowest score was 2 points. Most of the students scored between 8 and 18.

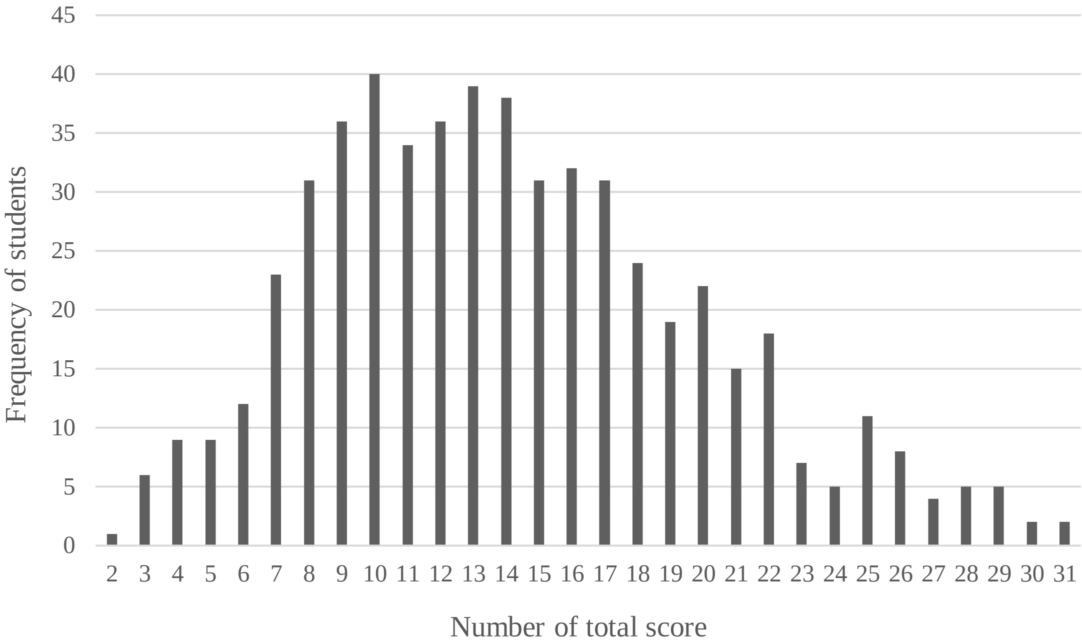

Figure 8. Overall distribution of all students' PSVT total scores

Figure 9 presents the frequency distribution of PSVT *developments* construct scores of all students. For example, 11 students answered all items in this construct correctly. Moreover, this distribution was almost normally distributed with a slight positive skewness.

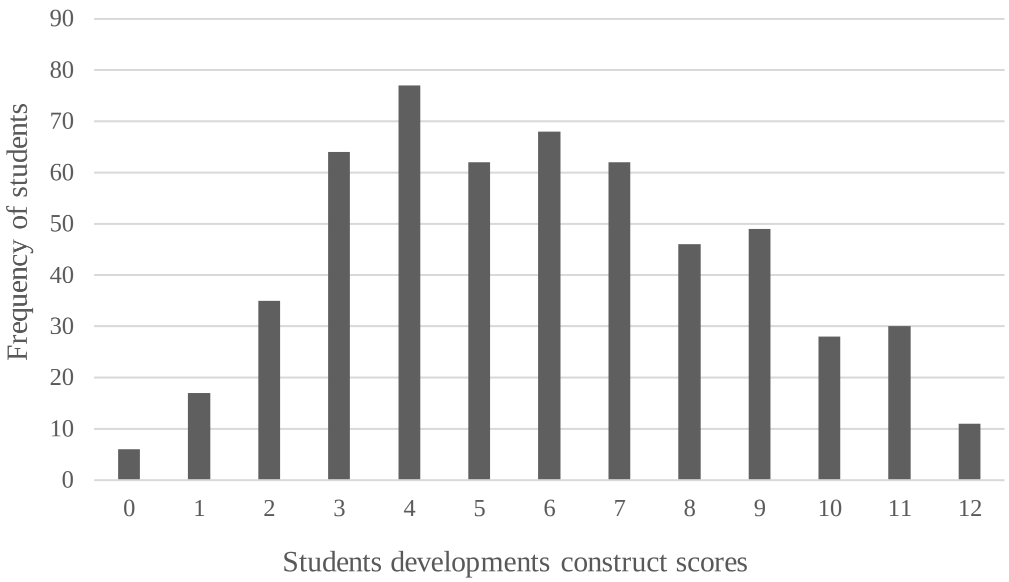

Figure 9. PSVT developments construct: Frequency distribution of all students' scores

Figure 10 represents the frequency distribution of all students' PSVT *rotation* construct scores. As can be seen from Figure 3, the frequency distribution resembles the pattern of a normal distribution with a slight positive skew.

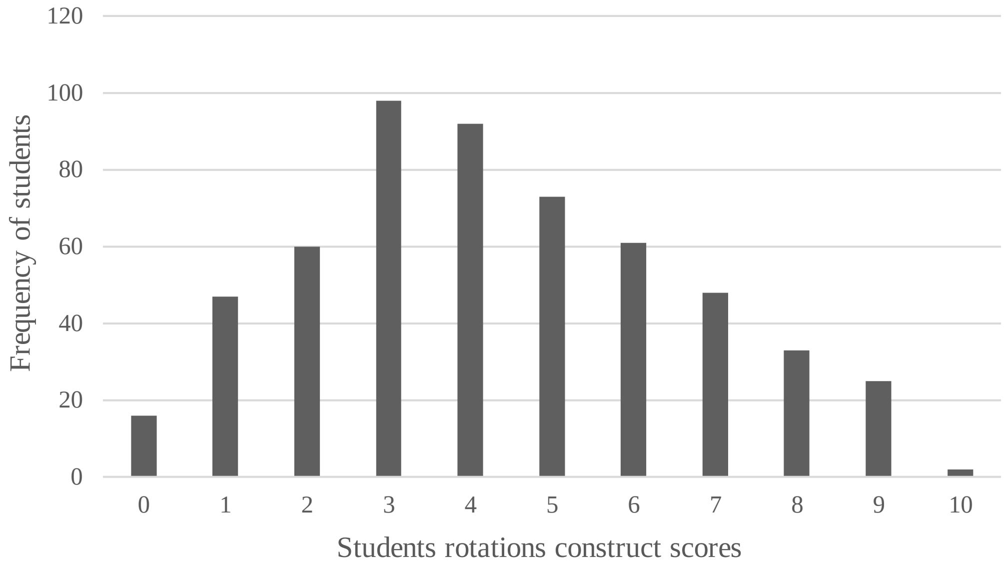

Figure 10. PSVT rotations construct: Frequency distribution of all students' scores

Figure 11 shows the frequency distribution of PSVT *views* construct score for all students. As can be seen from figure 11, the frequency distribution approximately has the pattern of a normal distribution with a slight positive skew.

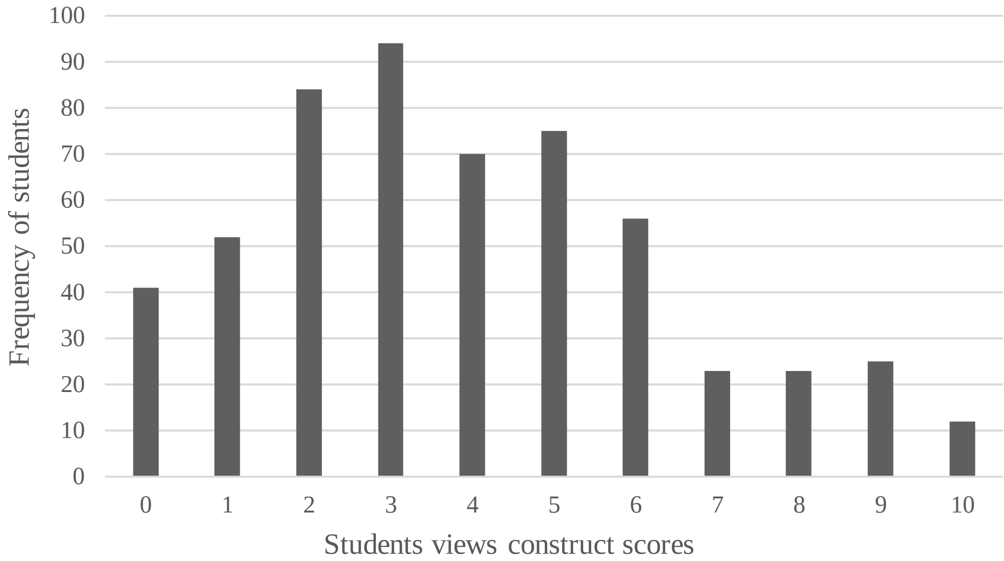

Figure 11. PSVT views construct: Frequency distribution of all students' scores

There was a clear difference between the constructs of the PSVT with respect to the mean score values. The highest mean score (5.93) was observed on the *developments* construct. The lowest correct mean score (3.93) was observed on the *views* construct (see. Table 5). The findings of PSVT showed that high school students had difficulty in answering questions that require three-dimensional object manipulation through the use of different reference viewpoints. Students had a higher mean score of about two points on questions involving the folding of three-dimensional objects.

Determining the levels of students' spatial visualization ability based on total PSVT scores

This section also gave information about the first research question which was "*what are the students' spatial visualization ability levels and its constructs as measured by*

Purdue Spatial Visualization test?". Based on the descriptive statistics of the test and its constructs, the value of the cut off score was determined. The researcher used normal distribution of ability tests as a norm. The maximum total score of the test was 36 and hence the population mean was 18 (μ=18). The mean of the sample was 14.19 and the researcher observed that the average of the sample was lower than the hypothesized population mean. In other words, the majority of the students composing were located to the left of the population mean. This indicated that the sample was leaned at the lower spatial ability side.

The PSVT can be classified as a typical ability test. Ability tests scores results show a normal distribution pattern. The properties of a normal distribution are as follows. The mean, median, and mode are all equal. These statistical measures are commonly referred to as *average*. Moreover, the density function of a normal distribution is symmetric around its average and adds up to 1. Three standard deviations to the left and right from the mean cover 99.7% of the population.

As stated earlier, the PSVT was a typical ability test with a maximum score of 36. Hence, it follows that the population average is μ=18 with a standard deviation of σ= 6.

What follows in Figures 12-16 below is the projection of population and sample probability density function over students' PSVT total scores histogram, developments construct scores histogram, rotations construct scores histogram, and views constructs scores histogram graphs.

As seen in Figure 12, the normal distribution probability function of the population (μ=18, σ=6) is shown in red. Also, the normal distribution probability function of the sample of students' PSVT total scores (*M*=14.19, *SD*=5.84) is shown in blue. The sample distribution has a lower mean, but still shows a pattern of normal distribution, slightly shifted to the lower end scores.

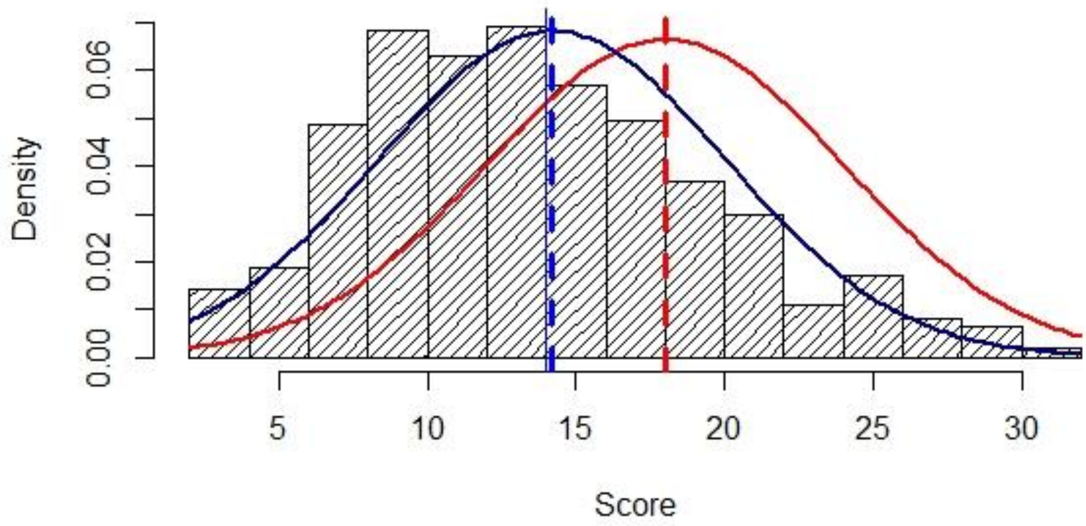

Figure 12. Normal curve of population and sample based on all students' total score

As displayed in Figure 13, the normal distribution probability function of the population (μ=6, σ=2) is shown in red. The normal distribution probability function of the sample of students' PSVT developments construct total scores (*M*=5.93, *SD*=2.83) is presented in blue. The sample distribution has a lower mean, but still shows a pattern of normal distribution, slightly shifted to the lower end scores.

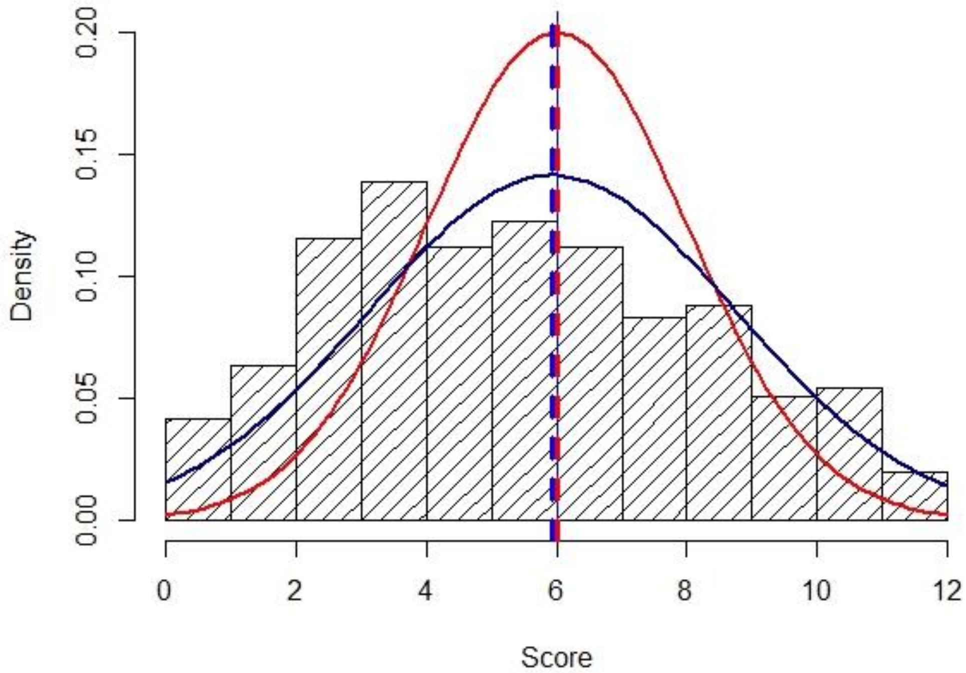

Figure 13. Normal curve of population and sample based on all students' PSVT developments construct score

As seen in Figure 14, the normal distribution probability function of the population (μ=6, σ=2) is shown in red. The normal distribution probability function of the sample of students' PSVT views construct total scores (*M*=4.33, *SD*=2.30) is shown in blue. The sample distribution slightly shifted to the lower total scores as it has a lower mean, but still shows a pattern of normal distribution.

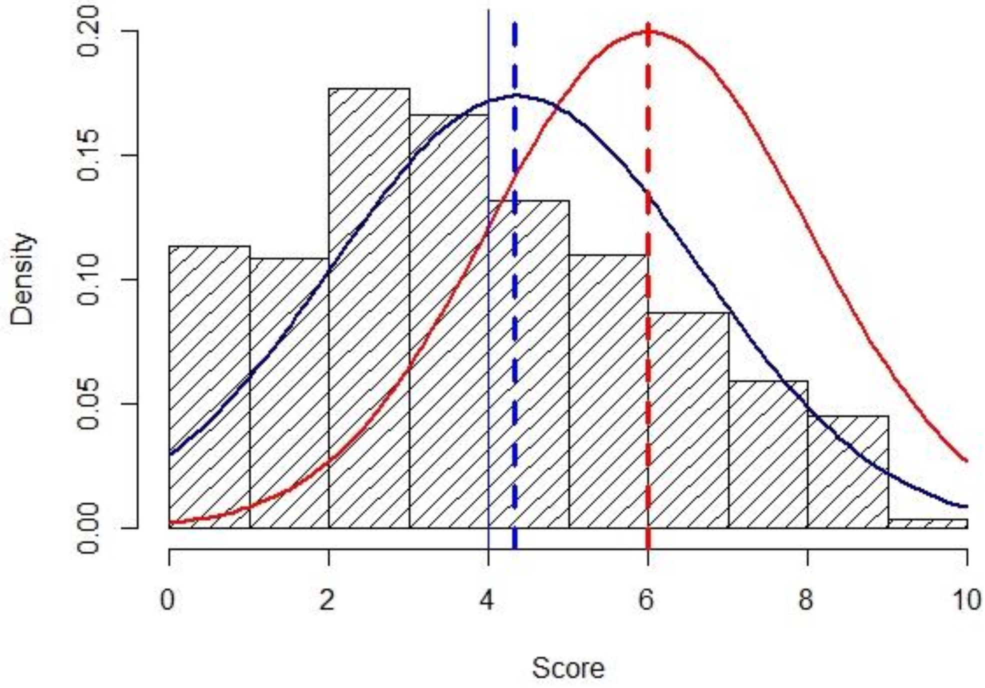

Figure 14. Normal curve of population and sample based on all students' PSVT rotations construct score

As seen in Figure 15, the normal distribution probability function of the population (μ=6, σ=2) is shown in red. The normal distribution probability function of the sample students' PSVT views construct total scores (*M*=3.93, *SD*=2.51) is shown in blue. Even though the sample's distribution has a pattern of normal distribution, it has a lower mean.

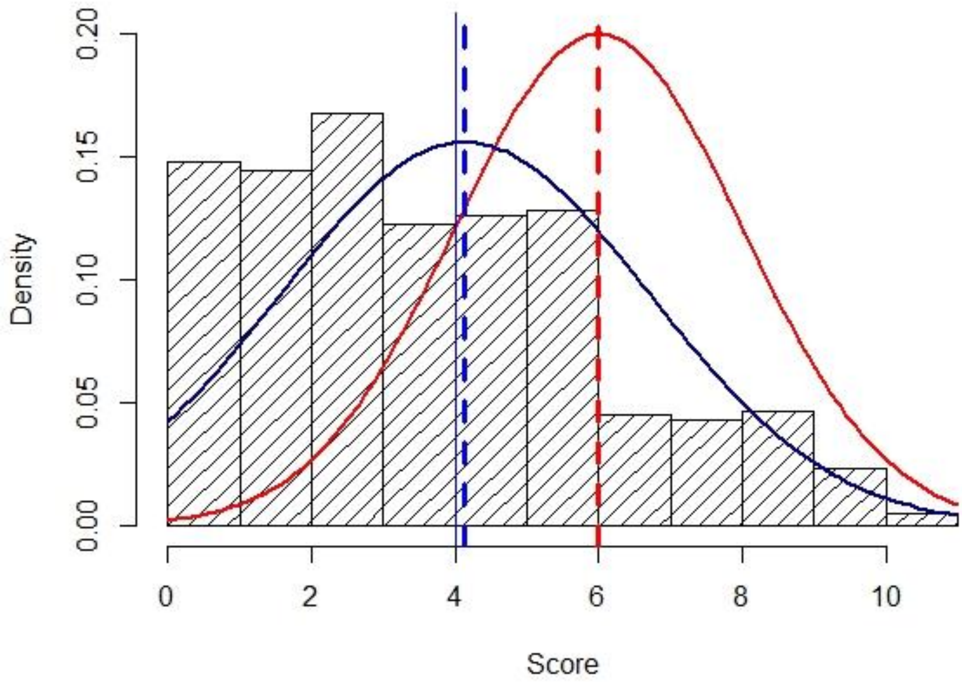

Figure 15. Normal curve of population and sample based on all students' PSVT views construct score

The following scale was used to classify the student as having high, mid-level and low spatial ability. Students with a value greater than or equal to 24 correct answers were categorized as "High Spatial Visualization Ability (HSVA)"; students with a value between 12 and 24 were classified as "Mid-level Spatial Visualization Ability (MSVA); and students with a value less than or equal to 12 correct answers were categorized as "Low Spatial Visualization Ability (LSVA)". In this context, the students were classified as three groups as it follows; HSVA, MSVA, and LSVA. Additionally, the same approach was used for the three constructs. Consequently, the classification of students' spatial visualization ability levels was formed. The count of students for each group were given in Table 6.

Table 6
Students' classification of spatial visualization abilities

	SVA Level		
	# of HSVA	# of MSVA	# of LSVA
Constructs	n (%)	n (%)	n (%)
Developments	164 (29.55%)	192 (34.59 %)	199 (35.86 %)
Rotations	60 (10.81%)	182 (32.79 %)	313 (56.40 %)
Views	60 (10.81%)	154 (27.75 %)	341 (61.44 %)
Total	42 (7.57%)	276 (49.73 %)	237 (42.70 %)

Note. NoS: Number of participants, *HSVA:* High Spatial Visualization Ability, *MSVA:* level Spatial Visualization Ability, *LSVA:* Low Spatial Visualization Ability.

After examining students' spatial visualization ability levels that were shown in Table 6, the highest number of students for HSVA were found in the "developments" construct (29.55%). Whereas, HSVA students showed lower performance in "rotations and views" constructs (10.81%). In general, according to the students' PSVT scores, it was found that 7.57% of the students were classified as HSVA; 49.73% of the students were classified as MSVA and 42.70% of the students were classified as LSVA.

Correct, incorrect, and unanswered percentage of PSVT responses

This section gave information about the percentage of the correctly, incorrectly, and unanswered student responses on the PSVT which also refers to the first question "*what are the students' spatial visualization ability levels as measured by Purdue Spatial Visualization test*". These outcomes also showed which construct of the PSVT was most and/or less frequently answered. Percentages of students' correct answers, incorrect answers, and unanswered questions were displayed in Table 7.

Table 7
The percentages of answered and unanswered questions by construct

Constructs	Correct answers	Incorrect answers	Unanswered answers
Developments	49.40%	47.21%	3.39%
Rotations	36.11%	57.84%	6.05%
Views	32.78%	58.56%	8.66%
Total	54.53%	39.43%	6.04%

As seen in Table 7, the students were relatively successful (49.2%) in the developments construct. The findings of the study showed that most of the correct answers were given in this “developments” construct. Another important finding was the small number of non-answered questions and the high number of incorrect answers. The most difficult part for students was the “views” construct. Table 7 showed that 58.56% of the answers given to this section were incorrect, also 8.6% was unanswered. In the views construct, the sum of the percentage of the students' unanswered and incorrect questions was found to be 67%. A final remark is that the students marked about 90% of the questions in the test. Considering all the answers given to the test, 54.3% of the answers were correct while; 39.43% of the answers were incorrect.

In the following section, descriptive statistics was conducted on students’ PSVT total and its construct scores based on the variables gender, school type and grade. In Table 6, the scale was used to classify the student as having high, mid-level and low spatial ability. For the following section, descriptive statistics was also conducted on students’ levels of spatial visualization ability based on the variables gender, school type and grade. In summary, this section provided answer for the second, third and fourth research questions.

PSVT total and its constructs scores: Gender

The second research question was "*do male and female high school students have significantly different levels of spatial visualization ability and its constructs*". Table 8 represented descriptive statistical results regarding the second research question.

Table 8
Descriptive statistical results of students' PSVT total and the constructs scores based on gender

Gender	Measure	Total	Developments	Rotations	Views
Female	Mean	13.53	5.71	4.11	3.71
	N	310	310	310	310
	SD	5.453	2.819	2.190	2.317
	Minimum	2	0	0	0
	Maximum	31	12	10	10
	Median	13	5	4	3
	Range	29	12	10	10
	Kurtosis	-0.130	-0.694	-0.453	-0.138
	Skewness	0.439	0.228	0.319	0.481
Male	Mean	15.04	6.21	4.62	4.21
	N	245	245	245	245
	SD	6.211	2.816	2.405	2.708
	Minimum	3	0	0	0
	Maximum	31	12	10	10
	Median	14	6	4	4
	Range	28	12	10	10
	Kurtosis	-0.343	-0.812	-0.826	-0.702
	Skewness	0.472	0.184	0.138	0.415

There were 310 female students and 245 male students that correspond to 55.86% and 44.14% of the sample respectively. As seen in Table 8, female students' mean score was found to be 13.53 and male students' mean score was found to be 15.04. When compared, the genders' PSVT mean scores were slightly different. Female students' PSVT developments, rotations and views constructs scores were found to be 5.71, 4.11, and 3.71; male students' PSVT developments, rotations and views constructs scores were found to be 6.21, 4.62, and 4.21. Even though the mean scores differences were not too much in count, male students' constructs' mean scores were greater than female ones.

Female and male students' PSVT total score distribution had skewness values of 0.438 and 0.472 respectively. The score distribution for both genders was slightly positively skewed. Similarly, female and male students' score distribution had kurtosis values of -0.130 and -0.343 respectively. These values indicated the scores had a few numbers of extreme outliers.

Furthermore, male students' total score had a standard deviation of 6.21 while female students had a standard deviation of 5.45. Male students' total score range was between 9 and 21 while female students' total scores range were between 8 and 19. The male students' scores spread was slightly greater than female scores spread. However, the lowest value of total score (2) was obtained by a female student, and the greatest value of total score (31) was scored both by a female and male student.

As can be seen in Figure 16 above, the total count of female students were more than male students in the lower range of the scores. This pattern held true for the upper range too, male students count was more in the high scores range than female students.

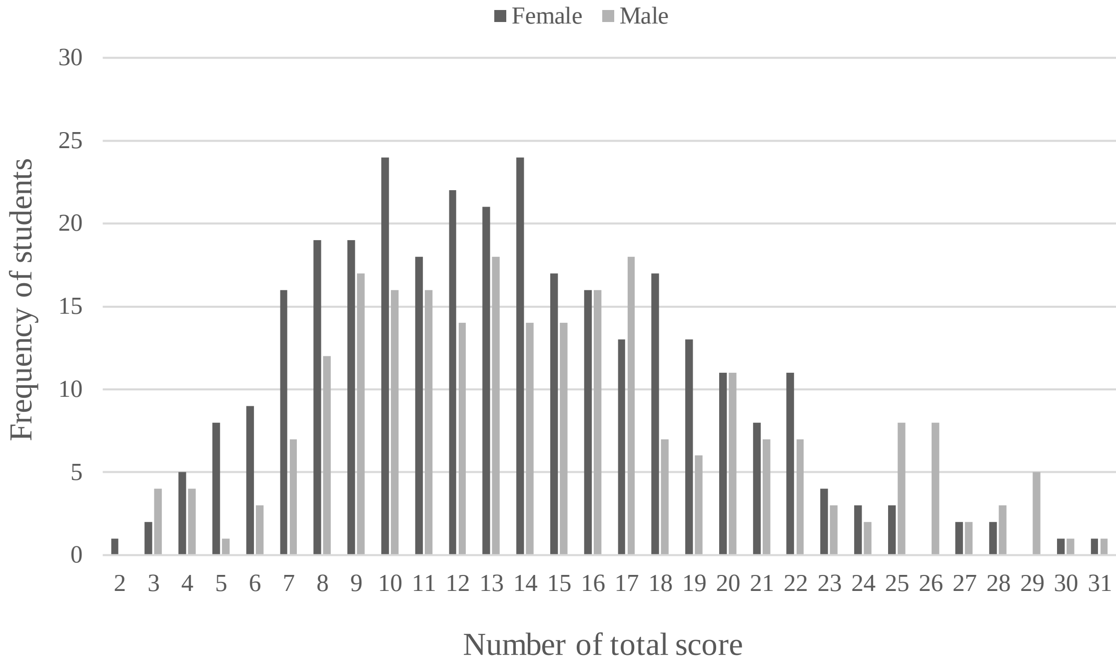

Figure 16. The distribution of students' total scores based on gender

Students' levels of spatial visualization ability: Gender

The percentage distribution of PSVT scores by spatial visualization ability levels (high, mid-level, and low level) by gender is shown in Table 9. When compared by gender, the count of male students was higher in the HSVA group. However, this difference seemed to disappear at the MSVA level, here the distribution of PSVT scores among the gender was almost the same. For the LSVL, the difference was observed again in favour of male, however not as strong as in the HSVA category.

Table 9
Statistics of gender for spatial visualization ability levels

	SVA Level		
	# of HSVA	# of MSVA	# of LSVA
Gender	n (%)	n (%)	n (%)
Female	12 (3.87%)	155 (50%)	143 (46.13%)
Male	30 (12.24%)	121 (49.39%)	94 (38.37%)

Note. SVA: Spatial Visualization Ability

PSVT total and its constructs scores: School type

The third research question was "*do the students' spatial visualization ability levels and the constructs of the tests vary with respect to school type*". Descriptive statistical result regarding PSVT and its constructs were represented in Table 10 below and provide information on the third research question.

Table 10
Descriptive statistical results of students' PSVT total and constructs scores by school types

School type	Measure	Total	Developments	Rotations	Views
Private	Mean	13.44	5.73	4.11	3.60
	N	211	211	211	211
	SD	6.221	2.982	2.355	2.710
	Minimum	2	0	0	0
	Maximum	31	12	10	10
	Median	13	5	4	3
	Range	29	12	10	10
	Kurtosis	0.242	-0.726	-0.484	-0.148
	Skewness	0.781	0.287	0.454	0.708
State	Mean	14.66	6.05	4.47	4.14
	N	344	344	344	344
	SD	5.557	2.723	2.257	2.354
	Minimum	3	0	0	0
	Maximum	31	12	10	10
	Median	14	6	4	4
	Range	28	12	10	10
	Kurtosis	-0.327	-0.762	-0.681	-0.496
	Skewness	0.332	0.169	0.137	0.379

In total, there were three schools involved in this study. 38.02% (n=211) students were from a private school, and 61.98% (n=344) students were from two state schools. As illustrated in Table 10, the number of students attending state school were greater than those attending private school. The mean PSVT score of state school students (14.66) was slightly greater than private school students' mean score (13.44). The median score of state and private school students was calculated to be

14 and 13 respectively. These values indicated a slight skewness to the right for both groups of schools.

State school students' PSVT developments, rotations and views constructs scores were found to be 6.05, 4.47, and 4.14; private school students' PSVT developments, rotations and views constructs scores were found to be 5.73, 4.11, and 3.60. State school students' mean scores were greater than private school students for each three constructs.

Private school students score distribution skewness value was 0.781 and the kurtosis value was 0.242. State school students' skewness value was 0.332 and the kurtosis value was found to be -0.327. Hence, both groups had positive skewness and illustrated that scores had a normal distribution pattern. Total scores of private school students had larger spread distribution than state school students and private school students had a standard deviation value of 6.221 and state school students had a standard deviation value of 5.557.

As shown in Figure 17, the top two scores were 30 and 31. One student from each school type had received these scores. The number of state school students mostly distributed between the total scores of 14 and 27. On the other hand, the number of private school students was more in number for the three lowest total scores.

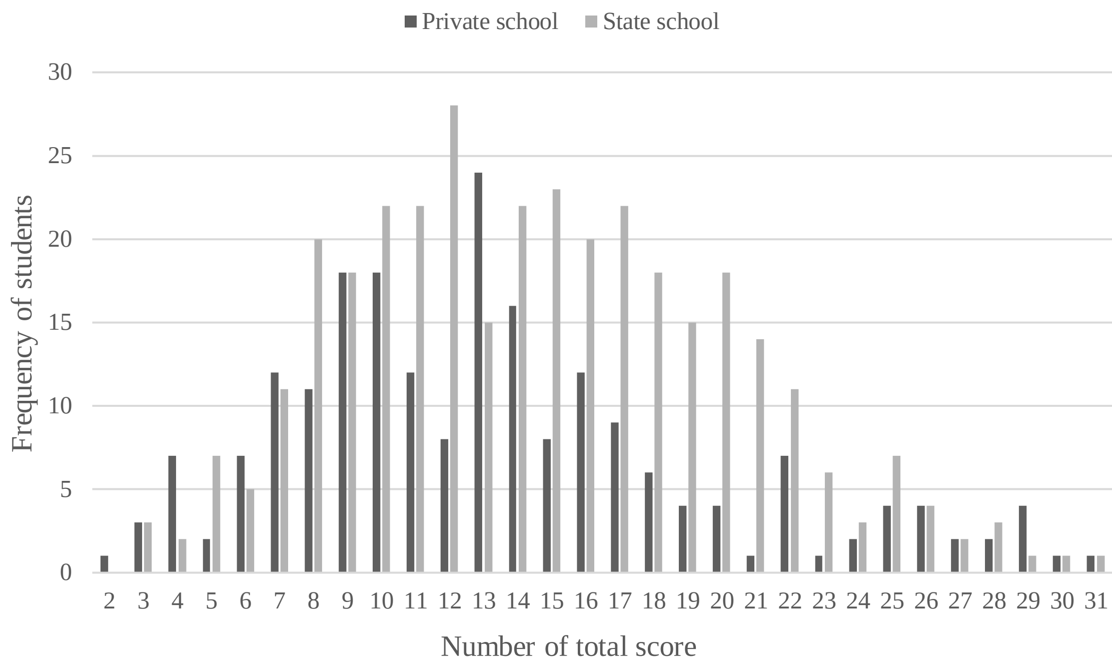

Figure 17. The distribution of students' total scores based on school type

Students' levels of spatial visualization ability: School type

Table 11 shows the percentage distribution of PSVT scores by spatial visualization ability levels and by type of school. When the school type-based responses to PSVT were compared, 9.48% (n = 20) of the private school students were placed in HSVA, while 6.39% (n = 22) of the state school students were placed in HSVA level. The percentage of private school students was greater in the HSVA level. Also, 53.49% (n = 184) of state school students was greater than 43.60% (n = 99) of private school students with MSVA level. However, 46.92% (n = 99) of private school students were greater than the percentage of state school students 40.12% (n=138) with LSVA level.

Table 11
Statistics of school types for spatial visualization ability levels

	SVA Level		
	# of HSVA	# of MSVA	# of LSVA
School types	n (%)	n (%)	n (%)
State school	22 (6.39%)	184 (53.49%)	138 (40.12%)
Private school	20 (9.48%)	92 (43.60%)	99 (46.92%)

Note. SVA: Spatial Visualization Ability

PSVT total and its constructs scores: Grade

This study also attempted to investigate the question "*do the students' spatial visualization ability levels and the constructs of the test change with respect to grade*". Table 12 showed descriptive statistical results for the fourth research question.

Table 12
Descriptive statistical results of students' PSVT total and constructs scores by grade levels

Grade	Measure	Total	Developments	Rotations	Views
9^{th} Grade	Mean	14.09	6.02	4.32	3.74
	N	207	207	207	207
	SD	5.106	2.572	2.180	2.140
	Minimum	3	1	0	0
	Maximum	31	12	9	10
	Median	14	6	4	4
	Range	28	11	9	10
	Kurtosis	-0.224	-0.768	-0.663	-0.323
	Skewness	0.327	0.225	0.038	0.440
10^{th} Grade	Mean	14.22	5.73	4.24	4.25
	N	158	158	158	158
	SD	5.952	2.854	2.312	2.651
	Minimum	3	0	0	0
	Maximum	30	12	9	10

Table 12 (cont'd)
Descriptive statistical results of students' PSVT total and constructs scores by grade levels

Grade	Measure	Total	Developments	Rotations	Views
10th Grade	Median	14	6	4	4
	Range	27	12	9	10
	Kurtosis	-0.259	-0.738	-0.515	-0.587
	Skewness	0.347	-0.004	0.405	0.386
11th Grade	Mean	14.28	5.95	4.32	4.01
	N	126	126	126	126
	SD	6.090	3.033	2.307	2.661
	Minimum	4	0	0	0
	Maximum	30	12	10	10
	Median	13	5	4	4
	Range	26	12	10	10
	Kurtosis	-0.257	-0.850	-0.581	-0.557
	Skewness	0.580	0.324	0.288	0.372
12th Grade	Mean	14.30	6.05	4.63	3.62
	N	64	64	64	64
	SD	7.285	3.149	2.640	2.876
	Minimum	2	0	0	0
	Maximum	31	12	10	10
	Median	13	5	4	3
	Range	29	12	10	10
	Kurtosis	-0.393	-0.914	-1.044	-0.228
	Skewness	0.739	0.380	0.288	0.799

As reported in Table 12 above, 37% (n=207) of students were from ninth-grade, 28% (n=158) were from tenth-grade, 23% (n=126) were from eleventh grade and 12% (n=64) were from twelfth-grade students.

As the students' grades increased, the mean score values slightly increased as well. Grade 12 students obtained the highest mean score (14.30) and the lowest mean score was obtained by grade 9 students (14.09). For four grades, median score value of students was smaller than mean score except grade 9 had a greater median score value than mean for the views construct. And, grade 10 had a greater median score value than mean for the developments construct.

Standard deviation value of 7.285 for 12th grade indicated a widespread distribution of scores and standard deviation value of 5.106 for 9th grade showed a narrow spread of distribution in comparison with the other grades. As reported in Table 12, one 9th and one 12th grade student scored the highest PSVT score (31). The lowest PSVT score (2) was scored by a 12th-grade student.

As shown in Figure 18 below, the distribution of students' scores within the same grade was reported. Distribution of students' scores showed generally a normal distribution pattern for all the grades.

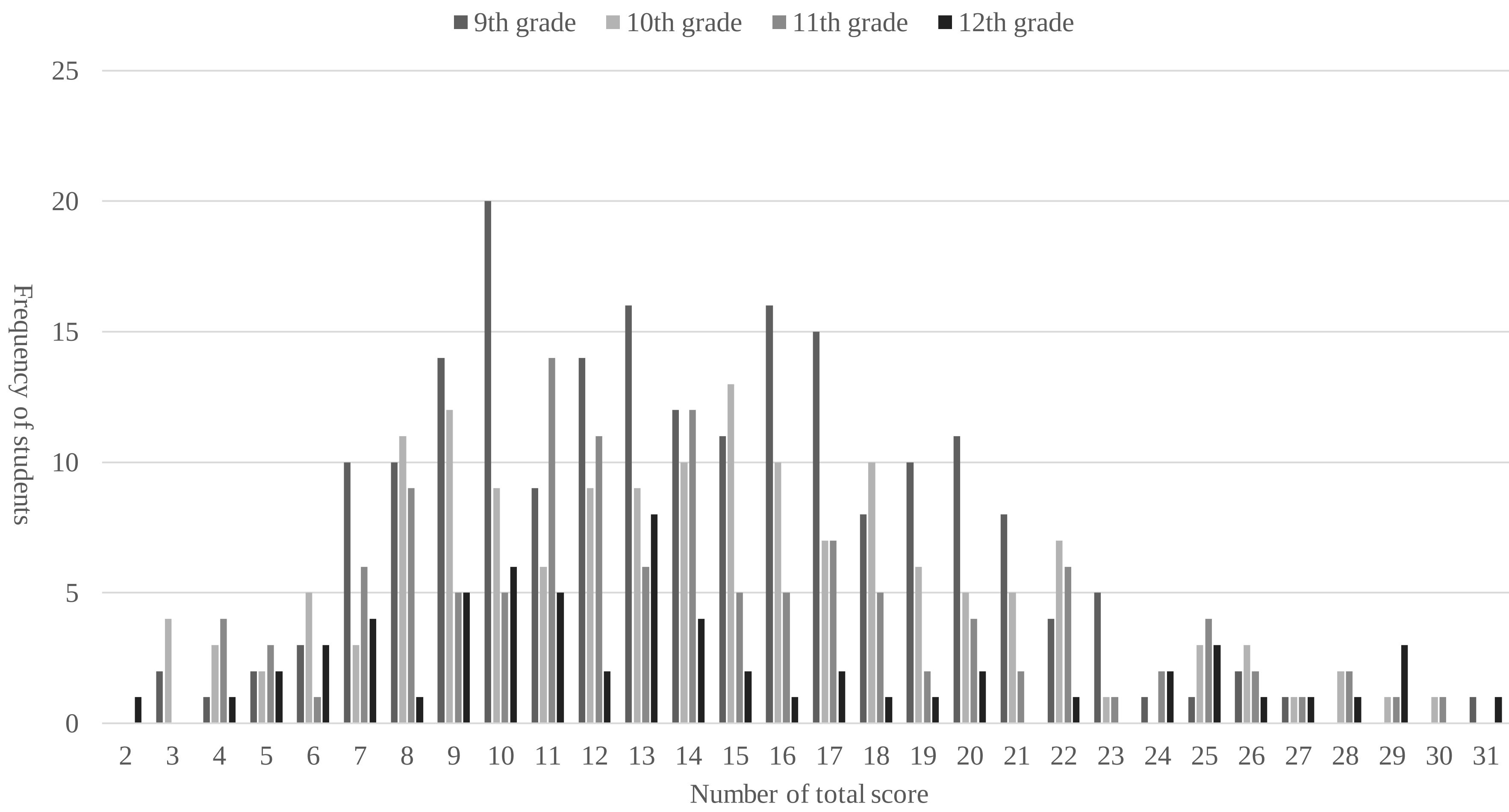

Figure 18. The distribution of students’ total scores by grade

Students' levels of spatial visualization ability: Grade

Table 13 shows the percentage distribution of students' PSVT scores by levels (high, mid-level, and low level) and by grades. When comparison made by grades, the percentage of twelfth-grade students (n=12, 18.75%) in the HSVA category was greater, then the students from the eleventh-grades (n=13, 10.32%), tenth-grades (n=11, 6.96%), and ninth-grades (n=6, 2.90%) respectively. For the MSVA category, the distribution showed a reversed pattern. The percentage distribution for the LSVL category was similar for all grades.

Table 13
Statistics of grades for spatial visualization ability levels

	SVA level		
	# of HSVL	# of MSVL	# of LSVL
Grades	n (%)	n (%)	n (%)
9th grade	6 (2.90%)	116 (56.05%)	85 (41.55%)
10th grade	11(6.96 %)	83 (52.54%)	64 (40.50%)
11th grade	13 (10.32%)	55 (43.65%)	58 (46.03%)
12th grade	12 (18.75%)	22 (34.38 %)	30 (46.87%)

Note. SVA: Spatial Visualization Ability

PSVT total and its constructs scores: SES

Table 14 shows statistical result of students' SES levels (high, middle and low level). 33.3 % of the students had high level of SES, 44.14 % of the students had middle level of SES and 22.53 % of the students had low level of SES.

Table 14
Statistics of students' SES levels

	SES Level		
	# of high level	# of middle level	# of low level
n (%)	185 (33.3 %)	245 (44.14%)	125 (22.53%)

Further evidence towards the research questions

General statistical descriptive results were given for the all students' PSVT total and its constructs scores by gender, school types, grades, and socioeconomic status. Normality for the factors were checked in the previous section. In this section, the researcher compared whether there was a statistically significant difference between students' PSVT mean scores and the variables gender, school types, and grades using independent samples t-tests and ANOVA. In addition, correlation coefficient of students' PSVT scores and end of spring semester mathematics course grades was calculated. Also, correlation coefficient of students' PSVT scores and socioeconomic status was reported. These correlational results provided information for the fifth and sixth research question.

Statistical analysis between female vs. male PSVT mean score differences

As presented in Table 15 above, independent samples t-test was conducted on students' PSVT mean scores by gender in order to determine if there was a statistically significant mean difference between female and male students' PSVT total score. The alpha level of .05 was used for this statistical test. There was a statistically significant mean difference in the PSVT total scores between female (*M* =13.53, *SD* = 5.453) and male (*M* = 15.04, *SD* = 6.211) conditions; *t* (488.612) = -3.010, *p* = .003.

Table 15
Independent samples t-test for PSVT total scores: Gender

	F	Sig.	t	df	Sig. (2-tailed)	Mean difference
Total score	3.905	.049	-3.010	488.612	.003	-1.515

One should note that there were only about 1.51 points difference between the PSVT mean scores by gender. The students were free to answer all the questions without being punished for incorrect responses provided. Below, follows a graphical representation of a descriptive statistic regarding female and male behaviours while answering the PSVT items with the hope to shed more light on the possible difference between the PSVT mean score differences by gender.

PSVT scores item analysis by gender

Figure 19 above shows the count of “Unanswered items” by gender for each item on the PSVT. As can be clearly seen, female students were consistently more reluctant while answering the questions. It seemed that female students left questions unanswered even though they had been given the opportunity to guess without punishment. Please note that this pattern is true for the very first batch of questions as well. Indicating that time was not an important factor or pressure for female unanswered counts. One could also clearly observe that rotations construct, and views construct were perceived more difficult by both groups because of the fact that the ratio of the unanswered item increased for both of these two constructs.

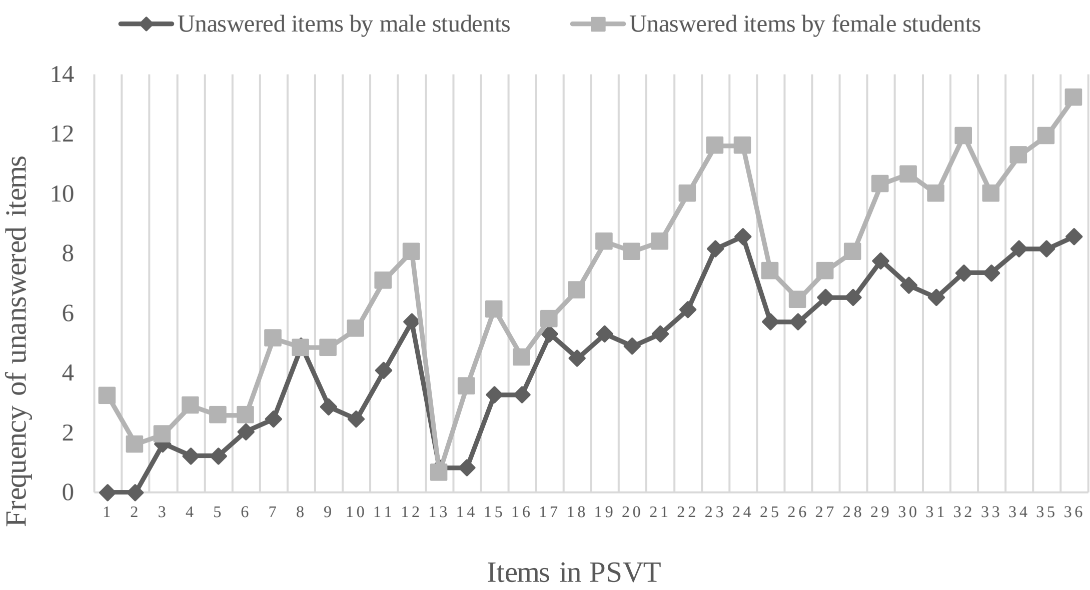

Figure 19. The count of unanswered items by gender

Figure 20 displays the distribution of item difficulty for each item on the PSVT by gender. Item difficulty was a psychometric measure that basically relays on the correct answer ration for a particular item. Based on Figure 13 above, one can deduce that female students perceived the PSVT somewhat more difficult than male students. In total, female students found 24 items difficult, while male students found 8 items out of 36 items difficult. Four of the items had an equal item difficulty value. Items 21, 24, 26, 28 and 35, for both male and female students and items 7, 12, 30, 32 for female students were at chance level, so that these items may have some issues.

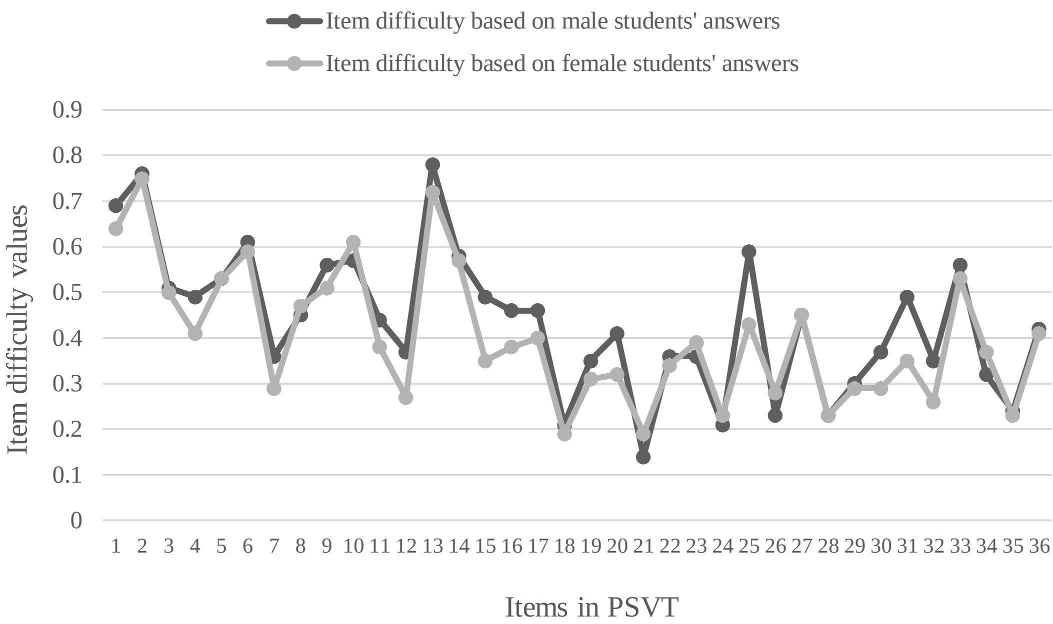

Figure 20. Item difficulty values for each item by gender

Figure 21 displays the distribution of item discrimination for each item on the PSVT by gender. Item discrimination was also a psychometric measure that essentially refers to the power of an item to differentiate among students based on how well they possess the ability being measured.

According to Figure 21 above, one can deduce that items were in general differentiate at a similar level for male students than female students. Item 21 and 25 did not work well.

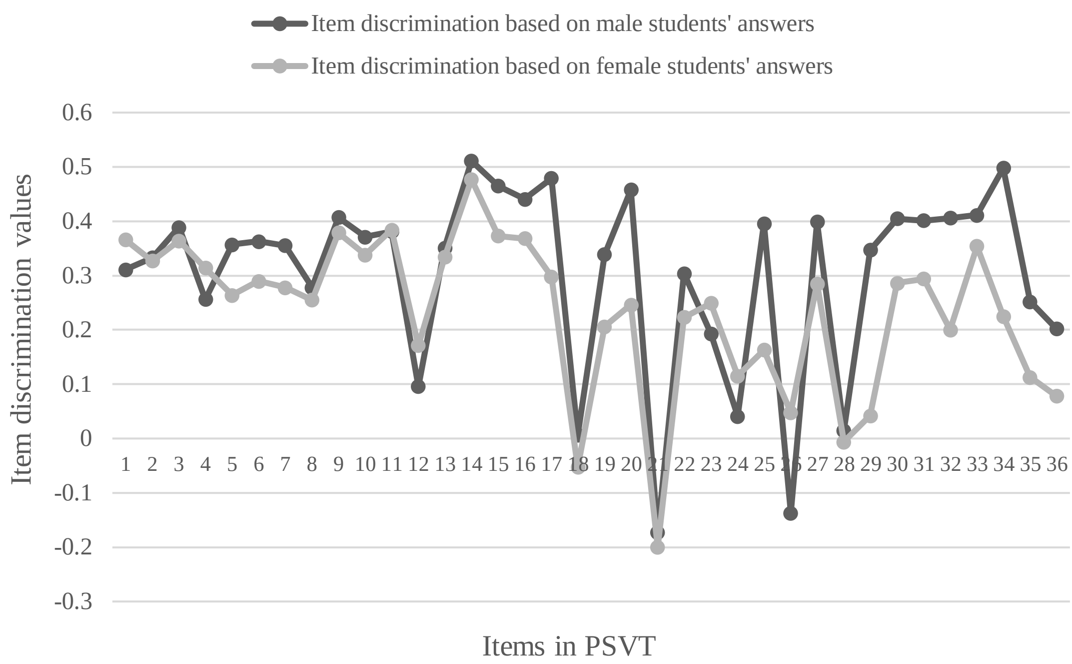

Figure 21. Item discrimination for each item by gender

Statistical analysis between female vs. male PSVT mean score differences by constructs

As Table 16 suggests, the result of *t*-test revealed that there seems to be statistically significant mean difference for developments construct between the of male students (*M* = 6.21, *SD* = 2.816), and female students (*M* = 5.71, *SD* = 2.819), *t* (553) = -2.083, *p* < .038. There seems to be statistically significant mean difference for rotations construct between the scores of male students (*M* = 4.62, *SD* = 2.405) and female students (*M* = 4.11, *SD* = 2.190), *t* (499.187) = -2.600, *p* < .010. For the mean scores of views construct, there seems to be statistically significant mean difference between the scores of male students (*M* = 4.21, *SD*=2.708) and female students (*M* =

3.71, *SD* = 2.317), *t* (480.988) = -2.297, *p* = .022. Also, the alpha level of .05 was used for this statistical test.

Table 16
Independent samples t-test for PSVT constructs total scores: Gender

	F	Sig.	t	df	Sig. (2-tailed)	Mean difference
Developments	0.000	.984	-2.083	553	.038	-0.502
Rotations	5.656	.018	-2.600	499.187	.010	-0.514
Views	9.174	.003	-2.297	480.988	.022	-0.499

Statistical analysis between private and state school students' PSVT mean score differences

As shown in Table 17 above, independent samples t-test was used to conclude if there was a statistically significant mean difference between private and state school students across total scores. Also, the alpha level of .05 was used for this statistical test. The result of analysis showed there was a statistically significant mean difference between the scores of private school students (*M* = 13.44, *SD* = 6.221) and state school students (*M* = 14.66, *SD* = 5.557) conditions; *t* (553) = -2.406, *p* = .016 in favour of state school students.

Table 17
Independent samples t-test for PSVT total scores: School type

	F	Sig.	t	df	Sig. (2-tailed)
Total score	0.711	.400	-2.406	553	.016

Statistical analysis between private and state school students' PSVT mean score differences by constructs

As shown Table 18, the result of *t*-test revealed that there seems to be no statistically significant mean difference for developments construct between the scores of private school's students (*M* = 5.73, *SD* = 2.982), and state schools' students (*M* = 6.05, *SD* = 2.723), *t* (553) = -1.294, *p* = .196. There seems to be no statistically significant mean difference for rotations construct between the scores of private school's students (*M* = 4.11, *SD* = 2.355) and state schools' students (*M* = 4.47, *SD* = 2.257), *t* (553) = -1.804, *p* = .072. For the mean scores of views construct, there seems to be statistical mean difference between the scores of private school's students (*M* = 3.60, *SD*=2.710) and state schools' students (*M* = 4.14, *SD* = 2.354), *t* (553) = -2.485, *p* = .013. Also, the alpha level of .05 was used for this statistical test.

Table 18
Independent samples t-test for PSVT constructs total scores: School type

Constructs	F	Sig.	t	df	Sig. (2-tailed)	Mean difference
Developments	2.689	.102	-1.294	553	.196	-0.320
Rotations	0.026	.872	-1.804	553	.072	-0.362
Views	2.909	.089	-2.485	553	.013	-0.542

Statistical analysis among students' PSVT mean score differences by grades

As seen from Table 19, Levene's test was carried out for the homogeneity of variance test, and the assumption of homogeneity of variance was not met for this analysis, *F* (3.551) = 3.891, p = .009. There was a significant difference between the three group's variances. Also, an alpha level of .05 was used for the one-way ANOVA statistical test.

Table 19
Test of Homogeneity of Variances

Levene's Statistic	df1	df2	Sig.
3.891	3	551	.009

Since the equal variance assumption was not met, the researcher used an adjusted *F* statistic. As seen in Table 20, a Welch's ANOVA test was conducted to determine whether the mean difference between grades was statistically significant. As a result, it was found that there was not a statistically significant difference between the mean scores of any of the grades, *F* (3, 211248) = .039, *p* = .990. Alpha level was set at

.05. The mean scores of 9th grade (M=14.09, SD=5.106), 10th grade (M=14.22, SD=5.952), 11th grade (M=14.28, SD=6.090), 12th grade (M=14.30, SD=7.285) were found.

Table 20
Robust test of equality of means: Grades

	Statistics	df1	df2	Sig.
Welch	.039	3	211.248	.990

Correlation analysis between students' PSVT scores and mathematics course grades

As shown in Table 21, the Pearson product-moment correlation coefficient was computed to assess the relationship between the students' PSVT total scores and mathematics grades. There was a significant positive correlation between the students' mathematics grades (M = 71.79, SD = 19.48) and PSVT total score (M = 14.19, SD = 5.84), r (544) = .283, p < .001. Overall, there was a small, positive, and significant correlation between students' test scores and mathematics grades. Increases in spatial visualization ability level were slightly correlated with increases in mathematics grades.

Table 21
Correlation analysis between students' PSVT total scores and mathematics course grades

	Total score
Mathematics grades	.283*

*. p < .01 level (2-tailed).

Also, the correlation coefficient between students' PSVT developments, rotations and views construct total scores and mathematics grades was calculated. As shown in Table 22, the result of the Pearson correlation showed that there was a significant positive correlation between students' developments construct and mathematics grades, *r* (544) = .234, p < .001. Also, there was a positive correlation between students' rotations construct and mathematics grades, *r* (540) = .249, p < .001; students' views construct and mathematics grades *r* (544) = .166, *p* = .037.

Table 22
Correlation analysis between students' PSVT constructs' scores and mathematics grades

	Developments construct's total score	Rotations construct's total score	Views construct's total score
Mathematics grades	.234*	.249*	.166*

*. p < .01 level (2-tailed).

Correlation analysis between students' PSVT scores and socioeconomic status

As given in Table 23, product-moment correlation coefficient was computed to assess the relationship between the students' PSVT total scores and SES levels. There was a significant and positive correlation between students' PSVT total scores (*M* = 14.19, *SD* = 5.84) and SES (*M* = 64.51, *SD* = 15.566), *r* (555) = .088, p = .037.

Table 23
Correlation analysis between students' PSVT total scores and SES

	Total score
SES	.088**

**. p <.05 level (2-tailed).

Furthermore, correlation coefficient between students' PSVT developments, rotations and views construct total scores and SES level was reported in Table 24. The result of Pearson correlation showed that there was a positive and non-significant correlation between students' developments construct and SES, *r* (555) = .074, *p* = .081; students' rotations construct and SES, *r* (555) = .061, *p* = .151; students' views construct and SES *r* (555) = .067, *p* = .117.

Table 24
Correlation analysis between students' PSVT construct scores and SES

	Developments construct's total score	Rotations construct's total score	Views construct's total score
SES	.074	.061	.067

Conclusion

In the current study, the researcher investigated descriptive result on students' PSVT scores to check the normality and to determine the students' spatial visualization ability levels. Descriptive results displayed on PSVT total scores and the constructs scores based on the variables gender, school type, and grade. Also, statistical results for students' levels of spatial visualization ability by gender, school type, and grade provided. Afterward, the study was also aimed to find out further evidence towards the research questions. Hence, an independent samples t-test was conducted to determine whether the difference between gender and school types were statistically significant. Welch's ANOVA test was conducted to find out whether the mean difference between grade levels was statistically significant. Moreover, Pearson correlation coefficients were computed to find out if there were relationships between the PSVT total score of students and their mathematics course grades, also for their socioeconomic status.

In this chapter, the findings from the study data which were collected via PSVT and a demographic form were presented. The next chapter will provide the discussion and conclusion of these findings, general results, implications for practice, and recommendation for further research, and limitations of the study.

CHAPTER 5: DISCUSSION

Introduction

This chapter provides a conclusion regarding the research conducted in this study. Furthermore, it provides a discussion of the major findings concerning the literature and concludes with discussions on possible implications for practice, implications for further research and its limitations.

The current study was intended to describe Turkish high school students' spatial visualization levels. In chapter four, statistical analyses and its related results on students' spatial visualization levels were reported. This research aimed to answer six questions regarding students' spatial visualization abilities. Descriptive analyses conducted on students' gender, age, and school types to describe spatial visualization ability. Lastly, correlation results between students' PSVT total score and mathematics course grades; students' PSVT total score and SES level were determined. The discussion of correlation results was related to the fifth and sixth research questions. Therefore, the following six research questions were investigated to determine students' spatial visualization levels.

1. What are the students' spatial visualization ability levels and its constructs as measured by Purdue Spatial Visualization test?
2. Do male and female high school students have significantly different levels of spatial visualization ability and its constructs?
3. Do the students' spatial visualization ability levels and the constructs of the test vary with respect to school type?

4. Do the students' spatial visualization ability levels and the constructs of the test change with respect to grade?
5. Do the students' spatial visualization ability levels and the constructs of the test relate to their mathematics course grades?
6. Do the students' spatial visualization ability levels and the constructs of the test relate to their socioeconomic status?

Major findings

Discussion on descriptive data results

This section concludes the findings of descriptive statistical outcomes of students' PSVT mean scores based on their gender, age, school types and socioeconomic status.

The PSVT mean score of all 555 students that were enrolled in the study was found to be 14.19 points, out of a possible 36 points. This mean score value was within the difficulty range for a test (Nunnally, 1994, p.91). The Cronbach alpha was found to be .790 which is an acceptable reliability value for tests (Nunnally, 1994, p.257). The comparison of the sample means score value with a hypothetical population mean (μ=18) showed that a larger percentage of the Turkish high school students constituting this sample was at the lower level PSVT scale. The mean score of the sample was about four points smaller than the population means. With regards to the population statistics, 42.70 % (n=237) of the students were in the LSVA level, 49.73 % (n=276) of the students were in the MSVA level, and 7.57 % (n=42) of the students were in the HSVA level (see. Table 6). These results, that is students' overall distribution pattern, was found to be similar to some other studies that utilized the PSVT. For instance, Kösa (2011) conducted an experimental study with 12th graders and used the PSVT as a pre-test and post-test. Before the treatment, control and experimental group students' mean score was found to be 14.69 and 12.23 respectively. But, after the treatment, the experimental group students' mean score was found to be 18.67. To give more examples, Baki et al. (2011) conducted an experimental study with pre-service first-year mathematics teachers. The mean score of the sample was found to be 18. The reason for this relatively high mean score value of their sample might be that the average age of the students constituting their sample was older than the average age of the students of the current sample. The mean score values of different samples utilized in the PSVT can be examined (Birinci, 2016; Sevimli, 2009). Turgut and Yılmaz (2012) conducted a study on seventh and eighth-grade students. Their results were parallel; however, some used another spatial visualization ability tool to assess students' spatial ability levels. In light of the limited numbers of studies, we observed that the sample means generally are lower when compared with the population mean.

The PSVT assessed three constructs; developments, rotations, and views. The comparison of the sample means scores for each construct with the hypothetical population mean scores showed that for the developments construct fewer students were placed on the lower level scale (developments 35.86 %) than for the other two constructs. That is, for the rotations and views constructs a larger percentage of the students were found to be at the lower level of the PSVT scale; rotations (56.40 %), and views (61.44 %). So, students performed better in the developments construct. Again, the other studies had reported a similar result for the developments construct (Baki et al., 2011; Birinci, 2016; Dündar, 2014; Kösa, 2011; Sevimli, 2009). For instance, Dündar (2014) used preservice teachers who were enrolled in a primary mathematics education department investigated if there were any statistical differences for each construct; developments, rotations, and views. Students' development construct mean score was at 6.50 of his study. He, too, reported that students performed better in the developments construct than the rotations and views constructs. The overall performance on the developments construct, where the mental manipulation of two-dimensional objects was required, were better. It may be due to being familiar with the objects that place in the developments construct since the students, during their secondary education in Turkey, are exposed to the topic that involves mentally folding-up 2-D representations of 3-D objects. Due to contrastaints in the national curriculum, students have been less exposed to the questions that require to rotate objects around the Cartesian axes (rotations construct) or to view a 3-D object from different perspectives (views construct). Similar results were also reported in studies conducted abroad. For example, Michaelides (2002) conducted a study with 5th and 8th-grade students trying to understand their mental reasoning while solving spatial types of questions. He reported that students showed higher difficulties when trying to solve problems that needed the mental manipulation of objects from a different perspective. At this point, there might be some other signs explaining constructs' difficulties.

The other point is the number of unanswered items by all the students of the PSVT increased in the views section. An initial plausible explanation might be the time factor. As the test progressed students had less time to answer the last part of the PSVT as they may have lost time in the earlier parts of the test. As stated in chapter 3, the constructs are asked in an organized manner, so the last items (25-36) pertained to the views construct. However, we have also observed that the item's difficulty degrees increased towards the end of each construct. This outcome was an indication that the students tried to answer the questions sincerely. How else could we explain the increase in responses for the first few questions of each construct? Hence, time should not be considered as the only factor to explain the frequency of unanswered items for each construct. In Sevimli's (2009) study along this line; 44% of the students did not answer the items in the views section.

The following section explored further students' spatial visualization levels regarding different variables such as gender, school types and grades.

Discussion on results on gender

The second part of the analysis reported on the results of the variable gender based on the research question "do male and female high school students have significantly different levels of spatial visualization ability and its construct?". The PSVT mean score of female students was found to be 13.53 and mean score of male students was found to be 15.04. Result of independent samples t-test analysis revealed there was statistically significant mean difference, t (488.612) = -3.010, p = .003. Furthermore, result of independent samples t-test analysis revealed a statistically significant mean difference between genders for developments construct t (553) = -2.083, p = .038; rotations construct, t (499.187) = -2.600, p = .018; and views construct, t (480.988) = -2.297, p = .003 in favour of male. Male students had a greater mean score than female students. This result is in line with the results of Yazıcı's (2014) study with PSVT. He also found that males had greater value than female in each construct. Levine et al. (2005) studied with the students from different socioeconomic backgrounds. Their results revealed that the males from middle and high-SES backgrounds outperformed the females. Battista (1990) examined the relationship between spatial visualization, and gender in a study conducted with 75 male and 53 female high school students. An adapted version of the Purdue Spatial Visualization Test: Rotations was selected to measure students' ability for mental rotations of objects in space. Hence, the spatial visualization performance of male students was higher than female students. Also, Dündar (2014) reported t-test results showing statistically significant mean difference in favour of male, the total mean score difference of female and male students in his study were found to be 10.57. As indicated above, independent sample t-test results indicated a statistical difference between the mean scores of female and male students for the current study. There, however, were only 1.51 points of a mean score difference between the female and male students' PSVT total scores. So, it was worth investigating further in the current study.

To further investigate the mean difference, comparison of HSVA, MSVA and LSVA level students by gender was conducted. The count of male students was higher in the HSVA group. But this difference seemed to disappear at the MSVA level, for this level the distribution among the gender was almost the same. For the LSVL level, the difference was observed again in favour of male, however not as strong as in the HSVA category (see. Table 9). Sevimli (2009), who conducted a study with prospective teachers, reported similar results showing similarity with our findings. In his study, 13.3 % of the male prospective teachers were in a high level, and 8.9 % of the female ones were in a high spatial visualization level. Hence, high spatial visualization level male students were larger in the sample. Also, 6.7% of the male prospective teachers were in low level, and 11.1 % of the female ones were in low level spatial visualization level.

As indicated below, one should note that there were only about 1.51 points of a mean difference between the PSVT total scores of female and male students. Because this was a relatively small mean difference, combined with the relatively low total mean score we feel that we have obtained the very same result as what was being discussed in the literature review about gender. Hence, low mean score difference investigated in terms of magnitude of gender difference, the researcher stated a graphical representation of a descriptive statistic regarding female and male behaviours while answering the PSVT items (see. Figure 19, 20 and 21). Taking the graphs into consideration, this result demonstrated that both male and female students had spatial visualization level approximately similar levels. In literature, several studies have also found that the magnitude of gender difference was small (Fennema, 1974; Hyde, 1981; Linn & Petersen, 1985; Maeda & Yoon, 2013). Since female and male students have begun to benefit from these trainings it has been found that even the small gender difference could be reduced by training (Ben-Haim et al., 1985). Hyde (1981) claimed gender had only a minimal effect on explaining students' spatial test scores. In addition to small difference, some studies have found no significant difference in terms of gender in spatial ability level (Gold et al., 2018; Karaman & Toğrol, 2009; Seng & Chan, 2000; Turgut & Yılmaz, 2012). In the literature review of Monahan et al. (2008) stated that spatial visualization ability has small effect size and statistically nonsignificant results in gender differences. However, in their study, they examined results of a computer-based version of one mental rotation test by comparing it with the result of paper and pencil-based test version. Touch-screen technology was used for the computer-based version and the results compared with the paper and pencil-based test version. Results showed that males performed better than females in all cases, but gender difference effect sizes (measured by Cohen's d) decreased from large for the paper-and-pencil based version to medium for the computer-based version.

In light of these outcomes, it is noteworthy to report that following studies on gender differences found that male outperformed females. To give examples, Reilly et al., (2017) reported that on average males perform better than females in tests that measure visual-spatial ability. t-test results reported by Yenilmez and Kakmacı (2015) found a significant difference in favour of males. There are many more studies that emphasized that males performed better on this subject matter. These types of discussions go back as much as early 1960 (Maccoby & Jacklin, 1974).

Moreover, one can conclude that since the students were volunteers, no extra credit or other kind of encouragement was provided. All the answers provided by the students were assumed to be provided with their full and sincere cooperation. Even though male students were constantly less conservative while answering the questions, female students were consistently more reluctant while answering the questions. Maeda and Yoon (2013) discussed gender differences results in the light of test conditions, they stated males outperform females on the test when an increased time-limit was introduced. For the current study, there was also a time limitation which in turn may have caused additional external stress for female students. That is, if the female students had answered at the same ratio, just by pure chance, they would have obtained a similar overall mean score. The small mean difference between female and male students may have emerged for this reason, however, both of the genders had lower scores than expected.

In the shade of our findings and the related literature, it seems that there will be a much lively discussion going on in this field of research with respect to gender.

Discussion of results on school types

The analysis reported on the results of the variable school type was based on the research question "do the students' spatial visualization ability levels and the constructs of the test vary with respect to school type?". The PSVT mean score of the private school's students was found to be 13.44 and the mean score of the state schools' students was found to be 14.66. To test the mean difference of spatial visualization ability concerning school type, independent samples t-test was used. The results of the analysis showed that there was statistically significant mean difference among the students' PSVT mean scores for their spatial visualization ability, t (553) = -2.406, p = .016, in favor of state schools. Moreover, the analysis of independent samples t-test revealed no statistically significant difference between private and state school students' PSVT mean scores for developments and rotations constructs. However, the result of the independent samples t-test showed a statistically significant mean difference between private and state school students' PSVT mean scores for views of the items pertaining to construct. Again, one should note that the PSVT mean scores are on the lower part of the scale. In other words, the overall mean scores for both types of school are low, hence the stated statistical mean difference reported should be interpreted with this fact in mind. In the literature, Kayhan's (2005) study showed that there was no effect of school type on 9th-grade students' spatial visualization abilities. However, Kayhan (2005) categorized schools as general Anatolian, vocational, general, science and İmam Hatip high schools.

Furthermore, when the school type-based responses to PSVT were compared to spatial ability levels, 9.48% of the private school students were placed in HSVA, while 6.39% of the state school students were placed in HSVA (see. Table 11). It is important to note that the sample size of students between the two types of school was different. The number of students from the state schools was much larger than the private schools. Even with the sample size considerations, one would have expected the opposite outcome. If we recall that the student selection process was constrained due to external factors explained in chapter 3, this might explain this difference. One other possible explanation difference may be because the ratio of high-level SES students was larger for the private schools (59.24 %) than state schools (17.44 %). Or some other external variable that needs further investigation. For example, Robichaux (2002) argued that spatial visualization could be influenced by one's childhood experiences, parents' occupations, and family income. If the sample were random, the samples should have the same characteristics and averages. For instance, state school students' SES levels were generally middle and low (82.56%), while private school students' mid- and low- SES levels were small (40.76%). These could be valid reasons for explaining the findings of the present study.

Discussion of results on grades

The third analysis reported on the results of the variable grades considering the research question "do the students' spatial visualization ability levels and the constructs of the test change with respect to grade?". The PSVT mean score values of the students from each grade increased slightly as the students' grades increased. Moreover, to test mean difference of students' PSVT scores with respect to grades, Welch's ANOVA was used as a statistical analysis. The results of analysis showed that there was no statistically significant mean difference among the students who were from grades nine, ten, eleven, and with respect to their spatial visualization ability, F (3, 211248) = .039, p = .990. In terms of PSVT constructs, overall performance on the developments construct was better, because a two-dimensional form of the objects was more than the other constructs. The difference, however, was not statistically significant for any grade according to Welch's ANOVA results.

Some studies along these lines concluded similar results. For example, Ben-Chaim et al. (1985; 1988) measured the spatial visualization abilities of fifth, sixth, seventh and eighth-grade students. As a result, the performances of the students were directly proportional to their level. Also, in another study conducted by the same researchers, they utilized a test to measure students' spatial visualization ability and found spatial visualization scores of 5th, 6th, 7th, and 8th-grade students increased statistically (Ben-Chaim et al., 1988). He concluded that results improved with maturity and age. Moreover, Turğut and Yılmaz (2012) concurred and stated that eighth graders spatial visualization abilities should be higher than seventh graders. However, they found the reverse to be true and they supported it with the idea of constructivism-based, activity-weighted curricula placed more emphasis in the 7th grades. Michaelides (2002) acknowledged that older students performed better in three-dimensional manipulation. However, in his study, he did not find any age and gender differences in the use of strategies in spatial abilities. In the shade of our findings and the related literature, the findings support the outcome that student's spatial visual ability performance improved as grades increased.

Among HSVA level students, twelfth grade students had the greatest percentage value (18.75%) while ninth graders were the lowest (2.90 %). The distribution among the grades was almost the same for the LSVL students. In general, most of the students were dispersed in MSVA and LSVA level which showed a similar distribution of the overall PSVT total scores (see. Table 11). At this point we should point out that the number of 9th-graders represented the largest population in the study. In other words, the likelihood of 9th graders placed into the HSVA category by pure chance would be higher. Since we were not able to observe this fact, we are of the opinion that we have collected another evidence that there seems to be a positive relationship between special ability and students grade level. Moreover, we have observed that the normal distribution mean shifts towards the higher scores in favour of twelfth graders, so another point of indication that the students' scores indeed are grade (and most likely age) related. One plausible reason accounting for this shift might be the educational environments and total time the students are exposed to the content.

Discussion of results on mathematics course grades

This results section includes discussion on correlational analysis results between students' spatial visualization ability levels and mathematics course grades based on the research question "do the students' spatial visualization ability levels and the construct of the test relate to their mathematics course grades?". It was concluded that there was a significant and positive correlation between students' mathematics course grades and spatial visualization ability levels. Yenilmez and Kakmacı (2015) found 6th grade students with higher cumulative mathematics grades performed better in the spatial visualization test than those with lower grades. Kayhan (2005), in her study in which she investigated the spatial ability of high school students, revealed a positive and significant correlation between mathematical achievements. In her study, students' mathematics achievement was determined by their cumulative mathematics course scores. A moderate positive and significant relationship was found between spatial ability and mathematics achievement in the study with 7th and 8th grade students (Turğut & Yılmaz, 2012). A good number of researchers indicate that spatial ability is positively related to mathematics achievement scores (Battista, 1990; Cheng & Mix, 2012; Fennema, 1974; Seng & Chan, 2000).

The reason for the small and positive relationship between mathematics grades and spatial ability might be since algebra and geometry are integrated topics in mathematics curricula in Turkey. Students' mathematics course grades are not just a grade that measures geometric concepts. For instance, in a study by Weckbacher and Okamoto (2014), the high school students' mathematics achievement and spatial abilities were investigated. Results highlighted, a significant relationship between spatial ability and both geometry grades and the standardized geometry measure. However, no significant relation emerged between spatial ability components and algebra grades in their studies. It can be deduced or speculated that spatial abilities play a more significant role in learning and maturing of the geometry concepts, which brings improvements in the performances of the students in the subject of mathematics.

Discussion of results on SES levels

This section includes correlational analysis results between students' spatial visualization ability levels and SES levels to investigate the research question "do the students' spatial visualization ability levels and the construct of the test relate to their socioeconomic status?". It was found that there was a small, significant, and positive correlation coefficient between students' spatial visualization and SES levels. On the other hand, no statistically significant correlation was found for each construct, but the correlation coefficient was positive. As we have found, Verdine et al., (2014) too, reported a positive correlation between socioeconomic status and spatial ability levels.

A longitudinal study by Levine et al., (2005) was conducted with the students from different SES. The students were asked to do two spatial tasks requiring mental transformations. The results revealed that the males from middle and high-SES backgrounds outperformed the females. On the other hand, the males from low-SES did not reveal any differences between these two genders (Levine et al., 2005).

In light of our findings and limited related literature, results showed, spatial ability performance of students increases as socio-economic level increases.

General results

The present study aimed at describing Turkish high school students' spatial visualization level as it is described as the ability to visualize the state of the object after the movement of the parts, folding an 3D object, reshaping the of the objects in different ways in space, and imagine an object from different perspectives in mind.

According to the results obtained from the research, it was seen that a great portion of students were located at the low-level score range of the PSVT (42.70 %). So, the students’ spatial visualization abilities were relatively low. In the spatial visualization test, the PSVT mean score of male students was greater, and a statistically significant difference was in favor of males. However, according to the descriptive analysis results and graphs, one can speculate that the spatial visualization abilities of the students should not be attributed as a truly gender difference factor. This result can be attributed to the fact that it was not possible to obtain equal samples sizes. . Welch’s ANOVA result showed there was no statistically significant difference in PSVT mean scores between different grades although twelfth-grade students' spatial visualization levels were higher than the other grades. So, older students scored higher than the younger students on the PSVT. A small, positive and significant relationship was found between students' spatial visualization and mathematics achievement. Also, a small, positive and significant relationship was found between students' spatial visualization and SES level.

Implications for practice

Turkish students’ spatial visualization ability level distribution was at the lower level of those samples found in the literature. Moreover, when spatial ability is formed in the early ages, it may bring advantages to students for making decisions about their professions and even daily lives. Also, as it was discussed in chapter two, it is important to be aware that students’ spatial abilities are the type of skill that can be developed hypothetically through the following aspects.

First of all, it is important to know the fact that visual spatial ability helps students to be successful in many areas especially in geometry. In this sense, teachers must be aware of the importance of developing this ability and combining it with teaching methods to enhance students' spatial visualization ability before they start their careers. Therefore, prospective math teachers should take additional courses on spatial ability and as it relates to teaching and learning.

Second of all, students did not show adequate performance in the questions that require the rotation of objects or to perceive an object from different perspectives. However, students performed better when they came across with familiar objects that they were exposed during their secondary education. Hence, curriculum should be developed based on grade levels accordingly because each grade requires different methods to integrate these varied skills into their lessons.

Implications for further research

Despite a comparatively high number of students that participated in this study, the sample size was relatively small and restricted only to one district. A study that uses samples from different regions of the country can be evaluated by comparing within itself or international studies' results. Another way to go about this is to conduct a longitudinal study. This would allow repeated applications to follow particular individuals' spatial visualization abilities over a long period. These types of studies also require observation to collect quantitative and qualitative data outcomes without considering any other factors (Caruana, Roman, Hernández-Sánchez, & Solli, 2015).

In the current study, it was found out that students' spatial visualization ability levels were relatively low. For example, as the study investigated three different sub-constructs, most of the students performed better in the developments construct rather than the other two constructs. We can interpret these results in three different ways.

First of all, regarding the curriculum, kindergarten to twelve grade students have been exposed to the nets of 3D objects topic throughout their school year. Net of 3D objects topic is related to the devolvement construct of the test. It can be the reason, why students showed a better performance in this construct of the test. However, the other constructs, views, and rotations, only covered in the high school curriculum. If the students exposed to the topics of three views of objects or rotations of objects with the topic nets of objects from an early age, it might help to develop their space concept reasonably.

Second of all, since the test mean that measure the spatial visualization ability of the students are relatively low, it can be researched whether these results have a culture-specific effect or a norm. The research can also examine the effects of the different cultural dimensions. Thus, it can be concluded whether these results are the norm or different results in different cultures.

Third of all, if the techniques and stages used by students in solving questions are taken into account, it may be clearer to explain why students have difficulty in the other two sections. For a better identification of students’ spatial abilities and techniques and or strategies that students use while solving spatial-visual type questions, the focus can be on the techniques and stages that students follow while solving questions.

One way of carrying out similar studies is to improve a similar computerized version of the PSVT. For example, a computerized version of sample question for development construct is shown in Figure 22. Each question in the test can be written as computerized version. Then, the current study results conducted with the paper and pencil-based test can be compared with the computerized version of the test results. By doing this, problem solving strategies could be studied as well.

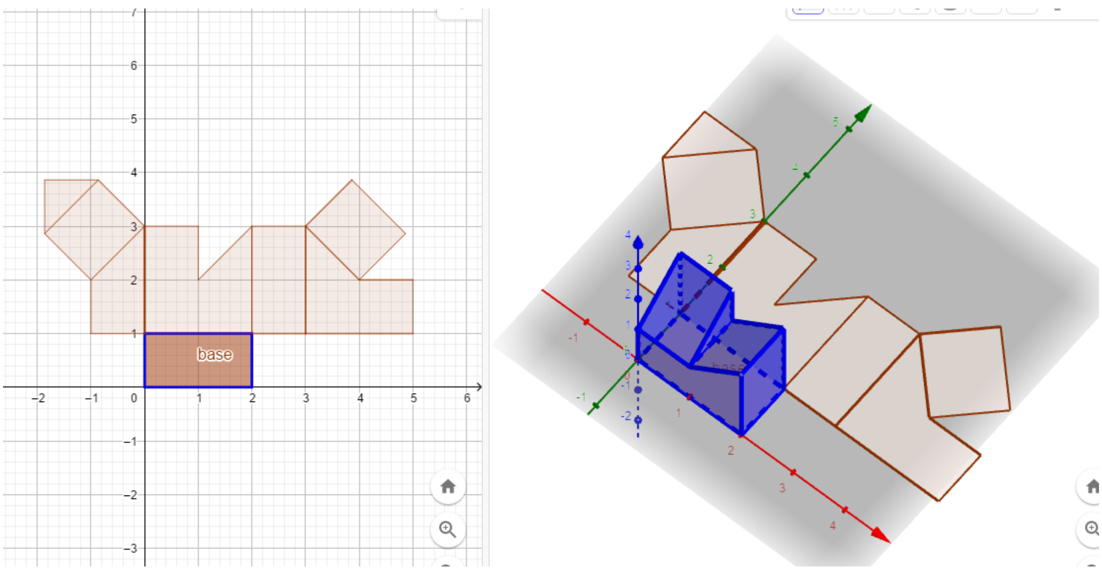

Figure 22. 2D and 3D Rendered chapter 3 figure 5 GeoGebra 6.0

In terms of mathematics achievement scales, the relationship between spatial ability and students' mathematics and geometry achievement can be examined with a scale that measures geometric and algebraic concepts deeply.

The use of different spatial ability tests and preference of different scientific methods may affect the variables that give conflicting results for gender differences. There are other ways to go about finding the gender difference in spatial ability. In the literature review section, it was stated that age, socioeconomic status, environmental and cultural factors vary the gender difference in spatial ability. In further research, a qualitative research method could be used, and the relation of these factors can be examined in terms of gender. In addition to this, conducting a study with students from different socio-economic levels is recommended as well. Moreover, to evaluate the effects of factors that possibly related to spatial ability, it may be convenient to conduct experimental studies on the subject. Also, experimental studies may lead to specific results, and these results may indicate the contribution of educational environments.

The count of male students was higher in the HSVA group. But this difference seemed to disappear at the MSVA level, for this level the distribution among the gender was almost the same. For the LSVL level, the difference was observed again in favor of males, however not as strong as in the HSVA category. Further studies can investigate HSVA students' results to conclude if it is a chance factor or if gender is a strong factor that predicts spatial visualization ability.

When answering the questions, students consider that there is no punishment or extra credits. Therefore, looking at the ratio of correct and incorrect answers and non-answers of multiple-choice questions may give a more comprehensive result on the results of the test.

To avoid the overlap between age and grade, the sample can be also conducted with elementary and secondary school students.

It should be reflected that spatial visualization ability as a component of spatial ability is different but related to mathematical ability. It is also important to realize that this ability is an important factor in math and geometry performance, cognitive processes, perception and interpretation of the environment, and development of logical reasoning skills. In this respect, it is important to create awareness about spatial visualization ability.

Limitations

All the answers provided by the students were assumed to be provided with their full and sincere cooperation.

It was assumed that all questions were understood by the students in the same way and answered under the same environmental/classroom conditions.

It was assumed that all students were exposed to the same national mathematics curriculum.

The sample was limited to schools in Çankaya district of Ankara, Turkey.

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APPENDICES

Appendix A: Turkish version of Purdue Spatial Visualization Test

009199-1

PSVT

PURDUE UZAMSAL GÖRSELLEME TESTİ

Roland Guay, PhD

Lütfen size testi nasıl cevaplayacağınız anlatılana kadar kitapçığı açmayınız

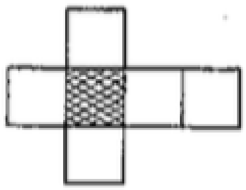
purdue university

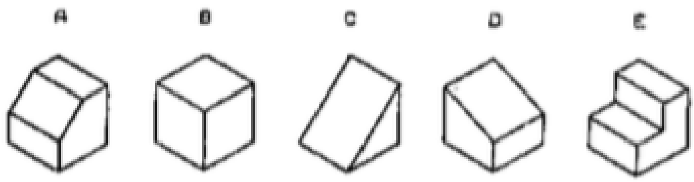
Uyarı: Bu kitapçık üzerine herhangi bir işaretleme yapmayınız. Cevaplarınızı cevap kâğıdına işaretleyiniz.

BÖLÜM–1: OLUŞTURMA

YÖNERGE

Bu testin ilk bölüm 12 sorudan oluşmaktadır. Bu sorular sizin üç boyutlu nesneleri katlayarak ne şekilde görselleştireceğinizi belirlemek üzere tasarlanmıştır. Aşağıda bu testin ilk bölümünde yer alan soru tiplerine yönelik bir örnek verilmiştir.





Yukarıda beş tane üç boyutlu cisim ve bir tane açılım bulunmaktadır. Açılım üç boyutlu bir nesnenin iç yüzeyini göstermektedir. Açılımdaki taralı kısımlar cismin tabanını göstermektedir. Sizden istenen;

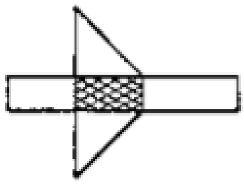
1) Bu açılımın üç boyutlu nesne olarak katlandığında, zihninizde nasıl gözüktüğünü belirlemeniz,

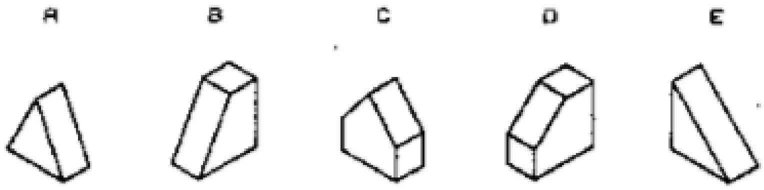
2) Yapılan katlamalar ile oluşan üç boyutlu şekli, A, B, C, D, E şıkları arasından seçmenizdir.

Yukarıda gösterilen örneğin doğru cevap hangisidir?

A, C, D, E şıkları yanlıştır. Verilen açılımın katlanmasıyla B şıkkındaki gibi bir nesne elde edilebilir. Bu testin üç bölümündeki her bir sorunun yalnızca bir doğru cevabı bulunmaktadır.

Şimdi aşağıdaki örneğe bakınız ve verilen açılım katlandığında elde edilebilecek üç boyutlu cismi şıklar arasından belirlemeye çalışınız? Verilen açılımın cismin içerisini ve taralı kısmın cismin alt yüzeyini gösterdiğini unutmayınız.



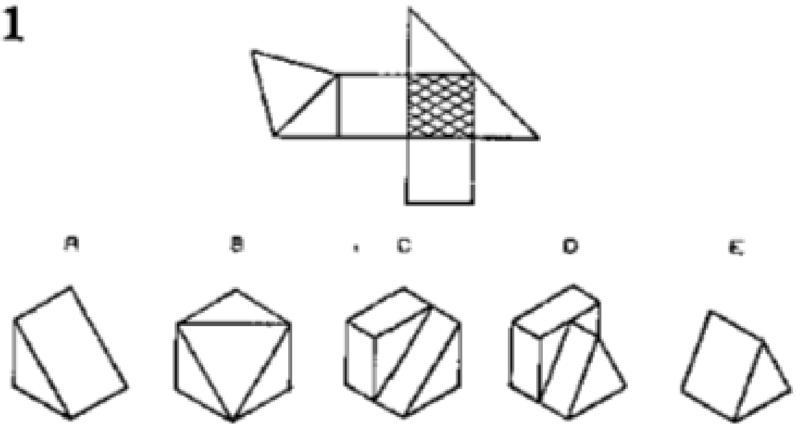


Örnekteki doğru cevap E şıkkıdır.

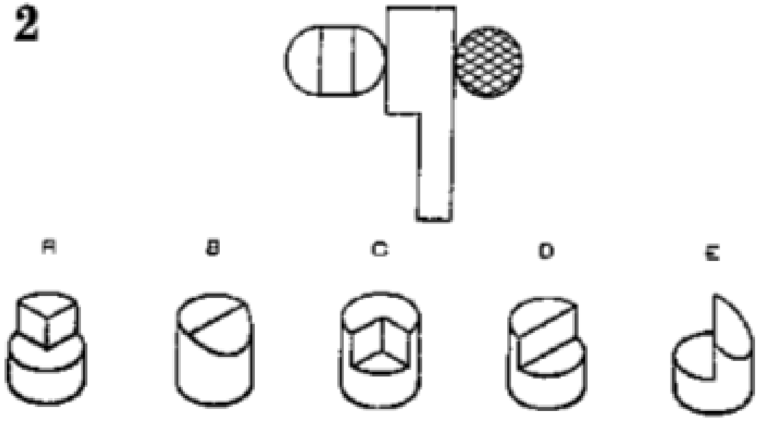
Test boyunca her bir soru için belirlediğiniz cevapları, cevap anahtarına koyu renkli kalemle işaretleyiniz.

> Uyarı: Bu kitapçık üzerine herhangi bir işaretleme yapmayınız. Cevaplarınızı cevap kâğıdına işaretleyiniz. Başlarken gerekli açıklamalar yapılacaktır.

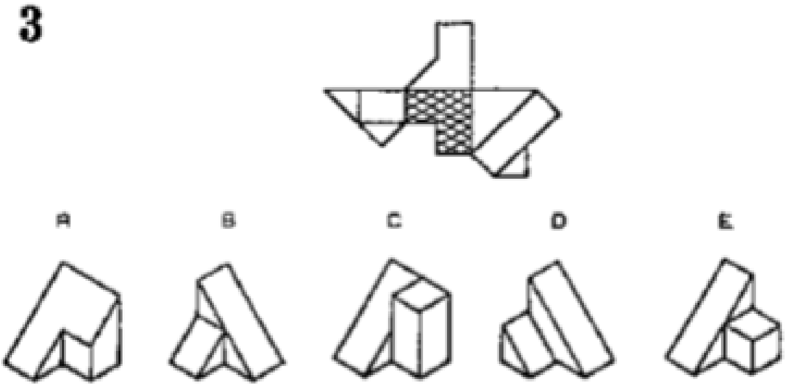
1



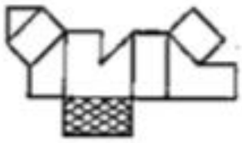
2

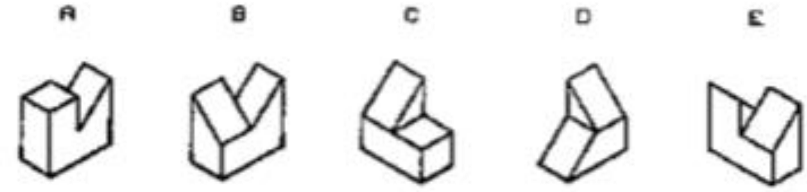


3

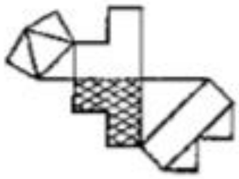


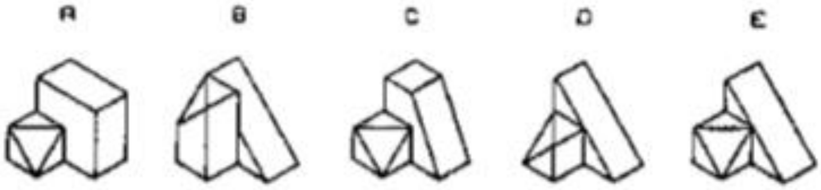
4





5





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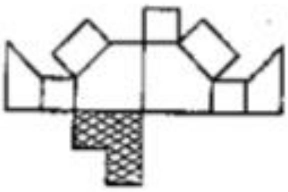
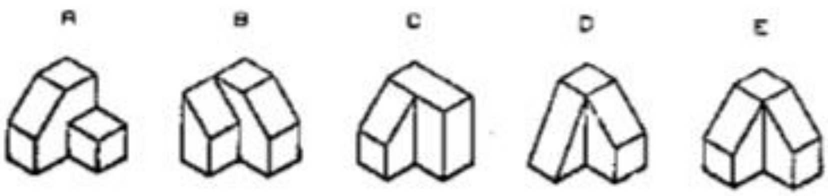
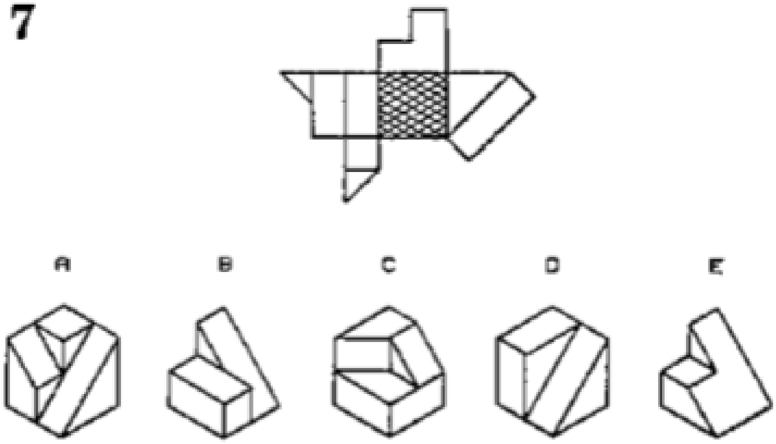
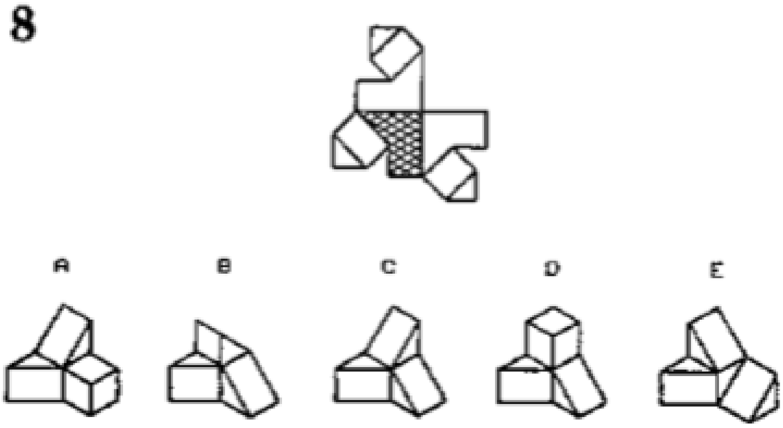




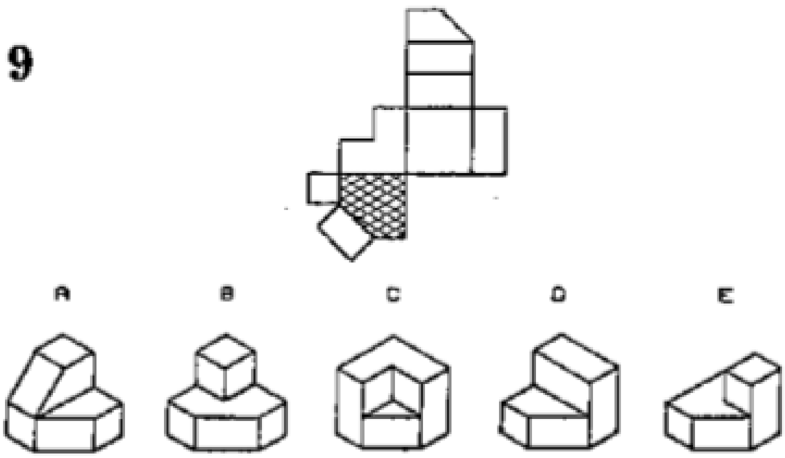
7



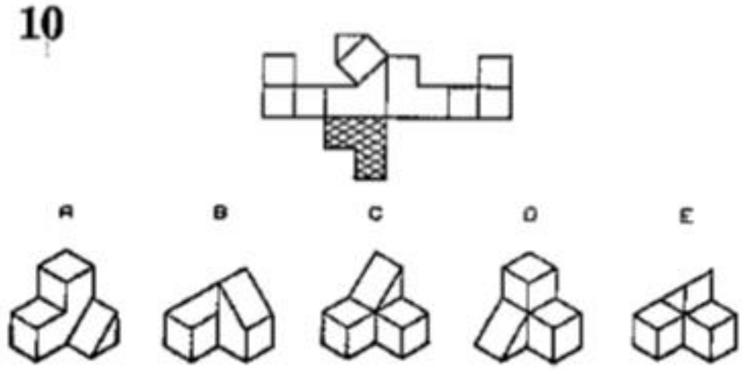
8



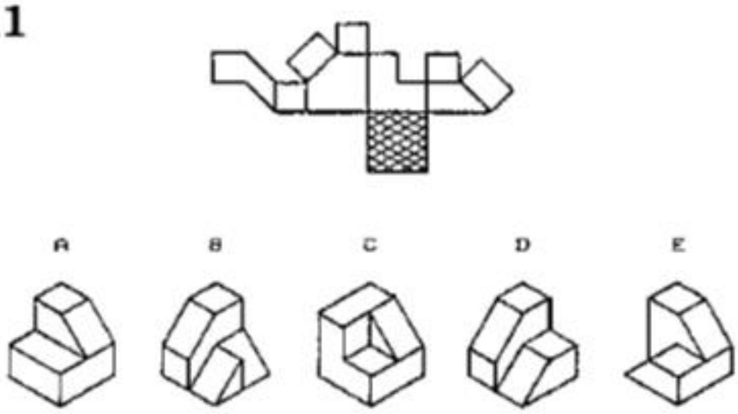
9



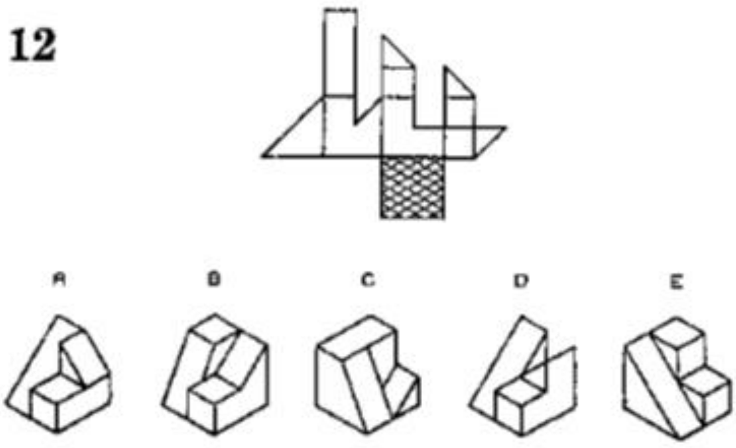
10



11



12



Uyarı: Bu kitapçık üzerine herhangi bir işaretleme yapmayınız. Cevaplarınızı cevap kâğıdına işaretleyiniz.

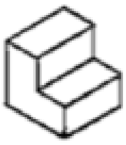
BÖLÜM–2: DÖNDÜRME

YÖNERGE

İkinci bölüm 12 sorudan oluşmaktadır. Bölümdeki sorular üç boyutlu nesnelerin döndürülmesini ne şekilde görselleştireceğinizi belirlemek üzere tasarlanmıştır. Aşağıda görülen soru tipi ikinci bölümde bulanan soru tipilerine bir örnektir.

Şeklinin döndürülmüş hali

'dir



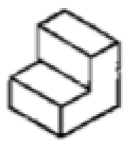
Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A

B

C

D



E

Sizden istenen,

1) Sol üst kısmında yer alan nesnenin, sağ üst kısımdaki nesneye dönüşmesi için gerekli adımları bulmanız,

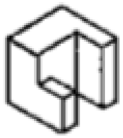
2) Sorunun orta kısmında bulunan nesnenin tam olarak aynı adımlar ile döndürüldüğü zaman nasıl göründüğünü bulmanız,

3) Orta kısımda bulunan cisim, gerekli adımlar uygulanarak döndürüldüğünde, elde edilen görünümün verilen şıklardan hangisinde (A, B, C, D veya E) doğru olarak gösterildiğini bulmanız, istenmektedir.

Yukarda gösterilen örnekte doğru cevap hangisidir?

A, B, C, E cevapları yanlıştır. Gerekli döndürme adımları uygulandığında D şıkkının doğru olduğu görünmektedir. Her sorunun yalnızca bir doğru cevabı olduğunu hatırlayınız.

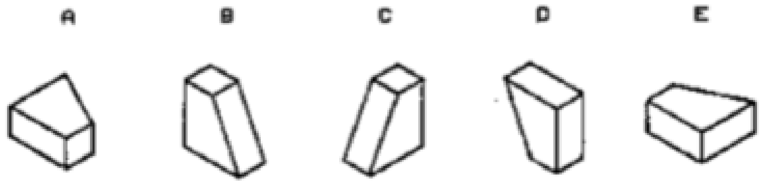
Şimdi bir diğer örneğe geçelim. Aşağıda verilen örnekte döndürülme işlemi uygulandıktan sonra doğru pozisyonda bulunan şekli belirlemeye çalışınız.



Şeklinin döndürülmüş hali

'dir.

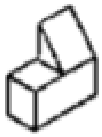
Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

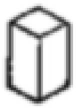
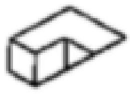
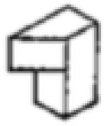
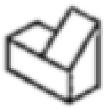


Dikkat ederseniz, bu örnekte verilen döndürme yönergesi daha karmaşıktır. Bu örnek için doğru cevap B şıkkıdır.

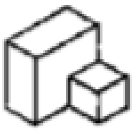
Uyarı: Bu kitapçık üzerine herhangi bir işaretleme yapmayınız. Cevaplarınızı cevap kâğıdına işaretleyiniz. Başlarken gerekli açıklamalar yapılacaktır.

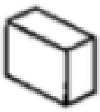
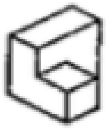
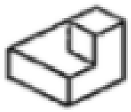
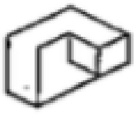
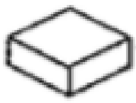
13  Şeklinin döndürülmüş hali  'dir.

 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A 
B 
C 
D 
E 

14  Şeklinin döndürülmüş hali  'dir.

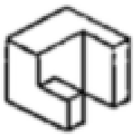
 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

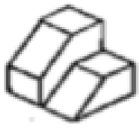
A 
B 
C 
D 
E 

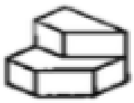
15  Şeklin döndürülmüş hali  'dir.

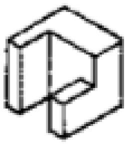
 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A 
B 
C 
D 
E 

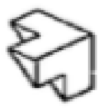
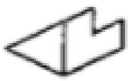
16  Şeklinin döndürülmüş hali  'dir?

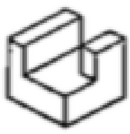
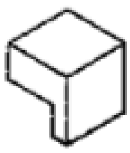
 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A 
B 
C 
D 
E 

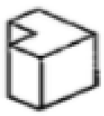
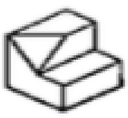
17  Şeklin döndürülmüş hali  'dir.

 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A 
B 
C 
D 
E 

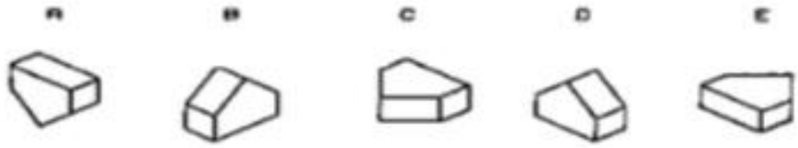
18  Şeklin döndürülmüş hali  'dir.

 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?

A 
B 
C 
D 
E 

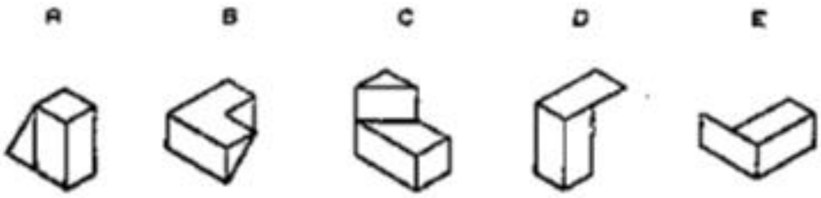
19  Şeklin döndürülmüş hali  'dir.

Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



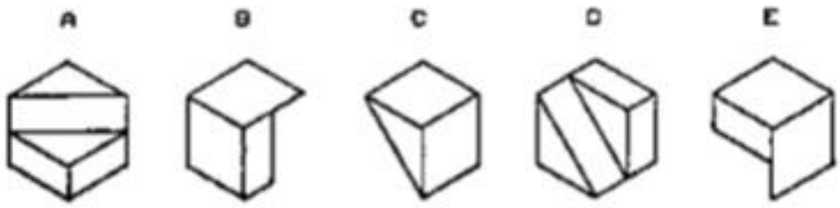
20  Şeklin döndürülmüş hali  'dir.

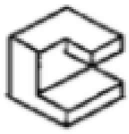
Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



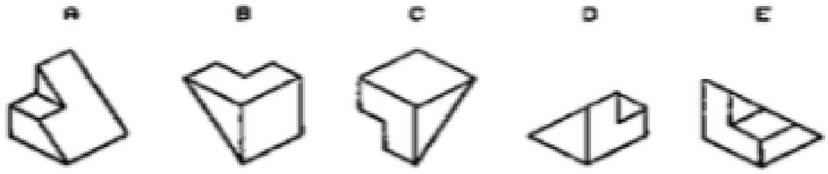
21  Şeklin döndürülmüş hali  'dir.

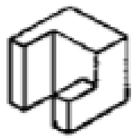
Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



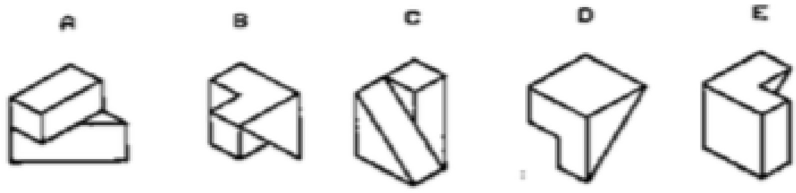
22  Şeklin döndürülmüş hali  'dir.

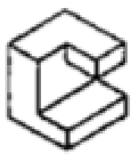
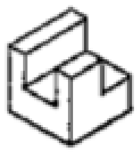
 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



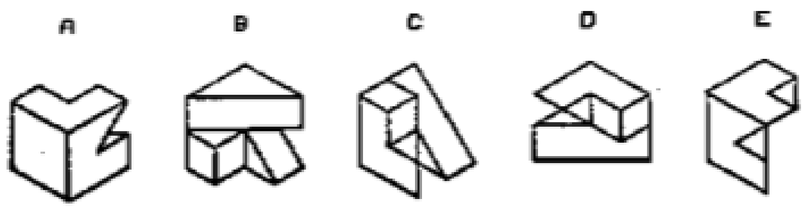
23  Şeklin döndürülmüş hali  'dir.

 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



24  Şeklin döndürülmüş hali  'dir.

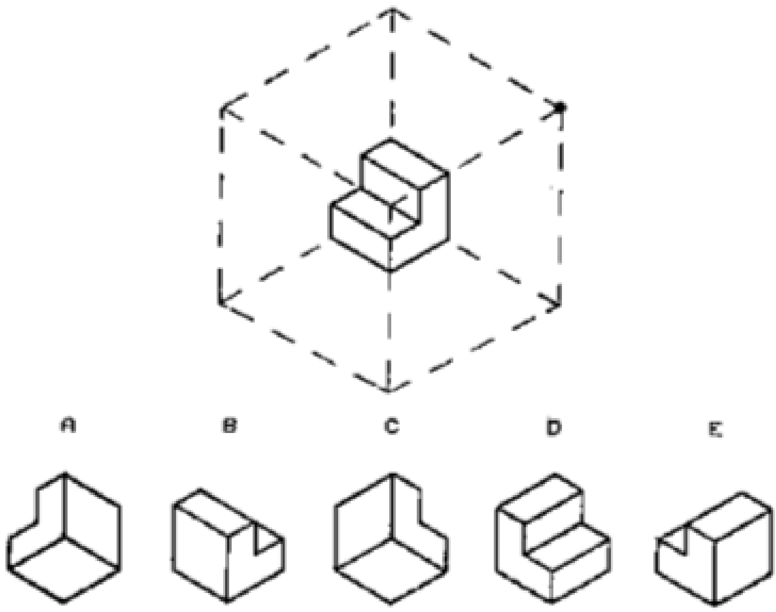
 Şeklinin döndürülmüş hali aşağıdakilerden hangisidir?



BÖLÜM–3: GÖRÜNÜMLER

YÖNERGE

Testin üçüncü bölümü 12 sorudan oluşmaktadır. Bu sorular, sizin çeşitli bakış açılarından, üç boyutlu cisimleri ne şekilde görselleyebileceğinizi belirlemeye yönelik olarak tasarlanmıştır. Aşağıda verilen soru, üçüncü bölümde yer alan soru tiplerine bir örnektir.



Yukarıdaki örnek saydam bir kutunun ortasına yerleştirilmiş bir cismi göstermektedir. Beş çizim aynı cismin farklı noktalardan bakıldığında oluşan görüntülerini temsil etmektedir. Saydam kutunun sağ üst köşesinde yer alan siyah nokta, cisme bakılması istenen durumu göstermektedir.

Sizden istenen;

1) Bu saydam kutunun köşesindeki siyah noktanın sizinle cam kutu arasında oluncaya kadar hareket etmesi gerektiğini hayal etmeniz,

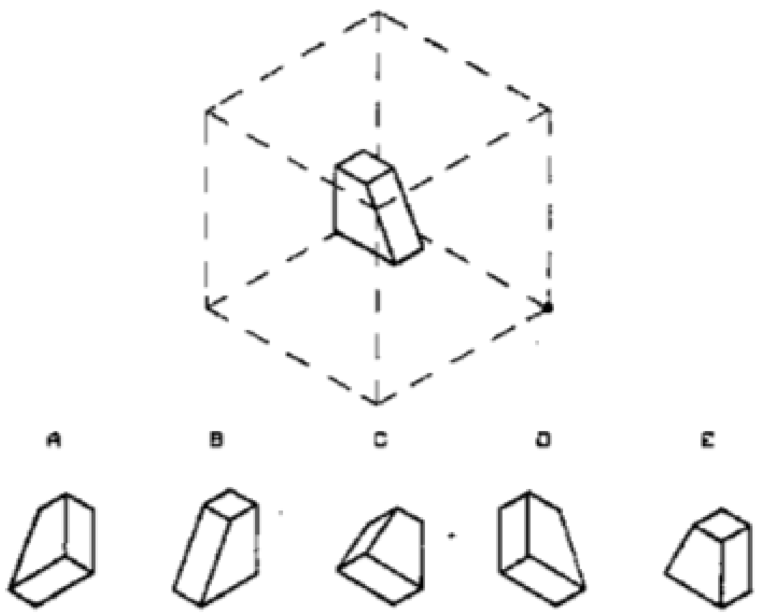
2) Bu bakış açısı doğrultusunda saydam kutuda içerisindeki nesnenin zihninizde nasıl göründüğünü bulmanız,

3) Verilen A, B, C, D ve E şıkları arasında size göre doğru olan cevabı işaretlemenizdir.

Yukarıda verilen örnekte doğru cevap hangisidir.

A, B, C ve D şıkları yanlıştır; sadece E şıkkı verilen bakış açısı doğrultusunda cismin görünümünü temsil etmektedir. Önceki bölümlerde olduğu gibi her sorunun yalnızca bir doğru cevabı bulunmaktadır.

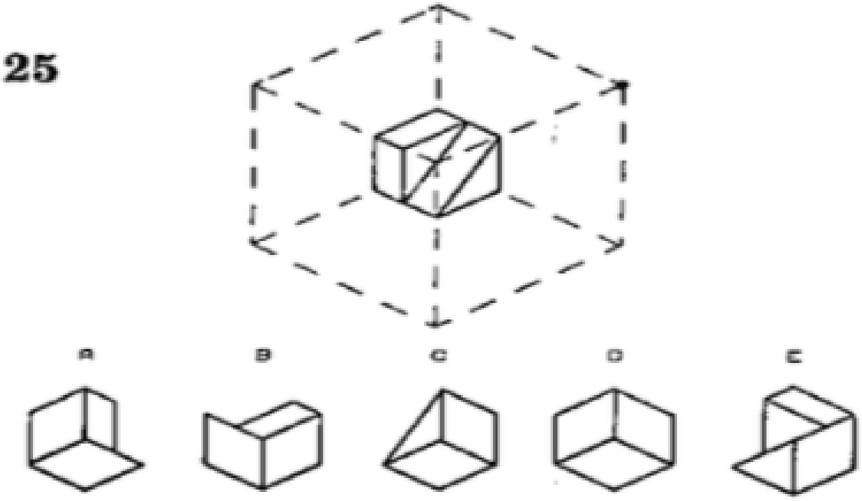
Şimdi aşağıda verilen bir sonraki örneğe bakarak, gösterilen noktadan cisme bakıldığında cismin nasıl göründüğünü bulunuz. Nesne saydam kutunun ortasına konumlandırılmıştır. Siyah nokta, sizinle nesne arasında kalacak şekilde cismi hareket ettirerek zihninizde görselleyiniz.



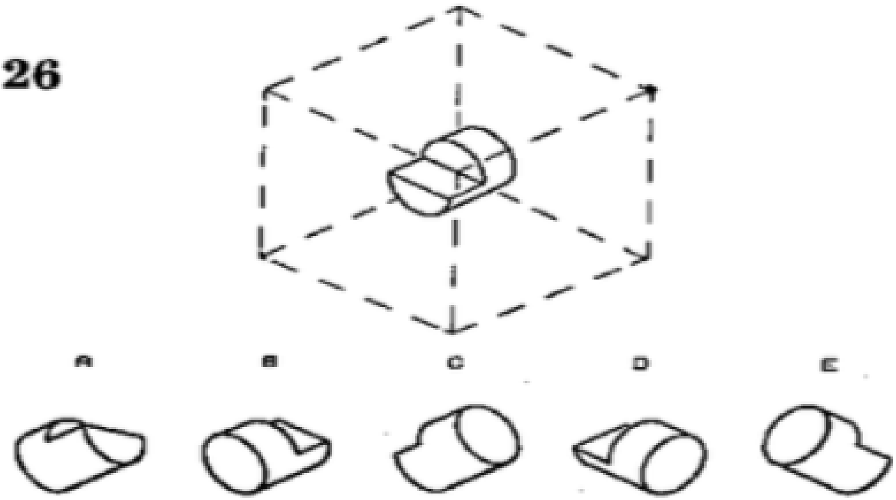
Bu örneğin doğru cevabı C şıkkıdır.

Ne zaman başlayacağınız size söylenecektir.

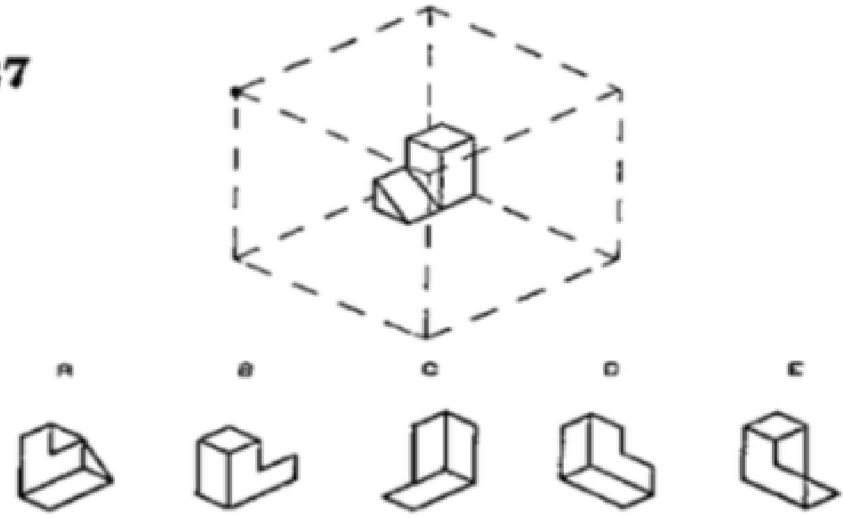
25



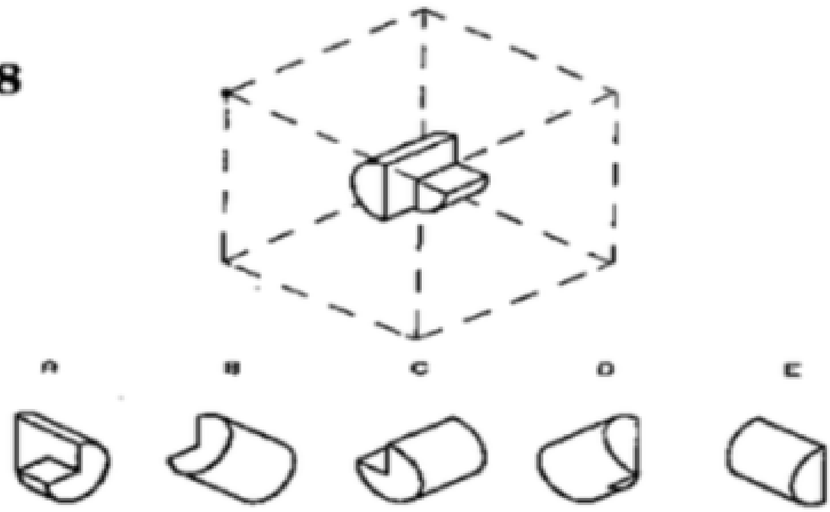
26



27



28



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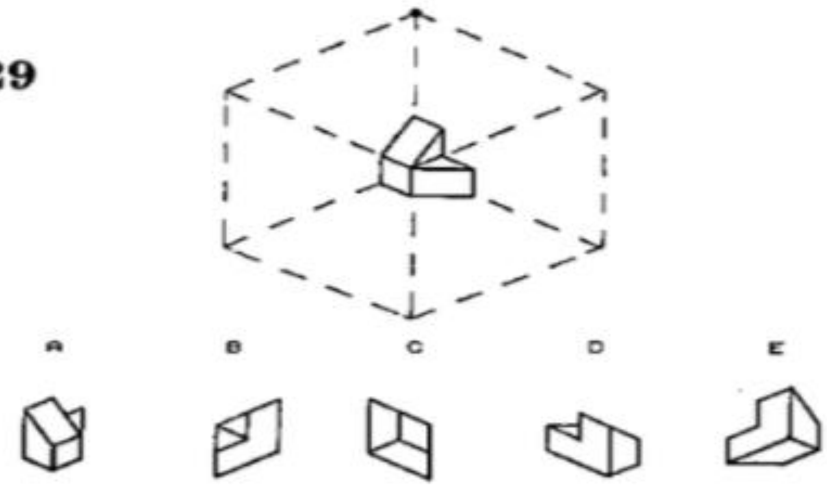
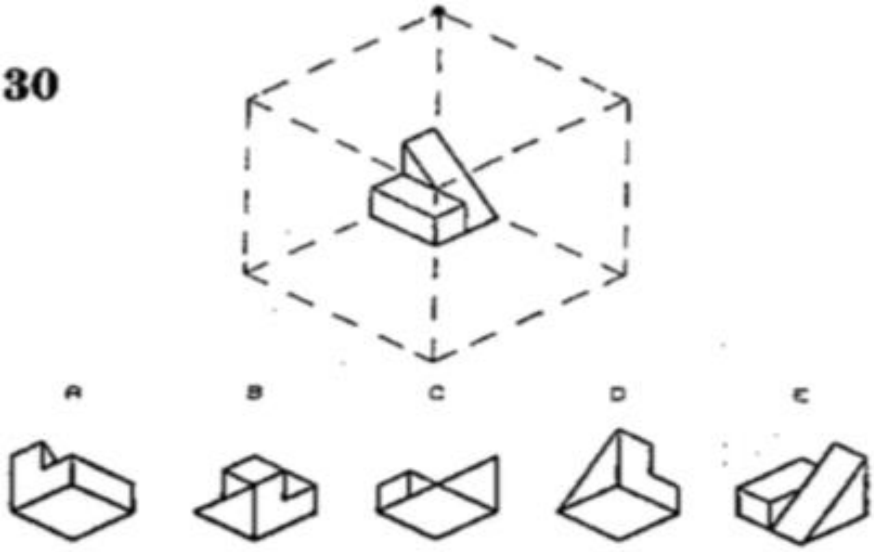
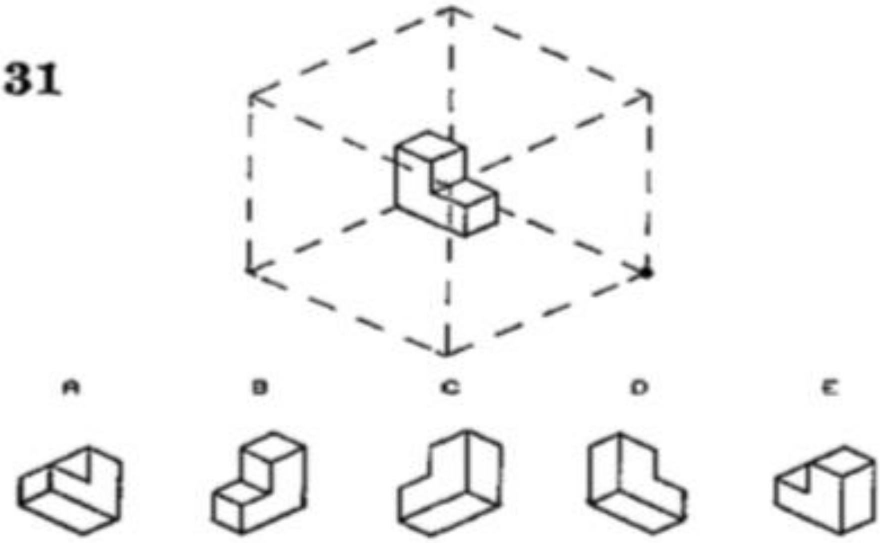


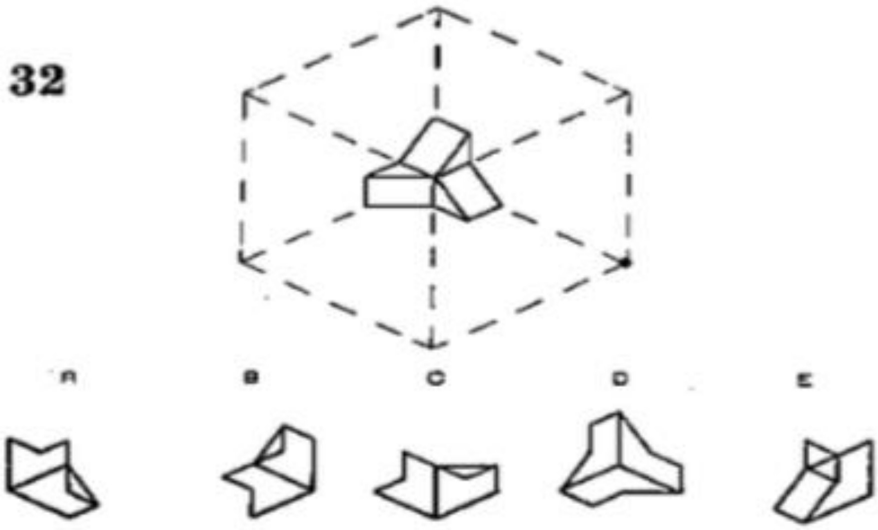
30



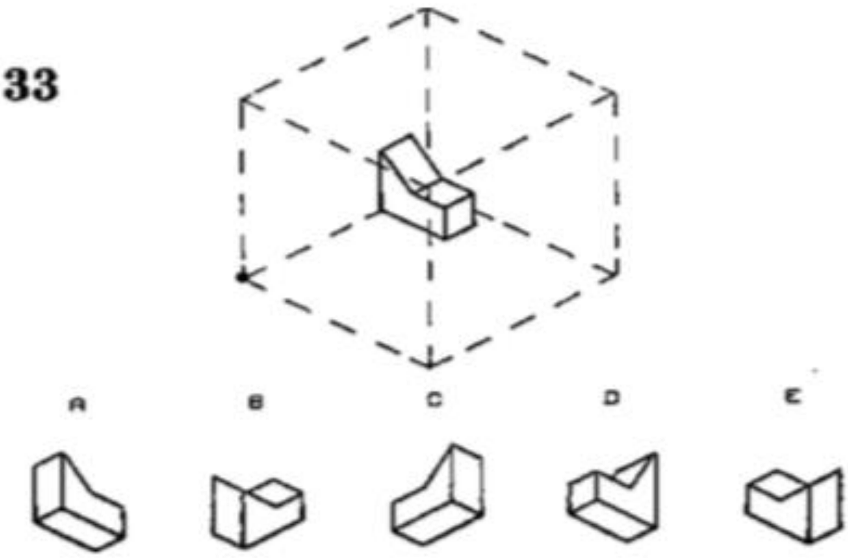
31



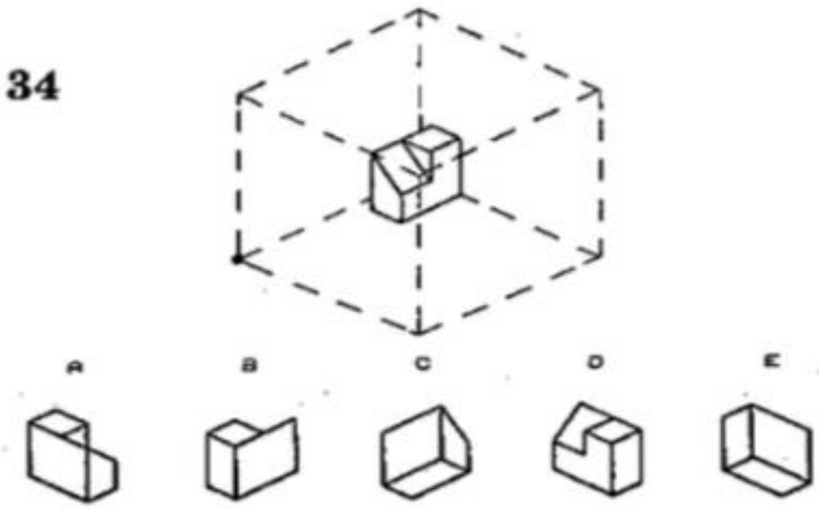
32



33



34



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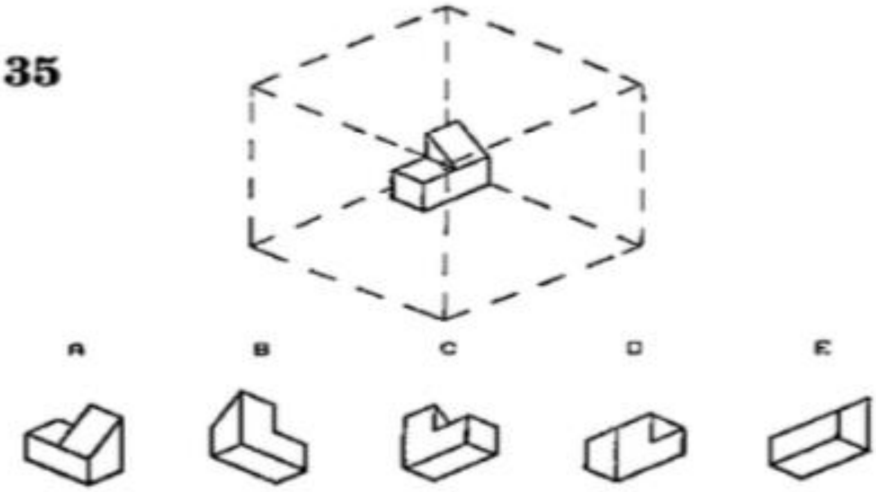

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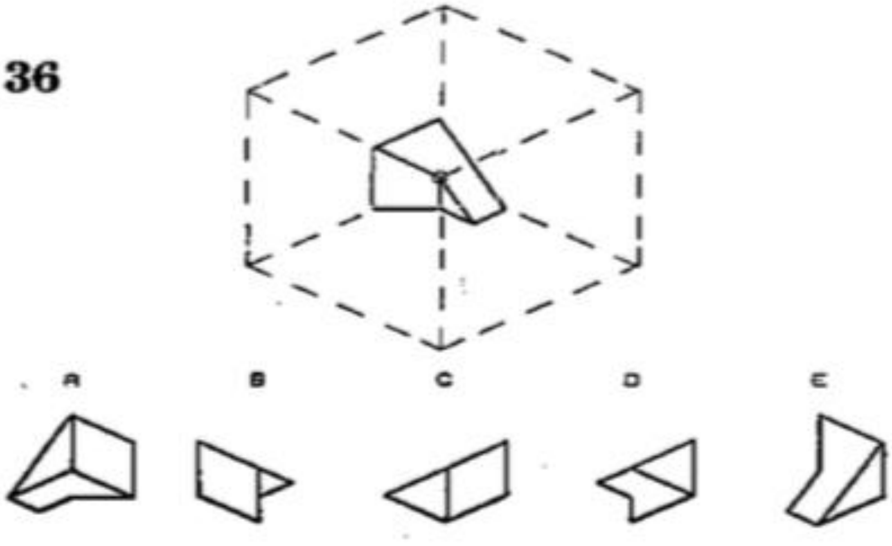

Appendix B: Demographic Form

1. **Adınız:**

2. **Cinsiyet:**
   - o Kız
   - o Erkek

3. **Doğum yılı:**

4. **Sınıf:**
   - o 9
   - o 10
   - o 11
   - o 12

5. **Takip edilen öğretim programı**
   - o IGCSE
   - o Uluslararası Bakalorya Programı
     - o Matematik standart
     - o Matematik ileri seviye
   - o Millî Eğitim Bakanlığı (MEB) Müfredatı

6. **Geçen seneki matematik dönem sonu notunuz:** …./100

7. **Annenizin eğitim durumu**
   - o İlkokul mezunu
   - o Ortaokul mezunu
   - o Lise mezunu
   - o Üniversite mezunu
   - o Yüksek lisans mezunu
   - o Doktora mezunu

8. **Babanızın eğitim durumu**
   - o İlkokul mezunu
   - o Ortaokul mezunu
   - o Lise mezunu
   - o Üniversite mezunu
   - o Yüksek lisans mezunu
   - o Doktora mezunu

9.

a. Anne ikinci dil biliyor mu?
   - o Evet
   - o Hayır

b. Baba ikinci dil biliyor mu?
   - o Evet
   - o Hayır

10. **Ailenizin toplam aylık gelir miktarı nedir?**
    - o 1500 ve altı
    - o 1500-4500
    - o 4501-9000
    - o 9000 üzeri

11. **Evde kendinize ait bir çalışma odanız var mı?**
    - o Evet
    - o Hayır

12. **Kaç kardeşiniz var?**
    - o Yok
    - o 1
    - o 2
    - o 3
    - o 4+

13. **Evinizdeki ısıtma sistemi:**
    - o Doğalgaz
    - o Kalorifer
    - o Soba
    - o Elektrikli soba

14. **Aşağıdaki alanlardan hangisini veya hangilerini daha çok seviyorsunuz?(birden fazla seçeneği seçebilirsiniz.)**
    - o Sayısal ağırlıklı alanları
    - o Sosyal ağırlıklı alanları
    - o Sanat ağırlıklı alanları
    - o Spor ağırlıklı alanlar

Appendix C: Permission for PSVT

Re: Purdue Test İzni

From eyup.sevimli@gop.edu.tr
To dilara.toplu@bilkent.edu.tr
Date Today 15:19

Dilara Hanım Merhaba,
Purdue Uzamsal Görselleme Testini referans vererek kullanmanızda bir sakınca yoktur. Değerlendirme sürecinde aklınıza takılan bir şey olursa yazın lütfen.
Ekte ayrıca cevap anahtarını da yolluyorum.
İyi çalışmalar, başarılar.

2018-09-18 14:59, dilara.toplu@bilkent.edu.tr yazmış:

> Merhaba Dr. Sevimli,
>
> Ben Bilkent Üniversitesi Eğitim Programları, Öğretim ve Pedagojik Formasyon Programında yüksek lisans öğrencisi Dilara Toplu.
>
> Şu anda, öğrencilerin uzamsal yeteneklerini değerlendirmek için bir araştırmaya başlıyorum. Tezim de Purdue Uzamsal Görselleme Testini kullanmayı planlıyorum. Türkçeye adapte edilmiş halini sizin "Matematik Öğretmen Adaylarının Belirli İntegral Konusunda ki Temsil Tercihlerinin Uzamsal Yetenek ve Akademik Başarı Bağlamında İncelenmesi (2009)" teziniz de buldum. Bu maili araştırmamda kullanma izni almak için yazıyorum. Araştırmamda bu testi kullanmak için izninizi almak isterim.
>
> Saygılarımla,
>
> Dilara Toplu
> Bilkent Üniversitesi, CITE

--
Doç.Dr. Eyüp SEVİMLİ

Gaziosmanpaşa Üniversitesi Eğitim Fakültesi, Matematik Eğitimi Anabilim Dalı Öğretim Üyesi

Assoc.Prof.Dr.Eyup SEVIMLI, Lecturer at the Department of Mathematics Education, Gaziosmanpasa University-TURKEY

Appendix D: Approval of the MoNE

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.19707974 — 18.10.2018
Konu : Araştırma İzni

BİLKENT ÜNİVERSİTESİNE
(Eğitim Bilimleri Enstitüsü)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 02/10/2018 Tarihli ve 5675 sayılı yazınız.

Enstitünüz Eğitim Programları ve Öğretim yüksek lisans öğrencisi Dilara TOPLU'nun yürüttüğü, **"Ankara'nın Çankaya İlçesindeki Lise Öğrencilerinin Görsel ve Uzamsal Becerileri Üzerine Bir Çalışma"** konulu tez çalışması kapsamında uygulama talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Görüşme formunun (23 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme (1) Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Güvenli Elektronik İmzalı
Aslı İle Aynıdır.
19/12/2018

Adres: İnayet Mah. Alparslan Türkeş Cad. 4/A Yenimahalle/ANKARA
Elektronik Ağ: www.meb.gov.tr
e-posta: istatistik06@meb.gov.tr

Bilgi için: D. KARAGÖZEL
Tel: 0 (312) 221 02 17
Faks: 0 (312) 221 02 16

24.10.18
EBE

Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden 6ffa-8214-3a5b-84e3-8cf6 kodu ile teyit edilebilir.