THE RELATIONSHIPS AMONG PRESERVICE TEACHERS' SPATIAL VISUALIZATION ABILITY, GEOMETRY SELF-EFFICACY, AND SPATIAL ANXIETY

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ABSTRACT

THE RELATIONSHIPS AMONG THE PRESERVICE TEACHERS' SPATIAL VISUALIZATION ABILITY, GEOMETRY SELF-EFFICACY, AND SPATIAL ANXIETY

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The main purpose of this study was to investigate preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety regarding undergraduate program and gender. The other purpose of the study was to investigate the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety.

The data were collected from 1007 third and fourth grade preservice teachers who were enrolled in Elementary Mathematics Education (EME), Elementary Science Education (ESE), and Early Childhood Education (ECE) programs of four universities in Ankara. The measuring instruments were Spatial Visualization Test (SVT), Geometry Self-Efficacy (GSE) Scale, and Spatial Anxiety (ANX) Scale.

The results indicated that there was a significant difference between undergraduate programs regarding spatial visualization ability levels. The EME students had significantly higher SVT scores than the ESE and the ECE students. Moreover, it was concluded that males had significantly higher spatial visualization scores than females. In addition, ECE students' geometry self-efficacy was significantly lower than that of both EME and ESE students. The geometry self-efficacy scores of female preservice teachers were found significantly lower than of male preservice teachers. Furthermore, the significant difference in spatial anxiety levels was found only between EME and ESE students where EME students' spatial anxiety levels were higher than ESE students. Moreover, ECE students had the lowest spatial anxiety among other programs. The spatial anxiety levels of males were less than females in all three undergraduate programs.

Finally, Pearson product-moment correlation analysis indicated a positive correlation between GSE and SVT scores. Moreover, the negative correlation was found between ANX and SVT scores, and between ANX and GSE scores.

Keywords: Spatial Visualization Ability, Geometry Self-Efficacy,
Spatial Anxiety, Preservice Teachers

ÖZ

İLKÖĞRETİM ÖĞRETMEN ADAYLARININ UZAMSAL YETENEKLERİ, GEOMETRİYE YÖNELİK ÖZ-YETERLİK ALGILARI VE UZAMSAL KAYGILARI ARASINDAKİ İLİŞKİ

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Bu çalışmanın temel amacı ilköğretim öğretmen adaylarının uzamsal görselleştirme yetenekleri, geometriye yönelik öz-yeterlik algıları ve uzamsal kaygıları arasındaki ilişkinin cinsiyet ve devam edilen program açısından incelemektir. Çalışmanın bir diğer amacı ise ilköğretim öğretmen adaylarının uzamsal görselleştirme yetenekleri, geometriye yönelik öz-yeterlik algıları ve uzamsal kaygıları arasındaki ilişkinin incelenmesidir.

Veriler, Ankara'daki dört büyük üniversitenin ilköğretim matematik öğretmenliği (EME), ilköğretim fen bilgisi öğretmenliği (ESE) ve okul öncesi öğretmenliği (ECE) programlarının üçüncü ve dördüncü sınıflarında öğrenim görmekte olan 1007 öğretmen adayından toplanmıştır. Çalışma kapsamında kullanılan ölçekler Uzamsal Görselleştirme Testi (SVT), Geometriye Yönelik Öz-Yeterlik Algısı (GSE) ölçeği ve Uzamsal Kaygı (ANX) ölçeğidir.

Analiz sonuçları devam edilen programlar arasında uzamsal görselleştirme yeteneği açısından anlamlı fark olduğunu göstermiştir. EME öğrencilerinin SVT puanları ESE ve ECE öğrencilerininkinden anlamlı derecede yüksek bulunmuştur.

Ayrıca, erkeklerin uzamsal görselleştirme puanlarının kızlarınkinden anlamlı derecede yüksek olduğu sonucuna varılmıştır. Sonuçlar ECE öğrencilerinin geometriye yönelik öz-yeterlik algılarının hem EME hem de ESE öğrencilerininkinden anlamlı derecede düşük olduğunu göstermiştir. Bunun yanında, kız öğretmen adaylarının geometriye yönelik öz-yeterlik algıları erkeklerinkinden anlamlı derecede düşük bulunmuştur. Uzamsal kaygı seviyesi açısından anlamlı fark ise sadece EME ve ESE öğrencileri arasında bulunmuştur ve EME öğrencilerinin uzamsal kaygı seviyeleri ESE öğrencilerininkinden daha yüksek çıkmıştır. Bunun yanında, ECE öğrencilerinin uzamsal kaygıları diğer programlardaki öğrencilere nazaran daha düşük bulunmuştur. Üç programda da öğretmen adaylarından erkeklerin uzamsal kaygı seviyeleri kızlarınkinden daha düşük bulunmuştur.

Son olarak, Pearson product-moment korelasyon analizi sonuçları GSE ve SVT puanları arasında pozitif ilişki olduğunu göstermiştir. Ayrıca, ANX ve SVT puanları ve ANX ve GSE puanları arasında da negatif korelasyon bulunmuştur.

Anahtar Kelimeler: Uzamsal Görselleştirme Yeteneği, Geometriye Yönelik Öz-Yeterlik Algısı, Uzamsal Kaygı, Öğretmen Adayları

To My Mother, Father, and Brother

Who have always shown their love and trust in me

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LIST OF ABBREVIATIONS

ANOVA: Analysis of Variance

ANX: Spatial Anxiety

ECE: Early Childhood Education

df: Degrees of Freedom

EME: Elementary Mathematics Education

ESE: Elementary Science Education

GSE: Geometry Self-Efficacy

H_0: Null Hypothesis

M: Mean

MGMP: Middle Grades Mathematics Project

MoNE: Ministry of National Education

N: Number of Participants

NCTM: National Council of Teachers of Mathematics

RQ: Research Question

SD: Standard Deviation

SVT: Spatial Visualization Test

2D: Two Dimensional

3D: Three Dimensional

CHAPTER 1

INTRODUCTION

According to the Multiple-Factors Theory, intelligence originates from several primary mental abilities which are verbal comprehension, word fluency, number facility, spatial visualization, associative memory, perceptual speed and reasoning (Thurstone, 1973). In other words, spatial visualization is an important factor in human intelligence. The world is a three dimensional place and human beings perceive the outside in a spatial way. Therefore, educators and psychologists have been interested in spatial ability for many years (Unal, 2005). Gardner (1993a) suggests in his Multiple Intelligences Theory that spatial ability is one of the seven intelligences and it plays a crucial role in many occupations and in solving mathematical problems, in daily activities like finding your way, reading map, and drawing. He defined the spatial intelligence as “the ability to form a mental model of a spatial world and the ability to operate using that model” (Gardner, 1993a, p. 9).

The importance of spatial ability in education has been known for many years and many studies have been conducted. In most of the studies related to this ability, researchers asserted that there would be a relationship between spatial ability and science achievement and spatial ability and mathematics achievement. Moreover, National Council of Teachers of Mathematics [NCTM] (1989, 2000) emphasized the necessity of spatial ability in geometry learning and teaching. Thus, spatial ability is one of the important factors to be searched in teaching and learning mathematics. However, there is no specific definition for spatial ability. The researchers asserted that spatial ability has components but a controversy exists related to the number of components of spatial ability. Most of the researchers have argued that spatial ability could be categorized into two as *spatial visualization* and *spatial orientation* (Battista, 1994; Bodner & Guay, 1977; Clements, 1998; Extrom, French, Harman, & Derman, 1976; Guilford & Lacey, 1947; Hegarty & Waller, 2004; Lohman, 1979; McGee, 1979). Spatial visualization was described as “the ability of mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object” (McGee, 1979, p. 893). In the same way, spatial orientation was defined as “the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unfocused by the changing orientations in which a spatial configuration may be presented” (McGee, 1979, p. 897). In present study, the researcher focused on spatial visualization component of spatial ability.

Literature review also showed that spatial ability of an individual can be improved with the help of some applications like giving a treatment, using concrete materials, manipulatives, various toys and computer programs (Battista, Wheatley, & Talsma, 1982; Ben-Chaim, Lappan & Houang, 1988; Bishop, 1973, 1980; Dixon, 1995; Okagi & Frensch, 1994; Olkun, 2003b; Robichaux, 2000; Robichaux & Rodrigue, 2003; Sundberg, 1994; Werthessen, 1999). In her study, Robichaux (2000) concluded that spatial visualization abilities of undergraduates majoring in architecture, mathematics education, mathematics and mechanical engineering were developed gradually with their childhood experiences. Similarly, Sundberg (1994) observed an increase in spatial abilities of 6^{th}, 7^{th} and 8^{th} grade students after the instruction based on concrete materials. Thus, teachers’ role in developing spatial ability of students is quite important. In other words, it could be deduced that the spatial visualization abilities of teachers should be high in order to assess their students’ visual abilities. However, literature review revealed that most of the studies related to spatial ability were conducted with the students of middle school, elementary school, primary school, and young children but less attention is given to the teachers especially to preservice teachers. In addition, there are many studies which focus on the gender difference in spatial ability of students (Allivatos & Petrides, 1997; Baenninger & Newcombe, 1989; Grimshaw, Sitarenios, & Finengan, 1995; Harris, 1981; Kimura & Hampson, 1994; Linn & Petersen, 1985; Lytton & Romney, 1991; Richardson, 1994; Signorella & Jamison, 1986). Therefore, in the present study, sexual difference in spatial visualization abilities of preservice teachers was also evaluated. Since teachers are the potential candidates who could affect students’ spatial abilities, their own spatial ability levels should be evaluated.

Thus, preservice teachers who are the inservice teachers of future will be the concern of this study.

According to Bandura (1977), self-efficacy refers to “beliefs in one’s capabilities to organize and execute the courses of action required in order to produce given attainments” (p. 3). In the literature, there are studies examining the relationship between self-efficacy and mathematics performance or mathematics self-efficacy and other variables such as computer self-efficacy and mathematics performance. However, the studies investigating the self-efficacy specific to geometry are limited. Geometry has an important place in mathematics and its relationship with spatial ability was emphasized in many studies. It is believed that geometry self-efficacy of preservice teachers could have positive relationship with their spatial visualization abilities. Therefore, geometry self-efficacy will be one of the concerns of the present study.

The other variable of the present study will be spatial anxiety, which was defined as “anxiety about environmental navigation” (Lawton, 1994, p. 767). Literature review illustrated that spatial anxiety is an important factor affecting individual’s behavior and performance (Lawton, 1994). Moreover, gender difference was detected in spatial anxiety levels of the participants in terms of success in mathematics performance (Wigfield & Eccles, 1992), navigation performance (Hund & Minarik, 2006), strategy preference (Hund & Minarik, 2006; Lawton, 1994), and environmental learning (Schmitz, 1997). In addition, the relationship among spatial perception and mental rotation, two components of spatial ability, and spatial anxiety was investigated in some studies (Lawton, 1994, 1996). However, the number of studies investigating the relationship between spatial anxiety and spatial visualization ability which is another component of spatial ability is limited. Thus, in the present study, the relationship among spatial visualization, geometry self-efficacy and spatial anxiety was investigated.

1.1 Purpose of the Study

The aim of this study was to investigate the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety in terms of undergraduate program and gender. Moreover, the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety was evaluated in this study.

1.2 Research Questions

The following research questions were investigated in the present study. After each research question, sub-questions and formulated hypotheses were given.

RQ1. Is there a significant difference in preservice teachers' spatial visualization abilities in terms of undergraduate program and gender?

Sub-question 1: Is there a significant difference in preservice teachers' spatial visualization abilities who are enrolled in elementary mathematics education (EME), elementary science education (ESE), and early childhood education (ECE) programs?

H_0: There is no significant difference in preservice teachers' spatial visualization abilities who are enrolled in EME, ESE, ECE programs.

Sub-question 2: Is there a significant difference in spatial visualization abilities of male and female preservice teachers?

H_0: There is no significant difference in spatial visualization abilities of male and female preservice teachers.

RQ2. Is there a significant difference in preservice teachers' geometry self-efficacy scores in terms of undergraduate program and gender?

Sub-question 1: Is there a significant difference in preservice teachers' geometry self-efficacy scores who are enrolled in EME, ESE, and ECE programs?

H_0: There is no significant difference in preservice teachers' geometry self-efficacy scores who are enrolled in EME, ESE, and ECE programs.

Sub-question 2: Is there a significant difference in geometry self-efficacy scores of male and female preservice teachers?

H_0: There is no significant difference in geometry self-efficacy scale scores of male and female preservice teachers.

RQ3. Is there a significant difference in preservice teachers' spatial anxiety scores in terms of undergraduate program and gender?

Is there a significant difference in preservice teachers' spatial anxiety scores who are enrolled in EME, ESE, and ECE programs?

H_0: There is no significant difference in preservice teachers' spatial anxiety scores who are enrolled in EME, ESE, and ECE programs.

Is there a significant difference in spatial anxiety scores of male and female preservice teachers?

H_0: There is no significant difference in spatial anxiety scores of male and female preservice teachers.

RQ4. Is there a significant relationship among spatial visualization ability (SVT), geometry self-efficacy (GSE), and spatial anxiety (ANX) scores of preservice teachers?

H_0: There is no significant relationship among SVT, GSE, and ANX scores of preservice teachers.

1.3 Significance of the Study

The researches in spatial ability has emerged in 1940s slowly and speeded up in 1990s but no sufficient scientific studies have been done on spatial ability in Turkey (Guzel & Sener, 2009). In Turkey, the importance was started to be given to spatial ability after the elementary school curriculum reform which has started in 2003 (MoNE, 2005, 2006). New objectives and activities were added to elementary curriculum to improve spatial abilities of students. The importance of teachers' spatial abilities or their knowledge on spatial ability emerges at this point because they are the people who are responsible for students' learning. Therefore, in this study, the main focus was on preservice teachers' spatial ability. To state differently, it is believed that if preservice teachers can improve their spatial abilities when they are undergraduate students, they could positively affect their students' spatial ability when they become inservice teachers. In other words, as indicated, today's preservice teachers are tomorrow's inservice teachers and they are the people who will evaluate and develop students' spatial visualization abilities in future. In addition, the courses which aim to improve spatial ability of preservice teachers in education faculties are so limited. In order to show the necessity of incorporating such courses, the spatial ability levels of preservice teachers should be investigated. Thus, the results of the study are supposed to direct the attention of teacher educators and curriculum developers to the development of spatial visualization abilities of preservice teachers.

In most of the studies, researchers asserted that there is a relationship between spatial visualization ability and science achievement, and spatial visualization ability and mathematics achievements. In addition, spatial visualization ability is used in many other technical occupations such as architecture, mechanical engineering, civil-engineering, and electric-electronic engineering (Ben-Chaim et al., 1988; Olkun, 2003b; Robichaux, 2000). For instance, mechanical engineers draw the parts of machines from different points of views in designing process. Similarly, civil engineers should be able to think spatially in order to draw the 3D plans of buildings (Bayrak, 2008). These technical occupations require high level knowledge of geometry and also spatial visualization ability. To state differently, it was claimed that spatial visualization ability has an important role in understanding geometry (Unal, Jakubowski, & Corey, 2009). Therefore, geometry self-efficacy of students comes into question since individuals' belief in their ability to be successful in geometry might have relationship with their spatial visualization ability. Thus, geometry self-efficacy was selected as one of the concerns of the present study.

In addition, spatial visualization ability exists in many fields of education such as science education and early childhood education. For instance, science teachers use spatial visualization abilities in laboratory applications and in their courses to make their students imagine what they want to explain like digestive system of human beings or construction of electrical schemes. Similarly, early childhood teachers use their spatial visualization in creativity and visual art courses. Therefore, in the present study, the preservice teachers who are enrolled in elementary mathematics education, elementary science education, and early childhood education undergraduate programs were involved.

Literature review illustrated that spatial anxiety is a crucial factor affecting individual's behavior and performance (Lawton, 1994). The results of the study of Hund and Minarik (2006) indicated that there was a negative relationship between spatial anxiety and navigation performance. The success in wayfinding and navigation tasks requires high spatial visualization ability. Thus, the other concern of the present study is selected as spatial anxiety since it is quite possible to have an effect on spatial visualization abilities of participants.

Gender is a crucial variable to be considered in scientific researches (Armstrong, 1981; Ethington, 1992; Halat, 2008; Kaufman, 2007; Lloyd, Walsh & Yailagh, 2005). It is also a source of concern for mathematics educators (Leder, 1992). In many studies, males outperformed females in measurement, geometry, spatial geometry, analytic geometry and trigonometry (Battista, 1990; Fennema & Carpenter, 1981). As it can be seen, male performance was better than that of female in areas based on spatial visualization ability. However, there is not sufficient number of research investigating the gender difference in spatial visualization abilities of preservice teachers in Turkey. Thus, gender was selected as a concern to be searched in this study.

Most of the researchers studying on spatial ability investigated the duo relationship such as spatial ability versus mathematics achievement. However, the present study consists of geometry self-efficacy, spatial anxiety, undergraduate program being involved and gender constructs together. In other words, the present study aims to investigate the relationship among spatial visualization, spatial anxiety and geometry self-efficacy of preservice teachers. Moreover, the differences between spatial visualization ability, geometry self-efficacy and spatial anxiety of preservice teachers were investigated in terms of undergraduate program and gender. Therefore, it is believed that this study will be beneficial for teacher educators and curriculum developers to arrange teacher education programs in order to educate more successful and qualified teachers in terms of spatial capability.

1.4 Definition of Important Terms

In previous sections, purpose, research questions and significance of the study were presented. In the following list, the constitutive and operational definitions of the important terms in research questions and hypotheses were given.

Spatial Ability is defined as "The mental manipulation of objects and their parts in 2D and 3D space" (Olkun, 2003b, p. 8). However, in the present study, terms of *spatial visualization ability* and *spatial ability* were used interchangeably since spatial visualization test was used to measure both spatial orientation and spatial visualization abilities of the participants.

Spatial Visualization Ability is defined as "The ability of mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (McGee, 1979, p. 893). In this study, spatial visualization abilities of the participants were measured with Spatial Visualization Test (SVT) which was developed by Lappan, Fitzgerland, Phillips, Winter, Ben-Chaim, Friedlander, Oguntebi and Yarbrough in the *Middle Grades Mathematics Project* (MGMP) (1983) at Michigan State University.

Spatial Anxiety is defined as "Anxiety about environmental navigation" (Lawton, 1994, p. 767). In this study, spatial anxiety of participants was measured with a Spatial Anxiety (ANX) Scale developed by Lawton (1994).

Geometry Self-Efficacy is defined on the base of the self-efficacy definition of Bandura (1977) which is "Beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments". Thus, in this study, geometry self-efficacy is defined as the beliefs of individuals in their capabilities to organize and execute the courses of action required to produce given attainments related to specific geometric task or problem successfully. In this study, geometry self-efficacy scores of participants were measured with Geometry Self-Efficacy (GSE) Scale which was developed by Cantürk-Günhan and Başer (2007).

Preservice Teachers are defined as the undergraduate students studying at elementary education departments of faculty of education. The present study consists of three undergraduate programs; Elementary Mathematics Education (EME), Elementary Science Education (ESE) and Early Childhood Education (ECE). Thus, preservice teachers refer to the 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} year students studying at the indicated undergraduate programs. The pilot study was administered to 1^{st} and 2^{nd} year students and the sample of the main study was 3^{rd} and 4^{th} year students.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the literature review of the present study is presented. Based on the content and main objectives of the study, this chapter is classified into three sections: definitions and components of spatial ability, related studies on spatial ability and summary of literature review.

2.1 Definitions and Components of Spatial Ability

In this section, the definitions of spatial ability as an important term will be explained and its components will be clarified.

2.1.1 Definitions of Spatial Ability

Many different terms exist and are used interchangeably to refer to spatial ability in the literature such as *spatial visualization, spatial skills, spatial orientation, spatial relations, spatial perception, spatial thinking, spatial sense and spatial intelligence*. Researchers have not agreed on a single definition of spatial ability. For instance, Lohman (1993) expressed the definition of *spatial ability* as the skill of generating, retaining, retrieving, and transforming well-structured visual images. Another definition emphasizing the characteristics to be considered in spatial tasks such as the speed and the difficulty of tasks was stated by Carroll (1993) as the ability to manipulate visual patterns as revealed by the level of difficulty and complexity in visual stimulus materials handled successfully, regardless the speed of task solution. Furthermore, Yakimanskaya (1991) defined *spatial thinking* as a kind of mental activity which helps an individual to construct spatial images and manipulate them to solve problems (as cited in Gutiérrez, 1996). Another definition for spatial ability was expressed by Olkun (2003b) as "the mental manipulation of objects and their parts in 2D and 3D space" (p. 8). National Council of Teachers of

Mathematics [NCTM] (1989) also clarified *spatial sense* as an intuitive feeling to comprehend the environment and the objects in it. As can be seen, rotating, manipulating or transforming a visual object are common capabilities in most of the definitions. Moreover, being able to visualize how the appearance of the object will change after a motion takes place is one of the common characteristics of spatial ability.

2.1.2 Components of Spatial Ability

In the literature, a controversy exists related to the components of spatial ability. Many researchers have argued that spatial ability can be categorized into two as *spatial visualization* and *spatial orientation* (Battista, 1994; Bodner & Guay, 1977; Clements, 1998; Ekstrom, French, Harman, & Derman 1976; Guilford & Lacey, 1947; Hegarty & Waller, 2004; Lohman, 1979; McGee, 1979). For instance, McGee (1979) described spatial visualization as "the ability of mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (p. 893). For spatial orientation, McGee (1979)'s definition is "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations in which a spatial configuration may be presented" (p. 897). Similarly, Battista (1994) pointed out that spatial visualization is the insight and performance of imagined movements of objects in space while spatial orientation means comprehending and studying the relationships between the positions of the observer and the objects in space. Correspondingly, Salthouse, Babcock, Skovronek, Mitchell and Paimon (1990) stressed the importance of the observer's mental activity in spatial visualization with the definition "the mental manipulation of spatial information to determine how a given spatial configuration would appear if portions of that configuration were to be rotated, folded, repositioned, or otherwise transformed" (p. 128). Furthermore, Velez, Silver and Tremaine (2005) supported Battista (1994) stating that "spatial orientation is the ability to accurately estimate changes in the orientation of an object whereas spatial visualization is the ability to recognize and quantify the orientation changes in the scene" (p. 512). That is, spatial visualization has been accepted as one's estimation of his position with respect to a visual object in the space and entails no mental rotation.

In the literature review, it was seen that spatial visualization and spatial ability terms were used interchangeably in some research studies (Battista, 1990; Battista, Wheatley, & Talsma, 1982). For visualization, Bishop (1983) stated two abilities; *visual processing* and *interpretation of figural information*. He defined visual processing as "The visual processing of a non-figural data into visual terms, the manipulation and extrapolation of visual imagery, and the transformation of one visual image into another (Bishop, 1983, p. 177). Other ability was defined as "The interpretation of figural information, involving knowledge of the visual conventions and spatial 'vocabulary' used in geometric work, graphs, charts and diagrams of all types and the 'reading' and interpreting of visual images, either mental or physical" (Bishop, 1983, p. 177). These definitions show that spatial visualization is not only the ability to comprehend the appearance of an image, but also to interpret the given visual information with the help of reasoning.

Some other researchers divided spatial ability into three components: *spatial perception, mental rotation* and *spatial visualization* (Boulter, 1992; Linn & Petersen, 1985; Tartre, 1990; Voyer, Voyer, & Bryden, 1995). Boulter (1992) stated that the thing expected from individuals in spatial perception tests is focusing on disembedding or overcoming distracting cues, and the individuals can either ignore or correct the misleading cues in these tests. Mental rotation requires rotation of two-dimensional or three-dimensional objects in mind while spatial visualization entails complicated, multistep manipulations of a spatially presented object (Boulter, 1992). Likewise, Linn and Petersen (1985) defined *spatial visualization* as an ability which involves complicated multi-step manipulations of spatially presented information. They described *spatial perception* as the ability to designate spatial relations despite distracting information. Furthermore, rotating 2D or 3D figures quickly and accurately was accepted as *mental rotation* (Linn & Petersen, 1985).

Many researchers specified the difference between spatial visualization and spatial orientation. For instance, Tartre (1990) asserted that if all parts of the given object are moved or changed, then it is spatial visualization. As for spatial orientation tasks, there are no need to move objects mentally and it is enough to move the observer or change the perspective of the observer (Tartre, 1990). Besides, Tartre (1990) defined spatial orientation tasks as “organizing, recognizing, making sense out of a visual representation, reseeing it or seeing it from a different angle, but not mentally moving the object” (p. 217). He stated that the thing moved or changed in spatial orientation task is the perspective of the observer. In addition, Clements (1998) provided a clarification for spatial visualization as it is the ability to comprehend and perform the imagined movements of two or three-dimensional objects. According to Clements (1998), an individual should be able to generate and manipulate the image mentally in spatial visualization tasks. It was noticed in the literature review that spatial visualization was the most common and the most emphasized and the most searched term among other components of spatial ability (Cakmak, 2009).

As suggested by the points mentioned above, there is no single and accurate definition of spatial ability and classification of sub-dimensions of spatial ability. Spatial ability is a mental activity and also an important element of intellectual ability for an individual (Boulter, 1992). Since it is a mental ability, it is quite difficult for researchers to measure spatial ability. Fennema and Sherman (1997) asserted that the most related component to mathematics achievement is spatial visualization. Thus, the present study will focus on spatial visualization.

2.2 Research Studies on Spatial Ability

In this section, the research studies related to the importance of spatial ability, the factors affecting the development of spatial ability, gender differences in spatial ability, the relationship between spatial ability and mathematics achievement, the relationship between spatial ability and geometry will be summarized. In addition, research studies related to spatial ability in Turkey, self-efficacy and the relationship between spatial ability and spatial anxiety will be explained.

2.2.1 Studies on the Importance of Spatial Ability

In Turkey, the education reform on elementary curriculum has begun in 2003 and the pilot application started in 2004-2005 academic year for the 6^{th} to the 8^{th}

grade students. After the changes in elementary mathematics curriculum, more importance was started to be given to spatial ability in elementary mathematics lessons (MoNE, 2005, 2006). The instructional objectives in new mathematics curriculum related to spatial ability include statements like; “students will be able to determine and draw the line of symmetry, to explain rotation, to explain reflection, and to identify symmetry of the 3D shapes” (MoNE, 2005, 2006). A mental transformation of images is what is needed for spatial sense and it is in contrast with logical-deductive reasoning but both strategies can be used in the solution of mathematical problems (Battista, 1990). For instance, students can use step-by-step algorithms (verbal, logical-deductive) to solve a mathematics problem or they can draw a diagram of the solution (spatial). The students, who are able to use either method when the problem cannot be solved with memorized algorithms, can be accepted as more advantageous when compared to their peers (Casey, Nuttall, & Pezaris, 2001). Likewise, Cakmak (2009) claimed that the elementary students whose spatial abilities are insufficient had difficulties in understanding basic mathematical concepts.

The worldwide known artists and scientists such as Michelangelo, Leonardo da Vinci, Einstein, Newton and Galileo are claimed to have affected the fields of science, music, mathematics and art with the aid of their high spatial abilities (Lord & Claussen, 2002). It is believed that people who have high spatial visualization ability are very good at solving puzzles, reading maps, navigating and creating different representations for problems (Higgins, 2006). The characteristics of visualizers with a low spatial ability and a high spatial ability were clarified by Kozhenikov, Hegarty, and Mayer (2002). It was claimed that “visualizers with low spatial ability are adept at visual imagery and have the ability to represent the form, color, brightness, and other aspects of an object’s appearance. These people are good at pictorial imagery and excel at constructing detailed and vivid mental images” (as cited in Mann, 2005, p. 11). As for high spatial ability visualizers, Kozhenikov et al. (2002) declared that “They are good at schematic imagery which refers to the representation of the spatial relationships between parts of an object and how those objects move or are represented in space. They can easily perform mental rotations on complex three-dimensional images."(as cited in Mann, 2005, p. 12).

The standards of NCTM (1989, 2000) in USA, the largest mathematics teachers' organization in the world, highlighted the importance of spatial sense on mathematics teaching. The main reason to develop children's spatial ability is that "spatial understandings are necessary for interpreting, understanding, and appreciating our inherently geometric world." (NCTM, 1989, p. 48). It is believed that the success in scientific and technical occupations, which require a high level 3D perspective, such as engineering, architecture, mechanical surgery, physics, chemistry, artisan, and certain industrial positions are significantly related to the expertise in spatial ability (Kinsey, Towle, O'Brien, & Bauer, 2008; Smith, 1964; Snow & Yalow, 1982). In the same way, Sherman and Fennema (1978) emphasized the importance of spatial visualization in architecture, engineering and mathematics branches. Gardner (1993b) maintained that the crucial factor that enables an individual to advance in science is the spatial ability (as cited in Shea, Lubinski, & Benbow, 2001). Shea, Lubinski, and Benbow (2001) carried out a longitudinal study on 321 students (220 male, 101 female) whose age ranged from 12 to 14. Two subtests of Differential Aptitude Tests: Mechanical Reasoning Test and Spatial Relations Test were implemented on the sample. Mechanical Reasoning test assesses the ability to recognize everyday physical forces and principles, while Spatial Relations Test measures the ability to visualize concrete objects and manipulate those visualizations. The results of the study showed that the individuals, whose spatial ability were higher compared to their verbal ability, were more likely to select occupations related to engineering and computer science-mathematics areas. In contrast, the individuals with the inverse ability were more likely to be attracted by occupations related to humanities, social sciences, organic science and legal fields. On the other hand, the spatial ability level was claimed to be a good indicator for an individual's success in working with computer-based 3D design environment (Gerson, Sorby, Wysocki, & Baartmans, 2001) and an important indicator of educational-vocational tracks that the individual selected for himself/herself (Shea, Lubinski, & Benbow 2001).

However, there are certain weaknesses of being a spatial learner as well as strengths. Mann (2005) synthesized these strengths and weaknesses in her literature review and listed like in Table 2.1.

Table 2.1 Strengths and Weaknesses of Spatial Learners (Mann, 2005, p. 19)

Area of Strength	Perceived Weakness
Grasps relationships between systems	Has difficulty grasping isolated details
Excels with complex, higher level content	Struggles with easy or basic content
Is reflective	May be seen as a daydreamer
Has excellent memory for specific information	Has difficulty with rote memorization
Is preoccupied with ideas	Possesses weak social skills
Is able to manipulate visual images	Processes verbal communication slowly
Exhibits creative talent	Struggles in traditional academic settings
Excels at mathematical concepts	Has poor mathematical computation skills
Uses metaphoric language effectively	Rarely uses concise descriptions in language
Has strong reading comprehension skills	Has weak reading decoding skills
Is aware of physical properties and patterns	Is slow to process conventional understandings
Possesses a vivid imagination	Has difficulty putting stories into written form

As seen in Table 2.1, spatial learners can comprehend the relationships between systems but they have difficulties in learning isolated details. Moreover, they can easily deal with higher level content but they have difficulties in easy or basic content. In the same way, the other items consist of some strengths and weaknesses of spatial learners.

Spatial ability is closely related to students' learning. Guzel and Sener (2009) claimed that spatial ability develops the comprehension of symbols, shapes, and figures. They also pointed out the importance of spatial ability in mathematics achievement, specifically geometry achievement, since it helps students to understand drawings easily, to interpret the visual representations, to notice the links between different concepts easily, to make generalizations about complex concepts, and to think in a multidirectional way (Guzel & Sener, 2009). Furthermore, mathematics educators think that improvement in spatial abilities and geometric senses will enable students to be prepared better in learning number and measurement ideas as well as other advanced mathematical topics (NCTM, 1991).

Taking all the above studies into consideration, the importance of spatial ability on individuals' mathematics and geometry achievement and on their occupation preference arises. Moreover, NCTM (1989, 2000) emphasized the necessity of spatial ability in learning and teaching geometry. Although there were some weaknesses of spatial learners, their strengths make them more advantageous against others. Thus, spatial ability is one of the important factors to be searched in teaching and learning areas.

2.2.2 Studies Regarding the Factors Affecting the Development of Spatial Ability

There is no consistent consensus among researchers about whether spatial ability is a genetic capability or can be learned through life with the help of teaching activities. For example, Sedgwick (1961) asserted in his study that it is perhaps a genetic skill and not teachable by specific nurture. On the other hand, the study of Ben-Chaim, Lappan and Houang (1988) concluded that spatial ability can be improved when appropriate instruction is supplied. Goldstein and Chance (1965) also argued that a skill which can be modified or improved with a small training could not be a stable attribute.

In the literature, several studies reported that spatial visualization skills increase with grade level (Fennema & Sherman, 1977; Guay & McDaniel, 1977; Ben-Chaim et al., 1988). For instance, Ben-Chaim et al. (1988) conducted a study on fifth through eighth grade students to investigate differences in spatial visualization abilities and effects of instruction on spatial visualization skills by grade, sex and site. They found a positive correlation between grade level and spatial visualization skills. After the treatment, the gain by boys and girls was found to be similar and their spatial visualization was developed in the same way. Moreover, they concluded that the spatial visualization ability increases with increasing socioeconomic status. Likewise, spatial ability was considered to be affected by previous experiences, the variety of activities, and socioeconomic status (Higgins, 2006). Thus, it was declared that spatial visualization skills can be learned and are teachable (Ben-Chaim et al., 1988).

The other possible factor which was claimed to develop spatial ability was the existence of some form of treatment. Bishop (1980) accepted spatial ability as a teachable skill and he emphasized the importance of a detailed analysis to construct a clear relationship between the ability being taught and the instruction. For instance, Noyes (1997) investigated the effect of treatment on spatial abilities of 5^{th} and 6^{th} grade students and discovered that the provided intervention caused a significant increase in the spatial ability scores of the students in experimental group. Another study regarding the improvement of spatial ability by training was conducted by Brinkmann (1966) on eighth grade students. The 60 students were assigned into two groups according to their visualization pretest scores and gender. One group received no training while the treatment group received the programmed instruction in elementary geometry including topics like points, lines, angles, planes for three weeks. In order to measure spatial ability, Spatial Relations Test, a subtest of Differential Aptitude Test was used. The results indicated that the performance of the treatment group was significantly higher than the control group in spatial visualization and geometry inventory and Brinkmann (1966) discovered that spatial visualization can be improved by training. In another experimental study, which was conducted by Battista et al. (1982), the cognitive development for geometry learning and spatial visualization of preservice teachers were examined. They also investigated the effect of instruction type on development of spatial ability. The Purdue spatial visualization test was used to measure spatial visualization abilities of the participants. The results of the study showed that the participants who took spatial activities obtained significantly higher scores. Thus, the researchers asserted that the reason for this difference was the type of activities like paper folding, tracing and symmetry but they suggested further research studies to decide whether the geometry instruction including spatial activities would be more beneficial for students or not.

Many researchers claimed that it is possible to improve spatial ability if appropriate materials are provided (Battista et al., 1982; Ben-Chaim et al., 1988; Moses, 1977; Onyancha, Derov, & Kinsey, 2009; Robichaux & Rodrigue, 2003; Sorby & Baartmans, 2000). For instance, Robichaux (2000) conducted a research study to explain the development of spatial ability. She discovered that spatial visualization ability could be developed gradually with one’s childhood experiences which were affected by family income, gender, and occupations of family members. Likewise, Sundberg (1994) administered an experimental study on 800 sixth, seventh and eighth grade students and found that spatial ability of the spatial group was greater than that of the geometry group. As a consequence, she asserted that spatial ability could be improved with instruction based on concrete materials in the middle grades (Sundberg, 1994). Similarly, Bishop (1973) asserted that being taught with manipulative materials improves the spatial abilities of primary school students. Students appear to be able to build ideas about shapes better through active participation in lessons, rather than passive observation (Bishop, 1973). In the same way, geometry and visualization were claimed to be improved with digital manipulatives (Dixon, 1995; Olkun, 2003a) and concrete manipulatives (Battista, Clements, Arnoff, Battista, & Borrow, 1998; Sundberg, 1994). In addition, this idea was supported by educational and psychological research which alleged that children should explore the objects fully, considering their parts, characteristics, and transformations (Clements, 1998). These provide the opportunity to look at the impact of 2D and 3D representations on the development of spatial ability.

Another factor improving spatial ability was suggested as toys which were played in childhood. There were some research studies conducted on young children regarding their toy playing behavior and spatial ability. For instance, in the study, a possible relation between toy playing in childhood and spatial ability was examined (Tracy, 1987; Roorda, 1994). The results supported the view that playing with various toys improves spatial ability of children considerably.

Since the development of technology is quite fast, its use in educational areas is inevitable. Multimedia software programs are also asserted to be beneficial in terms of development of spatial ability in some studies. For instance, Gerson, Sorby, Wysocki and Baartmans (2001) conducted an experimental study and compared a group of students who worked with software and workbook and another who had traditional lessons. The students in the group who worked with software recorded better performance in a quiz and the standardized test administered at the end of the study. A similar study was conducted on mechanical engineering students by Onyancha, Derov, and Kinsey (2009). They investigated the improvement of the spatial abilities of engineering students who took the Computer Aided Design course with a pre-post test design. At the end, the spatial ability scores of students were found to be significantly higher after the course (Onyancha et al., 2009). Likewise, Sorby and Baartmans (2000) prepared a course named ‘Introduction to Spatial Visualization’ at Michigan Technological University in order to develop the spatial abilities of freshman students. Specifically, the students who scored poorly on spatial ability tests and the ones who are interested in the course were enrolled in the course. The course consisted of topics like isometric drawing, orthographic sketching, flat pattern development and object rotating. They declared that the spatial abilities of the students in the experimental group, in which the students enrolled the course, were significantly higher than that of the control group. Moreover, in another study, Okagaki and Frensch (1994) claimed that the computer game Tetris developed the spatial visualization performance and mental rotation pace of college students. According to Raquel (2001), Geometer’s Sketchpad, a program in which a student can explore geometric concepts and manipulate the geometric structures interactively, was propounded as another beneficial computer program for spatial ability. She conducted a study on 18 tenth grade students. Since Geometer’s Sketchpad program provides students an environment where they can discuss, explore, estimate, assume and share ideas with their peers, it would help them to think and manipulate images easily so they can think spatially (Raquel, 2001). The results indicated that the spatial abilities of the students were significantly developed with the help of an instruction in which students worked on challenging questions about 3D geometric objects. Indeed, Raquel (2001) suggested Geometer's Sketchpad based instruction to make students think coherently and improve their spatial abilities.

It was claimed that teachers affect their students not only in terms of personal behavior but also intellectually so they should develop their own spatial visualization ability before improving their students' (Martin, 1968). Furthermore, Stancil and Melear (1991) asserted that unless teachers encourage their students to think visually and provide homework improving spatial visualization, they cannot expect students to comprehend or show an increased interest in their lessons. Clements (1998) advised teachers to make students express their ideas with multiple representations, such as drawing images, building models, dramatizing situation, and expressing their ideas verbally. In addition, the concepts related to space and shape can be learned by actively engaging in manipulatives, computer programs, and drawings. The number of teaching programs which enable such learning has been growing gradually (Clements, 1998). Likewise, Werthessen (1999) claimed that hands-on materials were beneficial for the development of spatial visualization, mental rotation and self-efficacy. When students actively interact with concrete models and computer programs, they will gain different perspectives. However, in the study of Eastman and Barnett (1979), there was no significant difference between the spatial visualization abilities of students who were taught by using manipulatives and who were taught by the demonstration teaching method. Thus, methods for improving the spatial skills need to be planned carefully and their feasibility and sensibility should be evaluated (Sherman, 1979).

Actually, there is no consistent consensus among researchers about whether spatial ability can be improved or not. Although most of the studies revealed that it can be improved with the help of appropriate materials or treatments, there were few studies resulting that spatial ability cannot be improved. In addition, based on the studies mentioned above, most of the research studies were conducted on middle school, elementary school, primary school students and young children but the number of studies conducted on preservice teachers is limited. Thus, in the present study, the spatial ability levels of preservice teachers were investigated.

2.2.3 Studies on Gender Difference in Spatial Ability

The importance of gender in learning mathematics is emphasized by many researchers as it is a crucial variable to be considered in scientific researches (Armstrong, 1981; Ethington, 1992; Halat, 2008; Kaufman, 2007; Lloyd, Walsh & Yailagh, 2005). According to Lawton (1994), there is not an agreement among researchers about the existence of gender difference in spatial ability (Kaufman, 2007; Lawton, 1994; Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Postma, Jager, Kessels, Koppeschaar, & van Honk, 2004; Voyer, Voyer, & Bryden, 1995). For example, a study was conducted on 145 high school students to investigate the effect of spatial visualization on gender difference in geometry by Battista (1990). He used Purdue spatial visualization test to measure participants' spatial visualization level and paper and pencil tests to measure logical reasoning, geometry knowledge and geometrical problem solving strategies. In the end, it was found that there was a sexual difference between high school students' spatial visualization, regarding their geometry performance but there was not a sexual difference related to geometric problem solving strategies of students (Battista, 1990). Battista (1990) claimed that spatial visualization and logical reasoning can be accepted as two important agents in learning geometry for all students but these factors can affect males and females differently.

In the literature, male performance on spatial visualization is superior to female performance in most of the situations (Battista, 1990; Harris, 1981; Sherman, 1980; Linn & Petersen, 1985; Voyer, 1995). The reasons for the gender difference in spatial ability are attributed to many factors by researchers. Some of these reasons are; genetic explanations (Allivatos & Petrides, 1997; Grimshaw, Sitarenios, & Finengan, 1995; Harris, 1981; Kimura & Hampson, 1994; Linn & Petersen, 1985), educational experiences (Richardson, 1994), parental encouragements towards gender-typed activities (Lytton & Romney, 1991), social experiences (Baenninger & Newcombe, 1989), and gender role identification (Signorella & Jamison, 1986). First of all, researchers believe that the left hemisphere of an individual is described as responsible for analytical/logical thinking in both verbal and numerical operations while right hemisphere was specialized in spatial tasks and artistic efforts (Capraro, 2001). Capraro (2001) stated that according to the brain psychology, the distribution of functions between the cerebral hemispheres of the brain caused the gender differences in verbal and spatial ability. That is to say, spatial tasks are performed in right hemisphere of the brain whereas verbal tasks are carried out in left hemisphere. Left hemisphere was claimed to affect the progress of spatial ability in a negative way. Therefore, females, who automatically use verbal strategies for problem solving, are more likely to have low spatial ability (Coluccia & Louse, 2004). On the other hand, boys were propounded to have higher right hemispheric specialization (Allivatos & Petrides, 1997). In addition, some researchers emphasized the importance of gender difference in spatial visualization in school curricula (Casey et al., 2001; Kersh, 1981; NCTM, 2000). Verbal skills have the greatest emphasis in mathematics lessons while spatial skills are not mentioned in most of the curriculum (Casey et al., 2001). On the base of this information, girls are at risk for low spatial ability while boys' verbal ability is supported in mathematics lessons by the teacher.

Another explanation for sexual difference in spatial visualization is learning, practice, and socialization (Harris, 1981; Linn & Petersen, 1985). The difference in spatial ability can be caused by the difference in the amount of time spent in spatial activities. In general, the games that are preferred mostly by males in their childhood contribute to the improvement of their spatial ability seriously (Lawton & Morrin, 1999). Team sports, Lego construction, and video games can be considered as the activities developing spatial ability of a child (Coluccia & Louse, 2004). A study was conducted on 1-year-old children to investigate toy preference of girls and boys and they discovered that there exists a difference in toy preference between boys and girls (Jacklin, Maccoby, & Dick, 1973). It was claimed that boys preferred vehicles and blocks which were beneficial for spatial manipulation whereas girls preferred stuffed animals and dolls which improved social skills (Etaugh & Liss, 1992; Voyer et al., 1995). Namely, it is reasonable to say that boys are more advantageous in terms of improving spatial ability than girls.

The nature of spatial task is also accepted as one of the factors of gender difference in spatial ability in large scale meta-analysis (Hamilton, 1995; Linn & Petersen, 1985; Voyer, 1995). Linn and Petersen (1985) investigated the sex differences by taking the categories of spatial ability into consideration. They founded that large gender difference was detected in mental rotation and manipulation of objects in favor of males. However, there was medium gender difference for spatial perception and small gender difference for spatial visualization tasks (Linn & Petersen, 1985). Besides, Maccoby and Jacklin (1974) asserted in their meta-analysis that males are better in visual-spatial tasks in early adolescence and adulthood. They attributed the sexual difference in mathematics achievement to the difference in visual-spatial tasks.

Moè and Pazzaglia (2006) claimed that motivational aspects also affect the spatial abilities of males and females. It is believed that men are faster than women in answering questions. Unless time is limited, girls can be as successful as boys in spatial tests (Birenbaum, Kelley, & Levi-Keren, 1994) but the task difficulty (Collins & Kimura, 1997) and the accuracy in the answers (Scali, Brownlow, & Hicks, 2000) increase the gender difference in spatial tests.

Another factor that was estimated to cause gender difference in spatial ability is cultural effect (Richardson, 1994). According to Richardson (1994), it is always stated in the literature that males are better than girls in spatial ability and this causes males to gain self-confidence in this field and inverse is valid for females. Since there is a stereotype that males think better in spatial situations, females lose their self-confidence in spatial tasks. Therefore, males get spiritual advantage over females and develop various strategies in spatial tasks with self-confidence (Richardson, 1994). In addition, Fennema and Sherman (1977) advocated that taking space-related courses may cause sexual differences in spatial ability tests. Space-related courses are preferred by boys because they get higher scores in those lessons. On the other hand, there is a disagreement in the existence of gender difference in spatial visualization. In a more recent comprehensive review done by Masters and Sanders (1993), a large gender difference is confirmed to exist in favor of boys. On the contrary, another study on sexual difference in spatial visualization was conducted on 13-year-old children by Armstrong (1985). The results of that study supported that girls have better performance than boys in spatial visualization test.

Some studies gave emphasis on gender difference in geometry and the reasons for the difference. For instance, Fennema and Carpenter (1981) examined the mathematics items of National Assessment of Educational Progress and noticed the significant gender difference in favor of males especially in geometry and measurement areas. They offered spatial visualization as a differentiating factor in geometry problems. According to many studies, the correlation coefficient changes from .30 to .60 and males always outperform females (Ben-Chaim et al., 1988; Fennema & Tartre, 1985; Harris, 1981; Johnson & Meade, 1987).

Yet, there are also some studies resulting in no significant gender difference in spatial visualization (Boulter, 1992; Fennema & Sherman, 1977, 1978; Manger & Eikeland, 1998; Pleet, 1990). For instance, Boulter (1992)'s and Fennema & Sherman (1977, 1978)'s studies accomplished as there is no sex-related differences between middle school students. To illustrate, Boulter (1992) conducted a study on the 7^{th} and the 8^{th} grade students to investigate the instruction in transformational geometry on spatial ability and no significant effect of instruction was found in the study. In addition, there was no sexual difference in spatial abilities of the students. Moreover, Manger and Eikeland (1998) conducted a study investigating the relationship between gender and spatial visualization ability and mathematics achievement of 724 sixth grade students. They concluded that males are more successful than females in terms of mathematics achievement but there is no significant sexual difference in terms of spatial ability.

Taking all the above studies into consideration, some measures that should be taken by mathematics teachers to lessen gender difference in spatial ability were advised. They play important role in improving students' spatial abilities. For instance, teacher can present not only the analytical solution but also visual solutions to students (Casey et al., 2001). Secondly, Casey et al. (2001) advised that textbooks should encourage multiple representations of solutions. In addition, Robichaux (2000) advised some methods to lessen gender difference among students. She suggested giving opportunity to all students to construct models, draw pictures and manipulate blocks frequently. In this way, females will join activities voluntarily to work with their peers and improve their spatial ability at the same time so gender difference in spatial ability will be lessened (Robichaux, 2000). As it was declared in many studies that girls' performance was worse than boys, the teachers should encourage girls to have more spatial experiences like model building, sewing clothes, drawing 3D objects to improve their technical skills (Quasier-Pohl & Lehmann, 2002). Therefore, it was advised that families should give opportunities to girls to have technical experiences beginning from early childhood like repairing their bicycles (Quasier-Pohl & Lehmann, 2002). Moreover, they suggested that computer courses which were designed by considering the interests and experiences of girls should be developed to lessen gender gap in terms of spatial ability. In this way, girls will have the chance of modifying their achievement-related self-concept about technical skills (Bussey & Bandura, 1999). Hence, teachers should try to provide such an environment, which is full of spatial tasks, to develop spatial abilities of both girls and boys starting at early ages (Ben-Chaim et al., 1985; Connor, Serbin, & Schackman, 1977).

As can be seen, many studies focused on the gender differences in students' spatial ability and the reasons for the difference. The teachers' spatial ability also plays an important role in development of students' spatial ability. Therefore, in the present study, whether there is a gender difference in spatial visualization ability levels of preservice teachers are evaluated.

2.2.4 Studies on Relationship between Spatial Ability and Mathematics Achievement

In the literature, numerous studies resulted in the strong relationship between spatial ability and mathematics achievement of students (Battista, 1980, 1994; Fennema & Sherman, 1977; Guay & McDaniel, 1977; Guzel & Sener, 2009; Jakubowski & Unal, 2004; Manger & Eikeland, 1998; Mitchelmore, 1976; Sherard, 1981). The need for collection of more data before one can interpret a reliable relationship between spatial visualization and mathematics learning was stressed by Lean and Clements (1981) and Bishop (1980). Smith (1964) analyzed whether spatial ability is correlated with mathematical conceptualization or not. His study is an evidence of the positive correlation between these variables. Learners with greater spatial ability usually do well in high-level mathematical problems (Smith, 1964). However, he also indicated that it does not mean that those learners with greater spatial ability will acquire easily low-level mathematical concepts and skills (Guay & McDaniel, 1977). Furthermore, Guay and McDaniel (1977) described the positive relationship between mathematical thinking and spatial ability in elementary grades, but, they also emphasized that the relationship is valid for both low- and high-level spatial abilities.

As spatial ability and mathematics achievement was claimed to be positively correlated, engagement with more spatial activities was suggested to improve mathematical thinking of the learners (Battista, 1994; Mitchelmore, 1976). According to Battista et al. (1982), the research studies did not explain the relationship between spatial ability and mathematics achievement sufficiently, therefore, the necessity of spatial ability for learning some mathematics topics was not considered.

There also exists a controversy among researchers about the presence of relationship between spatial visualization and mathematical problem solving. Some studies have made inferences as a strong relationship (e.g., Barrat, 1953; Moses, 1977; van Garderen & Montague, 2003), whereas others have found little or no relationship (Campbell, Collis, & Watson, 1995; Friedman, 1992; Lean & Clements, 1981). Fennema and Tartre (1985) discovered that students who had high spatial visualization ability performed better in translating the symbols into drawings although the better drawings did not always mean the correct solutions to problems. In addition, Moses (1977), in her experimental study related to spatial ability of 5th grade students, investigated the relationship between spatial ability and mathematical problem solving and effects of instruction consisting perceptual tasks. She used the Card Rotation Test and Punched Holes Test, Figure Rotation Test, Form Board Test and Cube Comparison Test (Ekstrom, French, Harman, & Derman, 1976) in order to measure spatial ability. A mathematical problem solving instrument was also developed for the study. Before and after treatment, all tests were administered on two groups. The results revealed that spatial ability was a good predictor of students' problem-solving performance and training with perceptual tasks had a positive effect on spatial ability but not on problem solving performance. Moreover, she found a positive correlation between spatial ability and problem solving performance.

In summary, it was declared by many studies that spatial ability has a positive relationship with mathematics achievement. However, there are some studies claiming that there is no relationship between these variables. Thus, more research studies are needed to make this issue clear.

2.2.5 Research Studies on Relationship between Spatial Ability and Geometry

Geometry occupies a crucial place in mathematics curriculum because it provides students to improve deductive structure by combining the theories of mathematics with real life situations (Hvizdo, 1992). The main goal of geometry course was stated as to improve students' spatial abilities by giving various representations in teaching the relations and three dimensional shapes (Ben-Chaim, Lappan, & Houang, 1989, as cited in Boulter, 1992). Ben-Chaim et al. (1989) claimed that experiences with concrete materials have a significant effect on geometry achievement of students (as cited in Boulter, 1992). Similarly, Sherard (1981) stressed the importance of geometry in mathematics curriculum by defining geometry as an integrating source for arithmetical, algebraic, and statistical concepts' visualization. Many researchers claimed that spatial ability has an important role in understanding geometry (Unal, Jakubowski, & Corey, 2009). Therefore, it is convenient to say that spatial visualization has a great importance in geometry.

In the same way, NCTM (2000) stressed the importance of geometry with the statement "geometry is a natural place for the development of students' reasoning and justification skills" (p. 40). Also, for K-12 instructional programs, NCTM (2000) suggested four abilities which were expected from students: "(a) analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships, (b) specify locations and describe spatial relationships using coordinate geometry and representational systems, (c) apply transformations and use symmetry to analyze mathematical situations, and (d) use visualization, spatial reasoning, and geometric modeling to solve problems"(p. 41). As can be seen, visualization is one of the four main concepts in teaching geometry curriculum (NCTM, 2000). As spatial visualization is a critical factor in mathematics learning, it is convenient to say that spatial visualization has an important effect on geometry achievement.

Wheatley (1990) claimed that spatial sense includes various abilities such as drawing tables, graphs and diagrams, looking for patterns. If a teacher's geometry knowledge was limited and/or his spatial ability level was low, he may not be proficient to comment on curriculum revisions or meet the needs of students (Unal et al., 2009). Most of the teachers disregard the pictorial level and teach directly in abstract level. Students who have spatial sense have the chance of using their ability to solve problems but others have difficulties since their concept knowledge is insufficient (Bruner, 1966 as cited in Casey et al., 2001). Bruner (1966) suggested teachers to spend less time on rules and algorithmic operations and more time on showing spatial models to make students comprehend basic concepts. Likewise, Clements (1998) defended that many primary school teachers do not make an effort in order to improve young children's spatial ability although it is claimed that spatial reasoning is known to be an important factor for people to interpret the physical environment and to comprehend the mathematics and science lessons. In his study, Clements (1998) examined the geometric and spatial thinking of young children and asserted that geometry helps students to comprehend, interpret and reflect their surroundings. He examined young children's spatial ability in terms of spatial orientation and spatial visualization components. For spatial orientation, he suggested teachers to make their students create mental maps suitable for their age. For instance, a map with toys such as houses, cars and trees can be constructed by a 3-years-old child. On the other hand, for spatial visualization, Clements (1998) advised teachers to make their students gain experiences related to perspective by block building activities. In such activities, children should notice various viewpoints and in the end should be able to decide the viewpoint from which the given view can be seen (Clements, 1998). In addition, he praised computer activities, to improve the navigational skills of students, manipulative works such as pattern blocks and tangram, and pictures especially for 5 or 6 years of children. Moreover, the pictures were advised to be quite various in order to improve students' creativity (Clements, 1998). The results of the study showed that spatial ability supports geometry achievement and creative thought in all topics of mathematics (Clements, 1998).

The subsection of geometry related to spatial ability tasks is called transformational geometry and it includes translations (slides), reflections (flips), and rotations (turns) of objects on two-dimensional plane and three-dimensional space (Boulter, 1992). Boulter (1992) pointed out the existence of the relationship between spatial ability and geometry achievement, specifically transformational geometry. Rotating images mentally and using spatial sense are required in transformational geometry tasks so it is supposed from students with high spatial ability to show a better performance in those tasks (Boulter, 1992).

In contrast to above studies, there are few studies resulting that there is little or no relationship between spatial ability and geometry achievement. For example, Pandiscio (1994) examined the theoretical relationship between mental rotation and proficiency in certain geometric tasks. The results of the study showed that the measure of spatial ability does not significantly predict geometry achievement of high school students.

As mentioned above, the importance of spatial visualization, one of the components of spatial ability, in terms of children's mathematics and geometry achievement was emphasized in many research studies (Bulut & Koroglu, 2000; Linn & Petersen, 1985; Clements & Battista, 1992; Fennema & Sherman, 1977; Guay & McDaniel, 1977; Lean & Clements, 1981). Although spatial visualization is a prerequisite for mathematics and geometry achievement, the activities developing spatial visualization abilities of students do not take place in school curricula (Ben-Chaim et al., 1988). In a recent study, Higgins (2006) stated that the topics related to spatial ability exist under geometry topics in school curriculum. Since spatial ability level of students affect their mathematics and geometry achievements, elementary school curricula should be developed in a way to improve spatial abilities of students (Hvizdo, 1992).

The situation in Turkey is not different from other countries. Olkun (2003a) defended that the former geometry curriculum does not support students to develop their spatial abilities and the source of this problem may be teachers who are not sure whether an activity improves spatial ability or not. Hence, the school curricula should be revised by considering the improvement of spatial visualization abilities of students. In addition, teachers should be informed about the importance of the concept. Based on the results of all the studies mentioned above, the attention of educators should be directed to the learning and teaching of geometry and spatial thinking since the achievement of students in geometry and spatial reasoning is quite low (Clements, 1998). Thus, in the present study, the spatial visualization level of preservice teachers was investigated to attract the attention of educators and policy makers to this issue in Turkey.

2.2.6 Research Studies Related to Spatial Ability in Turkey

There also exist some studies related to the improvement of spatial ability with the help of treatment or course in Turkey. For instance, Boyraz (2008) conducted an experimental study on 7th grade students and examined the effects of two geometry based computer instruction on spatial ability and students' attitudes toward mathematics and technology. She suggested curriculum developers to design geometry curriculum in a way to develop spatial ability of students. She also advised the computer based instruction to be taken into consideration during curriculum development process. Moreover, Boyraz (2008) claimed that mathematics textbooks in elementary schools in Turkey do not include activities developing spatial abilities of students. Therefore, she concluded that mathematics textbooks' authors should add such activities to textbooks in order to improve spatial abilities of students. Another similar study conducted in Turkey was related to the improvement of spatial abilities of middle grade students with the help of engineering drawing activities (Olkun, 2003b). He selected engineering drawing for the treatment since it was used in many technical occupations in real life and it could be accepted as a concrete experience which is helpful in improving spatial visualization performance. In the end, the results showed that spatial ability can be developed with engineering drawing treatment.

In another study, Yıldız (2009) investigated how the usage of 3D virtual environment affects the spatial visualization and mental rotation abilities of 5th grade students. A pretest-posttest experimental design (Quasi-experimental design) was used and the results revealed that there was a statistically significant difference between experimental group and control group in terms of spatial visualization test scores. Nevertheless, for mental rotation scores, there was no difference between groups. Moreover, a study was conducted by Bayrak (2008) to investigate the effect of an instruction consisting curricular activities such as transformation, computer-based manipulative and origami on spatial ability. Spatial ability test (Ekstrom et al., 1976) was used to measure spatial abilities of 6th grade students. The results revealed that there was a significant effect of instruction on spatial visualization and spatial orientation.

Cakmak (2009) aimed to find the effect of origami-based instruction on spatial visualization and spatial orientation abilities of 6th, 7th and 8th grade students. The results revealed that there is a significant positive effect of the treatment on both spatial visualization and spatial orientation abilities of students. In another similar study, the effect of high school type and logical thinking ability and technical drawing course on spatial ability was investigated (Kayhan, 2005). The sample of the study was 251 ninth grade students who were enrolled to general, Anatolian, foreign language, commercial vocational and industrial vocational high schools. Kayhan (2005) used Spatial Ability Test (card rotation, cube comparison, paper folding and card rotation parts) by Ekstrom et al. (1976) and Group Test of Logical Thinking. It was revealed in the results of the study that high school type has no effect on spatial ability while mathematics achievement, logical thinking and technical drawing courses have a significant positive relationship with spatial ability. In addition, she claimed that after technical drawing course, the participants' spatial ability was developed significantly. In another study, Guzel and Sener (2009) directed the attention of teachers to the improvement of spatial ability and claimed that in order the lesson to be more effective, teacher should use visual materials and use his/her body language effectively.

The effect of spatial ability on other courses was also investigated in some studies. For instance, the effect of mathematics achievement, spatial ability and logical thinking ability on achievement in Physics course for 9th grade students was examined by Delialioglu (1996). The results of his study revealed that there exists a significant positive relationship between spatial ability and physics achievement.

2.2.7 Self-Efficacy

There are various definitions for self-efficacy in the literature. Bandura (1977)'s formal theoretical definition of self-efficacy is "Perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). In addition, Zimmerman (1995) defined self-efficacy as an individual's value judgements related to his or her capability of executing a task successfully. Moreover, Schunk (1991) defined academic self-efficacy as individuals' beliefs that they can successfully perform given academic task at specified levels. Social cognitive theorists asserted that people's choices, efforts and anxiety levels are affected by their self-efficacy beliefs (as cited in Isiksal & Askar, 2005).

According to Bandura (1986), there are four sources of self-efficacy: (a) enactive mastery experience, (b) vicarious experience, (c) verbal persuasion, and (d) physiological and affective states.

Bandura (1986) also claimed that enactive mastery experience, specifically past success and failure, has the greatest influence on self-efficacy. Success is asserted to encourage self-efficacy beliefs while failures have reducing effects (Bandura, 1986). According to Bandura (1997), if failures occur just before the strong self-efficacy establishment, they have a reducing impact on an individual's capabilities to perform well. Moreover, easily obtained successes are claimed to be detrimental for people since they may be discouraged and disheartened when faced with difficulties (Bandura, 1997).

The second source was vicarious experience that means an individual's arrangements in his or her efficacy beliefs after observing other people's or models' performances (Usher & Pajares, 2008). Schunk (2000) claimed that "observing similar others succeed raises observers' self efficacy and motivates them to try the task because they believe that if others can succeed, they can as well" (p. 109). This source of self-efficacy is claimed to be most influential in case the observer has limited experiences or is unsure about his/her capabilities (Bandura, 1997; Pajares, 1997).

Verbal persuasion is the third source of self-efficacy. When an individual does not have self evaluation for the performances on tasks, he/she needs appraisals of others such as parents and teachers (Usher & Pajares, 2006). This source of self-efficacy may not influence the individual for a long time; the effects of such source may be short-term (Usher & Pajares, 2009). Even it may have negative influences in self-efficacy beliefs since it is easier to undermine self-efficacy of an individual (Bandura, 1997).

The fourth and last source, physiological and affective states, includes feelings such as stress, mood, tension, emotion, and pain. These feelings may affect the judgements on self-efficacy of individuals (Hodges & Murphy, 2009). That is, the anxiety that may be felt when starting a new task may cause misinterpretations.

It was asserted that an individual who has high self-efficacy belief feel serenity in approaching difficult tasks but an individual who has low self-efficacy belief may think that things are more difficult than they really are so he/she feels stress, anxiety and depression towards that task (Pajares, 2007). That is, if a person believes that his action cannot produce the outcome that he wants, he has little encouragement to act or to face difficulties (Pajares, 2002). Thus, self-efficacy beliefs encourage human motivation, achievement and happiness (Pajares, 2002). Similarly, Gawith (1995) claimed that even a person has the necessary ability to do a task; he/she cannot be successful unless he/she has self-efficacy related to the task (as cited in Cantürk-Günhan & Başer, 2007). In the same way, Bandura (1977) claimed that self-efficacy beliefs determine whether an individual will attend the task and the amount of effort the individual will perform in case of interferences. In most of the studies, self-efficacy was used in order to explain the reason for the performance variety between people who have similar knowledge and abilities (Pajares & Miller, 1995).

Many studies were conducted to examine the relationship between mathematics performance and other variables like attitudes toward mathematics, mathematics self-efficacy (Hacket, 1985; Hackett & Betz, 1989; Isiksal & Askar, 2005; Pajares & Miller, 1995). Mathematics self-efficacy beliefs were defined by Hackett and Betz (1989) as assessing the situational confidence of an individual in his/her capability to perform a specific mathematical task or problem successfully. There are studies measuring the mathematics self-efficacy beliefs of elementary school and high school students and preservice teachers. For instance, Isiksal (2005) conducted a study in order to investigate the effect of gender and year in program on coursework and self-efficacy beliefs of preservice teachers in Turkey. She found significant difference in self-efficacy beliefs and performance of preservice teachers in terms of gender and year in the program. Females outperformed males on performance scores that contradict previous studies in the literature. Similarly, self-efficacy scores of females were higher than that of males (Isiksal, 2005). Another study was administered with 262 undergraduate students who were enrolled in an introductory psychology course to determine their mathematics self-efficacy expectations (Hackett & Betz, 1981). The results of the study revealed that mathematics self-efficacy scores of males were significantly higher than females. Moreover, males had greater positive attitude towards mathematics and greater confidence in mathematics performance (Hackett & Betz, 1981). In addition, Isiksal and Askar (2005) carried out an experimental study investigating the effect of spreadsheet and dynamic geometry software on the achievement and mathematics self-efficacy of 7th grade students. There were two experimental groups; one took the Excel software program and the other group took Autograph software program. There was also a control group. In that study, mathematics self-efficacy and computer self-efficacy scales were used to determine the participants' self-efficacy beliefs. Moreover, mathematics achievement test was used in evaluating the mathematics performance. The results revealed that Autograph group had highest scores in both achievement test and self-efficacy scale. The researcher investigated the results in terms of gender and concluded that boys obtained significantly higher scores in computer self-efficacy scale and were more willing to join the computer activities. However, there were no effects of treatments in mathematics self-efficacy and mathematics performance.

The relationship between spatial ability and science disciplines was revealed to be positive in the literature. For instance, Kinsey, Towle, O'Brien and Bauer (2008) analyzed the spatial ability and self-efficacy and their effect on retention for engineering students. They reported that there was a significant correlation between self-efficacy and spatial ability and this meant that higher spatial ability leads to higher self efficacy scores for engineering students. In addition, the results revealed that spatial ability was important with respect to the retention of engineering.

Literature review showed that there were limited studies examining the relationship between spatial ability and geometry self-efficacy. Furthermore, there were few studies focusing on the geometry self-efficacy beliefs of preservice teachers, which is an important part of mathematics lesson. As indicated above, there is a close relationship between spatial ability and geometry performance. Thus, geometry self-efficacy will be another concern of the present study.

In the next section, the relationship of spatial ability and spatial anxiety, another variable of this study, will be mentioned.

2.2.8 Spatial Anxiety

An individual can learn from environment by encoding visual images, by changing his/her perspective regularly and by doing senso-motoric interactions (Schmitz, 1997). Therefore, it is safe to say that the effects of human feelings such as anxiety and confidence should be examined in research studies. Spatial anxiety was defined as "anxiety about environmental navigation" (Lawton, 1994, p. 767). Moreover, Schmitz (1999) defined spatial anxiety as "worry about becoming lost" (p. 75). The effects of spatial anxiety on individual's behaviors were examined in some research studies. For instance, Lawton (1994) found the relationship between spatial anxiety and the use of strategies. It is believed that spatial anxiety prevents one from focusing on the clues in the environment to find his way. According to the results of Lawton (1994)'s study, if an individual has greater spatial anxiety, he is liable to get lost.

In the literature, there exist some studies examining the spatial anxiety in terms of gender. For example, Wigfield and Eccles (1992) investigated the gender difference in mathematics achievement and students' anxieties and self confidence about their success. The results of their study showed that girls have lower self-confidence and greater spatial anxiety than boys. Moreover, girls got lower grade on mathematics tasks than boys and this result supported the relationship between self-confidence and spatial anxiety and capability.

In another study, Schmitz (1997) examined whether there exists a relationship between anxiety and environmental learning in 3D wayfinding tasks or not, and examined the effect of gender on these tasks. A maze was prepared for the study and each individual in the sample was made to find the way in that maze one by one. Then their strategies, anxiety level and the time spent on wayfinding task were evaluated. The results indicated that male had less anxiety and performed faster in the maze compared to girls. On the contrary, girls showed high levels of anxiety, used landmarks while running in the maze and they were slower than males. This supports the ideas that there is a gender difference in terms of anxiety level and strategy selection and there is a negative correlation between spatial anxiety and walking speed in the maze and higher anxiety prevents people from exploring unfamiliar places in daily life (Bryant, 1982; Kozlowski & Bryant, 1977). In another study, Hund and Minarik (2006) investigated the relationship between spatial anxiety and navigation performance. The results of this study supported the previous studies. They found a negative relationship between variables since the ones who had greater anxiety made more navigation errors.

In Malinowski (2001)'s study, males outperformed females in finding targets by using map and compass in a military orienteering test. Moreover, in O'Laughlin and Brubaker (1998)'s study, girls showed more anxiety in drawing the plan of a floor and they were not as successful as boys in wayfinding task in a building. Similarly, Lawton (1994) also declared the greater anxiety of girls in navigation tasks.

He reported that males preferred global reference points such as cardinal directions, North, South, East and West, to explain their strategies whereas females preferred landmarks. On the other hand, there are also studies resulting in no gender difference in wayfinding tasks and anxiety levels. Likewise, Bryant (1982)'s study was one of the studies that found a nonsignificant gender difference in anxiety. In the same way, an experimental study was also conducted by Hund and Minarik (2006), and it was noticed that there was not a significant gender difference related to spatial anxiety.

The former studies claimed that one of the reasons for gender difference was genetic sex hormones (Kimura, 2002). Another reason was declared as the stress and anxiety of a known stereotype such as "males' spatial ability is greater than females" (Osborne, 2001; Spencer, Steele, & Quinn, 1999). Another important reason was; giving less freedom to girls to explore the surroundings in their childhood (Herman, Heins, & Cohen, 1987; Matthews, 1986). Lawton and Kallai (2002) explained that since boys are freer to interact with outside environment, they feel less anxiety while finding their way and this causes a gender difference in wayfinding tasks.

There were studies that concentrate on the relationship between anxiety and gender. For instance, the Hungarian and American samples were compared in terms of sexual difference in wayfinding preferences and anxiety levels (Lawton & Kallai, 2002). It is found that when the concern level about safety increases, the anxiety increases as well (Lawton & Kallai, 2002). Since the outside world is more dangerous for girls than boys, their anxiety level is higher in both Hungarian and American girls. As a result, the decisions of girls related to choosing rotation, and even job preferences were affected by anxiety level. For instance girls may prefer longer but more familiar roads and jobs that do not require travelling unfamiliar places (Lawton & Kallai, 2002).

In another study of Lawton et al. (1996), it is asserted that the environment should be more complicated in order to detect a sexual difference in terms of navigation. Furthermore, spatial anxiety was found to be negatively related to spatial perception and mental rotation tasks in Lawton (1994, 1996)'s studies. It is clear that individuals who has low spatial sense and high spatial anxiety become confused and anxious, thus lose their way unconsciously.

Based on the studies above, it can be said that spatial anxiety is a crucial factor affecting individual's behavior and performance. Moreover, there are lots of studies showing a gender difference in spatial anxiety of individuals in terms of success in mathematics performance, navigation performance, strategy preference, and environmental learning. The relationship between spatial perception and mental rotation, two components of spatial ability, and spatial anxiety was also investigated. However, the number of studies investigating the relationship between spatial visualization ability, another component of spatial ability, spatial anxiety, and gender were limited. Thus, one purpose of the present study was to explore the relationship between spatial visualization ability and spatial anxiety in terms of gender.

2.3 Summary of Literature Review

In summary, the importance of spatial ability in education has been known for many years and many research studies have been conducted. Yet, there is no specific definition for spatial ability. Moreover, spatial ability has components and the number of components generally changes between two and three among researchers. In present study, the researcher focused on spatial visualization component of spatial ability.

As can be seen above literature review, in most of the studies, researchers asserted that spatial ability has a relationship with achievement in science and mathematics lessons. In addition, NCTM (1989, 2000) stressed the necessity of spatial ability in geometry learning and teaching. Thus, spatial ability is one of the important factors to be searched in teaching and learning mathematics.

Literature review also showed that spatial ability of an individual can be improved with the help of treatment, concrete materials, manipulatives, various toys and computer programs (Battista et al., 1982; Ben-Chaim et al., 1988; Bishop, 1973, 1980; Dixon, 1995; Noyes, 1997; Okagi & Frensch, 1994; Olkun, 2003b; Robichaux & Rodrigue, 2003; Sundberg, 1994; Werthessen, 1999). Therefore, teachers' role in developing spatial ability of students is quite important. Since, most of the studies were conducted on middle school, elementary school, primary school students and young children; there is a need to investigate the spatial ability level of preservice teachers.

In the literature there are also studies that focus on the gender difference in spatial ability of students. Moreover, the reasons of the gender difference were investigated in many studies (Allivatos & Petrides, 1997; Baenninger & Newcombe, 1989; Grimshaw et al., 1995; Harris, 1981; Kimura & Hampson, 1994; Linn & Petersen, 1985; Lytton & Romney, 1991; Richardson, 1994; Signorella & Jamison, 1986). Some of the suggested reasons are genetic (Allivatos & Petrides, 1997; Grimshaw et al., 1995; Harris, 1981; Linn & Petersen, 1985), some are educational (Richardson, 1994), some are motivational (Moè & Pazzaglia, 2006) and some are cultural (Richardson, 1994). Since teachers are the potential candidates who could improve spatial abilities of students, their own spatial ability levels should also be investigated. Therefore, in the present study, the spatial ability levels of preservice teachers are investigated. In addition, gender difference in terms of spatial ability of preservice teachers is evaluated.

Self efficacy was claimed by social cognitive theorists to affect individuals' decisions, efforts and anxiety levels (Isiksal & Askar, 2005). Literature consists of studies examining the relationship between self-efficacy and mathematics performance or mathematics self-efficacy and other variables such as computer self-efficacy, mathematics performance. However, the studies investigating the geometry self-efficacy are limited. Therefore, one of the concerns of the present study will be geometry self-efficacy.

The other variable that was taken into consideration in the present study is spatial anxiety. Literature review revealed that spatial anxiety is a crucial factor affecting individual's behavior and performance (Lawton, 1994). Moreover, there is a sexual difference in spatial anxiety levels of the participants in terms of success in mathematics performance (Wigfield and Eccles, 1992), navigation performance (Hund & Minarik, 2006), strategy preference (Hund & Minarik, 2006; Lawton, 1994), and environmental learning (Schmitz, 1997). In addition, the relationship between spatial perception and mental rotation, two components of spatial ability, and spatial anxiety was investigated in some studies (Lawton, 1994, 1996). However, the number of studies investigating the relationship between spatial visualization ability, another component of spatial ability, and spatial anxiety are limited. Thus, in the present study, the relationship between spatial visualization and spatial anxiety was investigated.

Above literature review shows that most of the researchers studying on spatial ability investigated the duo relationship such as spatial ability versus mathematics achievement. However, the present study consists of geometry self-efficacy, spatial anxiety, undergraduate program and gender constructs together. In other words, the present study aims to investigate the relationship among spatial visualization, spatial anxiety and geometry self-efficacy of preservice teachers. Moreover, preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety were investigated in terms of undergraduate program and gender.

CHAPTER 3

METHODOLOGY

In this chapter, methods and procedures of the study are discussed. Particularly, design of the study, population and sample, instruments, data collection procedures, data analysis, assumptions and limitations, and lastly internal and external validity of the study are stated.

3.1 Design of the Study

The main purpose of this study was to investigate the relationships among preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety in terms of undergraduate program and gender. The other purpose of the study was to investigate the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety. In order to investigate the research questions, quantitative methods were used. Specifically, two associational research types, causal-comparative research and correlational research, were preferred. Data were analyzed through one-way ANOVA, independent samples t-test, two-way ANOVA, and Pearson Product-Moment Correlation.

3.2 Population and Sample

The target population of the study was all preservice teachers in Central Anatolia Region. Twelve universities in Central Anatolian Region have elementary education undergraduate program. All preservice teachers enrolled in elementary teacher education programs (Elementary Mathematics Education, Elementary Science Education, and Early Childhood Education) in five large universities in Ankara were identified as an accessible population of the present study. The students who were enrolled in 3rd and 4th grades of four universities (private and state universities) in Ankara were the sample which was one third of the target population.

Convenience sampling method was used in order to select the sample of the study. In convenience sampling method, researchers collect data from the individuals who are available (Fraenkel & Wallen, 2006). To collect more representative data, all universities in Ankara which have elementary education undergraduate program were selected. One of the universities was a private university (University 4) whereas other three (University 1, 2 and 3) were state universities. Participants were 1007 preservice teachers who were studying at 3rd and 4th grades of four universities. The reason of selecting 3rd and 4th grade students was that they completed the most of the courses of their programs. In addition, it was quite difficult to reach 1st and 2nd graders since they took most of their courses at various departments. Table 3.1 summarizes the number of students in each university in terms of gender.

Table 3.1 Number of Preservice Teachers Participated in the Study Based on the Universities

	Male	Female	N
University 1	38	120	158
University 2	55	222	277
University 3	124	359	483
University 4	7	82	89
Total	224	783	1007

Particularly, there were 158 (15.66%) participants from the 1st university, 277 (27.45%) from the 2nd university, 483 (48.07%) from the 3rd university, and 89 (8.82%) from the 4th university. As it can be seen in Table 3.1, the number of female participants was greater than male participants in each university. This is the characteristics of education faculties in Turkey since teaching seems as a female profession like in many other countries (Isiksal, 2005). Moreover, the 3rd university has the greatest number of students among others. The number of male participants was quite low compared to females in the 4th university.

Table 3.2 illustrates descriptive statistics of the participants in terms of gender and undergraduate program.

Table 3.2 Number of Female and Male Participants Based on the Undergraduate Programs

	Female	Male	Total
EME	286	114	400
ESE	331	105	436
ECE	166	5	171
Total	783	224	1007

As it can be seen in Table 3.2, the number of female participants was 783 (77.76%) and this number is three times more than the number of male participants which was 224 (22.24%). In addition, in all undergraduate programs, the number of male participants was less than that of female participants. For instance, the number of females was 331 while the number of males was only 105 for ESE undergraduate program. The least number for males was in ECE undergraduate program with 5 participants which is quite low. Moreover, the number of participants in ECE undergraduate program (*N* = 171) was less than EME (*N* = 400) and ESE (*N* = 436) undergraduate programs.

In the next section, data collection instruments are explained in detail.

3.3 Instruments

The purpose of the present study was to investigate the relationship between preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety in terms of gender and undergraduate program. In addition, the relationship among spatial visualization ability, geometry self-efficacy, and spatial anxiety of preservice teachers were evaluated. To gather the data, Spatial Visualization Test

(SVT), Geometry Self-Efficacy (GSE) Scale and Spatial Anxiety (ANX) Scale were used. These tests are explained in detail in the following sections.

3.3.1 Spatial Visualization Test (SVT)

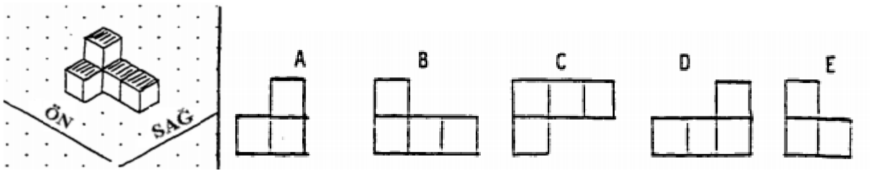
Spatial abilities of preservice teachers were measured with "Spatial Visualization Test" (SVT) which was developed by Lappan, Fitzgerland, Phillips, Winter, Ben-Chaim, Friedlander, Oguntebi, and Yarbrough (1983) in the *Middle Grades Mathematics Project* (MGMP) at Michigan State University. In fact, the scale was developed for 6^{th}, 7^{th}, and 8^{th} grade students in the project. However, as Robichaux (2000) mentioned, the test was implemented on adults in many studies since some of the images are complex for elementary school students to rotate or imagine. Therefore, the scale was accepted to be appropriate for preservice teachers after consulting the mathematics education experts. Moreover, according to Olkun (2003b), the SVT measures both spatial visualization and spatial relations abilities. Thus, in this study, SVT was used to measure preservice teachers' spatial ability.

The scale consists of 32 multiple-choice questions. In general, the items of the test consist of the 2D and 3D views of the building. In this test, preservice teachers were expected to imagine the appearance of the building the top view of which was given, to calculate the number of cubes to construct the building the corner view of which was given, to imagine the view from another corner view of the building, and to imagine the top view of the building with the help of given two-dimensional views. Moreover, there are some questions to make individuals imagine the final appearance when some cubes are added or taken out of the building given. Further, imagining the combination of the two given buildings is another type of question in the test. For the final form of the SVT, see Appendix A. The sample items of SVT are illustrated in *Figure 3.1*. The objectives of the SVT could be categorized into 10 as in Table 3.3.

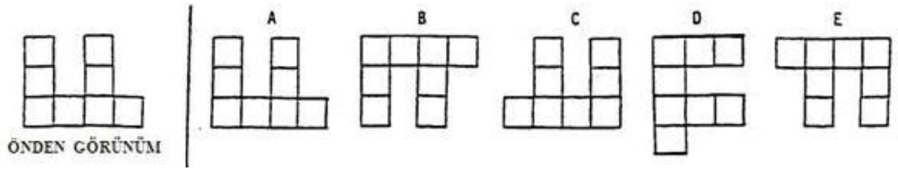
Table 3.3 Objectives of SVT Questions (Turgut, 2007, pp. 46-47)

Questions Numbers	Explanation for Question Type
1, 2, 3	3D corner view of the building is given. 2D view of the building from front, back, right or left is asked.
4, 5, 6	2D view of the building from front, back, right or left is given. The 2D another view of the building is asked.
7, 8	3D corner view of the building is given. The number of cubes to construct the given building is asked.
9, 10, 11	Top view of a building is given. 2D view of the building from front, back, right or left is asked.
12, 13	3D corner view of the building is given. The number of cube that the signed cube touches face to face is asked.
14, 15, 16, 17	Top view (without number of cubes inside the squares), front view and right side view of a building are given. Top view with number of cubes are written inside the cubes is asked.
18, 19, 20, 21	3D corner view of the building is given. A cube is signed and the final view when a cube is added over the signed cube or next to signed cube is asked.
22, 23, 24	Top view of a building is given. One of the corner views of the building is asked.
25, 26	Two 3D buildings are given. Any combination of these two buildings is asked. The buildings can be rotated mentally.
27, 28, 29, 30, 31, 32	3D corner view of the building is given. Any of other corner views of the building is asked.

1. ÖN-SAĞ köşeden görünümü verilen yapının **SAĞ**'dan görünümü aşağıdakilerden hangisidir?



5. ÖN'den görünümü verilen yapının **ARKA**'dan görünümü aşağıdakilerden hangisidir?



10. Kuş bakışı görünümü verilen yapının **ÖN**'den görünümü aşağıdakilerden hangisidir?

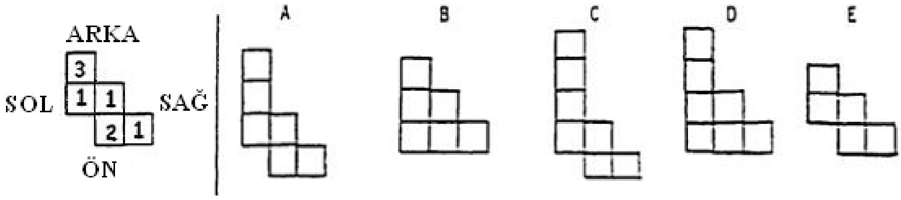


Figure 3.1 Sample items of spatial visualization test.

For instance, the numbers written inside the squares in question 10 in *Figure 3.1* represent the number of cubes on that area. In that question, participants were expected to select the 2D view belonging to the front side of the given building.

MGMP spatial visualization test was previously used by Ben-Chaim, Lappan and Houang (1988) and in that study they administered the test with Differential Aptitude Space Relations Test on the students in grades 8 through 12. In order to provide evidence for validity, they calculated the correlation coefficient as .66 that means large correlation according to the guidelines suggested by Cohen (1988, pp. 79-81). In addition, in the literature, the Cronbach's alpha value was reported to change in the range of .72 and .86 which was of satisfactory value for Fraenkel and

Wallen (2006). Thus the SVT was highly reliable and valid and appropriate to be used in the present study.

The participants obtained “1” if their answer for an item is true, otherwise, they obtained “0” points. The researcher calculated an SVT total score for each participant to determine the spatial ability levels. That is, an individual who answer all 32 items correct will gain 32 points as an SVT score.

3.3.2 Geometry Self-Efficacy (GSE) Scale

The Geometry Self-Efficacy (GSE) Scale was developed by Cantürk-Günhan and Başer (2007) in order to measure the self-efficacy of the individuals about geometry. The scale consists of 25 items on a 5-point Likert type items (1-Never, 3-Undecided, 5-Always). Obtaining high score in this scale means that the participants have high geometry self-efficacy. The scale has three sub-dimensions which are positive self-efficacy beliefs, beliefs on the use of geometry knowledge, and negative self-efficacy beliefs. A sample item for each sub-dimension is given in Table 3.4.

Table 3.4 Sample Items of GSE Scale Sub-Dimensions

Sub-Dimension	Sample Item
Positive self-efficacy beliefs	When I see a geometrical shape, I can remember its properties.
Beliefs on the use of geometry knowledge	I believe that if I select a job related to the use of geometrical knowledge in the future, I will be successful.
Negative self-efficacy beliefs	I cannot explain the relationships between geometrical shapes.

Reliability analysis and factor analysis of GSE were employed by Cantürk-Günhan and Başer (2007) and the scale was found to be highly reliable and valid. For the final form of the GSE scale, see Appendix B.

3.3.3 Spatial Anxiety (ANX) Scale

The spatial anxiety (ANX) scale was developed by Lawton (1994) to measure the level of anxiety felt by an individual in eight situations which require spatial/navigational skills. The scale was a 5-point scale and it consisted of 8 items with two end points labeled 1-Not at all and 5-Very much. Obtaining high score from this scale means that the participants have higher spatial anxiety. Sample items of ANX scale is given in Table 3.5.

Table 3.5 Sample Items of ANX Scale

Leaving a store that you have been to for the first time and deciding which way to turn to get to a destination
Pointing in the direction of a place outside that someone wants to get to and has asked you for directions, when you are in a windowless room.
Trying a new route that you think will be a shortcut without the benefit of a map.

As indicated before, the education language is Turkish in all of the universities in the present study so the scale was translated into Turkish by the researcher. After the pilot study, it was overviewed and implemented to the sample of the study.

3.4 Pilot Study

The aim of the pilot study was to check validity and reliability of the instruments that were translated into Turkish and to determine the possible difficulties that may occur in the actual administration. For these purposes, the pilot study of SVT, GSE and ANX scales was conducted with 115 preservice teachers who were freshman and sophomore preservice teachers from elementary mathematics education (EME), elementary science education (ESE) and early childhood education (ECE) programs in the 1st university. There were 91 females and 24 males in the pilot study. Thus, these preservice teachers in the pilot study did not constitute the sample of the present study.

First of all, the SVT and ANX scale questions were translated into Turkish by the researcher since the education language is not English in all four universities in the present study. GSE scale was in Turkish so there was no need to translate it. The appropriateness of the expressions in terms of cultural and psychological aspects is important in translating a scale into another language (Hambleton, 2005). Therefore, following the translation process, the tests were controlled by two experts from mathematics education program, two English teachers and twelve teacher educators. They examined the tests for whether the meanings of sentences were the same in original test and the translated version of the test and whether the sentences were clear for pre-service teachers. With the help of their interpretations, the spatial visualization test and spatial anxiety scale were finalized. All three tests were administered on the students at one time in the pilot study. Then, reliability analysis and item analysis were employed. In the application process of the pilot study, the researcher also considered the questions of participants to understand whether the statements, images and views in the questions were clear or not. After the pilot study, no change was done on GSE and ANX scales. However, the researcher decided to change the order of SVT items, since the participants had difficulties to concentrate on the questions in the pilot study. That is, the items measuring the same objectives were not successively ordered in the original test. Therefore, the participants had difficulties in understanding the questions when passing from one item to another measuring the other objective. Thus, they got bored and lost time. For the final forms of tests, see Appendices A, B and C.

3.4.1 Reliability and Validity of Spatial Visualization Test

Initially, item analysis was employed by ITEMAN software in order to evaluate item difficulty and item-discrimination of SVT items. Item difficulty was defined by Hopkins, Stanley and Hopkins (1990) as "the percent of the group tested that answered the question correctly" (p. 268). In suitable tests, most of the items were desired to be moderate. The percentages of the SVT questions in terms of difficulty were summarized in Table 3.6.

Table 3.6 Percentage of SVT Questions in terms of Item-Difficulty

Item difficulty	Percentage of questions (%)
Easy	9.1
Moderate	77.3
Difficult	13.6

As it can be seen in Table 3.6, 77.3 percent of the questions were moderately difficult. The percentages of difficult (13.6) and easy questions (9.1) were low, so the scale was appropriate in terms of item difficulty.

As indicated, the other information that is yielded by item analysis is item discrimination which measures "how effectively the item discriminates between examinees who are relatively high on the criterion of interest and those who are relatively low" (Crocker & Algina, 1986, p. 313). For item discrimination, the thumb adapted by Hopkins, Stanley and Hopkins (1990) from Ebel (1965) was used. The guideline is given in Table 3.7.

Table 3.7 Item Guideline for Item-Discrimination

Point-Biserial Correlation	Item evaluation
.40 and greater	Very discriminating item
.30 – .39	Discriminating item
.20 – .29	Reasonably discriminating item
.10 – .19	Marginally discriminating item, usually subject to improvement
.10 and below	Unproductive item for the test reliability purposes

This guideline was said to be used when describing the contribution of an item to the reliability of the test, and the item's sensitivity to measuring individual differences (Hopkins, Stanley, & Hopkins, 1990). The item analysis results reported that 72.7 percent of the items had point biserial correlation value as .40 and greater so they were very discriminating items. Moreover, 22.7 percent of the items had biserial correlation value between .30 and .39, which means those items were discriminating items. Lastly, the percentage of the items that had point biserial correlation value between .20 and .29 was 4.5 percent and those items were reasonably discriminating items. Since there was no item in SVT that had point biserial correlation value less than .19, there was no need to revise an item or remove an item from the scale.

In addition, the items were evaluated in terms of their difficulties. By considering the item analysis results, for each question, the most intended wrong items were revised and the drawings of those questions were renewed.

For the scales which were dichotomously scored, *r* value was calculated with Kuder-Richardson formulas in order to check internal consistency. KR-21 is used when the scale is dichotomously scored and difficulties of items were equal (Crocker & Algina, 1986). However, based on the results of item analysis, the difficulties of SVT items were not equal. “KR-20 does not require the assumption that all items are of equal difficulty” (Fraenkel & Wallen, 2006, p. 160). Therefore, Formula 3.1 (Pallant, 2007) was used in the present study.

$$KR\text{-}20 = r = \frac{K}{(K-1)}\left[1- \sum_{i=1}^{K} p_i . q_i \;\; / \sigma^2_{total}\right] \quad (3.1)$$

In the Formula 3.1, K is the number of items, p_i is the proportion of people with a score of 1 on the kth item, q_i is the proportion of people with a score 0 on the kth item, and σ^2_{total} is the variance of the scores on the total test.

It was claimed that “For research purposes, a useful rule of thumb is that reliability should be at least .70” (Fraenkel & Wallen, 2006, p. 161). In the present study, r was found as .73 which means SVT could be accepted as reliable. Similar to this value, in item analysis of SVT results, alpha value was reported to be .73 which is satisfactory for reliability of tests in social studies (Fraenkel & Wallen, 2006). Thus, the test was reported to be reliable.

Validity of a test means the degree to which the test measures what it intends to measure reference. In order to assure content validity, the opinions of mathematics educators and doctoral students were considered. With the help of their comments, the order of the spatial visualization test items was changed. The items aiming to measure the same capability were brought together.

3.4.2 Reliability and Validity of Geometry Self-Efficacy (GSE) Scale

For the reliability of GSE scale, Cantürk-Günhan and Başer (2007) administered a pilot study on 385 elementary students. The Cronbach alpha values for each sub-dimension of the scale calculated by Cantürk-Günhan and Başer and the researcher of the present study were summarized in Table 3.8.

Table 3.8 Cronbach Alpha Values

Sub-Dimensions	Number of items	Cronbach's alpha	Alpha Values of the Present Study
Positive self-efficacy beliefs	12	.88	.89
Negative self-efficacy beliefs	6	.70	.75
Beliefs on the use of geometry knowledge	7	.70	.83
General	25	.90	.93

According to the information given in Table 3.8, the reliability of the GSE scale was satisfactory (.90). In the present study, Cronbach's alpha value for three sub-dimensions were reported to be .89 for *positive self-efficacy beliefs* sub-dimension, .75 for the *negative self-efficacy beliefs* sub-dimension, and .83 for *beliefs on the use of geometry knowledge* sub-dimension. Moreover, for the whole scale alpha value was calculated by the researcher as .93 which was of quite high value according to the criteria of Fraenkel and Wallen, (2006). Thus the scale was found to be highly reliable in both analyses.

Cantürk-Günhan and Başer (2007) conducted factor analysis to check validity of the scale. They mentioned that the items loaded in three factors explained the 42.4 percent of the variance.

According to the factor analysis results conducted by the test developers, the first factor explains 27.41 percent of the variance with 12 items; the second factor explains 9.81 percent of the variance with 6 items; third factor explains 5.20 percent of the variance with 7 items.

In the same way, in the present study it was reported that the items loaded in three factors explained the 53.3 percent of the variance. In Table 3.9 the factors and the variances that they explained are summarized.

Table 3.9 Factors and Variances GSE Scale Items

Factors	Total	% of Variance	Cumulative %
1	9.939	39.76	39.76
2	1.973	7.89	47.65
3	1.418	5.67	53.32

According to the factor analysis results conducted by the researcher, the first factor which is related to *positive self-efficacy beliefs* explains 39.76 percent of the variance with 12 items; the second factor which is related to *negative self-efficacy beliefs* explains second 7.89 percent of the variance with 6 items; third factor which is related to *beliefs on the use of geometry knowledge* explains 5.67 percent of the variance with 7 items. Thus, construct-related evidence was provided for validity. In addition, for content-related validity of the scale, the ideas of the experts who are faculty members, teacher educators and doctoral students were taken into consideration.

As a result, the GSE scale was reported to be highly reliable and valid.

3.4.3 Reliability and Validity of Spatial Anxiety (ANX) Scale

Lawton (1994) asserted that, the scale items were generated by two psychologists. In the test development procedure, 419 people were involved and their expressions about what makes them feel anxious while finding a way were evaluated (Lawton, 1994).

For reliability of ANX scale, the Cronbach's alpha was reported by Lawton (1994) to be .80. This value means that the ANX scale was highly reliable (Fraenkel & Wallen, 2006). The researcher of the present study also calculated Cronbach's alpha after the pilot study as .87 which also assured high reliability for the scale.

According to the analyses of Lawton (1994), the oblique factor analysis results showed that the scale has only one factor. The factor loading values were in the range of .60 and .75. The researcher translated this scale into Turkish and consulted experts in order to assure content validity. With the help of their interpretations, the spatial anxiety scale was revised. In order to assure construct validity, the researcher also conducted factor analysis. Before running the analysis, the researcher checked the assumptions, *sample size*, *factorability of the correlation matrix*, *linearity* and *outliers among cases*, which are indicated by Pallant (2007).

Pallant (2007) stated that there should be at least five cases for each item in order to assure sample size assumption. ANX scale includes eight items so at least fourty cases are sufficient. The pilot study included 115 cases therefore sample size assumption was assured.

The factorability of the correlation matrix assumption requires three rules. Specifically, at least some correlations should be $r = .3$ or greater in correlation matrix, the Bartlett's test of Sphericity should be significant ($p = .05$) and Kaiser-Meyer-Olkin value should be .6 or above (Pallant, 2007). The correlation matrix values are illustrated in Table 3.10.

Table 3.10 Correlation Matrix

		anx1	anx2	anx3	anx4	anx5	anx6	anx7	anx8
Correlation	anx1	1.00	-.50	.57	.72	.41	.61	.43	.51
	anx2	.50	1.00	.52	.53	.34	.37	.21	.35
	anx3	.57	.52	1.00	.51	.45	.43	.48	.39
	anx4	.72	.53	.51	1.00	.33	.51	.44	.55
	anx5	.41	.34	.45	.33	1.00	.51	.39	.22
	anx6	.61	.37	.43	.51	.51	1.00	.45	.46
	anx7	.43	.21	.48	.44	.39	.45	1.00	.58
	anx8	.51	.35	.39	.55	.22	.46	.58	1.00

As it can be seen in Table 3.10, most of the correlations are above .3 so this rule is assured. The values of Kaiser-Meyer-Olkin and Bartlett's test of Sphericity are listed in Table 3.11.

Table 3.11 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.846
Bartlett's Test of Sphericity	Approx. Chi-Square	394.73
	df	28
	Sig.	.000

Table 3.11 illustrates that Bartlett's test of Sphericity is significant (p = .05) and Kaiser-Meyer-Olkin value is above .6. As a result, the factorability of the correlation matrix assumption was assured.

Pallant (2007) asserted that the relationship between the variables is assumed to be linear since factor analysis is based on correlation. Thus, linearity assumption was assumed to be assured in the pilot study.

Finally the outliers were checked before running factor analysis to assure outliers among cases assumption. There were no outliers among cases so the data set was suitable to conduct factor analysis.

In order to determine the number of factors, a few pieces of information should be checked (Pallant, 2007). Kaiser's criterion or the eigenvalue rule is one of them. Only the factors having eigenvalue 1 or more are retained for further investigation in studies (Pallant, 2007).

Table 3.12 Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.23	52.83	52.83

Table 3.12 illustrates the details about eigenvalues. As it can be seen, there was only one component that has eigenvalue of 4.23 > 1. Screeplot also illustrates the factors of the scales. The change or elbow in the shape of the plot gives clue about the number of the factors. *Figure 3.2* illustrates the screeplot of the analysis.

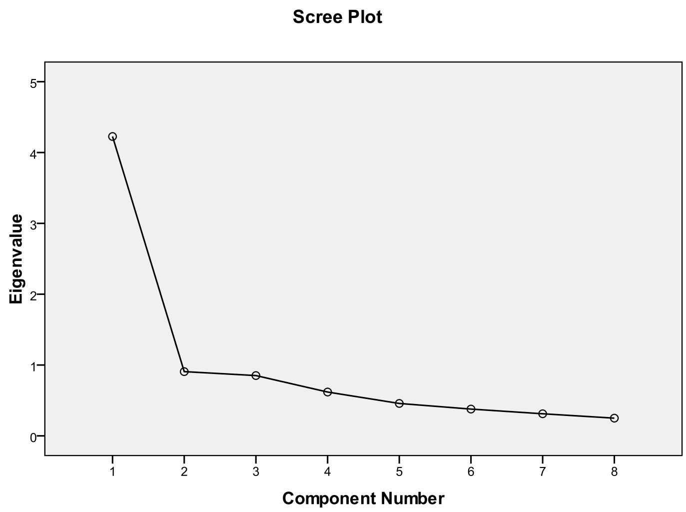


Figure 3.2 Screeplot.

If the screeplot is examined, it can be seen that there is a change after first component so ANX scale has one factor. Finally component matrix table showing unrotated loadings of each item was examined to determine the number of factors. Pallant (2007) stated that the items load quite strongly if its value is greater than .4 in component matrix table. Table 3.13 illustrates the component matrix loads.

Table 3.13 Component Matrix

	Component 1
anx1	.83
anx4	.81
anx3	.76
anx6	.75
anx8	.70
anx7	.68
anx2	.66
anx5	.61

The component matrix table illustrates that all items' loads are above .4 so all items load quite strongly.

Based on the factor analysis results, only one factor was found like Lawton (1994) and this factor explained 52.83% of the variance. As a result, ANX scale was reliable and valid for the study. For the final form of ANX scale, see Appendix C.

3.5 Data Collection Procedure

The necessary official permission was obtained from Middle East Technical University Human Subjects Ethics Committee before the data collection process. Moreover, the researcher took permission from four universities one of which was a private university.

The data of the pilot and actual study were collected during the second semester of the 2009-2010 academic year. First of all the data collection instruments were selected. In order to measure spatial ability of participants, Spatial Visualization Test (MGMP, 1983) was selected and translated into Turkish. Geometry Self-efficacy Scale (Cantürk-Günhan & Başer, 2007) was selected to measure geometry self-efficacy of the participants. The scale was in Turkish so there was no need to translate it. The last scale was Spatial Anxiety Scale (Lawton, 1994) to measure spatial anxiety of the participants. Moreover, the demographic information such as gender, university name, undergraduate program, and grade level was collected from the participants.

The pilot study was administered in order to control whether the measuring instrument items work or not, and to detect the possible problems that the researcher and the participants may confront during the administration. All three tests were filled in by the voluntary elementary education students who were studying at 1st and 2nd grades of the 1st university. The administration order of the tests was GSE, ANX, and SVT. In other words, Spatial Visualization Test was applied after the self-efficacy and anxiety scales. The reason for this order was to prevent the possible effect of the administration of SVT on the remaining tests. After the pilot study, reliability and validity of the scales were evaluated. Then, the scales were revised based on the results of the pilot study.

The actual study was administered on 3rd and 4th year preservice teachers of four universities in Ankara. All three scales were administered at one time on the participants by the researcher in their classrooms. The researcher mentioned the purpose of the study and how to answer each test to the participants at the beginning of the administration. In addition, consent form was prepared and signed by the participants to answer items honestly and to be informed about their responsibilities. The participants were not asked to write their names to make them feel comfortable in the process and to ensure confidentiality of the research data. Moreover, the researcher respected the rights of participants to refuse to participate in the study or to withdraw from participating at any time. All the participants filled in the tests voluntarily. There was no time limit for the application. In most of the classes, the application was done in final part of the lesson after the instructor has finished lecturing.

3.6 Data Analysis

In this study, quantitative research methodologies were used to analyze data through SPSS PASW program. For descriptive statistics; mean, standard deviation, skewness and kurtosis values were calculated. Independent samples t-test, one-way ANOVA, and two-way ANOVA were used in order to investigate the difference in spatial visualization ability, geometry self-efficacy and spatial anxiety of preservice teachers in terms of undergraduate program and gender. Moreover, Pearson product-moment correlation analyses were run to examine the relationship among three test scores (SVT, GSE and ANX). Eta square was calculated to investigate the practical significance of the results.

In the next section, assumptions and limitations of the study will be mentioned.

3.7 Assumptions and Limitations

The basic assumptions and limitations of the present study are discussed in this section.

At the beginning, the participants were assumed to respond to the items of the three instruments (SVT, GSE and ANX) honestly and independently. However, the time of the application was not the same for all classes. Some of the students took the tests in the morning, some of them in the afternoon, and some in the evening. This might affect students' thinking ability, concentration and mood. The students taking the scales in the evening might be tired and this might lessen their motivation which could be accepted as a limitation. Another issue for limitations could be sampling method. As universities were not selected with random sampling method, the generalization of the results of the study to a larger population will be limited. Moreover, the sample includes 3^{rd} and 4^{th} grade students of education faculties so this may restrict the researcher to generalize the solutions to all preservice teachers. Furthermore, spatial visualization ability test was used to measure spatial abilities of the participants and the relationship between spatial visualization scores and spatial anxiety scores was investigated. However, spatial anxiety scale was basically related to spatial orientation component of the spatial ability and this might be the other limitation. But, in this study, spatial anxiety scale was used since anxiety is accepted as a general construct. Moreover, spatial visualization test measures both spatial visualization and spatial orientation components of spatial ability as mentioned above.

3.8 Internal and External Validity of the Study

The issues discussed in this part of the method chapter are internal and external validities.

3.8.1 Internal Validity

Internal validity of a study refers to the observed difference on dependent variable caused by the independent variable of the study, not because of any other unintended variable (Fraenkel & Wallen, 2006). In general, for causal-comperative studies, the possible internal threats were *subject characteristics*, *mortality*, *location*, and *instrumentation* (Fraenkel & Wallen, 2006).

"The selection of people for a study may result in the individuals (or groups) differing from one another in unintended ways that are related to the variables to be studied" was defined as subject characteristics threat by Fraenkel and Wallen (2006, p. 170). To control subject characteristics threat, the students of the close grade levels (3^{rd} and 4^{th}) were chosen so their personal characteristic such as age was close to each other. In addition, data were collected from all students in the classrooms. Therefore, it was assumed that there was no subject characteristics threat.

Mortality, in other words loss of subjects, is another threat to be considered in research studies. However, Fraenkel and Wallen (2006) stated that there is no mortality threat for internal validity of correlational studies since the lost ones must be excluded from the study.

The researcher selected all 3^{rd} and 4^{th} classes in EME, ESE and ECE programs. However, when the administration was done, some of the students were absent. Therefore, some of the sample was lost inevitably. However, the researcher selected the courses that all of the 3^{rd} and 4^{th} grade students took in that semester by consulting their instructors because elective courses were not taken by all of the students in that grade. In this way, maximum participation was assured. Moreover, it was asserted that a researcher should have a score for each participant on both of the variables being measured in order to obtain a correlation (Fraenkel and Wallen 2006). The participants of the present study filled in all of the scales in the administration so each participant had a score for each variable. As a result, mortality should not be a threat for this study.

Fraenkel and Wallen (2006, p. 172) explained the location threat as “The particular locations in which data are collected, or in which an intervention is carried out, may create alternative explanations for results”. The location threat may also have an effect on the results of the study. The researcher administered the scales on students in their own classrooms but all classrooms did not have the same conditions. For instance, some of the classrooms were more crowded than others. Moreover, the time of application was variable. Some of the students took the tests in the morning, some in the afternoon, and some in the evening. This might affect students’ thinking ability, mood or concentration. In addition, the students taking the scales in the evening might be tired and this might lessen their motivation which can be accepted as a negative effect. Thus, this threat might affect the results of the study. However, the researcher tried to provide standard conditions for all classes.

Lastly, there can be some problems in the results of research studies related to the instrument of the study which is called instrumentation threat. When the instrument was changed or scored in a different way, instrument decay may occur (Fraenkel & Wallen, 2006). In the present study, the questions of two scales were adapted into Turkish but the scoring of those scales were the same. Moreover, the data were entered by optic form reader so there was no instrument decay threat. Another thing to consider controlling instrumentation threat was the characteristics of the data collector (Fraenkel & Wallen, 2006). Since the researcher was also the data collector and she administered the scales to all of the classes of the sample herself, the data collector characteristics were the same for all classes. Therefore this issue will not be a threat to the present study. The last issue to be thought for instrumentation threat was data collector bias which means that the data collector may change the result in the way intended unconsciously (Fraenkel & Wallen, 2006).

The data collector was trained by experts in terms of what to explain at the beginning of the application and how to behave in a standard way during the application. In addition, there was no treatment in the application that encourages the interaction and communication between the participants and the data collector. Therefore, data collector bias could not be a threat to the study.

3.8.2 External Validity

External validity can be defined as the degree to which the results can be generalized to the population (Fraenkel & Wallen, 2006). In order to generalize the results of the study to the population, the sample should represent the population in terms of nature and environmental issues. The target population of the study was all preservice teachers who study at the universities located in Central Anatolia Region. All preservice teachers enrolled in elementary teacher education programs in five big universities (one private and four state universities) in Ankara were accessible population of the study. The students who were enrolled in 3rd and 4th grade classes of four universities in Ankara were the sample of the present research study. The programs included in the study were EME, ESE, and ECE. The sampling method was convenience sampling so it is hard to generalize the results of the study to the population. In addition, in Central Anatolian Region, there are many universities but the universities located in Ankara accept students who get relatively higher scores at the national university entrance examination. As a result, the sample includes more successful students which limit the generalizability of the results. However, the results of the present study can be generalized in some clearly defined conditions. Fraenkel and Wallen (2006) defined this type of generalizability as ecological generalizability which means “the extent to which the results of a study can be generalized to conditions or settings other than those that prevailed in particular study” (p. 108). For instance, in the present study, the participants took most of pedagogical courses and gained the necessary knowledge related to the teaching profession. Moreover, they live in big cities, and their scores at the national university entrance exam were high. Thus the results of the present study can be generalized to the students having the conditions mentioned.

CHAPTER 4

RESULTS

The purpose of this research study was to investigate the difference between spatial visualization ability, geometry self-efficacy, and spatial anxiety of preservice teachers in terms of undergraduate program and gender. Besides, the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety was evaluated. The previous chapters were related to the review of the previous studies and method of the present study. This chapter summarizes the results of the study in two sections. Descriptive statistics are explained in the first section and inferential statistics of the quantitative analysis of the study are summarized in the second.

4.1 Descriptive Results

In this section, descriptive statistics regarding the Spatial Visualization Test (SVT), Geometry Self Efficacy (GSE) Scale and Spatial Anxiety (ANX) Scale will be given. The data were collected during the spring semester of the 2009-2010 academic year from elementary mathematics education (EME), elementary science education (ESE) and early childhood education (ECE) undergraduate programs' students. Totally, 1007 preservice teachers responded to all three scales.

The standard deviation and mean scores of SVT with respect to undergraduate program and gender are listed in Table 4.1.

Table 4.1 Descriptive Statistics of SVT with respect to Undergraduate Program and Gender

Gender	Undergraduate Program	M	SD	N
Female	EME	19.56	6.08	286
	ESE	17.40	5.62	331
	ECE	16.13	6.67	166
	Total	17.92	6.16	783
Male	EME	22.30	5.38	114
	ESE	20.62	6.62	105
	ECE	20.20	5.54	5
	Total	21.46	6.03	224
Total	EME	20.34	6.01	400
	ESE	18.17	6.03	436
	ECE	16.25	6.66	171
	Total	18.71	6.31	1007

The analysis for SVT was done with total scores of the items to obtain a spatial visualization level score for each participant. As can be seen in Table 4.1, the mean score for EME students was 20.34 (*SD* = 6.01), the mean score for ESE students was 18.17 (*SD* = 6.03) and that of ECE students was 16.25 (*SD* = 6.66). The mean scores of SVT for all undergraduate programs were reported as above midpoint score that is 16. This means that participants of the study had relatively moderate levels of spatial ability. If the SVT scores are examined in terms of gender, it can be noticed that the mean scores of males were greater than that of females for all undergraduate programs. Moreover, for both males and females, EME students had the greatest mean scores.

The standard deviation and mean scores of geometry self-efficacy scale scores with respect to undergraduate program and gender are listed in Table 4.2.

Table 4.2 Descriptive Statistics of GSE Scores with respect to Undergraduate Program and Gender

Gender	Undergraduate Program	M	SD	N
Female	EME	3.95	.45	286
	ESE	3.97	.50	331
	ECE	3.82	.65	166
	Total	3.93	.52	783
Male	EME	4.06	.53	114
	ESE	4.21	.46	105
	ECE	4.16	1.03	5
	Total	4.14	.52	224
Total	EME	3.98	.48	400
	ESE	4.03	.51	436
	ECE	3.83	.66	171
	Total	3.98	.53	1007

The analysis for GSE scale was done with mean scores of the items to obtain a geometry self-efficacy score for each participant. The results yielded that the geometry self-efficacy of the preservice teachers was relatively high. To illustrate, the mean score for EME students was 3.98 (*SD* = .48), for ESE students 4.03 (*SD* = .51) and for ECE students 3.83 (*SD* = .66) which were around 4 out of 5. When gender variable was inspected, the self-efficacy of the males was greater than that of females for all undergraduate programs. That is, the males had higher geometry self-efficacy with mean score 4.06 (*SD* = .53) for EME students, 4.21 (*SD* = .46) for ESE students and 4.16 (*SD* = 1.03) for ECE students. On the other hand, the geometry self-efficacy mean scores of females were 3.95 for EME students, 3.97 for ESE students and 3.82 for ECE students.

Finally, Table 4.3 is an overall summary of the descriptive statistics of spatial anxiety scores with respect to undergraduate program and gender and the standard deviation and mean scores are listed.

Table 4.3 Descriptive Statistics of ANX Scores with respect to Undergraduate Program and Gender

Gender	Undergraduate Program	M	SD	N
Female	EME	2.11	.68	286
	ESE	2.05	.70	331
	ECE	1.96	.65	166
	Total	2.05	.68	783
Male	EME	1.96	.73	114
	ESE	1.60	.59	105
	ECE	1.18	.14	5
	Total	1.78	.69	224
Total	EME	2.07	.69	400
	ESE	1.94	.70	436
	ECE	1.93	.66	171
	Total	1.99	.69	1007

The analysis for ANX scale was done with mean scores of the items to obtain a spatial anxiety score for each participant. Table 4.3 illustrates that the spatial anxiety of the preservice teachers was relatively low. The spatial anxiety mean score was reported for EME students as 2.07 (*SD* = .69), for ESE students as 1.94 (*SD* = .70) and for ECE students as 1.93 (*SD* = .66) which were around 2 out of 5. If gender variable was inspected, it can be concluded that the spatial anxiety of males was less than that of females for all undergraduate programs. That is, males had lower spatial anxiety scores compared to females with mean score 1.96 (*SD* = .73) for EME students, 1.60 (*SD* = .59) for ESE students and 1.18 (*SD* = .14) for ECE students. On the other hand, the spatial anxiety mean scores of females were 2.11 (*SD* = .68) for EME students, 2.05 (*SD* = .70) for ESE students and 1.96 (*SD* = .65) for ECE students.

4.2 Inferential Statistics

In the previous section, descriptive statistics of the number of participants and the standard deviation and mean scores of them regarding SVT, GSE and ANX scales with respect to gender and undergraduate program variables were given. As mentioned above, data were collected from 3^{rd} and 4^{th} grade students of all four universities. The difference in SVT, GSE and ANX scores of preservice teachers in terms of grade level was examined and no significant difference was found for three tests. As a result, the 3^{rd} and 4^{th} grade students were analyzed together in the analyses of the present study.

As mentioned above, the aim of this research study was to investigate the difference between spatial visualization ability, geometry self-efficacy and spatial anxiety of preservice teachers in terms of undergraduate program and gender. Moreover, the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety was evaluated. In order to examine the difference in SVT, GSE and ANX scores in terms of undergraduate program and gender, two-way ANOVA was performed. Yet, homogeneity of variance assumption was violated while examining the difference in SVT and GSE scores in terms of undergraduate program and gender since there were few male students in ECE undergraduate program. Thus, it was decided to use one-way ANOVA and independent samples t-test to investigate the difference in terms of undergraduate program and gender respectively. On the other hand, the assumptions were assured for ANX scores, so two-way ANOVA was used in order to examine the difference in terms of undergraduate program and gender on ANX scores of preservice teachers. Finally, Pearson product-moment correlation analysis was run to investigate the relationship among SVT, GSE and ANX scores of preservice teachers.

4.2.1 The Difference in Spatial Visualization Ability of Preservice Teachers in terms of Undergraduate Program and Gender

The first research question was "Is there a significant difference in preservice teachers' spatial visualization abilities in terms of undergraduate program and gender?". However, as mentioned above, the violation of homogeneity of variance assumption, the difference in terms of undergraduate program and gender were investigated separately with one-way ANOVA and independent sample t-test respectively.

4.2.1.1 The Difference in Preservice Teachers' Spatial Visualization Ability in terms of Undergraduate Program

Before conducting the analysis to investigate the difference in preservice teachers' spatial visualization ability levels regarding undergraduate program, assumptions were checked. In the next sections, the assumptions and analysis results are summarized.

4.2.1.1.1 Assumptions of One-Way ANOVA

Pallant (2007) mentioned the assumptions to be examined before conducting one-way ANOVA as *level of measurement, independence of observations*, *normality* and *homogeneity of variance*.

Pallant (2007) explained level of measurement assumption as "each of the parametric approaches assumes that the dependent variable is measured at the interval or ratio level" (p. 203). Namely, the dependent variable is expected to be continuous. In the present study, the dependent variable was the total scores of the participants for the SVT which was continuous.

Independence of observation assumption can be explained as "each observation or measurement must not be influenced by any other observation or measurement" (Pallant, 2007, p. 203). In this study, this assumption was assumed to be assured.

The other assumption to be considered before one-way ANOVA was normality. The expected issue for this assumption is the normal distribution of population, from which the samples are selected, for the parametric techniques (Pallant, 2007). In case, the sample size is large enough (e.g. 30+), the violation of this assumption should not cause any major problem (Pallant, 2007). In the present study, sample size was 1007 which is quite large. Moreover, the distribution for SVT scores for each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.4, skewness and kurtosis values of SVT for each group was summarized.

Table 4.4 Skewness and Kurtosis Values of SVT with respect to Undergraduate Program

	Skewness	Kurtosis	N
EME	-.43	-.45	400
ESE	.09	-.93	436
ECE	.31	-.90	171

Kunnan (1998) stated that the skewness and kurtosis values should be between +2 and -2 in order the distribution to be approximately normal. As it can be seen in Table 4.4 the skewness and kurtosis values were between -.93 and +.31 which means that there was no violation for the normality assumption. In addition, histograms with normal curves for EME, ESE and ECE groups are given in *Figure 4.1*, *Figure 4.2* and *Figure 4.3* respectively.

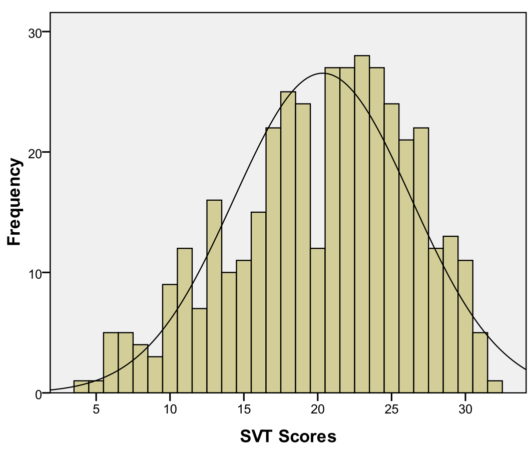


Figure 4.1 Histogram of SVT scores of EME undergraduate program.

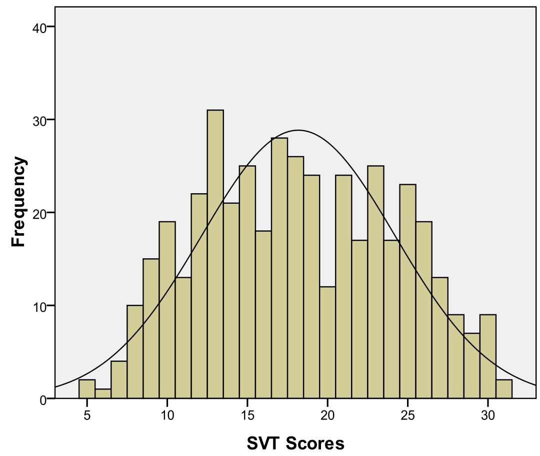


Figure 4.2 Histogram of SVT scores of ESE undergraduate program.

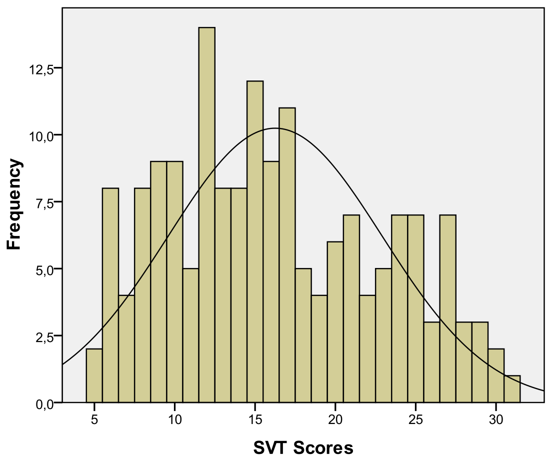


Figure 4.3 Histogram of SVT scores of ECE undergraduate program.

For each undergraduate program, the histograms with normal curves above also gave additional evidence for normality of SVT scores. In summary, normality assumption was assured in the present study for SVT scores.

Homogeneity of variance assumption means that samples were obtained from populations of equal variances. That is, the variability of each groups' scores was similar (Pallant, 2007). In this analysis, Levene's Test of Equality of Error Variances showed that the homogeneity of variance assumption was assured (p = .128).

4.2.1.1.2 One-Way ANOVA Results of Spatial Visualization Test (SVT)

One-way ANOVA results revealed that there was statistically significant difference ($F(2, 1004) = 29.47$, $p < .01$) among three undergraduate programs in terms of SVT scores.

In order to reveal the difference among undergraduate programs, the post-hoc analysis was performed and the results are presented in Table 4.5.

Table 4.5 Multiple Comparison for Post-Hoc Results

Undergraduate Program	Undergraduate program	Mean Difference	Sig.
EME	ESE	2.16	.000
	ECE	4.09	.000
ESE	ECE	1.92	.002

Post-hoc comparison using the Tukey HSD test indicated that the mean score for EME students ($M = 20.34$, $SD = 6.01$) was significantly different from ESE ($M = 18.17$, $SD = 6.03$) and from ECE ($M = 16.25$, $SD = 6.66$) students at the .01 level. In the same way, the mean score for ESE students was also significantly different from both ECE and EME students.

In *Figure 4.4* the relationship between undergraduate program and SVT scores is given.

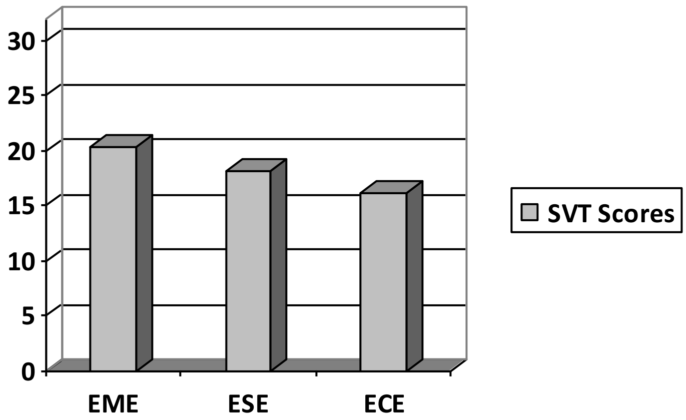


Figure 4.4 The SVT scores of EME, ESE, and ECE students.

As it can be seen in *Figure 4.4*, the mean score of EME undergraduate program was the greatest among other undergraduate programs and as mentioned above this difference was significant. Moreover, the spatial visualization levels of ECE students were significantly lower than EME and ESE students.

In addition, in order to analyze the effect size the *Formula 4.1* was used (Pallant, 2007, p. 247). The eta squared value was calculated as .06. According to the guidelines determined by Cohen (1988, pp. 284-287) this eta squared value corresponds to the small effect. Thus, small practical significance was detected in addition to the statistical significance. According to Pallant (2007), eta squared value should be multiplied by 100 in order to define it as a percentage. Thus, six percent of the variance in the SVT was explained by undergraduate program in this study.

$$Eta\ squared = \frac{Sum\ of\ squares\ between-groups}{Total\ sum\ of\ squares} \tag{4.1}$$

4.2.1.2 The Difference in Spatial Visualization of Preservice Teachers in terms of Gender

In order to investigate the difference in SVT scores of the preservice teachers in terms of gender, independent-samples t-test was conducted. In the following sections, the assumptions and analysis results were summarized.

4.2.1.2.1 Assumptions of Independent Samples T-Test

The assumptions to be considered before conducting independent-samples t-test are *level of measurement*, *independence of observations*, *normality* and *homogeneity of variance*.

For level of measurement assumption, the dependent variable is expected to be continuous. In the present study, the dependent variable was the mean scores of the participants for the SVT which was continuous.

In the present study, independence of observations assumption was assumed to be assured.

As indicated, the sample size of the study was 1007, which is sufficient to assure normality assumption. Moreover, the distribution for SVT scores for each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.6, skewness and kurtosis values of SVT for each group was summarized.

Table 4.6 Skewness and Kurtosis Values of SVT with respect to Gender

	Skewness	Kurtosis	N
Female	.00	-.87	783
Male	-.54	-.47	224

As it can be seen in Table 4.6 the skewness and kurtosis values were in the range of -2 and +2 which means that there was no violation for the normality

(Kunnan, 1998). In addition, histograms with respect to females and males are given in *Figure 4.5* and *Figure 4.6* respectively.

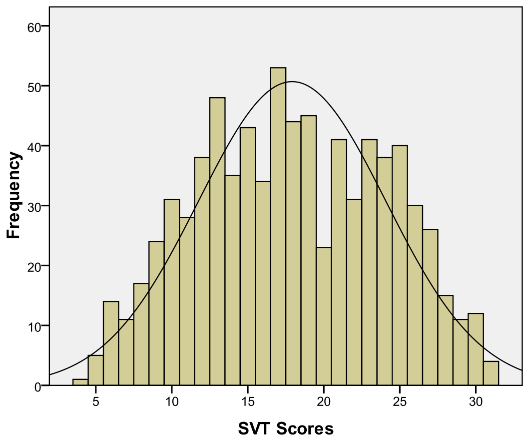


Figure 4.5 Histogram of SVT scores of females.

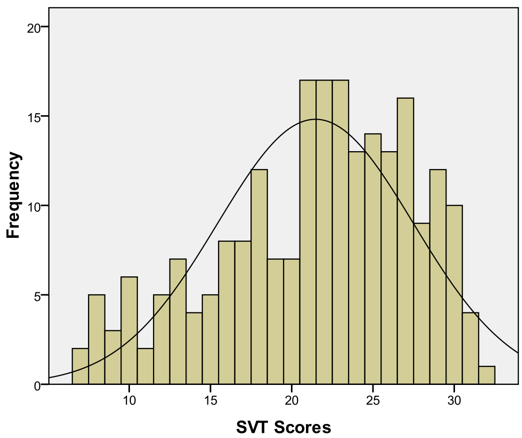


Figure 4.6 Histogram of SVT scores of males.

For females and males, the histograms with normal curves above also gave additional evidence for normality of SVT scores. In summary, normality assumption was assured in the present study for SVT scores.

Finally, Levene's Test of Equality of Error Variances showed that the homogeneity of variance assumption was assured (p = .284).

4.2.1.2.2 Independent Sample T-Test Results of Spatial Visualization Test (SVT)

According to the analysis results, there was statistically significant difference in the scores for females and males, $t(1005) = -7.63$, $p < .01$. The magnitude of the differences in the means was 3.55 in which males had higher score.

In addition, in order to analyze the effect size, *Formula 4.2* was used (Pallant, 2007, p. 236). The eta squared value was calculated as .05. Similar to the results above, this value corresponded to the small effect size which means that there was practical significance in addition to statistical significance. Also, five percent of the variance in the SVT was explained by gender.

$$Eta\ squared = \frac{t^2}{t^2 + (N_1 + N_2 - 2)} \qquad (4.2)$$

4.2.2 The Difference in Geometry Self-Efficacy of Preservice Teachers in terms of Undergraduate Program and Gender

The second research question was "Is there a significant difference in preservice teachers' geometry self-efficacy scores in terms of undergraduate program and gender?". Yet, as mentioned above, the violation of homogeneity of variance assumption, the difference in terms of undergraduate program and gender was investigated separately with one-way ANOVA and independent sample t-test respectively.

4.2.2.1 The Difference in Geometry Self-Efficacy of Preservice Teachers in terms of Undergraduate Program

Before conducting the analysis to investigate the difference in geometry self-efficacy of preservice teachers in terms of undergraduate program, assumptions were checked. In the next sections, the assumptions and analysis results are summarized.

4.2.2.1.1 Assumptions of One-Way ANOVA

As mentioned above, the assumptions to be considered are *level of measurement, independence of observations, normality* and *homogeneity of variance.*

For level of measurement assumption, the dependent variable is expected to be continuous. In the present study, the dependent variable was the mean scores of the participants for the GSE scale which was continuous. As indicated above, independence of observations assumption was assumed to be assured and the sample size of the study was quite large to assure normality assumption. Moreover, the distribution for GSE scores of each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.7, skewness and kurtosis values of GSE scores for each group was summarized.

Table 4.7 Skewness and Kurtosis Values of GSE Scores with respect to Undergraduate Program

	Skewness	Kurtosis	N
EME	-.39	.46	400
ESE	-.51	.26	436
ECE	-.79	.55	171

As it can be seen in Table 4.7, the skewness and kurtosis values were between -.79 and +.55, which means that there is no violation for the normality assumption (Kunnan, 1998). In addition, histograms with respect to EME, ESE and ECE undergraduate programs are given in *Figure 4.7*, *Figure 4.8* and *Figure 4.9* respectively.

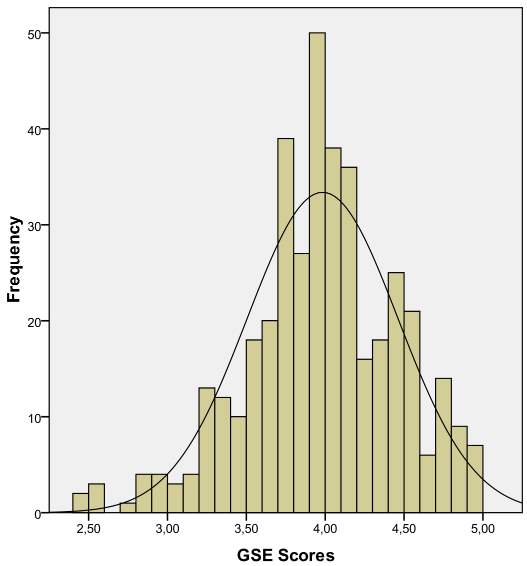


Figure 4.7 Histogram of GSE scores of EME undergraduate program.

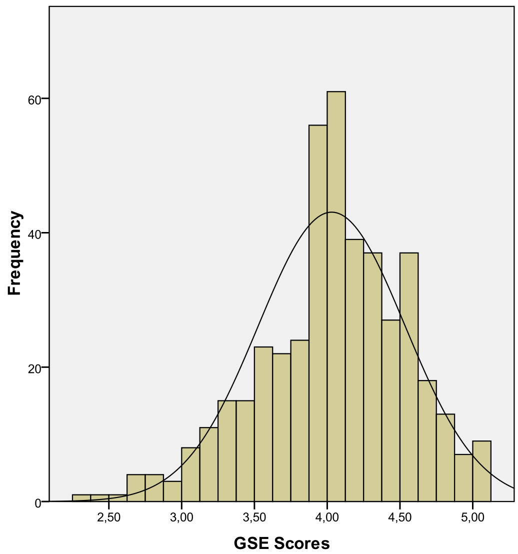


Figure 4.8 Histogram of GSE scores of ESE undergraduate program.

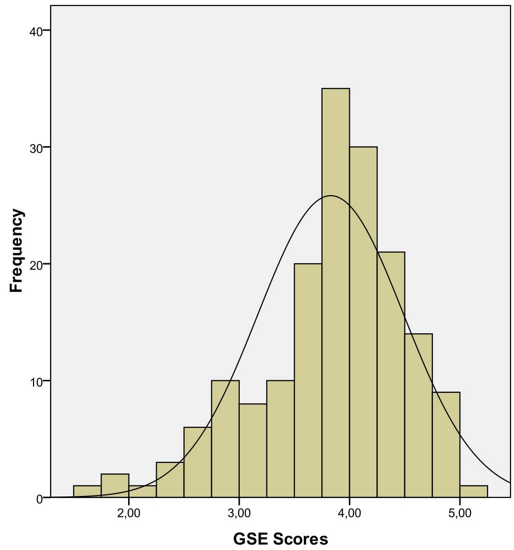


Figure 4.9 Histogram of GSE scores of ECE undergraduate program.

For each undergraduate program, the histograms with normal curves above also gave additional evidence for normality of GSE scores. In summary, normality assumption was assured for GSE scores. However, Levene's Test of Equality of Error Variances showed that the homogeneity of variance assumption was violated ($p < .01$). In such situations, Pallant (2007) suggests that Robust Test of Equality of Means table results should be reported. The table consists of two tests; Welsh and Brown-Forsythe. The results of those tests are summarized in Table 4.8.

4.2.2.1.2 One-Way ANOVA Results of Geometry Self-Efficacy (GSE) Scale

As indicated, homogeneity of variance assumption was violated so the Robust Tests for Means results were reported.

Table 4.8 Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	6.5	2	429.91	.002
Brown-Forsythe	7.75	2	479.19	.000

[a] Asymptotically F distributed

According to the analysis results given in Table 4.8, there was statistically significant difference at p = .01 level among three undergraduate programs in terms of GSE scores.

In order to reveal the difference among undergraduate programs, the post-hoc analysis was performed with Dunnet C analysis since homogeneity of variance assumption was violated. The results are presented in Table 4.9.

Table 4.9 Multiple Comparison for Post-Hoc Results

Undergraduate Program	Undergraduate Program	Mean Difference	Std. Error
EME	ESE	-.47	.03
	ECE	.15	.06
ESE	ECE	.20	.06

Post-hoc comparison using the Dunnett C test indicated that the mean score ECE students (*M* = 3.82, *SD* = .66) was significantly lower than ESE students (*M* = 4.03, *SD* = .50) and EME students (*M* = 3.98, *SD* = .48).

Finally, *Figure 4.10* illustrates the relationship between undergraduate program and GSE scores**.**

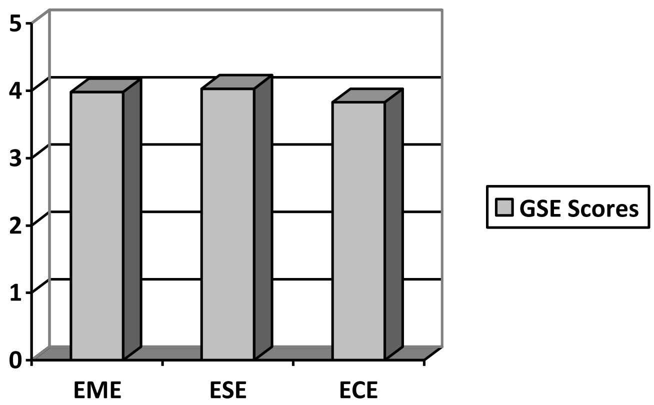


Figure 4.10 The GSE scores of EME, ESE, and ECE students.

As it can be seen in *Figure 4.10*, the mean score of ESE students was the highest. Moreover, the geometry self-efficacy of ECE students was significantly lower than that of EME and ESE students.

In addition, the eta squared value was calculated with the *Formula 4.1* as .02 corresponding to the small effect size which means there was practical significance in addition to statistical significance. Thus, in this study, two percent of the variance in the GSE scores was explained by undergraduate program.

4.2.2.2 The difference in Preservice Teachers' Geometry Self-Efficacy in terms of Gender

In order to investigate the difference in geometry self-efficacy of preservice teachers in terms of gender, independent-samples t-test was conducted. In the following sections, the assumptions and analysis results are summarized.

4.2.2.2.1 Assumptions of Independent Samples T-Test

As mentioned above, the assumptions to be considered are *level of measurement, independence of observations, normality* and *homogeneity of variance*. In the present study, the dependent variable was the mean scores of the participants for the GSE scale which was continuous, so level of measurement assumption was assured. In addition, independence of observations assumption was assumed to be assured and sample size ($N = 1007$) was appropriate to satisfy the normality assumption of the study. Moreover, the distribution for GSE scores for each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.10, skewness and kurtosis values of GSE scores for each group are summarized.

Table 4.10 Skewness and Kurtosis Values of GSE Scores with respect to Gender

	Skewness	Kurtosis	N
Female	-.68	.95	783
Male	-.71	.85	224

As it can be seen in Table 4.10 the skewness and kurtosis values were between -.71 and +.95, which means that there was no violation for the normality assumption (Kunnan, 1998). In addition, histograms with respect to females and males are given in *Figure 4.11* and *Figure 4.12* respectively.

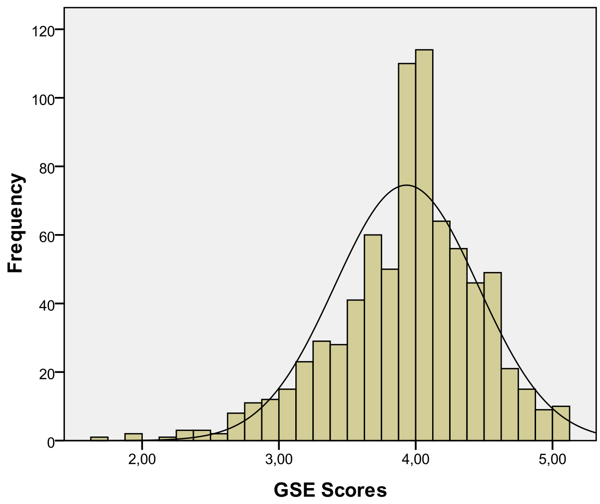


Figure 4.11 Histogram of GSE scores of females.

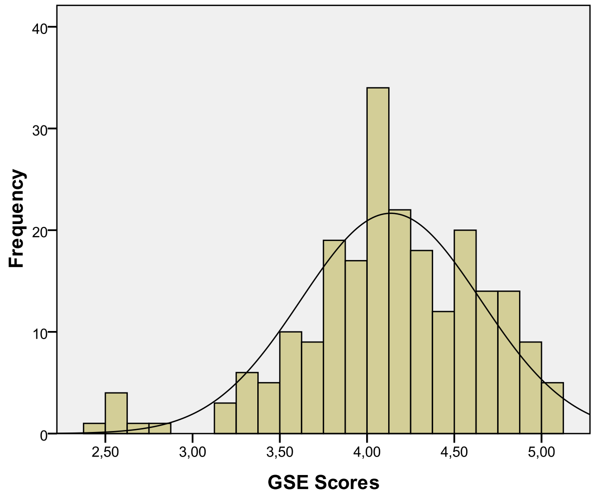


Figure 4.12 Histogram of GSE scores of males.

For females and males, the above histograms with normal curves also gave additional evidence for normality of GSE scores. In summary, normality assumption was assured in the present study for GSE scores. Additionally, Levene's Test of Equality of Error Variances showed that the homogeneity of variance assumption was assured (p = .954).

4.2.2.2.2 Independent Sample T-Test Results of Geometry Self-Efficacy (GSE)

According to the results, there was statistically significant difference, $t(1005) = -5.14$, $p < .01$, between geometry self-efficacy of females (M = 3.93, SD = .52) and males (M = 4.14, SD = .52) favoring male students.

The eta squared value which was calculated with the *Formula 4.2* was .03 for GSE scores. Similar to above, this value corresponded to the small effect size which means that there was practical significance in addition to statistical significance and three percent of the variance in the GSE scores was explained by gender.

4.2.3 The Difference in Spatial Anxiety of Preservice Teachers in terms of Undergraduate Program and Gender

The third research question was "Is there a significant difference in preservice teachers' spatial anxiety scores in terms of undergraduate program and gender?". In order to investigate the difference in preservice teachers' spatial anxiety in terms of undergraduate program and gender, two-way ANOVA was used.

4.2.3.1 Assumptions of Two-Way ANOVA

There are assumptions to be assured before conducting two-way ANOVA mentioned by Pallant (2007) as *level of measurement, independence of observations, normality* and *homogeneity of variance.*

In the present study, the dependent variable was the mean scores of the participants for the ANX scale which was continuous, so level of measurement assumption was assured. In addition, independence of observations assumption was assumed to be assured and sample size (N = 1007) was appropriate to assure the normality assumption of the study. Moreover, the distribution for ANX scores for each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.11, skewness and kurtosis values of ANX scores for each group are summarized.

Table 4.11 Skewness and Kurtosis Values of ANX Scores with respect to Undergraduate Program and Gender

	Skewness	Kurtosis	N
Female	1.01	1.16	783
Male	1.28	1.87	224
EME	.87	.70	400
ESE	1.16	1.71	436
ECE	1.07	1.21	171

As it can be seen in Table 4.11 the skewness and kurtosis values were between +.70 and +1.87, which means that there was no violation for the normality assumption (Kunnan, 1998). In addition, histograms with respect to females and males are given in *Figure 4.13* and *Figure 4.14* respectively.

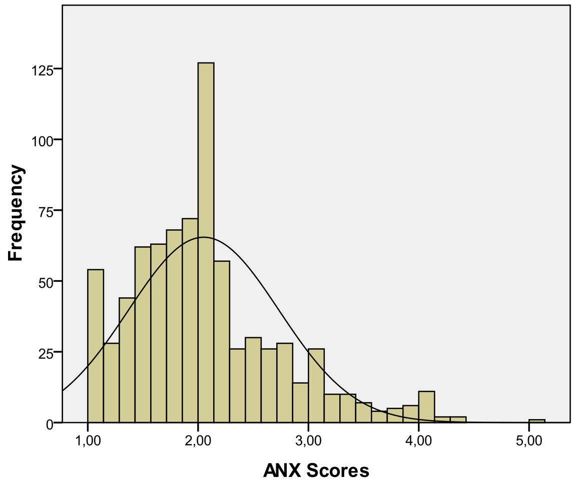


Figure 4.13 Histogram of ANX scores of females.

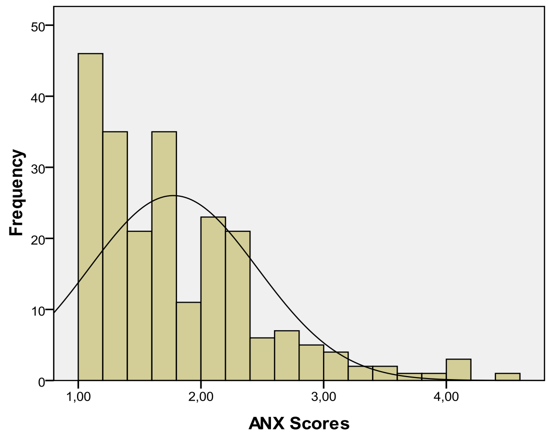


Figure 4.14 Histogram of ANX scores of males.

The histograms with normal curves also gave additional evidence for normality of spatial anxiety scale scores for males and females.

Moreover, the histograms for each undergraduate program are also given in *Figure 4.15*, *Figure 4.16* and *Figure 4.17* respectively for EME, ESE and ECE undergraduate programs.

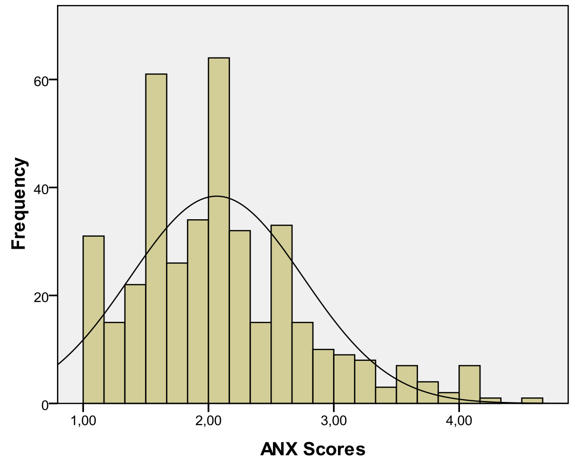


Figure 4.15 Histogram of ANX scores of EME undergraduate program.

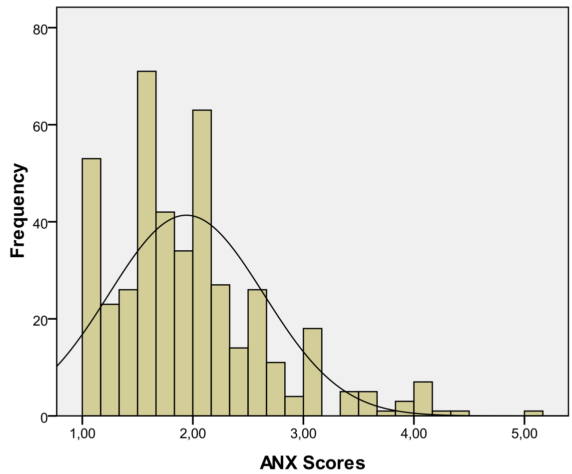


Figure 4.16 Histogram of ANX scores of ESE undergraduate program.

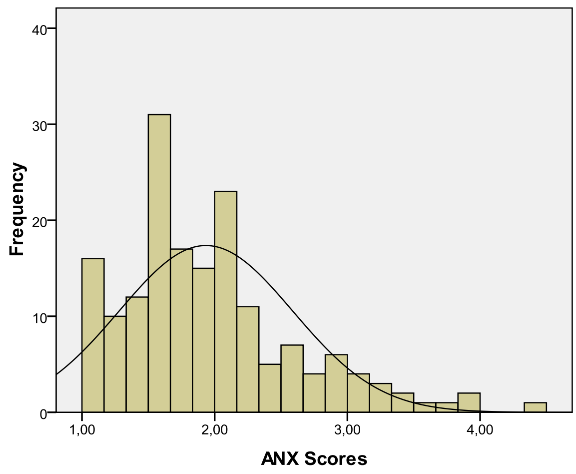


Figure 4.17 Histogram of ANX scores of ECE undergraduate program.

For each undergraduate program, the histograms with normal curves above also gave additional evidence for normality of ANX scores. In summary, normality assumption was also assured in the present study for ANX scores.

Finally, Levene's Test of Equality of Error Variances represented that the homogeneity of variance assumption was assured (p = .147).

4.2.3.2 Two-Way ANOVA Results of Preservice Teachers' Spatial Anxiety (ANX)

The results revealed that there was statistically significant main effect for undergraduate program, $F(2, 1001) = 10.43$, $p < .01$. In order to reveal the difference between undergraduate programs, the post-hoc results are summarized in Table 4.12.

Table 4.12 Multiple Comparison for Post-Hoc Results

Undergraduate program	Undergraduate program	Mean Difference	Sig.
EME	ESE	.12	.022
	ECE	.13	.085
ESE	ECE	.01	.992

Post-hoc comparison using the Tukey HSD test indicated that the mean score for EME students (*M* = 2.07, *SD* = .69) was significantly higher than that of ESE (*M* = 1.94, *SD* = .70) students. However, the mean difference between EME and ECE (*M* = 1.93, *SD* = .66) students was not significant. Likewise, the results indicated that the mean difference between ESE and ECE students was also not significant.

The effect size for undergraduate program was calculated as .02. Based on Cohen's (1998) criterion, this could be said to be small effect size. That is, although undergraduate program difference reached statistical significance, the actual difference in the mean values were small which means that the difference between undergraduate programs seemed to be of little practical significance.

The results also revealed that there was statistically significant main effect for gender, $F(1, 1001) = 17.93$, $p < .01$. That is, the spatial anxiety levels of males were significantly lower than that of females. The effect size for gender was calculated as .018. Based on Cohen's (1998) criterion, this could be said to be small effect size. Although gender effect reached statistical significance, the actual difference in the mean values was very small. This means that the difference between male and female students seemed to be of little practical significance. In this study, the interaction effect between undergraduate program and gender was not statistically significant, $F(2, 1001) = 5.23$, $p = .01$. If a significant interaction effect was found, the researcher could not easily and simply interpret the main effects (Pallant, 2007). As a result, there was no significant difference in the effect of undergraduate program on spatial anxiety scores of males and females.

Finally, *Figure 4.18* illustrates the relationship between undergraduate program, gender and anxiety.

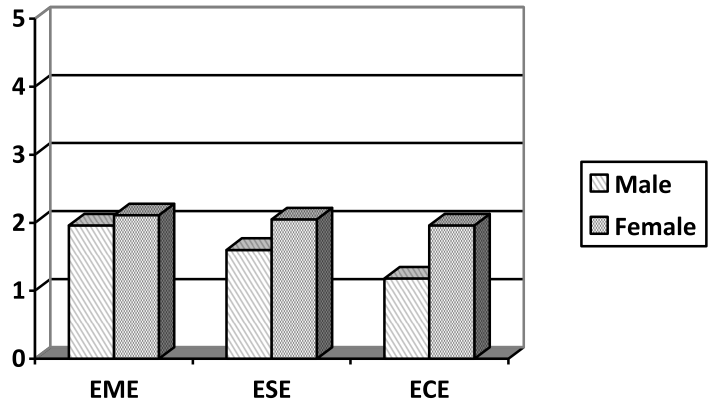


Figure 4.18 The relationship among undergraduate program, gender and ANX scores.

As it can be seen in *Figure 4.18*, the spatial anxiety mean scores of females were higher than that of males for all three undergraduate programs. Moreover, the spatial anxiety levels of the EME students were relatively higher than that of the students in ESE and ECE undergraduate programs.

4.2.4 Correlation among Spatial Visualization Ability, Geometry Self-Efficacy, and Spatial Anxiety of Preservice Teachers

The last research question to investigate was “Is there a significant relationship among spatial visualization ability (SVT), geometry self-efficacy (GSE), and spatial anxiety (ANX) scores of preservice teachers?”.

In order to investigate the strength and direction of relationship among these variables, if exists, Pearson product-moment correlation coefficient was calculated.

4.2.4.1 Assumptions of Pearson Product-Moment Correlation

The assumptions to be assured before conducting Pearson product-moment correlation are mentioned by Pallant (2007) as *level of measurement, related pairs, independence of observations, normality* and *homogeneity of variance.*

In the present study, the dependent variables were SVT, GSE and ANX scores which are continuous, so level of measurement assumption was assured.

It is expected that all of the subjects had a score for each variable to satisfy related pairs assumption (Pallant, 2007). In the present study, this assumption was assured since the participants had the score for all three variables.

In addition, independence of observations assumption was assumed to be assured and sample size ($N = 1007$) was appropriate to assure the normality assumption of the study. Moreover, the distribution for SVT, GSE and ANX scores for each group was normally distributed when skewness and kurtosis values, histograms and Normal Q-Q Plots were examined. In Table 4.13, skewness and kurtosis values of ANX scores for each group are summarized.

Table 4.13 Skewness and Kurtosis Values of GSE, SVT and ANX Scores

	Skewness	Kurtosis	N
GSE	-.66	.87	1007
SVT	-.1	-.9	1007
ANX	1.02	1.16	1007

As it can be seen in Table 4.13, the skewness and kurtosis values were between -.93 and +.31, which means that there was no violation for the normality assumption (Kunnan, 1998).

Linearity assumption requires a linear relationship between variables. In order to examine linearity, scatter plots were constructed for variables in pairs. *Figure 4.19,*

Figure 4.20, and *Figure 4.21* show the relationship between the SVT and ANX scores, SVT and GSE scores, and ANX and GSE scores respectively.

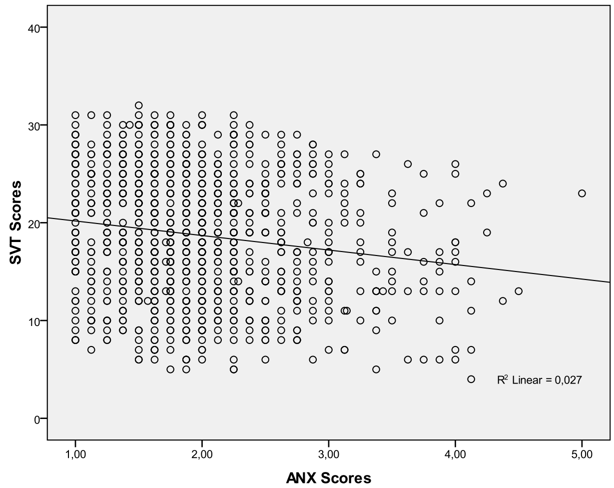


Figure 4.19 Scatterplot of SVT and ANX scores.

The spread of the points in the scatterplot indicate that there was a reasonable correlation between the variables. The fit line could be drawn, so the Pearson correlation could be used. The direction of relationship was negative since the line drawn through points downward from left to right. That is, high scores in SVT scores were associated with low scores in ANX scores. As a result, when spatial visualization ability of an individual increases, the anxiety level decreases and the relationship seems to be moderate.

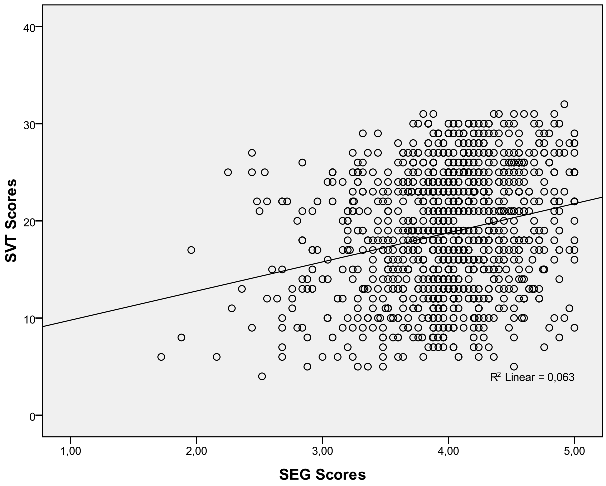


Figure 4.20 Scatterplot of SVT and GSE scores.

As it can be seen in *Figure 4.20*, the spread of the points in the scatterplot indicate that there was a reasonable correlation between the variables. The fit line could be drawn, so the Pearson correlation could be used. The direction of relationship was positive since the line drawn through points upward from left to right. That is, high scores in SVT scores associated with high scores in GSE scores. As a result, when spatial visualization ability of an individual increases, the geometry self-efficacy also increases and the relationship seems to be moderate.

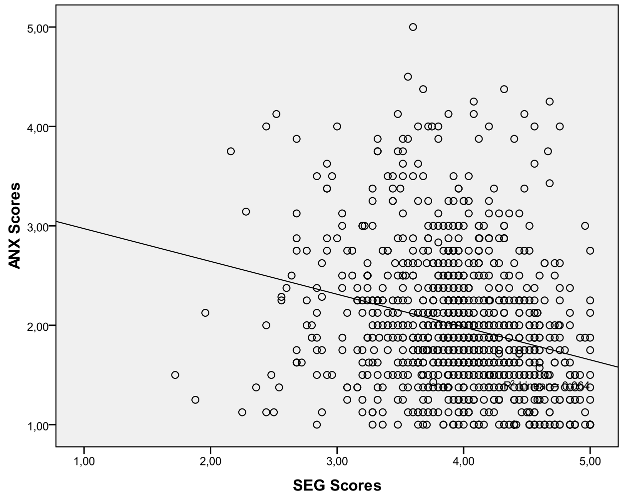


Figure 4.21 Scatterplot of ANX and GSE scores.

Finally, the spread of the points in the scatterplot indicate that there was a low correlation between ANX and GSE scores so homoscedasticity assumption was violated. The fit line could be drawn, so the correlation analysis could be done. The direction of relationship was negative since the line drawn through points downward from left to right. That is, high scores in ANX scores are associated with low scores in GSE scores. As a result, when spatial anxiety level of an individual increases, the geometry self-efficacy decreases and the relationship seems to be weak. Thus, the linearity assumption was assured with fit lines of scatterplots.

When scatterplots above were examined, the homoscedasticity assumption was assured in *Figure 4.19* and *Figure 4.20*. Therefore, the Pearson product-moment coefficient was used to investigate the correlations between SVT and ANX scores and between SVT and GSE scores. However, this assumption was violated in *Figure 4.21*, so non-parametric technique for correlation; Spearman's rank order correlation (rho) was used to determine the correlation between GSE and ANX scores.

Pallant (2007) suggests conducting the Missing Value Analysis to find the patterns in missing values in order to assure missing data assumption. In the SPSS analysis, "Exclude cases pairwise" option was used while computing mean scores and total scores in order not to lose data. Therefore, there was no missing data for GSE, SVT and ANX scores.

According to Pallant (2007), there may be strange looking numbers that take the form 1.24E-02 in the output which are of small values the SPSS has presented in scientific notation. However, there was no strange-looking number in the output, so strange-looking numbers assumption was assured.

4.2.4.2 Pearson Product-Moment Correlation Results

Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. Results revealed that there was a positive significant correlation between GSE and SVT scores of the preservice teachers, $r = .25, p < .01$. This means that the participants with higher spatial visualization ability tended to have higher scores in geometry self-efficacy test.

Similarly, the correlation between ANX and SVT scores of the participants was negative, $r = -.16, p < .01$. That is, the participants with higher spatial anxiety level tended to have lower scores in spatial visualization test

Finally, Spearman's rho was calculated for examining the correlation between ANX and GSE scores since the homoscedasticity assumption was violated. The results indicated a negative correlation between the variables, $r = -.28, p < .01$. That is, the participants with higher spatial anxiety level tended to have lower scores in geometry self-efficacy test.

4.2.5 Summary for the Analysis Results

The aim of this study was to investigate the difference among spatial visualization ability, geometry self-efficacy, and spatial anxiety of preservice teachers in terms of undergraduate program and gender. Moreover, the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety was evaluated. The results revealed that the preservice teacher's spatial visualization ability was at relatively moderate level. There was a significant difference between EME, ESE and ECE students in terms of spatial visualization levels at which the EME students had higher spatial visualization scores than the ESE and the ECE students. Moreover, it was concluded that males had significantly higher spatial visualization level than females. In the same way, the analyses on GSE scores indicated that the geometry self-efficacy of preservice teachers was relatively high. In addition, ECE students' geometry self-efficacy was significantly lower than that of the students of both EME and ESE undergraduate programs. The geometry self-efficacy of female preservice teachers was also found significantly lower than that of male preservice teachers.

The other findings of the analysis revealed that the spatial anxiety levels of preservice teachers were low and there was a significant difference between females and males. That is, males had less spatial anxiety than females in all three undergraduate programs. Furthermore, the spatial anxiety levels of preservice teachers were found to differ in terms of undergraduate program. Although the effect size was small, the spatial anxiety levels of EME students were significantly higher than ESE students. Moreover, ECE students had the lowest spatial anxiety scores among other programs.

Finally, Pearson product-moment correlation analysis indicated a positive correlation between GSE and SVT scores. That is, participants with higher spatial visualization ability tended to have higher scores in geometry self-efficacy test. Moreover, the negative correlation was found between ANX and SVT scores, and between ANX and GSE scores. This means that, participants with higher spatial anxiety level tended to have lower scores in spatial visualization test and geometry self-efficacy test.

CHAPTER 5

DISCUSSION

The main purpose of this study was to investigate preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety in terms of undergraduate program and gender. The other purpose of the study was to investigate the relationship among preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety.

This chapter consists of the discussion of the findings of the present study in line with the previous studies. Moreover, implications and recommendations for further studies will be presented.

5.1 Discussion of the Findings

In this section, the results of the research questions will be discussed.

5.1.1 Discussion of the Findings for Spatial Visualization Ability

The results of the first research question which was "Is there a significant difference in preservice teachers' spatial visualization abilities in terms of undergraduate program and gender?" showed that males obtained significantly higher scores in SVT than females. This finding is consistent with many studies in the literature emphasizing that spatial visualization abilities of females are lower than that of males (Battista, 1990; Harris, 1981; Maccoby & Jacklin, 1974; Sherman, 1980; Linn & Petersen, 1985; Voyer, 1995).

There are some possible reasons offered for the gender difference in the literature. One of the reasons might be the spatial experiences (Baenninger & Newcombe, 1995). According to Baenninger and Newcombe (1995), females have fewer spatial experiences out of school than males so they get lower scores than males in spatial ability tests. Even in early childhood, females prefer stuffed animals and dolls that improve social skills while males prefer vehicles and blocks that are beneficial for spatial manipulation (Etaugh & Liss, 1992; Voyer et al., 1995). Thus, the reason for the gender difference in the present study might be the spatial experiences. That is to say, male students in this study might have more spatial experiences than females, which is common in Turkish society that leads higher score in spatial visualization ability test.

Another possible reason for gender difference in spatial visualization ability might be genetic (Allivatos & Petrides, 1997; Grimshaw et al., 1995; Harris, 1981; Kimura & Hampson, 1994; Linn & Petersen, 1985). In the literature, it was claimed that the left hemisphere of an individual realizes for analytical/logical thinking in both verbal and numerical operations while right hemisphere is specialized in spatial tasks, artistic efforts, and body image (Capraro, 2001). Therefore, males who tend to use right hemisphere become more advantageous over females. The difference in spatial visualization abilities of females and males might be due to genetic reasons in this study.

Gender difference in spatial visualization ability might be due to the cultural effects (Richardson, 1994), which is the other possible reason. Females were claimed to lose their self-confidence in spatial tasks as there is a stereotype that males think more logically in spatial situations (Richardson, 1994).). In Turkey, such a belief is also common therefore the difference might be due to the stereotype favoring males for spatial performance.

In contrast to the findings of the present study, there are studies which found no difference between females and males regarding spatial visualization ability (Boulter, 1992; Capraro, 2001; Fennema & Sherman, 1977, 1978; Manger & Eikeland, 1998; Tartre, 1990). Moreover, Brienbaum, Kelley and Levi-Keren (1994) defended that if time is not limited in spatial tests, females can be as successful as males. Although time was not limited in the present study and the researcher waited until all participants finish the SVT, there was still a significant difference between females and males in terms of spatial visualization ability. Thus, the findings of the present study did not support the effect of time in gender difference. Furthermore, there were few studies arguing that females' spatial visualization ability level is higher than that of males (Armstrong, 1985), which were also inconsistent with the findings of the present study. As it can be seen, the existing studies are middle and high school oriented. There might be no difference in spatial abilities of children in middle school and high school years but the difference might emerge as they grow with the help of their spatial experiences.

As indicated before, in the literature, there were many studies investigating the impact of gender on spatial visualization ability (Battista, 1990; Capraro, 2001; Harris, 1981; Kaufman, 2007; Lawton, 1994; Linn & Petersen, 1985; Maccoby & Jacklin, 1974) however, limited research has been conducted to examine the spatial visualization ability in terms of undergraduate program which was the other variable of the present study. For example, Robichaux (2000) investigated the spatial visualization abilities of junior and senior undergraduates majoring in architecture, mathematics education, mathematics and mechanical engineering. She examined the spatial visualization ability levels of the participants and the relationship between certain background information and development of spatial visualization ability. The results revealed no significant difference in spatial visualization levels of so called undergraduates. However, the spatial visualization mean score of mathematics majors was less than other three undergraduate programs. Robichaux (2000) claimed that mathematics majors might think abstractly like pure mathematicians since mathematics professors do not teach spatially. That is why mathematics majors might have difficulties in spatial tasks. In this study, spatial visualization abilities of EME, ESE and ECE students were also investigated. The findings indicated that the spatial visualization abilities of preservice teachers differ regarding the undergraduate program they were studying at. EME students' spatial visualization ability was found significantly higher than that of ESE and ECE students. In addition, it was revealed that ESE students' spatial visualization level was significantly higher than of ECE students. These findings did support the claim of Shea, Lubinski and Benbow (2001) that is the students preferring the occupations related to engineering and computer science-mathematics areas were the ones whose spatial visualization ability were higher than their verbal ability. Thus, the reason for EME and ESE students' getting higher scores than ECE students in spatial visualization ability test might be due to the fact that EME and ESE students are more familiar to spatial concepts than ECE students as for their educational background. For instance, in the national university entrance exam, EME and ESE undergraduate programs accept students who took mathematics and science courses in advance levels at high school whereas most of the students who prefer ECE undergraduate program were graduates of vocational high schools in which mathematics and science courses were given in basic levels. In addition, EME and ESE undergraduate programs are based on the courses including the use of concrete materials like manipulatives, computer programs, and laboratory applications. Thus, the high school courses and the students' spatial experiences during higher education might influence EME and ESE students' spatial visualization abilities more positively than that of ECE students.

In addition to those findings, results indicated that, EME students who participated in this study did not have as high spatial visualization ability as expected. One possible explanation for this finding might be the fact that the importance has started to be given to the improvement of spatial visualization ability after the education reform on elementary curriculum in 2003 and it is still a new issue in Turkey. Therefore, there are not sufficient courses related to spatial visualization ability. Moreover, there is no course focused specifically on the improvement of spatial visualization abilities of students. Thus, the difference might appear because of the lack of attention given to the improvement of spatial visualization ability in some undergraduate programs.

5.1.2 Discussion of the Findings for Geometry Self-Efficacy Scores

As indicated before, according to Schunk (1991), individuals' beliefs about whether they can successfully perform given academic task at specified levels or not is called academic self-efficacy. Geometry self-efficacy can be accepted as an academic self-efficacy when the tasks are related to geometry topics. The findings of the present study could give some clues about geometry self-efficacy beliefs of preservice teachers in Turkey.

The results of the second research question which was "Is there a significant difference in preservice teachers' geometry self-efficacy scores in terms of undergraduate program and gender?" showed that there was significant difference between males and females regarding geometry self-efficacy. Specifically, males' self efficacy level was greater than that of females. This difference would be due to the stereotype that males are better than females in mathematics (Manger & Eikeland, 1998). Namely, geometry took a crucial place in mathematics curriculum. Thus, in the present study, the males' obtaining higher geometry self-efficacy scores than females might be because of this stereotype effect. Moè and Pazzaglia (2006) stated that if gender difference is stressed in a task, a subject can increase his or her performance but if the superiority of opposite gender is stressed, the subject can reduce his or her performance in that task. Thus, in this study, some of the females in sample might be exposed to feel superiority of males in mathematics and geometry performance by their parents or teachers in their daily life so this might affect their motivation and geometry self-efficacy. Therefore, geometry self-efficacy of females might be found less than that of males.

The other aim was to investigate the difference in geometry self-efficacy levels of preservice teachers in terms of undergraduate program. The findings revealed that ESE students' geometry self-efficacy was the highest among others. In addition, ECE students' geometry self-efficacy level was significantly lower than that of EME and ESE students. One possible reason might be that ECE students did not take any course related to geometry after high school so they might not be aware of their real capability in geometry and they might underestimate their capabilities. Besides, the educational background of ECE students might have influence on their beliefs since most of them were the graduates of vocational high schools. Although they take a few courses (for instance visual arts, material development, creative drama, creativity and children) in teacher education programs that might improve their spatial visualization ability their geometry self-efficacy was low. On the other hand, the higher self-efficacy of EME and ESE students could be regarded as an expected result. Both undergraduate programs' students studied in mathematics-science area at high school so they have various experiences related to mathematics, geometry and science lessons. In addition, they took some courses (ex. chemistry, physics, analytic geometry, lab applications, optics and modern physics) related to mathematics, geometry and science that they could interact with 3D objects and these experiences might increase their geometry self-efficacy.

5.1.3 Discussion of the Findings for Spatial Anxiety Scores

In this study, the third research question was; “Is there a significant difference in preservice teachers’ spatial anxiety scores in terms of undergraduate program and gender?”. Results indicated that there was significant difference in terms of both undergraduate program and gender on spatial anxiety of preservice teachers. The spatial anxiety levels of females were found to be greater than that of males for all undergraduate programs.

In the present study it was found that females had greater spatial anxiety than males, which was supported by many research studies cited in the literature review (Lawton, 1994; Schmitz, 1997; Wigfield & Eccles, 1992). To illustrate, Wigfield and Eccles (1992) examined the sexual difference in mathematics achievement and students’ anxieties and self confidence on their success and concluded that girls had lower self-confidence and greater spatial anxiety than boys. Consistent with the findings, Lawton (1994) found that girls had greater spatial anxiety than boys in navigation tasks.

In the literature, one of the possible reasons for gender difference in spatial anxiety of the preservice teachers was claimed to be due to genetic sex hormones (Kimura, 2002). The stress of stereotype which was “males’ spatial ability is greater than that of females” was the other possible reason for gender difference (Osborne, 2001; Spencer, Steele, & Quinn, 1999). That is, bearing in mind that males are better in spatial issues, females might feel spatial anxiety in tasks related to spatial capabilities. Giving less freedom to girls to discover their environment when they were children was the other reason asserted (Herman, Heins, & Cohen, 1987; Lawton & Kallai, 2002; Matthews, 1986). Likewise, Lawton and Kallai (2002) explained that since boys are freer to interact with their environment, they feel less anxiety in wayfinding and this results in a gender difference in wayfinding tasks. Thus, in the present study, males’ having less spatial anxiety than females might be because of the stereotype effect or the type of growing. Males might be freer to explore the environment in their childhood, so they might feel less anxiety in spatial tasks.

Lastly, the spatial visualization ability levels of participants might affect their spatial anxiety levels. It was assumed that the one whose spatial visualization ability is high might feel less anxiety in spatial tasks. The results indicated that males' spatial visualization abilities were higher than that of females. Therefore, their capability in spatial tasks might have effect on their beliefs and feelings about to what extent they can perform successfully. Thus, males might feel less spatial anxiety since their spatial visualization abilities were higher than that of females.

The other interesting finding of the study was that spatial anxiety levels of EME students were significantly higher than that of ESE students. However, the results revealed that there was no significant difference between spatial anxiety levels of ECE students with EME and ESE students. Indeed, ECE students had the lowest spatial anxiety scores among other programs. This finding was not consistent with the literature (Lawton, 1994, 1996). It was assumed in this study that the ones with higher spatial visualization abilities might have lower spatial anxiety. However, EME students, who had highest SVT scores, obtained highest ANX scores among other undergraduate programs. Similarly, ECE students, who had lowest SVT scores, obtained lowest ANX scores. The reason for this finding might be that they took some courses like creativity and children, and visual arts and material development which make them interact with 2D and 3D objects actively and this might make them feel less spatial anxiety. Moreover, EME and ESE students might underestimate their capabilities since they were not trained directly to improve their spatial visualization ability during their education. Another possible reason could be that EME students might think that spatial ability is a math related construct and thus they should get higher scores which could made them feel more anxious compared to students in other programs.

5.1.4 Discussion of the Findings for the Relationship among SVT, GSE and ANX Scores

The last aspect of the present study was investigating the relationship among spatial visualization ability, geometry self-efficacy and spatial anxiety of preservice teachers. The results of Pearson product moment correlation analysis revealed that there was a positive relationship between spatial visualization test scores and geometry self-efficacy scores of preservice teachers. Besides, the correlation between spatial visualization test scores and spatial anxiety scores of preservice teachers was negative. Finally, there was negative relationship between geometry self-efficacy scores and spatial anxiety scores of preservice teachers.

The positive relationship between spatial visualization ability and geometry self-efficacy was one of the expected findings since the literature review showed that there was a significant positive correlation between self-efficacy and spatial ability (Kinsey, Towle, O'Brien, & Bauer, 2008). For instance, Kinsey, Towle, O'Brien and Bauer (2008) examined the spatial ability and self-efficacy and their effect on retention for engineering students. They reported that there is a significant correlation between self-efficacy and spatial ability and this means that higher spatial ability leads to higher self efficacy scores. Thus, in this study it was assumed that preservice teachers who had higher beliefs in their abilities to obtain higher scores in geometry also obtained higher scores in spatial visualization test.

The other finding of the present study was that the spatial visualization ability of preservice teachers was negatively related to their spatial anxiety. This finding was supported by some studies in the literature. In one of these studies, spatial anxiety was found to be negatively related to spatial perception and mental rotation tasks which are components of spatial ability (Lawton, 1994, 1996). It is clear that the individuals, who have low spatial sense and high spatial anxiety, might be confused and anxious so they could make mistakes easily in spatial tasks. Thus, in this research study, preservice teachers' lower anxiety levels might affect their self-confidence positively and they got higher scores in spatial visualization test.

The last finding of this study was that there was a negative relationship between geometry self-efficacy of preservice teachers and their spatial anxiety. That is, preservice teachers who had higher geometry self-efficacy scores had lower spatial anxieties. It was stated in the literature that an individual whose self-efficacy level is high feel serenity in approaching difficult tasks but an individual whose self-efficacy level is low might think that things are more difficult than they really are so he/she feels stressed, anxiety towards that task (Pajares, 2007). This statement supported the finding of the present study since it claimed that self-efficacy and anxiety were negatively correlated. Thus, the preservice teachers, whose geometry self-efficacy levels were high, might feel more self-confident and serenity than others in executing spatial tasks so their spatial anxiety level might be found low in the present study.

5.2 Implications and Recommendations for Further Research

In the present study, the main focus was to investigate preservice teachers' spatial visualization ability, geometry self-efficacy and spatial anxiety in terms of undergraduate program and gender. Besides, the relationship among preservice teachers' spatial ability, geometry self-efficacy and spatial anxiety was evaluated. In the view of findings and in the critique of previous literature, some recommendations are offered for further studies.

The design of the study included some limitations for generalizability. For instance, the sampling method was convenience sampling which means that the researcher collects data from the individuals who are available (Fraenkel & Wallen, 2006). In order to make generalization of the findings to the population, further research including the randomly selected sample from the universities in Turkey could be performed. Moreover, the sample consisted of 3rd and 4th grade students of education faculties so this might restrict the researcher to generalize the solutions to all preservice teachers. The 1st, 2nd, 3rd and 4th grade students could be selected to compare the spatial visualization, geometry self-efficacy level and spatial anxiety levels of preservice teachers. In this way, the difference among grade levels could be observed more precisely. Besides, a longitudinal study could be conducted to see the changes in these levels of preservice teachers from 1st grade to 4th grade. In this way, the effect of the courses given in education faculties on spatial visualization ability, geometry self-efficacy and spatial anxiety of preservice teachers could also be investigated in further studies.

Furthermore, the researcher used a test to measure spatial visualization abilities of preservice teachers so only spatial visualization ability component of spatial ability was examined in the present study. A similar study could be conducted by using more comprehensive test containing other components of spatial ability like spatial orientation, spatial perception and mental rotation.

In the present study, the researcher investigated the existing spatial visualization levels of preservice teachers. In order to investigate the factors affecting the spatial visualization abilities of preservice teachers, an experimental study could be conducted. Furthermore, a qualitative research could be conducted for in-dept investigation.

Lastly, there are some implications for teacher educators, teachers and curriculum developers.

The findings revealed that spatial visualization ability levels of preservice teachers could be accepted as moderate. Therefore, the attention of teacher educators could be taken into the learning and teaching of geometry and spatial thinking since the achievement of students in geometry and spatial reasoning is quite low. Teacher educators could propose to improve the spatial visualization abilities of preservice teachers by arranging undergraduate course contents such as adding tasks improving spatial visualization ability to must courses to make all students benefit from these tasks. In addition, they can add elective courses aiming to improve spatial visualization abilities of preservice teachers. In these courses, they can use manipulatives, computer programs and concrete materials to make preservice teachers manipulate the objects and its parts in 2D and 3D space.

The spatial visualization abilities of the individuals could be improved from early childhood education till the end of undergraduate education, not only at the undergraduate education. Therefore, inservice teachers have a great importance in the improvement of spatial visualization abilities of their students. Based on the findings it could be deduced that inservice teachers could organize their lessons by considering the improvement of spatial visualization abilities of their students from early years. To put it clearly, the teachers could help all students to improve their spatial visualization abilities by building models, drawing, manipulating blocks, using hands-on materials, using computer programs during the instruction. Besides, they could prepare exam questions not only by asking in a written way, but also adding visual representations in order to make spatial learner students understand the questions better.

In addition, the curriculum developers could take action in organizing textbooks in a way that they include appropriate spatial activities for students. That is, curriculum developers could add activities and topics to the curriculum and textbooks highlighting the importance of spatial visualization ability in mathematics and science courses and even in early childhood education.

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APPENDICES

APPENDIX A

SPATIAL VISUALIZATION TEST (SVT)

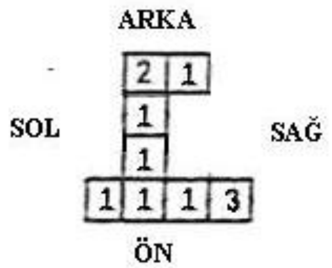
UZAMSAL GÖRSELLEŞTİRME ÖLÇEĞİ

Değerli Öğrenciler;

Bu ölçek sizin uzamsal görselleştirmeye yönelik becerilerinizi belirlemek için hazırlanmıştır. Soruları dikkatlice okuyunuz. Doğru olduğunu düşündüğünüz seçeneği işaretleyiniz. Bu sorulara vereceğiniz yanıtlar, araştırma amacıyla kullanılacak ve gizli tutulacaktır. Katkılarınızdan dolayı teşekkür ederiz.

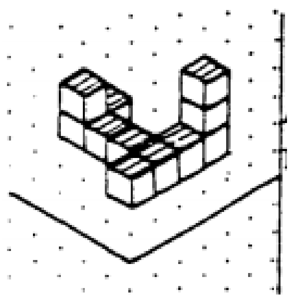
Şekil 1'deki görünümü dikkate alarak aşağıdaki 2 örneği inceleyiniz.

Şekil 1'de bir yapının kuş bakışı görünümü verilmiştir. Karelerin içinde yazılı rakamlar, o karede üst üste kaç küpün bulunduğunu göstermektedir.



Şekil 1

Örnek 1 :



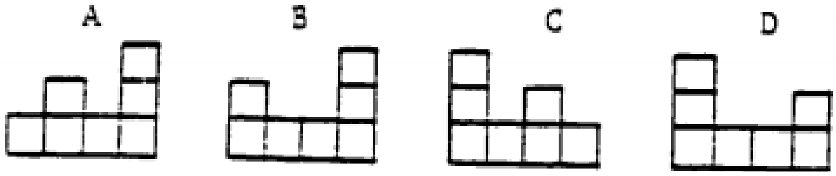
Yandaki şekil, **Şekil 1**'de kuş bakışı görünümü hangi köşeden görünümüdür?

A) ÖN-SAĞ
B) ARKA-SAĞ
C) ARKA-SOL
D) ÖN-SOL

(Doğru cevap **D**)

Örnek 2 :

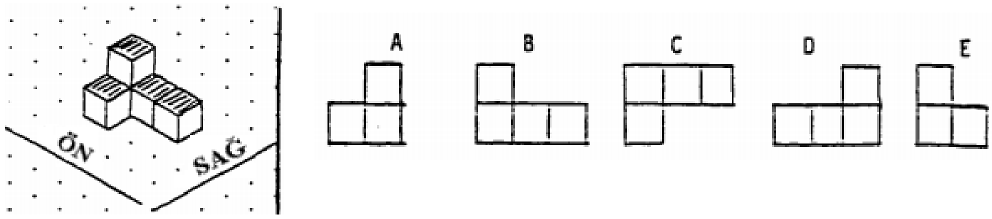
Aşağıdakilerden hangisi **Şekil 1**’de kuş bakışı görünümü verilen yapıya önden bakıldığında elde edilen görünümdür?



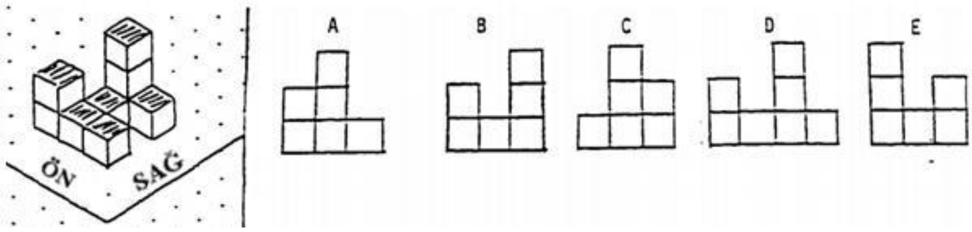
(Doğru cevap **A**)

SORULAR

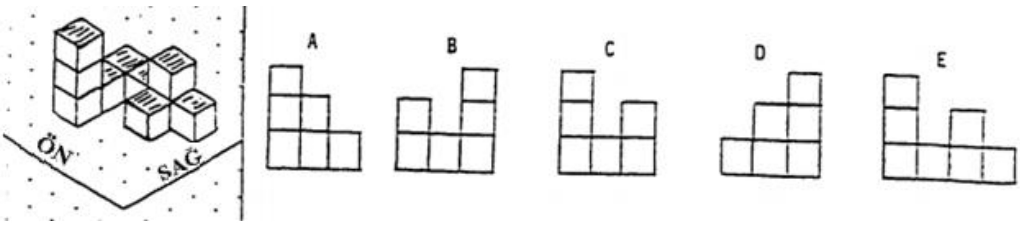
1. ÖN-SAĞ köşeden görünümü verilen yapının **SAĞ**’dan görünümü aşağıdakilerden hangisidir?



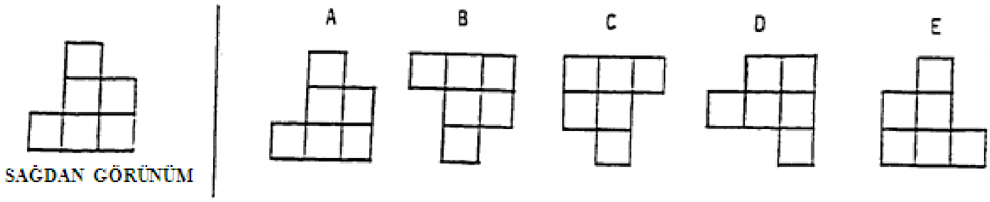
2. ÖN-SAĞ köşeden görünümü verilen yapının **ARKA**’dan görünümü aşağıdakilerden hangisidir?



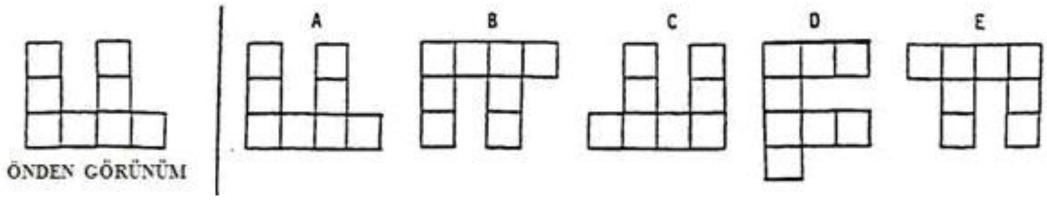
3. ÖN-SAĞ köşeden görünümü verilen yapının **SAĞ**’dan görünümü aşağıdakilerden hangisidir?



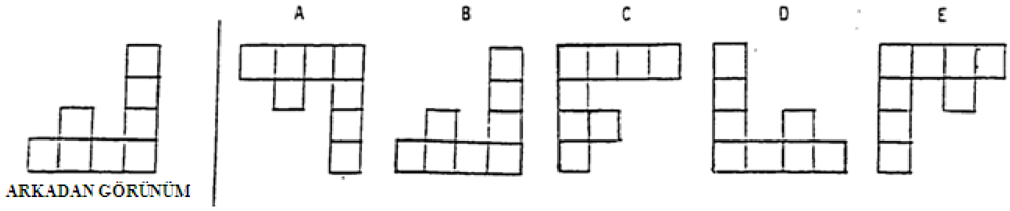
4. SAĞ'dan görünümü verilen yapının **SOL**'dan görünümü aşağıdakilerden hangisidir?



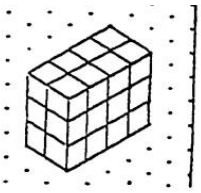
5. ÖN'den görünümü verilen yapının **ARKA**'dan görünümü aşağıdakilerden hangisidir?



6. ARKA'dan görünümü verilen yapının **ÖN**'den görünümü aşağıdakilerden hangisidir?

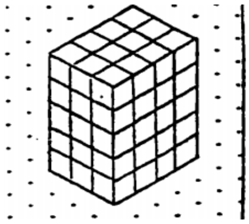


7. Aşağıdaki yapıyı inşa edebilmek için toplam kaç küp gereklidir?



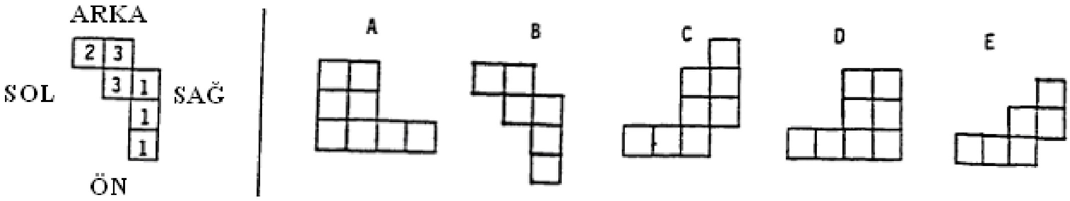
A	B	C	D	E
18	24	26	36	52

8. Aşağıdaki yapıyı inşa edebilmek için toplam kaç küp gereklidir?

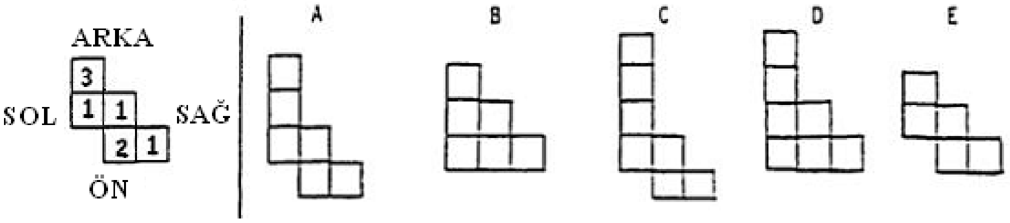


A	B	C	D	E
36	47	60	72	94

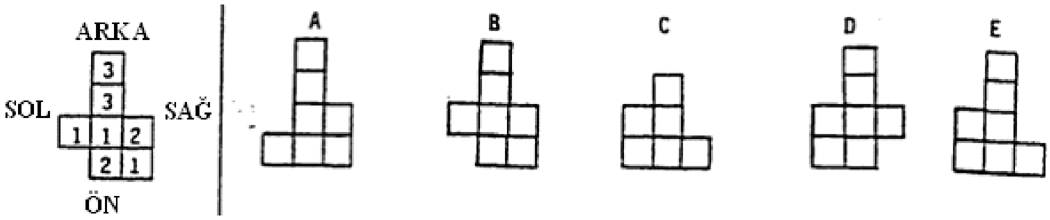
9. Kuş bakışı görünümü verilen yapının **SAĞ**’dan görünümü aşağıdakilerden hangisidir?



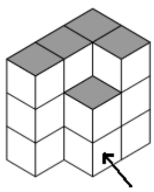
10. Kuş bakışı görünümü verilen yapının **ÖN**’den görünümü aşağıdakilerden hangisidir?



11. Kuş bakışı görünümü verilen yapının **ARKA**’dan görünümü aşağıdakilerden hangisidir?

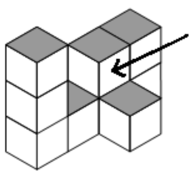


12. Aşağıda ok ile işaret edilen küp, **kaç tane** küp ile yüz yüze çakışmaktadır (yüzleri birbirine değmektedir)?



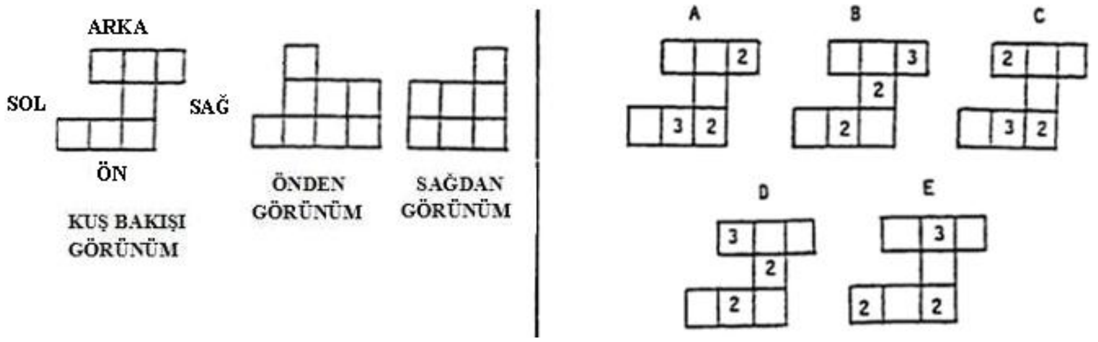
A	B	C	D	E
1	2	3	4	5

13. Aşağıda ok ile işaret edilen küp, **kaç tane** küp ile yüz yüze çakışmaktadır (yüzleri birbirine değmektedir)?

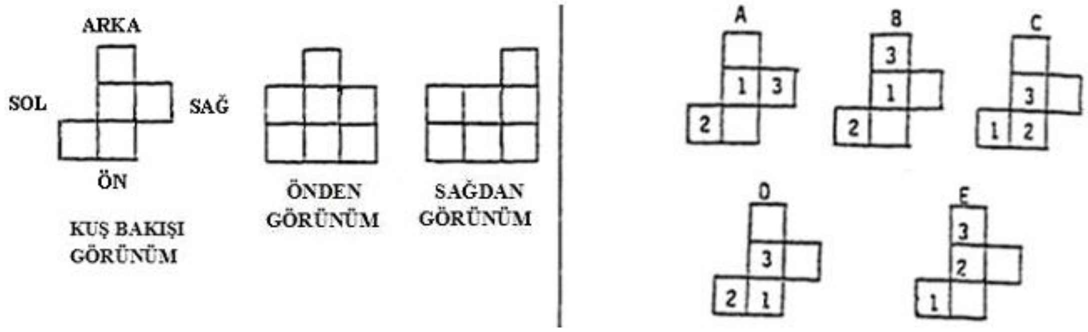


A	B	C	D	E
1	2	3	4	5

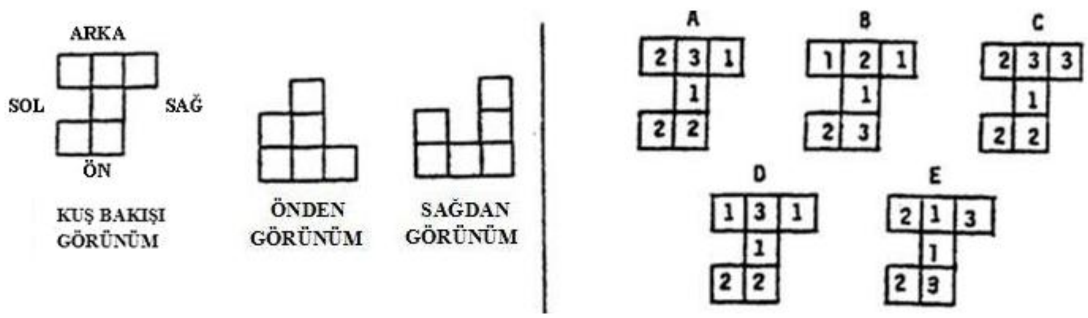
14. Bir yapının kuş bakışı, önden ve sağdan görünümleri verilmiştir. Aşağıdakilerden hangisi bu yapının kuş bakışı görünümüne uygundur.



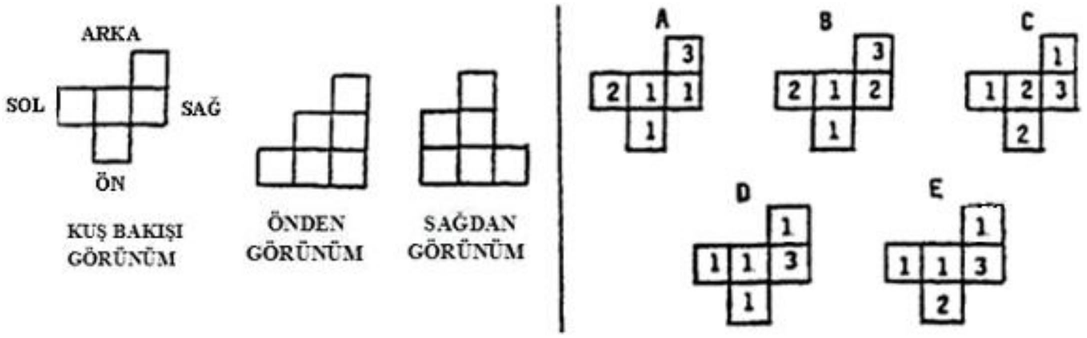
15. Bir yapının kuş bakışı, önden ve sağdan görünümleri verilmiştir. Aşağıdakilerden hangisi bu yapının kuş bakışı görünümüne uygundur?



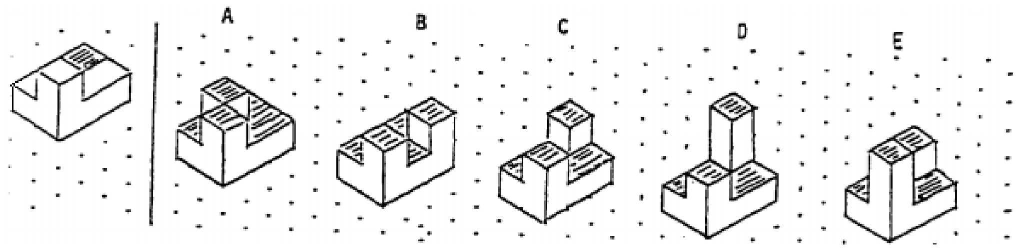
16. Bir yapının kuş bakışı, önden ve sağdan görünümleri verilmiştir. Aşağıdakilerden hangisi, **en fazla sayıda küp kullanılmak şartıyla**, bu yapının kuş bakışı görünümüne uygundur?



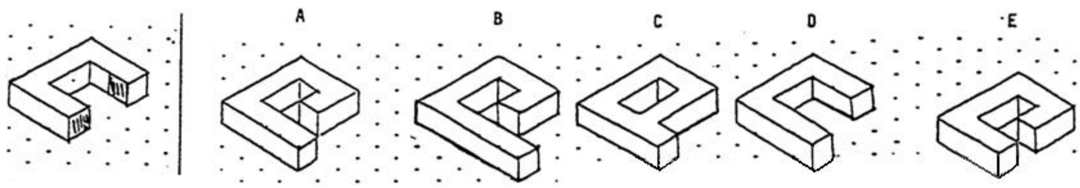
17. Bir yapının kuş bakışı, önden ve sağdan görünümleri verilmiştir. Aşağıdakilerden hangisi, **en az sayıda küp kullanılmak şartıyla**, bu yapının kuş bakışı görünümüne uygundur?



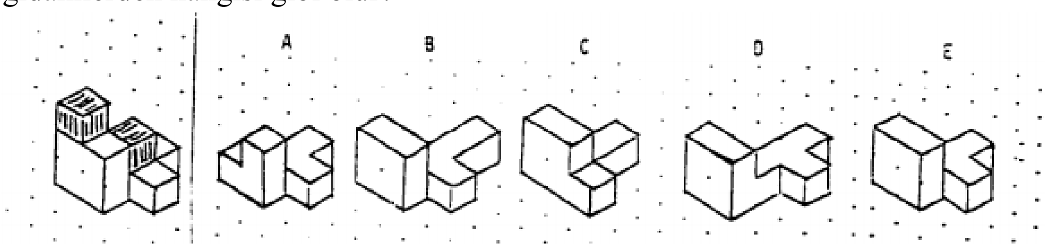
18. Aşağıda solda verilen yapının taralı yerine yeni bir küp eklenirse yapının yeni görünümü aşağıdakilerden hangisi gibi olur?



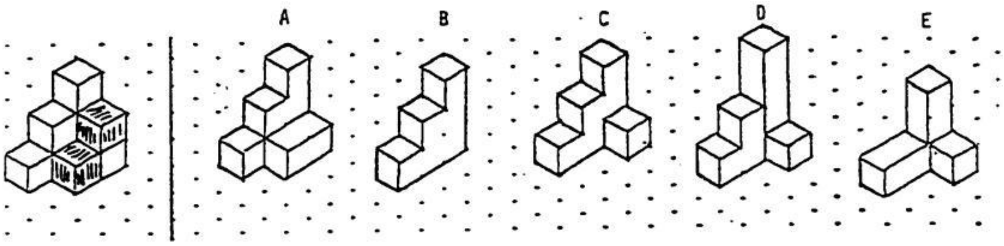
19. Aşağıda solda verilen yapının taralı yerlerine yeni birer küp eklenirse yapının yeni görünümü aşağıdakilerden hangisi gibi olur?



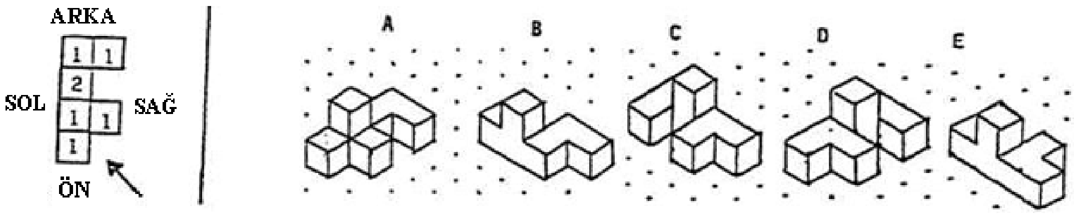
20. Aşağıda solda verilen yapıdan taralı küpler çıkarılırsa yapının yeni görünümü aşağıdakilerden hangisi gibi olur?



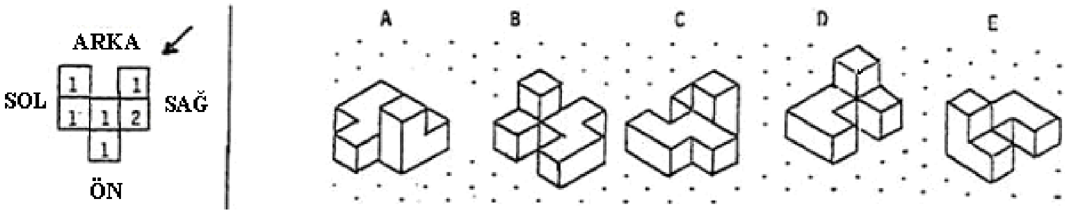
21. Aşağıda solda verilen yapıdan taralı küpler çıkarılırsa yapının yeni görünümü aşağıdakilerden hangisi gibi olur?



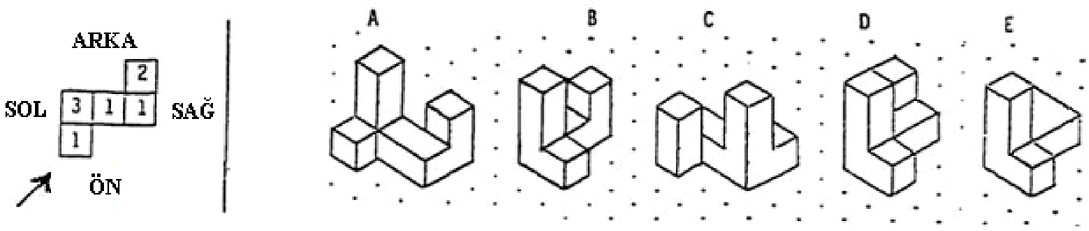
22. Kuş bakışı görünümü verilen yapının **ÖN-SAĞ** (ok ile gösterilen) köşeden bakıldığındaki görünümü aşağıdakilerden hangisi gibi olur?



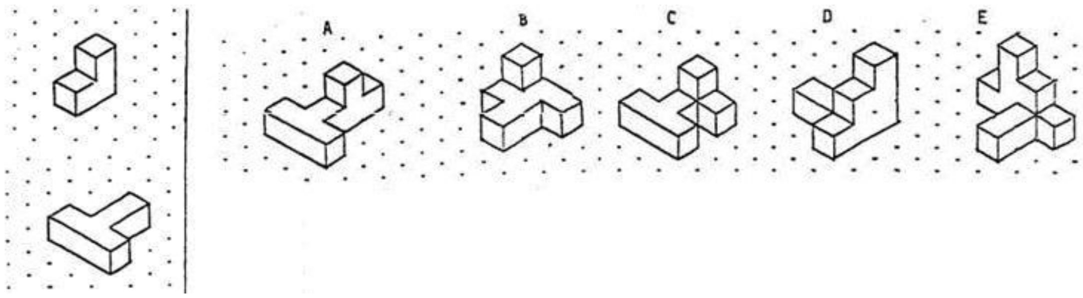
23. Kuş bakışı görünümü verilen yapının **ARKA-SAĞ** (ok ile gösterilen) köşeden bakıldığındaki görünümü aşağıdakilerden hangisi gibi olur?



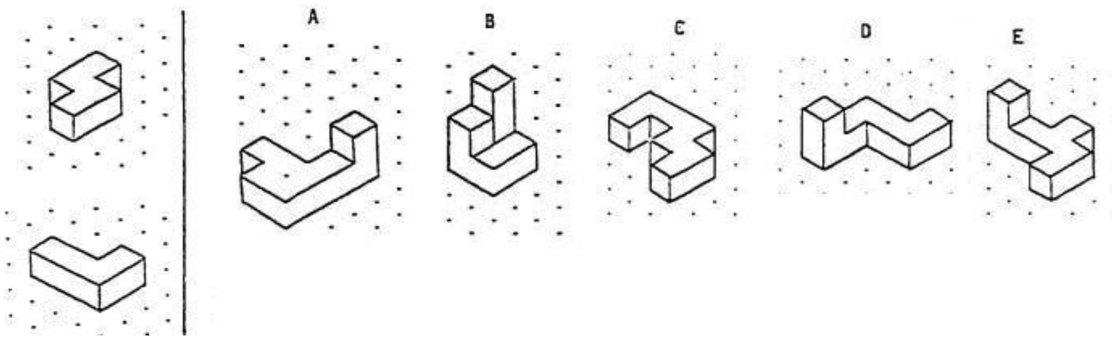
24. Kuş bakışı görünümü verilen yapının **ÖN-SOL** (ok ile gösterilen) köşeden bakıldığındaki görünümü aşağıdakilerden hangisi gibi olur?



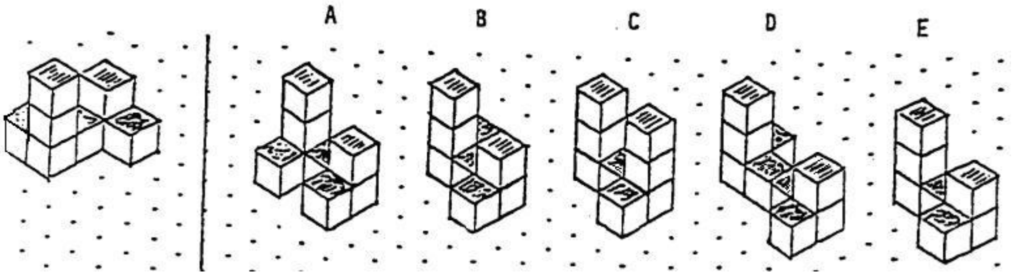
25. Aşağıda solda verilen iki yapının herhangi bir şekilde birleştirilmesiyle oluşan yeni yapı aşağıdakilerden hangisidir?



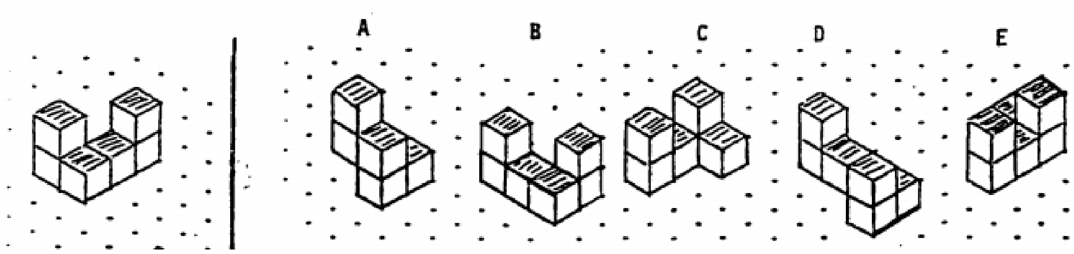
26. Aşağıda solda verilen iki yapının herhangi bir şekilde birleştirilmesiyle oluşan yeni yapı aşağıdakilerden hangisidir?



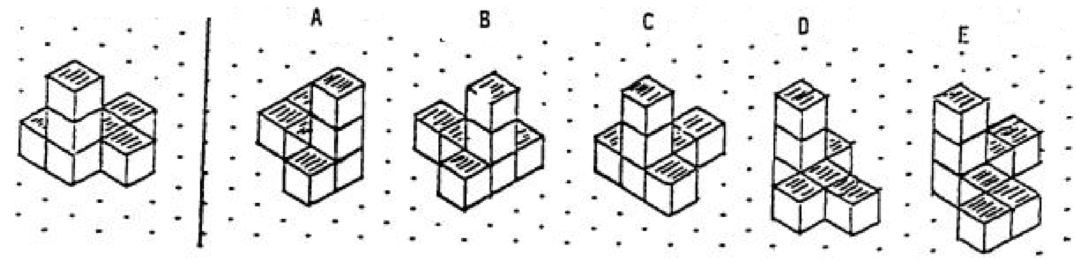
27. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



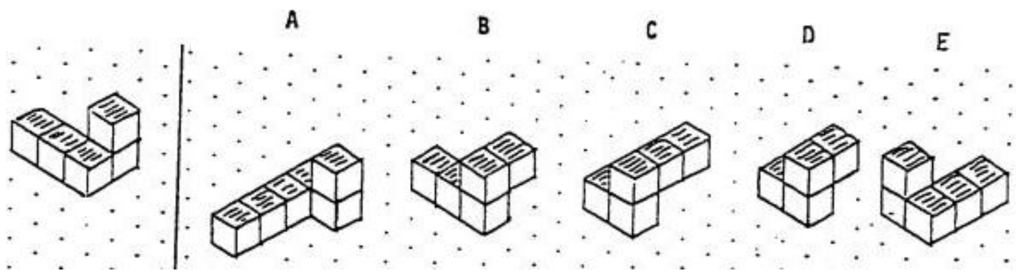
28. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



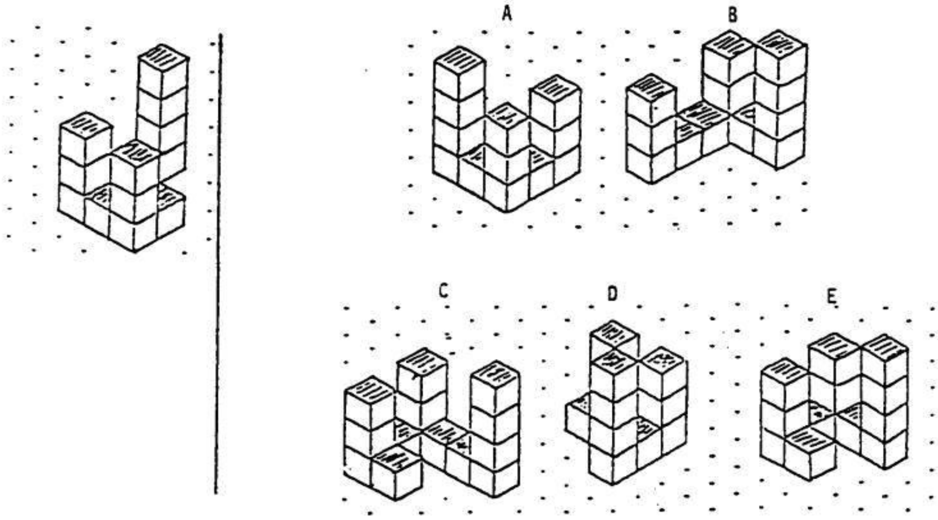
29. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



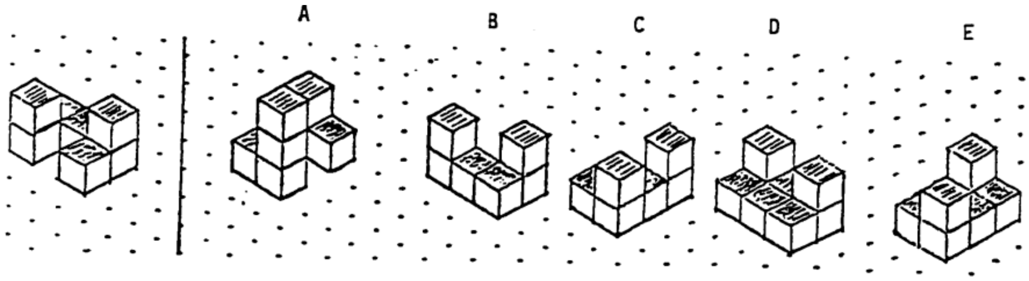
30. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



31. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



32. Aşağıda solda verilen yapının başka bir yönden görünümü aşağıdakilerden hangisidir?



APPENDIX B

GEOMETRY SELF-EFFICACY (GSE) SCALE

GEOMETRİYE YÖNELİK ÖZYETERLİK ÖLÇEĞİ

Cinsiyet : .... Sınıf: ....
Üniversite: ....
Bölüm: ....

Bu ölçekte 5'li derecelendirme yapılmış olup 1 hiçbir zaman, 2 ara sıra, 3 kararsızım, 4 çoğu zaman ve 5 her zaman olarak düşünülmüştür. Lütfen verilen ifadeler için 1-5 arası size en uygun olan rakamı işaretleyiniz.

	Hiçbir Zaman	**Ara Sıra**	**Kararsızım**	**Çoğu Zaman**	**Her Zaman**
1. Geometrideki kavramları rahatlıkla anlayabilirim.	1	2	3	4	5
2. Günlük yaşamda gördüğüm nesneleri geometrik şekillere benzetebilirim.	1	2	3	4	5
3. Geometride arkadaşlarım kadar iyi olmadığımı düşünüyorum.	1	2	3	4	5
4. Bir geometrik şekil gördüğümde onun özelliklerini hatırlayabilirim.	1	2	3	4	5
5. Bir geometri sorusu görünce ne yapılacağını bilemem.	1	2	3	4	5
6. Saatlerce çalışsam bile geometride başarılı olamayacağımı düşünüyorum.	1	2	3	4	5
7. Geometri ile el becerilerimi arttırabileceğimi düşünüyorum.	1	2	3	4	5
8. Geometri bilgimi diğer derslerde kullanabilirim.	1	2	3	4	5
9. Geometri konusunda yeterli bilgiye sahip değilim.	1	2	3	4	5
10.Geometri konusunda verilecek olan projelerde başarılı olacağımı düşünüyorum.	1	2	3	4	5

	Hiçbir Zaman	Ara Sıra	Kararsızım	Çoğu Zaman	Her Zaman
11.Geometri sorusu çözdükçe kendime olan güvenimin artacağını düşünüyorum.	1	2	3	4	5
12. Geometrik şekiller ile ilgili materyal geliştiremem.	1	2	3	4	5
13. Geometrik şekilleri kafamda canlandırabilirim.	1	2	3	4	5
14. Geometri ile ilgili problemler yazabilirim.	1	2	3	4	5
15. Geometri konusunda kendimi başarılı görüyorum.	1	2	3	4	5
16. Bir geometri problemini çözmek için gereken işlem basamaklarını çıkarabilirim.	1	2	3	4	5
17. Matematiksel problemleri çözerken geometrik şekillerden yararlanırım.	1	2	3	4	5
18. Geometrik şekiller arasındaki ilişkileri söyleyemem.	1	2	3	4	5
19. Geometrik şekillerin sahip oldukları çevre uzunluklarını tahmin edebilirim.	1	2	3	4	5
20. Yabancı bir yerde yolumu kaybedersem geometri bilgim ile yolumu bulabilirim.	1	2	3	4	5
21. Geometri ile ilgili sorun yaşayan arkadaşlarıma yardımcı olabilirim.	1	2	3	4	5
22. Bir geometrik şeklin özelliklerini duyduğumda şeklini çizebilirim.	1	2	3	4	5
23. Geometrik şekilleri kullanarak yeni bir geometrik şekil oluşturabilirim.	1	2	3	4	5
24. Bir geometri sorusunda işlemleri yaparken telaşa kapılacağımı düşünüyorum.	1	2	3	4	5
25. İleriki yıllarda geometri bilgisinin kullanıldığı bir meslek seçersem başarılı olacağıma inanıyorum.	1	2	3	4	5

APPENDIX C

SPATIAL ANXIETY (ANX) SCALE

UZAMSAL KAYGI ÖLÇEĞİ

Aşağıdaki durumlarda hissedeceğinizi düşündüğünüz kaygı seviyesini belirleyiniz. Her bir soru için size en uygun seçeneği işaretleyiniz.

	Hiç kaygılanmam	**Biraz kaygılanırım**	**Kararsızım**	**Çok kaygılanırım**	**Çok fazla**
1. Bilmediğim bir şehir veya bölgede aradığım yeri bulmaya çalışırken	1	2	3	4	5
2. İlk kez ziyaret ettiğim ve odaların karmaşık bir şekilde düzenlendiği bir yerde yolumu bulmaya çalışırken	1	2	3	4	5
3. Bilmediğim bir alışveriş merkezi, sağlık merkezi veya karmaşık büyük bir binada yolumu bulmaya çalışırken	1	2	3	4	5
4. Yolculuk sırasında kaybolduğumu farkedip daha sonra yönümü bulmaya çalışırken	1	2	3	4	5
5. Kapalı mekândayken dışarıdaki bir yere nasıl gidileceğini tarif ederken	1	2	3	4	5
6. İlk kez girdiğim bir binadan çıktıktan sonra hangi yöne gitmem gerektiğine karar verirken	1	2	3	4	5
7. Haritadan yararlanmadan kestirme olacağını düşündüğüm yeni bir yolu denerken	1	2	3	4	5
8. Bilmediğim bir şehir veya bölgede hangi yöne gideceğime karar verirken	1	2	3	4	5