INVESTIGATION OF EFFECT OF VISUAL TREATMENT ON ELEMENTARY SCHOOL STUDENT'S SPATIAL ABILITY AND ATTITUDE TOWARD SPATIAL ABILITY PROBLEMS

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ABSTRACT

INVESTIGATION OF EFFECT OF VISUAL TREATMENT ON ELEMENTARY SCHOOL STUDENT'S SPATIAL ABILITY AND ATTITUDE TOWARD SPATIAL ABILITY PROBLEMS

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The purposes of the study were to investigate the effects of visual treatment on students' opinion in terms of thinking process and students' opinion in terms of feelings in the spatial ability activities; to investigate the effects of visual treatment on student's spatial ability, spatial visualization and spatial orientation

The study was conducted in Ankara with 21 sixth-grade elementary school students. One group pretest-posttest design was used. Two measuring instruments were utilized: Spatial Ability Test and Spatial Problem Attitude Scale. Spatial Ability Test, which was developed by Ekstrom, consists of paper folding and surface development tests measuring the spatial visualization ability and card rotation together with cube comparison tests measuring the spatial orientation ability. The tests were translated into Turkish by Delialioğlu, (1996). Spatial Problem Attitude Scale was developed by researcher. The study employed both quantitative and qualitative research using a mixed method design. The researcher conducted 9 interviews with nine 6th grade students from the same class. The students were asked their opinion about the visual treatment in terms of thinking process and feelings in the spatial ability activities. Additionally, the class was observed during their activity time that continued 10 weeks and five hours per week.

In order to analyze the obtained data, Friedman and Wilcoxon tests as well as one-way repeated measures Analysis of Variance were used. To analyze data obtained from interviews, the phenomenographic method was used.

The results of the study indicated that there was a statistically significant change in students' spatial ability, spatial orientation and spatial visualization scores across three time periods (pre treatment, post treatment and retention). All three scores were significantly different from each other. Test scores were significantly higher immediately after the visual treatment than those before the treatment. The test scores one month later were significantly lower than those immediately after the treatment, but significantly higher than the scores before the treatment.

The findings suggest that visual treatment has positive effects on students' spatial cognitive process and their attitudes toward spatial ability problems. Selection of the appropriate visual treatment should be based on students' needs and their cognitive development level for providing better learning environment

Keywords: Spatial ability, spatial visualization ability, spatial orientation ability, visual treatment.

ÖZ

GÖRSEL ÖĞRETİMİN İLKÖĞRETİM ÖĞRENCİSİNİN UZAMSAL YETENEĞİNE VE UZAMSAL YETENEK PROBLEMLERİNE YÖNELİK TUTUMUNA ETKİSİNİN İNCELENMESİ

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Bu araştırmanın amacı görsel yöntemin, öğrencilerin düşünce süreçleri ve duyguları bağlamındaki görüşleri üzerine etkisini araştırmak ve görsel yöntemin öğrencilerin uzamsal yetenek, uzamsal görsel, uzamsal alıştırma üzerine etkilerini araştırmaktır

Araştırma Ankara'nın bir bölge ilköğretim okuluna kayıtlı 21 altıcı sınıf öğrencisi ile yürütülmüştür. Bir guruplu öntest-sontest araştırma deseni kullanılmıştır. Bu araştırma için iki ölçme aracı kullanılmıştır: Uzaysal Yetenek Testi ve Uzamsal Problem Tutum Ölçeği. Uzaysal yetenek testi Ekstrom tarafından geliştirilmiş olan kart çevirme, küp karşılaştırma, kâğıt katlama ve yüzey oluşturma testlerinden oluşmaktadır. İlk iki test uzaysal yeteneğin alt boyutlarından olan uzaysal yönelim yeteneğini ölçerken son iki test uzaysal görme yeteneğini ölçmektedir. Bu testler Türkçeye Delialioğlu tarafından çevrilmiştir (1996). Uzamsal problem tutum ölçeği ise araştırmacı tarafından geliştirilmiştir. Araştırmada karma metodu deseni kullanılarak nitel ve nicel araştırma yöntemleri uygulanmıştır. Aynı sınıfta öğrenci olan altıncı sınıf öğrencileri ile 9 görüşme gerçekleştirilmiştir. Öğrencilerden uzamsal aktivitelerdeki düşünce süreçleri ve duyguları bağlamında görsel yöntem hakkındaki görüşleri sorulmuştur. Buna ek olarak öğrenciler haftada 5 saat olmak üzere 10 hafta boyunca süren aktivite zamanlarında öğrenciler sınıf ortamında gözlemlenmiştir.

Elde edilen verileri analiz etmek için tek yönlü varyans analizi yöntemi, Friedman ve Wilcoxon testleri kullanılmıştır. Öğrenciler ile gerçekleştirilen görüşmelerden elde edilen verilerin analizinde öğrencilerin görüşleri fenomenografik yöntemle karşılaştırılmış, kategorilere ayrılmış ve yorumlanmıştır.

Araştırmanın sonuçları göstermiştir ki öğrencilerin uzamsal yetenek, uyum ve görsel skorlarında zamana dayalı güçlü ve anlamlı bir değişiklik bulunmuştur. Zamana dayalı her üç skor güçlü olarak birbirlerinden farklıdır. Görsel yöntemden sonra elde edilen test skorları, öncekilerden güçlü ve anlamlı olarak daha yüksek bulunmuştur. Yöntemden bir ay sonra elde edilen test skorları, yöntemin hemen arkasından elde edilen test skorlarından güçlü ve anlamlı olarak daha düşük olmasına rağmen yöntem öncesinde elde edilen skorlardan daha yüksektir.

Ayrıca görsel yöntem öğrencilerin uzamsal zihinsel süreçlerine, uzamsal problemlere karşı olan tutumlarında olumlu bir etkisi olduğu bulunmuştur. Daha iyi bir öğrenme ortamının sağlanması için uygun görsel yöntemin seçimi öğrencilerin zihinsel gelişim ve ihtiyaçlarına dayalı olmalıdır.

Anahtar Kelimeler: Uzaysal yetenek, uzaysal görme yeteneği, uzaysal yönelim yeteneği, görsel yöntem

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ABBREVATIONS	
SAT	: Spatial Ability Test
SOAT	: Spatial Orientation Ability Test
SVAT	: Spatial Visualization Ability Test
SD	: Standard Deviation
M	: Mean
Df	: Degrees of Freedom
α	: Level of Significance
p	: Probability
Std. Error	: Standard Error
ANOVA	: Analysis of Variance
SPSS	: Statistical Packages for Social Science
LSD	: Least Significant Difference
CAD	: Computer Aided-Design
PFT	: Paper Folding Test
CRT	: Card Rotation Test
SDT	: Surface Development Test
CCT	: Cube Comparison Test

CHAPTER 1

INTRODUCTION

Spatial ability is accepted as one of the most important intelligence type, which is necessary for students' achievement not only in their academic life but also in their daily life. Since, spatial ability is crucial for students both in their whole academic and daily lives, how to improve it has been an important issue for people in various disciplines such as mathematics, physics, geometry, geology, education, medicine etc (Battista, Whealthy & Talsma, 1982; Maier, 1996; Olkun, Altun & Smith, 2005; Piburn, Reynolds & McAuliffe, 2005; Trindade, Fiolhais & Almeida, 2002; Wanzel, Hamstra, Caminiti, Anastakis, Grober & Reznick, 2003). Moreover, students' opinion about treatment that aim to improve students' spatial ability in terms of their thinking process and feelings was another crucial issue that should be handled by the researchers The main aim of the study were to investigate the effects of visual treatment on students' opinion in terms of thinking process and students' opinion in terms of feelings in the spatial ability activities; to investigate the effects of visual treatment on student's spatial ability, spatial visualization and spatial orientation.

One of the studies that achieve to improve spatial ability by using visual treatment was performed by Clements and Owens (1998) and Alias, Black and Gray (2003). Clements et al. (1998) and Alias et al. (2003) stated that spatial visualization ability was essential in effecting students' cognitive construction and improving their problem solving design. The use of concrete materials provided a chance to encourage students to enhance their imagery and problem-solving processes (Clements & Owens, 1998). Moreover, Alias, et al. (2003) believed that great importance should be given to the concrete learning experiences before students reach formal operation stage of thinking. In addition to this, Ben-Chaim, Lappan and Houang (1985, 1988) found in their research that concrete experience

with cubes such as building; representing 3 dimensional constructs in 2-dimensional drawings and evaluating them were helpful in improving students' spatial ability.

Many studies which were different than the studies performed by using concrete materials showed that there was a relationship between sketching-drawing activities and spatial abilities. (Kayhan, 2005; Alias, Black & Gray, 2002; Olkun, 2003) According to Olkun, (2003) there are mainly two main reasons for selection drawing activities. First one is it has a practical base in real life situations and second one is concrete experience with geometrical objects are accepted supportive in improving students' performance in spatial visualization.

Activities used in that research were divided into two groups which were activities with concrete materials and virtual environment activities. These activities were used to enhance students' spatial ability. The reason for selecting these types of activities was based on findings of similar researches. Review of literature showed that these two types of activity helpful in enhancement of spatial ability.

An assortment of studies maintained that spatial ability could be improved by geometry education. Battista, Whealthy and Talsma (1982) stated that in his research students' spatial score were significantly higher at the end of the semester than at the beginning after they attend to geometry course. Kausfmann, Steinbugl, Dünser and Glück (2004) believed that using 3D dynamic geometry provide both complete evaluation study of geometry and improve spatial ability. In addition to this study Ives (2003) stated that using dynamic real world geometry activities in lectures increase the number and types of external mathematical representation used by students and dynamic models should be included into middle school mathematics curriculum for effective teaching.

As a result of these studies, in the present study effects of geometry education on students' spatial ability and attitude toward spatial ability activities were investigated.

Research performed by Clements and Battista, (1997) showed that using tetrominoes and Tetris type computer game had a positive effect on spatial competency and the ability of transform geometric shapes and get idea about the method which is units of units of students used in both spatial and numeric problems.

There has been a growing research base about using of virtual environment activities to enhance spatial ability. Research results suggest that using virtual environment activities improves students' spatial rotation, spatial visualization as a result spatial abilities and mathematics discoveries (Gabrielli, Rogers & Scaife, 2000; Keller, Moses & Hart, 2002; Kozhenikov & Thornton, 2006; Lisi & Wolford 2002; Passig & Eden, 2001; Olkun, Altun & Smith, 2005; Piburn, Reynolds & McAuliffe, 2005 Rafi, Amuar, Samad, Hayati & Mahadzır, 2005). It was found more beneficial for students to learn through Web-based virtual environment than usual classroom practices in the sense of improving the subjects' basic spatial ability (Rafi, Amuar, Samad, Hayati & Mahadzır, 2005). Another research about improvement of spatial ability by using virtual environment was performed by Lisi and Wolford in 2002. They claimed that students found computer game activities enjoyable and computer-based instructional activities could be used in schools for improving students' spatial ability. Additionally, on account of MBL (microcomputer-based) instruction, students' levels of spatial visualization increased significantly. Create isometric drawings, transform 3-D view of objects into 2-D drawings and generate 3-D isometric drawings from different 2-D views of geometric shapes so the spatial visualization ability skills achieved to improve by using applet-based instructional materials (Keller, Moses & Hart, 2002).

As a result, all these studies highlight the importance of using virtual environment activities to improve spatial ability. Therefore virtual environment activities were used to improve students' spatial ability.

According to Battista (1994) there was a significant and positive relation between mathematics and spatial thinking and it has often been suggested that involvement with spatial activities can improve students' mathematical thinking. Guay and McDaniel, (1977) supported that this relationship among elementary school students existed for low-level as well as high-level spatial abilities. However, (Erbilgin, 2003; Booth & Thomas, 2000) stated that students with higher Visio-spatial skills were better on producing different solution methods to the problems than students with lower Visio-spatial skills. In addition to this Tatre (1990) suggest in his research that '' spatial orientation skill appears to be used in specific and identifiable ways in the solution of mathematics problems'' (p.227). The way students select for solving mathematics problem depends on the difficulty of questions. Students prefer to select visual methods to complete difficult mathematics problems (Lowrie & Kay, 2001).

Another important aim of the study was put light to students' opinion about visual treatment in terms of their thinking process and feelings. There were mainly two reasons for examining students' attitude and their thinking process. First one was to provide better spatial ability activities and learning environment to students to improve their spatial ability. Second reason there was no such a study that examine students attitude and their thinking process about spatial ability in the literature.

Consequently, the purposes of the study were to investigate the affects of activity-based instruction on students' opinion about the visual treatment in terms of thinking process and in terms of feelings in the spatial ability activities; to investigate the effects of visual treatment on student's spatial ability, spatial visualization and spatial orientation. This research consisted of case studies with 6^{th} grade elementary school students on visual treatment.

1.1. Main and Sub-Problems of the Study and Associated Hypotheses

In this section main and sub problems and hypotheses are stated.

1.1.1 Main and Sub-Problems of the Study

The first main problem was stated as below;

P.1. What is the effect of visual treatment on sixth grade students' Spatial Ability, Spatial Orientation and Spatial visualization?

1.1 Is there a statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)?

1.2. Is there a statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention)?

1.3. Is there a statistically significant change in students' spatial visualization scores across three time periods (pre-treatment, post treatment and retention)?

The second main problem was stated as below;

P.2. What is sixth grade students' opinion about the visual treatment in terms of thinking process in the spatial ability activities and their feelings toward the spatial ability activities?

2.1 What is the students' opinion about the visual treatment in terms of thinking process in the spatial ability activities?

2.2 What is the students' opinion about the visual treatment in terms of feelings toward the spatial ability activities?

1.1.2. Hypotheses of the Second Main Problem in the Present Study

In order to examine the first main problem following hypotheses were stated in the null form and tested at a significance level of 0.05.

H_0.1.1. There is no statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)?

$H_0$1.2. There is no statistically significant change in students' spatial orientation scores across three time periods?

$H_0$1.3. There is no statistically significant change in students' spatial visualization scores across three time periods?

1.2. Definition of Terms

Spatial ability: Spatial ability means mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually (Caroll, 1993). In the present study spatial ability score refers to the sum of the spatial visualization score and spatial orientation score.

Spatial orientation: Spatial orientation is the ability to visualize and mentally manipulate spatial configurations, to maintain orientation with respect to spatial objects, and to perceive relationships among objects in space by (Ekstrom, 1976). In the present study spatial visualization ability score refers to the sum of card rotation test score and cube comparison test score.

Spatial visualization: Spatial visualization ability is defined as the ability to manipulate or transform the image of spatial patterns into other arrangements (Ekstrom, 1976). In the present study spatial visualization ability score refers to the sum of paper folding test score and surface development test score.

Visual treatment: Visual treatment is a kind of activity based-instruction that is performed by using different visual strategies (Chanlin, 1999). In the present study visual treatment refers nine activities composed of manipulative activity and virtual environment activity which promote learning spatial ability knowledge under different education settings.

Cognitive domain: Cognitive domain is the knowledge speed of events overwhelming the capacity to respond. It has three practical instructional levels including fact, understanding, and application. The fact level is a single concept and uses verbs like define, identify, and list. The understanding level puts two or more concepts together. The application level puts two or more concepts together to form something new (Piaget, 1964). In the present study cognitive domain is the mental process that students experience while dealing with spatial ability problems.

Feelings toward Spatial Problems: In the present study, feelings are the emotional reactions that are given by the students when they deal and face with spatial ability problems.

Spatial ability problems: In the present study, spatial ability problem is a kind of problem that required mental manipulation of objects and their parts in 2D and 3D space (Olkun, 2003).

1.3. Significance of the study

Comparisons of research findings concur that students' spatial ability could be enhanced by using appropriate visual treatment (Alias, Black&Gray, 2003; Ben-Chaim, Lappan & Houang, 1985; Clements & Owens, 1998; Kayhan, 2005; Olkun, 2003). However, students' cognitive processes and their feelings about activities that require spatial ability were not a common issue that was handled by the researchers before. Piaget (1964) determined the factors that contribute cognitive development at the "Jean Piaget Conference on Cognitive Studies and Curriculum Development". These factors are psychological development, direct experience with physical world, social transmission, and equilibration. Moreover, Copeland (1970) stated that as cognitive development is not a passive process; it involves acts or operations by the learner, such an environment that student acts or mental operations on objects in physical world involve revising partial understanding, broadening concepts and relating one idea to another. That is why

visual treatment was used in this research to have opinion about students' cognitive development and feeling. This was achieved by performing interviews with students.

Another important issue was the physical development of students. Piaget stated that, students should reach formal operational stage (at the age of 11-12) to understand the terms projective geometry, frame of reference, logical classification, Euclidean geometry and space are the bases of visual treatment in this study. Because of this reason, students selected to have opinion about their cognitive process and feelings were at the age of 11 and 12. Understanding the opinion of students' about their cognitive processes and feelings in visual treatment will provide a chance for teachers to prepare such an environment those students can learn spatial concepts better. When teachers know which activity is more beneficial and which activity get the attention of the students, they can easily select appropriate visual treatment.

Studies also showed that spatial ability is also an important issue in professional life. One of the areas which are in positive relations with spatial ability is medicine. (Wanzel, 2003; Brandt, Davles, 2004; Keenher, 2006). Effectiveness and safety are the most important parts of the surgical procedure. Keenher, Lippa, Montello, Tendick and Hgarty (2006) found in their research that 3-dimesional rotation ability played an important role in complex surgical procedure in terms of safety and effectiveness. Engineering is another important area that is directly related to spatial ability. Most of the areas of engineering, especially mechanical engineering, civil engineering and electric-electronic engineering require three-dimensional thinking ability. Mechanical engineering requires drawing different mechanical parts from different points of view while civil engineering requires thinking the plans of buildings in three dimensions and electric-electronic engineering requires abstract and three dimensional thinking to construct electrical schemes (Olkun 2003).

Because of the relationship between spatial ability and other disciplines such as mathematics, geometry, medicine, physics, chemistry and geology, a great

importance should be given for improving students' spatial ability. However, although there was a consensus about the importance of spatial ability, there were discrepancies in application. The new mathematics curriculum was put into practice in Turkey in 2005. One of the main aims of the new mathematics curriculum, which is basically founded on multiple-intelligence, was to improve students' spatial ability (MEB, 2005). In order to achieve this aim, a great importance was given to spatial ability and too many related activities such as construct cubes, perform perspective drawings, and find the open or close forms of three prisms and pyramids were included to the new curriculum. Moreover new curriculum gave importance to providing such an environment that students learn by act on objects in physical world and to providing activities with respect to their cognitive development ages. Hence, improving spatial ability and the ways to achieve it has become one of the most important issues for educators and curriculum developers. That is why; researcher paid attention to the activities that aim to enhance spatial ability. Activities should be based on students' cognitive levels, interests, feelings and opportunities. Activities performed for this study during 10 weeks to enhance students' spatial ability aim to have opinion about students' feelings and cognitive development for better learning environment.

CHAPTER 2

LITERATURE REVIEW

The literature related to the present study is reviewed in this chapter. On the basis of the content and the main objectives of the study, the literature is assorted into two sections; definitions of spatial ability, spatial visualization and spatial orientation, and the studies on spatial ability.

2.1. Theoretical Background.

At the conference "Jean Piaget Conference on Cognitive Studies and Curriculum Development" held in 1964 at Cornell University, Piaget stated four factors that contribute intellectual development. These are physiological development, direct experience with physical world, social transmission and equilibration. According to Piaget (1964) intellectual development involves acts and mental operation with physical world involves relating one idea to another. Moreover, knowledge is not copying the reality, to know something is to act on it, to modify it or transform it which is called operation. In other words, knowledge is something constructed by the student internally from actions he performs on objects. That is why, teacher plays a crucial role in providing an environment that students act with physical world and asking appropriate questions to perform better learning.

Piaget (1953) defined logical thinking as "conscious realization of the use one makes of a world or a concept in a process of reasoning" (p.147). Isaacs (1965) explained the study of Piaget about logical relations in his research. The aim of that study was to understand how children think about logical relations by

asking students to complete a unfinished sentence which was ended with conjunctions such as; because, therefore, then and discordance. According to research results the number of students' correct answers increased with their ages. For example boys at the age of 7 made true connection 36% of incomplete sentences, boys at the age of 8 made true connection %50 of incomplete sentences and boys at the age of 9 made true connection %88 of incomplete sentences. As it understood from this study, logical thinking ability show changes with respect to students' ages. Piaget (1964) classified children reasoning with respect to their ages. First stage is the pure transduction which extends to age seven, the second stage is concrete operational stage from age seven to twelve and last stage is the formal operational stage after the age of twelve. Just telling to think has not a meaning for students between the ages seven and twelve. Mathematics is an abstraction and not a part of physical world but students at concrete operational stage are not ready for abstract level. Copeland (1970) stated that mathematics for students at concrete operational stage should be a discovery through the physical world with concrete objects.

The other important issue was the way of introducing geometry with students with respect to their cognitive development. Copeland (1970) classified geometry types as; Euclidean geometry, projective geometry, metric geometry or measurement. Introduction with geometry starts with Euclidean geometry which involves line segments, triangles, squares and circles. Shapes and figures are referred to as "rigid" in shape means they don't bend or stretch. Movement of geometric shapes is possible but the size and shape remains the same (Copeland, 1970). However, Piaget believes that introduction of geometry should be topological. According to Copeland (1970) mathematics of topology are not considered rigid or fixed. Shapes may be starched or squeezed. Closed figures such as squares, circles and triangle are the same topologically. Because, each simple shape transform to each other by squeezing. Moreover it is also valid for three dimensional figures. In other words cube is topologically equivalent to sphere because cube could be squeezed from sphere. For example for a baby, face shape of his mother changes, when his mother getting closer to him or getting

apart from him. Shape is not a rigid thing for him as it was described in Euclidean geometry. Baby sees a topological structure changing in size and shape. The transformation of shape is called homeomorphism in topology. It is also valid for projective geometry her mother faces get different shapes with respect to position of his mother. In projective geometry an object is not considered by itself only, it is thought with its position in the space. Piaget (1953) summarizes" not until a considerable time after he has mastered the topological relationships does he develop notions of Euclidean and projective geometry" (p.75). In the conclusion of the Piaget's logico-mathematical model theory of cognitive development study, topological geometry is more close to modern geometry than historical development of it.

Cognitive development is important not only for learning geometry concepts but also for learning spatial knowledge. According to Piaget spatial ideas progressed at two different levels which were level of perception (as learned through the sense of touch and seeing) and level of imagination. These two levels follow each other. Since topological development first, topological activities should be performed first, and then help students in abstracting familiar Euclidean shapes have them begin with familiar objects such as ball, pencil which is the level of perception. Finally students should begin to work with Euclidean shapes such as squares, triangle, rectangles, and squares. The understanding of space by the students is difficult due to the conflict between intellect and perception. Piaget (1963) remarks that "motor activity of enormous importance for the understanding of spatial thinking" (p.13). Level of imagination could be achieved after the level of perception. Copeland (1970) stated that teacher asked to students define and draw the shape which is in the student's hand but didn't seen by the student.

Development of spatial knowledge is directly related to understand space. Copeland (1970) stated that vertical and horizontal axes are used to understand objects in space in their position and relative to each other. Objects are located above, below in relation to these axes. Locating objects relative to each other involves both an angular and distance measurement if horizontal and vertical axes are used as a frame of reference. Physical world provide an environment in the

form of vertical and horizontal axes. Students get floor as a reference of horizontal lines and objects such as tree, wall or geometric objects as a reference of vertical lines. However according to Piaget and Inhelder (1963) students' understanding of frame of reference by using vertical and horizontal lines depends on students' stage those they in. Piaget divided stages into three with respect to students' ages. These stages; stage 1, stage 2 and stage 3. Piaget concludes that students need to reach at the age of 11 or 12 to construct true conventional reference system that students compare distances and positions simultaneously. In the Piaget's study students were asked to examine the picture that is rotated 180. A student at the stage 1 is correct for only two topological relations. Students at the stage 2 three reference points were used by the student. Student at the stage 3 model 180 model did not cause difficulty and can be located correctly in each of 15 positions.

Piaget and Inhelder (1963) performed a study to understand child's conception of space. In their study students were asked to draw the shadow of the objects inclined at various angles and rotated to various positions such as side and end view. Pre-operational children place themselves at the object point of view, a topological concept, dominated by egocentrism. Students at the stage 2 represent the object as seen from their position rather than light source. For example if the pen is located horizontally, students draw horizontal line instead of circle. Students at operational age could easily predict the shadow of pencil by thinking from different point of view. Kopeland (1970) concluded that projective geometry, as far as three dimensional objects are concerned, should be performed after the ages 11.

In conclusions, the way to introduce geometry concepts such as space, angle, shapes (et.) to students, the way to enhance students' spatial knowledge and their ability to reasoning logically were directly related to students' cognitive development. Because of that reason, students' cognitive development stage should be the prior issue thought by the educators when they aim to enhance spatial knowledge of students.

2.2. Definitions of Spatial Ability, Spatial Visualization and Spatial Orientation

In this section some definitions related to spatial ability, spatial visualization ability and spatial orientation ability will be given.

2.2.1 Definition of Spatial Ability

Although, there was a general consensus about the importance of spatial ability in different disciplines and could be improved by using appropriate activities, there is no definite definition of the spatial ability. Definitions of spatial skills such spatial ability, spatial visualization and spatial orientation were given in different discipline studies but, as it understood from review of literature, definitions show changes. As an example, it was observed that spatial visualization and spatial ability definitions were used instead of each other in different studies. These are the definitions of spatial skills used in different studies.

Lohman (1993) believed that spatial ability is crucial for high-level thinking in science and mathematics, for the ability to produce and understand figure of speech in language, for innovativeness in many fields and defined spatial ability ''as the ability to generate, retain, retrieve, and transform well-structured visual images'' (p.188). It is accepted by the researcher that spatial abilities are fundamental constructs of all models of human abilities.

Another definition of spatial ability is given by Tatre in 1990. According to Tatre ''spatial skills are considered to be those mental skills concerned with understanding, manipulating, reorganizing, or interpreting relationships visually'' (p.216). In adaptation to this definition (Carroll, 1993) define spatial ability as ''ability to imagine, perceives, manipulate, reorganize, and retrieve visual images of objects or forms''.

Towle (2005) stated that spatial ability is an ability that correctly imagines three dimensional objects that are represented in two dimensions such as in Computer-Aided Design or detailed part drawing and very beneficial skill for engineers. Moreover, Olkun (2003) define spatial ability as the mental manipulation of objects and their parts in 2D and 3D space.

As it understood from different studies performed related with spatial ability it is difficult to designate the definition of spatial ability, because it is a multidimensional skill. However a review of literature review points out that most of the definitions draw from meta-analysis conducted by Linn and Petersen (1985). Since the Linn and Petersen's (1985) definition of spatial ability serve the purpose of THIS study, it will be used. Spatial ability has been defined as skill in "representing, transforming, generating, and recalling symbolic, nonlinguistic information" (Linn and Petersen, 1985, p. 1482).

Visual-spatial ability defined as a visual process that understanding the 3D information of geometric shapes concerning corner, edge, and surface relations and transforming this knowledge into 2-dimensional drawings or imagine (Wanzel, Hamstra, Caminiti, Anastakis, Grober & Reznick, 2003).

As it understood from review of literature review spatial ability is not a modular concept, it consists of many spatial components such as spatial visualization, spatial orientation and spatial perception. Thus, the evaluation of spatial ability should be done by using several tests for a complete evaluation (Voyer, 1995).

According to Osberg (1997) creative problem solving is depending on combining spatial relations, classification, transformation, and rotation and visualization activities together. Osberg (1997) defined spatial relations comprehending the connection between objects in space that are in animated and static environment. Additionally, he described transformation as transform an object from one place to another without physical representation of the transformation, he defined rotation as ability mentally rotate objects by

maintaining orientation and features during the process and defined visualization as the ability to construct, manipulate and interpret images in the mind.

According to Gardner, “spatial intelligence entails a number of loosely related capacities: the ability to recognize instances of the same element; the ability to transform or to recognize a transformation of one element into another: the capacity to conjure up mental imagery and then to transform that imagery; the capacity to produce a graphic likeness of spatial information; and the like” (p. 28).

Olkun (2003) defined spatial ability as ‘’the mental manipulation of objects and their parts in 2D and 3D space’’ (p.8).

Spatial thinking described as a mental activity which made it feasible to generate spatial images, which were created from the sensory cognition of spatial relationships expressed in a variety of verbal or graphical forms including diagrams, pictures, drawings, outlines, and manipulate them in the course of solving different practical and theoretical problem (Yakimanskaya, 1991).

Consequently, there are several definitions of the term spatial ability, in the present study it was defined as the ability to manipulate, generate, transform, reorganize or interpret relationships visually (Tatre, 1990).

2.2.2. Definitions of Spatial Visualization and Spatial Orientation

At the same time as examine the review of literature, it was observed that researchers identified two main aspects of spatial ability which were spatial visualization and spatial orientation. These are the researches that classified spatial ability and defined it.

D Kimura (1999) defined spatial visualization as ability to recognize and quantify the orientation changes in a scene, different than mental rotation of objects, the estimation of one’s position in relation to a static object. Another definition for spatial visualization was imagination ability of resulting image after

folding or assembling parts of an object and she describes spatial orientation as the ability to accurately estimate changes in the orientation of an object and testing this ability was performed by rotating 2D and 3D objects in 2D or 3D space. Additionally, she described spatial perception as person's ability to determine what the prevailing horizontal and vertical directions are in a scene where distracting patterns are present.

On the other hand, Bishop (1983) emphasized the two abilities in visualization; First ability was interpreting figural information which includes both reading and interpreting of the visual conventions and spatial vocabulary used in geometric work, graphs, charts and diagrams of all types. This ability mainly interested in the form of the stimulus materials presented. Second ability was visual processing of the information; includes translation of non-figural data into visual terms, manipulation of visual imagery and transformation of visual image into another.

Linn and Petersen (1985) as a result of meta-analysis of studies on spatial ability identified three main aspects of spatial tests, namely; spatial perception, spatial visualization and mental rotation. Spatial perception was defined as skill to decide spatial relationship with regards to adjustment to surroundings of their own bodies in spite of distracting information and mental rotation as the skill to turn a two or three dimensional figure rapidly and accurately (Linn and Petersen, 1985). Spatial visualization was defined by Linn & Petersen (1985) ability to solve complicated spatial ability tasks that requires multi-step manipulations.

Lohman (1979) in a review of studies on spatial ability identified two main aspects of spatial ability, namely; spatial orientation and spatial visualization. Lohman (1979) defined spatial orientation as ability is determine how a given object or set of objects would appear different than their original phase from a spatial perspective and defined spatial orientation as skill require people redirect themselves in respect to the objects in question. Spatial visualization necessitates complex mental rotation of objects asked in mental

paper folding or mental rearrangement of pieces of an object to form the whole object questions.

According to McGee (1979) spatial orientation includes the understanding of the organization of elements within a visual stimulus pattern. Moreover, Tatre (1990) propose that spatial orientation could be used for solving mathematics problems in definite and particular ways and these ways include approximation magnitude of the figure, showing mathematical relationship by adding marks, imagining and moving shapes' size and shape in the mind, finding the correct answer to a problem with visual framework without any aid was provided.

Spatial visualization defined by Humphreys and Taber (1973) as the ability to imagine the rotation of objects, the folding or unfolding of flat patterns, the relative changes of position of objects in space. McGee (1979) extended Humphreys & Taber's (1973) definition of spatial visualization by adding the skills to mentally rotate, manipulate, and twist two- and three-dimensional objects.

Spatial orientation is defined by Humphreys and Taber's (1973) as ability to organize the elements in a visual stimulus pattern and stay unconfused even if the presented spatial configuration is changed. Batista (1994) defined spatial visualization is to understand and perform movements of objects is space and spatial orientation is to operate the connections between the situations of objects in space with regards to one's own position.

Consequently there are many different definitions of spatial visualization and spatial orientation made by researcher. In the present study, definitions of Batista given in his research performed in 1994 were used. Batista (1994) defines spatial visualization and spatial orientation as Battista (1994) defined spatial visualization is imagination, comprehension and giving movement to an object in space; and spatial orientation understanding the relations between objects' position with regard to one's own position.

2.3. Studies on Spatial Ability

In this section, studies on the importance of spatial ability, studies on how to develop spatial ability of the students are summarized.

2.3.1. Studies on the Importance of Spatial Ability

The literature included a good deal of arguments about the possible relationship between spatial skills and mathematics. Guay and McDaniel (1977) investigated the relationship between mathematics achievement and spatial abilities among elementary school children. These findings suggest that there was a positive relationship between mathematics achievement and spatial abilities at elementary school level students who were at different grade level and sex. Moreover this relationship appeared to exist for low-level as well as high-level spatial abilities. In other words high mathematics achievers have greater spatial ability than low mathematics achievers and significant positive correlations observed.

The other study that found positive relation that applies to the learning of conceptual topics between spatial ability and mathematics achievement was performed by Battista in 1994. According to Battista (1994) school mathematics learning was performed by using near-rote memorization of procedures for manipulating symbols that is not conceptual in nature. However, spatial thinking and conceptual learning of mathematics are relational. Although, a girl student with high spatial ability demonstrated poor performance in school mathematics, she demonstrated outstanding mathematical ideas in interviews.

McGee demonstrated the difficulty of the problem proposed earlier determining the strength and width of the field in which a spatial factor may be found and explained that:

> Spatial visualization seems to be required in various perceptual-cognitive tasks involving the mental transformation of visual images, and it has been shown to be important for success in college mathematics, especially geometry and algebra (Mcgee, 1979, p.899).

Another research performed by Fennema and Sherman (1977) showed that spatial visualization was significantly correlated to mathematics achievement closely as connected as verbal ability. These findings are also coherent with the findings about importance of spatial visualization to mathematics learning in general (Fennema, 1975; Sherman, 1967).

Research studies indicated that spatial ability was not also crucial for mathematics achievement but also for problem solving ability. Study performed by Alias, Black and Gray (2002) examined problem solving skills with engineer students. Intend of the study was to test whether spatial visualization activities would affect problem-solving skills in structural design. The findings suggested that spatial visualization ability have an effect on problem solving in structural design which is the crucial skill in guaranteeing successful design of structures in a positive way. However, spatial visualization ability do not come into sight to support the learning of conceptual knowledge related to bending moments, axes and planes of references. It could be because of weaknesses in the prescribed learning materials.

In another Tatre (1990) study, fifty-seven tenth-grade students who scored high or low on a spatial orientation test were used to understand the effect of spatial orientation skill in the solution of mathematics problems. Research results showed that spatial orientation skills were beneficial in specific and identifiable ways in the solution of mathematics problems. These ways include approximation magnitude of the figure, showing mathematical relationship by adding marks, imagining and moving shapes' size and shape in the mind, finding the correct answer to a problem with visual framework without any aid was provided.

Additionally, Booth and Thomas (2000) performed another study related with problem solving ability. In his study a group of students with mathematics

difficulties were divided into two groups in terms of their visuo-spatial abilities. Arithmetic word problems were given students to solve in three different presentations: orally; with a picture; and with a diagram during an interview. The results show that the high visuo-spatial skill group performed significantly better on these problems than low visuo-spatial skill group.

In addition to these studies, it was maintained by researchers that there was a relationship between logical thinking ability and spatial ability. The study of Kayhan (2005) could be given as an example. The purpose of the study performed by Kayhan (2005) to investigate the relationship between mathematics achievement, logical thinking ability and spatial ability with 9th grade high school students from three different schools. After the study significant positive relationship found relationship between mathematics achievement, logical thinking ability and spatial ability.

In other study effects of spatial ability in promoting the logical thinking abilities of students with regard to programming language was investigated by Tai in 2003**.** The study showed that students with high spatial ability were better in logical thinking ability and computer programming than students with low spatial ability. Moreover those students had positive attitudes towards Computer-Assisted Learning (Tai, 2003).

A study was conducted by Hodgson (1996) with the university students to investigate the use of Venn diagrams to visualize set expressions. The results of the study showed that the

> Translation of set expressions provided a rich content for studying students' formation and use of procedures, their understanding and operationalization of set operations, and their ability to establish connections between alternative representations of mathematical concepts (Hodgson, 1996, p.176).

In another study performed by Erbilgin (2003) four 8th grade students were interviewed to understand the effects of achievement and spatial visualization on

students' use of multiple with respect to the concept of linear functions. The high spatial ability students were better at pattern finding and producing different solution, demonstrated a deeper understanding of the concept (linear equations) and each representation whereas the low achieving-low spatial ability student had the weakest understanding of the concept of linear equations among the four students.

Furthermore, Brandt and Davles (2004) performed another study about initial learning of a spatially complex surgical technical skill. The aim of the study was to examine correlation between Mental Rotation Test and performance of a spatially complex surgical skill. Research results showed that mentally rotation ability an object in 3 dimensions has a crucial role on initial learning of a spatially complex surgical technical skill. Surgical residency training and maintaining a progressive surgical practice could be achieved by improving spatial ability and increasing proficiency in learning surgical techniques. In addition to this it was found that in the research self-directed- learning was as effective as and more useful than traditional lecture-based learning.

A study was conducted by Ferk and Vratacnic (2003) with the primary, secondary and university students to determine the meanings different kinds of molecular structure representations used in chemistry teaching showed that spatial ability was also important for chemistry teaching. The results of the study showed that using 3D molecular models are the best way to introduce the topics about molecular structure for primary school teachers. Moreover it was suggested in the study that an opportunity should be given to students to construct 3D molecules and manipulate them in 3D with the use of mirrors. Another important point derived from study was the importance of guidance to draw students' 3D observations in two dimensions by using molecular models and the overhead projector for an effective teaching.

2.3.2. Studies on How to Develop Spatial Ability

A lot of research performed about improving spatial ability insisted that, there was a positive relationship between spatial training and the students' spatial skill enhancement (Herskowitz, Parzysz & Van Dormolen, 1996; Olkun, 2003; Osberg, 1997; Owens & Clements, 1998; Pallascio, Allaire & Mongeau, 1993).

In the study carried out by Gabrelli et al. (2000) Virtual Reality was investigated. The main goal of the study was to explain, how 6 years old children' performance was affected by a different type of virtual reality scene activities. Virtual reality technology provides a chance to design 3D worlds and navigation activities that have many similarities with occupations we deal with in the real world. The outcomes of the study exhibited that children were capable of developing and displaying different levels of allocentric knowledge about the virtual world depending on the way they had familiarized with it and on the characteristics of the task demands. Memory of objects' location in the virtual scene and the analysis of their way finding abilities within the scene were used to measure children's knowledge of the spatial layout of the environment. This finding contributes to enlighten the design of virtual reality technologies intended at supporting or evaluating spatial abilities in children at the age of six (Gabrielli, Rogers & Scaife, 2000).

Another study was carried out by Olkun (2003). In his study the effect of the engineering drawing application on spatial ability was investigated. The aim of the study was to provide activities for improving middle grade students' spatial ability with engineering drawing applications. There were mainly two reasons for choosing engineering drawings in this study. First one was drawing conventions are required in man technical occupations and engineering drawing has a practical base in real life situations. Second reason was concrete experience with geometrical objects were proved as a helpful in improving students' performance in spatial visualization. Research results exhibited that spatial ability is important and could be improve through engineering drawing activities (Olkun, 2003).

Furthermore, the study performed by Wolford and De Lisi (2002) focuses on the improvement of spatial visualization. In the study, pre- and post-test a group of third grade elementary school children participated 11 separate computer game seasons that took 30 minutes and completed a 2-dimensional Mental Rotation test. Students in experimental group exceed students in control group in mental rotation post-test performance but not in the pre-test. Research results showed that there was a significant increase in students' initial mental rotation performance after playing computer games that lead to Mental Rotation skills. The research results suggested that computer-based instructional activities could be used in schools to improve children's spatial abilities (Wolford & De Lisi, 2002).

The aim of the experiment performed by Passig and Eden et al. (2001) was to investigate effect of rotating Virtual Reality (VR) three-dimensional (3D) objects practicing on improving the spatial rotation thinking of deaf and hard of-hearing children compared to the practice of rotating two-dimensional (2D) objects. Students were divided into two groups: an experimental group, which included 21 deaf and hard of- hearing children, who played a VR 3D game, and a control group of 23 deaf and hard-of hearing children, who played a similar 2D (not VR) game research findings showed that practicing with VR 3D spatial rotations significantly improved the children's performance of spatial rotation, which improved not only their ability to perform better in other intellectual skills but also in their sign language skills.

The other study that focuses on the improvement of spatial visualization was constructed by Keller and Moses (2002). In the study, a new instrument that was curriculum-embedded applets for isometric drawings was developed to improve students' spatial visualization skills. The development process had three phases. First, a pilot study that includes interactive software and on-line investigations was administered to pre-service elementary teachers using an exploratory methodology. Second, applet and investigation's accuracy was improved and then tested with a large number of pre-service teachers. Moreover on-line assessment instruments were also developed in second phase. Third software is revised and

tested in collaboration with middle school and secondary curriculum projects. At the end of the study students' spatial visualization was improved. In addition to this students were able to create isometric drawings, connect isometric drawings with other 2-D representations of 3-D objects, and translate among these representations. Future teachers' pedagogical content knowledge about isometric drawings was also improved with this study.

The study carried out by Rafi (2005) supported this claim. The aspire of the study was to improve a group of pre-service teachers' spatial ability understanding for teaching Engineering Drawing for secondary school subjects. 98 pre-service teachers who took Computer Aided-Design (CAD) course participated to the study at Universiti Pendidikan Sultan Idris (UPSI). Participants were pre-tested at the beginning of the semester by using mental rotation and spatial visualization tests and then desktop WbVE was employed for five weeks in the CAD laboratories as an instructional treatment. It was concluded that post-test of the participants were significantly higher than their pre-test scores at the end of the study. These results decided to use in the development of the Virtual Environment teaching and learning prototypes for secondary school in Malaysia.

Other than studies on developing spatial ability activities Kozhevnikov and Thormton (2006) focuses on the improvement of spatial visualization. In this study, relationship between students' levels of spatial visualization ability and learning physicss in a microcomputer-based laboratory (MBL) environment was examined. In the study, pre- and post-test a group of undergraduate students who had taken an introductory physics course enrolled MBL instruction which primarily used computer-based activities and manipulative aids. As a result of MBL instruction students' spatial visualization ability improved. Different kinds of MBL activities that were performed by a group of science teacher were also caused to improve students' spatial visualization ability. The relationship between spatial visualization and performance on the physics test was due to visual graphical representations showed during the MBL instruction course in that research.

The study performed by Piburn et al., (2005) investigated the role of visualization in learning from computer-based images. The experiment designed by using web-based versions of spatial visualization tests, a geospatial test, and multimedia instructional modules built around QuickTime Virtual Reality movies. The study results conclude that spatial ability but not spatial orientation could be improved through computer-based instruction and engaging such activities help students to improve intellectual skills that are crucial in learning of science and geology. Moreover research results suggested that computer based materials could be extensively used in preliminary laboratory courses at colleges and universities.

Alias (2002) expressed the aim of their study as to determine effect of manipulative and sketching activities on engineering students' spatial visualization ability. Students were divided into two groups as treatment and control group. Treatment group engineer students manipulated objects and gain knowledge of sketch from observation and imagination in structural design class while control group continued their regular structural design class. There was a significant mean difference between students' spatial visualization ability scores in treatment group compared to control group. There was no difference both for male and female engineering students about the improvement of spatial ability and they took advantage of equally from the intervention.

In addition to this, Clements and Batista (2002) investigated the application and improvement of spatial thinking in an instructional unit on area and motions. Paper-pencil assessments and case studies were used to collect data and case studies were tested as pilot with 2 third graders and 3 third-grade classrooms. Research results showed that manipulative, papers and computer based activities not only has strong effects on spatial abilities but also provided data to understand students' methods for solving the unit's spatial and spatial-numeric problems. Degree of unitizing operation to devise spatial and numerical units and units of units were differentiated characteristic of this strategy.

Onyancha, Towle, and Kinsey (2000) expressed the aim of their study to examine the effect of targeted training on the spatial ability and self efficacy of

mechanical engineering freshmen in a college**.** Two different tools were developed and evaluated in the study for using in spatial ability training. First model was Physical Model Rotator (PMR) that provided rotation of physical model in CAD software. Second model was Alternative View Screen (AVS) that additionally supply a line version view of the object. Spatial ability tests were applied to students with poor spatial ability before and after PMR and AVS training that took for weeks to understand the efficiency of training program PMR and AVS have proved as a system to enhance spatial ability over a short period of time. So this system can be used to provide equality between freshman engineer students about their spatial ability knowledge. Moreover students' attitude toward PMR was positive and they found system very exciting.

Chapter Summary

In summary a review of literature reveals that spatial ability is very important not only in academic situations but also in our daily life. Researchers discovered relationships between spatial ability and understanding geometry concepts, chemistry, mathematics, as well as geology, medicine and engineering. They stated that spatial ability provide occupational choices or opportunities in professional and education life. This review has showed that students' spatial ability could be improved by using appropriate visual treatments. Researchers continue to discover the best way to achieve it. Researches has shown that a relationship exist between experience with certain spatial tasks and spatial ability performance, and these findings indicate that enhancement of spatial ability could be the result of variety of the activities used to achieve it.

Piaget distinguishes four main stages in the development of mental structures; sensory-motor stage, pre-operational stage, concrete operations stage, formal operation stage. These stages are very important in terms of understanding the capability of students; helping educators to understand how students learn at these ages and preparing the best learning environment. Hence, the cognitive

development stages are very crucial in teaching. Teachers should be aware of students' cognitive development and feelings when they deal with spatial ability activities. It was difficult for the educators to search a review of literature related to students' opinion about their cognitive development and feelings in spatial ability activities. The purposes of the study were to investigate the affects of activity-based instruction on students' opinion about the visual treatment in terms of thinking process and in terms of feelings in the spatial ability activities; to investigate the effects of visual treatment on student's spatial ability, spatial visualization and spatial orientation.

CHAPTER 3

METHODOLOGY

This chapter includes research design, variables, subjects, instruments, procedure, assumptions and limitations, internal and external validity of the present study.

3.1. Research Design of the Study

In the present study one-group pretest-posttest design was used (Fraenkel, 1996). The research design was depicted in Table 3.1

Table 3.1Research design of the study

Pre-Treatment Measuring Instruments	**Treatment**	**After treatment: Measuring Instruments**	**Retention Measuring Instruments**
Cube comparison test(CCT) Card rotation test(CRT) Paper folding test(PFT) Surface development test(SDT)	Visual treatment(VT)	Cube comparison test(CCT) Card rotation test(CRT) Paper folding test(PFT) Surface development test(SDT)	Cube comparison test(CCT) Card rotation test(CRT) Paper folding test(PFT) Surface development test(SDT) Interview

As seen in Table 3.1, the Spatial Ability Test (SAT) was administered in the present study. SAT was composed of four different tests which were; cube comparison, card rotation, paper folding and surface development tests. SAT was administered to 21 sixth grade elementary school students as a pre-test. SAT is a paper pencil test designed to measure students' spatial orientation ability and spatial visualization ability. After pre-test, visual treatment that was consisted of 9 different visual activities was performed with students for 10-week period. Visual treatment was consisted of four main activity types. These were; paper folding activities, computer-based activities, activities with manipulative and transformation geometry activities. SAT was applied to the students as post-test after treatment. One month break without visual treatment was given to the students and the last SAT was administered to examine retention effect. Lastly 9 students were randomly selected to interview. There were two main aims of the interview questions. The aims were to have student's opinion about the visual treatment in terms of thinking process and feelings in the spatial ability activities.

3.2 Subjects of the study

The subject of the study was twenty one sixth grade elementary school students. There were twenty one students in 6-A class in elementary school and all students in the 6-A class attend to study. The class was regular 6^{th} grade mathematics class. Convenience sampling was the sampling method in this study. This study was performed at a school in rural area.

This study is carried out in 2006-2007 education year. SAT was administered to the twenty one sixth grade students as pre-test at the beginning of semester and administered as post-test after the visual treatment. Moreover, SAT was administered once more after 4 weeks later as a retention test.

Nine students were selected from 21 sixth grade elementary school students by using random sampling. Twenty one sixth grade students' name written on equal size small pieces of paper and put into a bag. 9 students were selected

randomly from this bag. Researcher was the teacher of the students and visual treatment had been performed by the researcher gave a chance to get detail information about students both level of spatial ability and their behavior during the activities. However the knowledge that accumulate from students interview would limited. All of the students are about the ages 13-14 and none of them repeated class 6.

3.3. Measuring Instruments

In the present study, the following measuring instruments were used;

1- Spatial Ability Test (SAT)

2. Interview

3.3.1. Spatial Ability Test (SAT):

The Spatial Ability Test (SAT) is a kind of paper-pencil test which is used for evaluating spatial ability. Ekstrom (1976) developed the SAT and test translated into Turkish by Delialioğlu (1996). It is composed of two sub-tests, spatial visualization ability test and spatial orientation ability test. The SAT score is calculated by adding these two sub-tests. The questions in each test are given in Appendix A. Reliability; number of questions and duration are given in table 3.2. The aim of the test was to measure students' spatial ability knowledge. SAT was administered to 21 6^{th} grade elementary level students. In the present study the reliability coefficients were given in Table 3.2. They were calculated by KR-21.

Table 3.2 Reliability Coefficients, Number of Questions, Total Scores and the Durations for the Tests

	TESTS	RELIABILITY	NUMBER OF QUESTIONS AND TOTAL SCORES	DURATION
SVAT				
I)	PFT	0.79	20	12 MINUTES
II)	SDT	0.74	60	6 MINUTES
SOAT				
I)	CRT	0.78	160	6 MINUTES
II)	CCT	0.80	42	6 MINUTES

These are the sample questions SAT;

Paper folding test contains such questions; the square shaped paper on the left side of the vertical line is folded and then a hole is made. After unfolding the paper, which one of the shapes in the right side of the vertical line will appear?

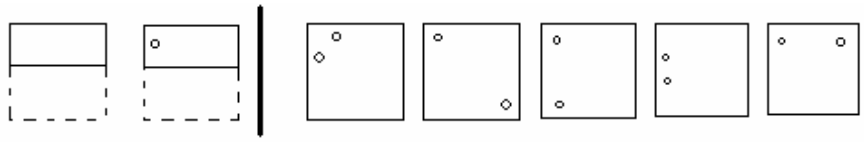


Figure 3.1: Sample Question of PFT (Ekstrom et al., 1976)

Surface development test contains such questions; when the paper is folded from the dotted lines, the subject on the right will be formed. By imagining the folding of the paper, match the numbered edges to the letters. P.c. the surface marked by X on unfolded paper on the left and on the subject on the right shows the same surfaces.

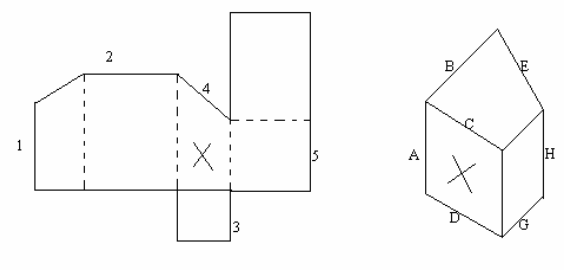


Figure 3.2: Sample Question of SDT (Ekstrom et al., 1976)

Cube comparison test contains such questions; In the following cubes all the numbers, figures and letters appears only once on each cube, but it can be in an unseen position. Then, find out whether the cubes on the left and the right are the same. If the cubes are the same then mark S (Same), otherwise mark D (Different).

Figure 3.3: Sample Question of CCT (Ekstrom et al., 1976)

Card rotation test contains such questions; Find out whether the shapes on the right side can be determined by rotating the shape on the left side of the vertical line, in other words examine whether the shapes are the same or different. If the shapes are the same as the shape on the left side of the vertical line then mark S (Same), otherwise mark D (Different).

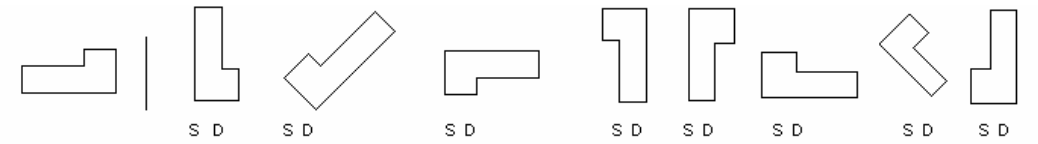


Figure 3.4: Sample Question of CRT (Ekstrom et al., 1976)

Spatial Orientation Ability Test

Spatial Visualization Ability Test composed of two sub-tests: Paper Folding Test (PFT) and Surface Development Test (SDT). Reliability coefficient, number of questions, total score of each test and duration required for each test is given in Table 3.2. Spatial visualization ability test (SVAT) score is calculated by adding PFT and SDT scores.

(i) Paper Folding Test (PFT): It was composed of multiple choice items that necessitate creating mental image, folding and unfolding a piece of paper in the mind. In the assessment of test, one point is given to each true choice. As there are 20 questions, the total score of PFT is 20. Twelve minutes were given to the students to complete test.

(ii)Surface Development Test (SDT): It necessitates creating a mental image of geometric shapes after folding a piece of paper, and matching items. There are five answers to match in each questions and one point is given to each true answer. As there are 12 questions the total score of SDT is 60. Six minutes were given to the students to complete test.

Spatial Orientation Ability Test

Spatial Orientation Ability Test composed of two sub-tests of two sub-tests: Card Rotation Test (CRT) and Cube Comparison Test (CCT). Number of questions, reliability coefficient, and duration required for each test and total score of each test is given in Table 3.2. The total spatial orientation ability test (SOAT) score is calculated by adding CRT and CCT scores.

(iii)Card Rotation Test (CRT): the aim of the test is to evaluate the ability to see similarities and differences between the shapes. Test composed of true-false items. One point is given to each true answer. There are 42 questions so; the total score of the test is 42. Six minutes were given to the students to complete test

(iv)Cube Comparison Test (CCT) : The test require to determine whether the given two cubes that have six faces with different letters, shapes and numbers

are same or not. Test composed of true-false items. Each question includes 8 items and one point is given to each true item. Since there are 20 questions the total score is 160. Six minutes were given to the students to complete test

3.3.2 Interview

Researcher conducted interviews with nine students. The interview questions and the purpose of them could be categorized into two parts. The first part of the interview questions includes questions to have opinion about the visual treatment in terms of thinking process in the spatial ability activities. The second part of the interview questions includes questions to have opinion about the visual treatment in terms of feelings in the spatial ability activities. Researcher wanted to gather specific information about students' opinion about visual treatment in terms of cognitive process and feelings during spatial ability activities to support inferential findings of the study. That is why interview was selected as a data collection method. After the interview, researcher analyzed each interview by using phenomenographic method to summarize findings about each question. A phenomenographic analysis seeks a "description, analysis, and understanding of experiences" (Marton, 1981, p. 180). Students' speech was categorized with respect to their meaning and then students' excerpted answers were fit in these categories. Therefore, the interview tables included the same questions for each student. I organized the findings as follows. I made a table for each question that includes students' opinion about visual treatment in terms of cognitive process and feelings. Each table was designed to have one column for each cognitive process and feelings category. Same feelings and cognitive process of students were settled to the same category that researcher construct in the tables. These tables facilitated the comparison of students with each other. Moreover interview results were analyzed by another person to provide reliability of the method.

The interviews were conducted in students' classroom environment. The aim of the study was explained in details for students to feel comfortable. It was reminded to students that giving the right answer was not expected, the only

important thing is their opinion about the questions. It was the first time for students to attend such an interview so they were enthusiastic and a bit nervous. A speech was made with students about their daily life to decrease their nervousness.

A speech recorder was used to record data during interview with the permission of students. Each interview took approximately 25-30 minutes for each student.

As a summary, to analyze data get from interviews, the views of student were categorized compared and commented by using phenomenographic method. 17 tables were prepared the summaries for each student. The following ones are the sample interview questions and aim of them.

1. What did you feel when you faced with spatial ability questions for the first time? The purpose of this question was to examine the effects of spatial ability questions on students' feelings.

2. In which ability you have feels change or improvement before and after the activities in general? The purpose of this question was to understand whether or not students put connection between spatial ability activities and lectures.

3.4. Treatment

Visual treatment activities were applied to 21 sixth grade elementary school students at the first semester of 2006-2007 education years. Activities were performed five days a week and activities took 10 weeks as extra curricular activities. Activity types were listed below; transformation geometry activity, computer-based activity, manipulative activity and origami. In addition to them in the mathematics courses orthographic and isometric projection, tessellations, transformation geometry, surface area and volume of prisms were taught. So the

course was the part of our treatment. The extra curricular activities were explained below:

The first activity was pentominoes applied during the first two weeks. Activity was performed at students' classroom. Detailed information about the activity was given by the researcher at the beginning. This activity was performed for 10 lecture time and each lecture took 45 minutes. Small groups were formed composed of four or five students by the researcher. It was explained to groups that they were required to join parts together with at least one common side. There were twelve parts in the set of unique parts named T, U, V, W, X, Y, Z, F, I, L, P, and N respectively. Rules that should be followed during the activity were given to students by the researcher. First, if one shape can be rotated to look like another, the two shapes are not considered to be different. Second, if one shape can be flipped to look like another, the two shapes are not considered to be different. Each small group was given a set of sheet of activity paper by the researcher. Students were to work together to discover all the possible ways in which five tiles could be arranged. Shapes discovered had to be different. Students were required to cut out discovered shapes from the squared paper and find out which shapes could be folded into boxes. They were also asked to combine all the discovered shapes to make a rectangle. The role of researcher was to examine students' work and helped students to solve their problems. Classroom observations about students' cognitive process and their feeling were performed during the activities in a written form. Photographs were taken by the researcher during the study.

Figure 3.5: Students work on pentominoes activity

Pentominoes activity provided good practice using the four-step problem solving process, which includes understanding the problem, devising a plan, carrying out a plan, and checking the work. In conclusion, this activity promoted an atmosphere of cooperation, support the development of the problem-solving process, supply spatial-ability skill exercises, Furthermore, and serve as concrete representations that help ease students' understanding of abstract notions.

The second, third and fourth activities were related with spatial problem solving with Cuisenaire Rod Patterns. Second activity was space filling activities with rods similar in sprit to tangram puzzles. Filling activity performed for one week, 5 lecture times and each lecture took 45 minutes. It was asked students to fill given space on the task by using ten colors of Cuisenaire Rods. Students were informed about the number of usage each rod. Each color rod should be used once in each task. Approximately ten minutes were given students to complete their task.

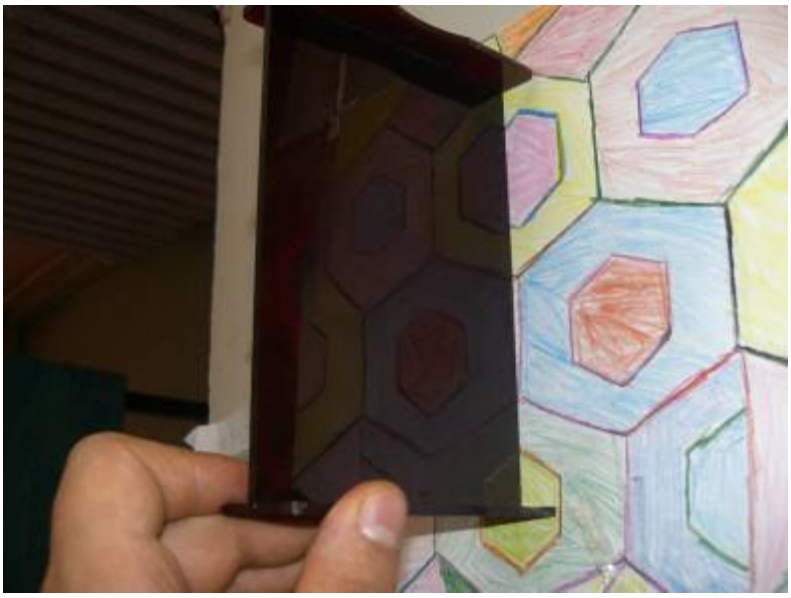


Figure 3.6: Students work on reflection activity

The third activity was rotation and reflection problems presented separately and together in analog puzzles and sequential chains. This activity was performed for one week, 5 lecture times and each lecture took 45 minutes. It was asked students mainly two types of question in that activity. First one was to find the type of rotation and reflection that would produce the resulting design in the task. Second one was to draw the design resulting from each reflection and rotation movement.

The fourth activity was architectural-type activities involving two dimensional rod designs. This activity was performed for one week, 5 lecture times and each lecture took 45 minutes. Students performed two different activities in that part. First one was to construct the different point of views of figures given in the task. Second one was to construct figure by looking at top, front and side views of figure given in the task.

These three kinds of activities were performed by using Cuisenaire Rods. The common aim of these three activities were to provide valuable spatial problem solving experience The students need to use the rods in solving all the problems that the concepts will have concrete foundation. Activities were

performed both individually and in small groups. Students were encouraged compare and discuss their answers and problem solving strategies. Worksheets were distributed to each student provides working space for the rods and spaces for the answers. Students worked in groups to fill in each design with the rods according to specifications given at the top of the page.

Figure 3.7: Students work on slides, flips and turn activity

The fifth activity was slides flips and turns. This activity was performed for one week, 5 lecture times and each lecture took 45 minutes. The fifth activity was divided into two parts. Part one, with its activities based on patterns of block and white squares in 5-by-5 grids, helped students recognize-and perform-translations, reflections and rotations. Definitions of slide flip and turn were given to the students before the activities. Students tried to shade the result-shape after transformation movement. Part two, which involves more elaborate geometric designs, challenges students to apply their knowledge of symmetry to finish shading in the incomplete black-and-white patterns. There were two kinds of symmetry in the activity which were reflective and rotational symmetry. Reflective symmetry was in which a line drawn through the center of figure divides it into two halves. Reflective symmetry is apparent in natural objects such as butterflies and leaves. Students were asked to shade the symmetry of figures in given task.

The sixth activity was the mirror puzzle. Mirror puzzle activity performed for one week, 5 lecture times and each lecture took 45 minutes. It was asked students to place a mirror on picture and asked to find given shape on the task. How it is changed depends on where students put the mirror. In the top left hand corner of each spread there was one design called ‘mirror master’. Mirror was placed on mirror master to get figures on the task. In other words, aim of the activity was to find where to place the mirror on the ‘mirror master’ so that what you see matches each of the other designs on the task. Researcher let students to move mirror on the ‘master mirror’ at the beginning of the activities. However it was banned to move mirror on ‘master mirror’. Students should to think where to put mirror before put it into practice.

The seventh activity was origami activities. Origami activity performed for one week, 5 lecture times and each lecture took 45 minutes. Origami brings extra meaning to a piece of paper by shaping it into a form that has symbolism. Students were familiar to origami activities from 5^{th} and 6^{th} grade mathematics class. Students were required to construct given shapes in task paper by folding papers in a given order. Students worked as a group. Researcher focused on modular origami because students were able to construct some basic origami figures. odular origami consists of folding several similar and comparatively simple shapes and fitting them all together to make a more complex construction.

The eighth activity was making shapes. This activity was performed for one week, 5 lecture times and each lecture took 45 minutes. There were two sets of activities which were making shape 2 and making shape 3. These two sets of activity consisted of 10 different shapes. Each activity shape was built up out of smaller sections. Whether students chose to complete all the sections of a model first or add each one to the growing model as it is finished does not matter. The models in these activities had curious properties such as rotate, fold, unfold, twist, and fit together in unexpected ways.

Figure 3.8: Students work on making shapes activity

The ninth activity was Tetris computer game activity. Tetris computer game activity was performed for one week, 5 lecture times and each lecture took 45 minutes. Tetris game activity was performed in computer laboratory and there was one computer, in which Tetris game was installed, for each student to perform activity. Tetris game provided three ways for students to change the position of figures. They can move, rotate and flip the figure across a line. These are called translation, rotation, and reflection alternately. So, Tetris was a good activity for students to practice rotations. Tetris game activity had three difficulty levels which were easy, medium and hard. Students performed activity at easy level in the first two days, they performed activity at medium level in the following two days and they performed activity at hard level last day. Students were required to finish activity to perform new one. Students' scores were recorded in computer environment. The role of researcher was to deal with problems that students faced with. Playing Tetris may help build more general visual-spatial skills and help students get better at mentally manipulating Tetris-like shapes, and not much more. A reasonable conclusion to draw from all this is: play Tetris is fun and it might build some brain power.

3.5. Procedure

The presents study could be handled in main three headlines;

In the first part;

SAT was administrated to the 6th grade elementary school students in their classroom environment by the researcher as pre-test. The aim of the study and how to answer the questions were explained in details before administrated the test. Moreover evocations were performed at the beginning of the parts of SAT. 6th grade elementary school students took visual treatment which has performed by the researcher for 10 weeks. The activity samples performed by the students are given in appendix C. SAT was implemented as pre treatment, post treatment and retention to the students.

In the second part;

Besides SAT test, I performed observation of the students during 10 week-period in their learning environment to understand students thinking process and their feelings about the visual treatment. I performed 10 different activities which are Pentominoes, Tetris and tangram games, spatial ability problem solving, translation-rotation-reflection, shading reflections, mirror puzzles, making shapes, origami, translation geometry-tessellations, reflect it hanged mirror. Each activity except pentominoes implemented in one week period (5 lecture-hours in total for each activity). Observations were performed during the time students engaged with their activities. Observations were performed during activities. Observations could be accumulated in two types which are face to face observations and group observations

In the third part;

The researcher has performed 9 interviews with students after the visual treatment. Each interview took approximately 15 minutes to 30 minutes. Interview durations show changes in respect of students' ability to express their feelings and thinking process. Interviews were recorded by voice recorder for better recall.

During the interview students were required to answer 17 questions to have opinion about the visual treatment in terms of thinking process, attitudes toward spatial ability problems and importance of spatial ability. Interview questions and purpose of questions were given in appendix B. Interview questions were prepared with respect to gaining from observations that was performed during visual treatment.

As a summary, activities were carried out during activity lessons over a 10-week period. 9 different spatial ability activities were performed with students and almost 5 school-days were spared for each activity. Daily activities took 45 minutes. Besides activities, researcher carried out classroom observations. During each activity hour, five of the twenty one target students were selected in both the whole class and small group settings. Observations were performed by moving one group to another in group working and by moving one student to another in individual working. During the interviews, students were required to deal with spatial ability activities. Researcher comprehended students' methods to solve spatial ability problems, had their feelings about the problems, and observed the way that they applied when they faced with any kind of trouble. Notes from the classroom observations, activity sheets that students studied in the class, were used in the preparation of questions for the interviews and in the data analysis process.

3.6. Analyses of the Data

The following techniques are used to analyze the data;

- Data of the present study were analyzed by using the SPSS package program.

- Data collected from the subjects were coded by the following techniques:

  - Students' scores for each part of the SAT was transferred to computer environment by SPSS package program

• Descriptive statistics were used by the following reasons:

- To get the means and standard deviations of the students' SAT scores.

- To find the distribution of the number and the frequencies of the subjects.

- To detect the outliers and to check that data recording error was made (data cleaning).

Two different tests were used to determine whether there is significant mean difference among students with respect to their SAT scores. Repeated measure of ANOVA was the parametric one. Freidman and Wilcoxon tests were the non-parametric one. Repeated measures ANOVA compares the means of three or more matched groups. The term repeated measures strictly applies only when treatments were given repeatedly to each subject, and the term randomized block is used and when treatment is randomly assigned within each group of matched subjects

• One-way repeated measures ANOVA was used by the following reasons:

- To determine whether there are significant mean differences among students with respect to their SAT scores.

- To determine the differences between the dependent variables simultaneously.

• α was set to be 0.05 as the probability of doing a Type I error

This hypothesis was also tested by using the Friedman test and Wilcoxon test because "Use parametric and nonparametric techniques to analyze data. When the results are consistent, interpretation will thereby be strengthened" (Fraenkel & Wallen, 1996, p.237). Friedman Test was used by the following reasons:

- To determine whether there are significant median differences among students with respect to their SAT scores.

- To determine the differences between the dependent variables simultaneously.

• α was set to be 0.05 as the probability of doing a Type I error.

3.7. Variables

The variables of this study can be categorized in five parts. The first part includes the variables of the first sub-problem of the study–"Is there a statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)" are stated as: the pre-test, post-test and ret-test scores of the students they got from spatial orientation

The variables for the second sub-problem of the present study –"Is there a statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention)" are stated as: the pre-test, post-test and ret-test scores of the students they got from spatial orientation

The variables for the third sub-problem of the present study –"Is there a statistically significant change in students' spatial visualization scores across three time periods (pre-treatment, post treatment and retention)" are stated as: the pre-test, post-test and ret-test scores of the students they got from spatial visualization

The fourth part includes the variables of the first sub-problem of the second main problem of the study –"What is the students' opinion about the visual treatment in terms of thinking process in the spatial ability activities". The dependent variable for the first sub-problem was students' opinion about the visual treatment in terms of thinking process, where the interviews of the 6th grade elementary school students are used. On the other hand the independent variable is spatial ability activities

The fifth part includes the variables for the second sub-problem of second main problem of this study -"What is the students' opinion about the visual treatment in terms of feelings in the spatial ability activities" The dependent variable for the first second sub-problem was students' opinion about the visual treatment in terms of feelings, where the interviews of the 6th grade elementary school students are used. On the other hand the independent variable is spatial ability activities.

3.8. Assumptions and Limitations

In this section, assumptions and limitations of the present study are discussed.

3.8.1. Assumptions

The main assumptions of the present study are the following:

- There was no interaction between the subjects to affect of the present study.
- The subjects were able to understand and interpret the items truly.
- The administration of the tests was completed under standard conditions.
- All subjects answered the measuring instruments accurately and sincerely.

3.8.2. Limitations

For this study, 21 6th grade elementary school students are selected by using convenient sampling. Visual treatment is performed with 10 spatial ability activities for 10 weeks. 9 interviews are conducted by the researcher. One of the assumptions is the sample size of the study. The sample may possibly not be fully

delegated of the population and the generalization is limited. The other limitation was the researcher was inexperienced about making observations and observations. To become more successful about inquiry depends on the experience that you face with. For conquering the problem, researcher read lots of qualitative research includes interview and observations especially their limitations part and performed interview with students different than 9 students. Another limitation, there was no control group in the study and therefore it does not prove that it was the visual treatment that produced positive changes among students' spatial ability scores. The other limitation study was limited to subjects at the sixth grades of the elementary schools in rural areas of Ankara during 2006-2007 academic years. Student's concentration during the study is another limitation for this study. Student's concentration and interest to the study show changes time to time. Students sometimes got bored about the activities. For minimizing this effect students are awarded with spatial ability related video games once a week. Students' problems they face with during the activities are talked with students and tried to find a solution their any kind of problem about every subject. This investigation was based on self-report data, which may be subject to bias.

3.9. Validity of the Study

In this section internal and external validity of the study is discussed.

3.9.1. Internal Validity

Internal validity of a study means that observed differences on the dependent variable, not due to some other unintended variable (Fraenkel & Wallen, 1996). One of the possible threats to internal validity of a study is subject characteristics. All students attend to study were at the same grade level so the subjects' ages were close to each other and their socioeconomic levels were the same. None of the students were lost during the study so; mortality effect was

eliminated. Another threat, which is history, was eliminated with the setting being consistent throughout the study. The pretest and posttest, as well as the 10-week visual treatment were administered at the same school and there was no such an event those effect students' responses and study procedure so; the history threat was controlled. Administering the tests to all students almost at the same time and same place controlled location threat. Another threat was instrumentation. To eliminate instrument decay all instruments used were carefully examined. Moreover, measurement instrument wasn't altered during the study which controls the instrumentation effect. Same data collector was used to eliminate data collector characteristics. However, application of instruments and treatment were not controlled by training implementers so data collector bias was not eliminated. Another threat was because of the small sample size. "A recommended minimum number of subjects is 100 for a descriptive study, 50 for a correlation study, and 30 in each group for experimental and causal-comparative studies" (Frankel & Wallen, 1996, p. 111). This study began with 21 pretest subjects; none of them were lost during the study. Such a small sample limited the ability to generalize the results to the other sixth grade school students. Reliability or validity has been established for SAT, SOAT and SVAT, and interview questions were coded by two different people so; generalization of the results of this study to the overall population was positively impacted. "Unless the instrumentation used is reliable, meaningful relationships (perhaps causal) with other variables will not be found" (Frankel & Wallen, 1996, p. 162). Instructor performed each activity over the same period of time to eliminate maturation effect. There was no such a control group that students perceive that they are receiving any sort of special attention so; attitude of subjects eliminated In addition to this, there was no such a student with extremely low or high scores on test so; regression to mean effect was eliminated. Lastly, 10-week period of time was given between pretest-posttest and one month break was given between posttest and retention to eliminate testing effect. Last treat was implementation effect. There was no other instructor perform treatment or by monitoring instruction so implementation effect was not eliminated.

3.9.2. External Validity

External validity is extending to which the results of a study can be generalized (Fraenkel & Wallen, 1996).

3.9.2.1. Population Validity

In the present study the sampling was convenient sampling but sample size was small therefore the generalizations of the findings of the study were limited. However, generalizations can be done on the subjects having the same characteristics with the subjects of the present study which were mentioned in the "subjects of the study" section.

3.9.2.2. Ecological Validity

Fraenkel and Wallen (1996) stated that the ecological validity is the degree to which results of a study can be extended to other setting or conditions. The measuring instruments were used in regular classroom settings. The study is on sixth grade elementary school students, therefore the results of the study can be generalized similar settings to this study.

CHAPTER 4

RESULTS OF THE PRESENT STUDY

The theoretical background of the study, the review of the previous studies and the method of the present study were stated in the previous chapters. In this chapter, analyze results conducted to get statistical evidence for our claims will be presented. This chapter contains three sections. The first section presents the descriptive statistics. The second section is the inferential statistics section where the results of the testing hypotheses associated to the problems are included. Finally, the third section of the chapter includes the conclusions derived from the present study

4.1. The Results of Descriptive Statistics

In this section the descriptive statistics of the data are given and the row scores are used. Table 4.1 shows the means and standard deviations, maximum and minimum values of the variables (SAT scores, SOAT scores, and SVAT scores)

Table 4.1 Means, Standart Deviations, Maximum and Minumum Values of SAT, SOAT and SVAT scores

	Test Type	Minimum	Maximum	Mean	SD
PRE	SAT	41	105	63. 62	15.46
	SOAT	20	75	46. 57	13.01
	SVAT	5	30	17.05	6.71
POST	SAT	76	193	119.05	31.00
	SOAT	52	132	89.95	23.09
	SVAT	17	61	29.10	10.81
RET	SAT	49	156	91.19	26.04
	SOAT	39	110	67.33	18.14
	SVAT	10	57	23.86	10.38

As it is seen in the table 4.1, mean scores of students at post-test are higher than pre-test in all three tests. However, mean scores of students at ret-test are lower than post-test but higher than pre-test in all three tests. These findings are valid for minimum-maximum scores and standard deviation of scores.

4.2. Inferential Statistics

In this section, the sub-problems of the study will be examined by means of their associated hypotheses which are in the null form and tested at a significance level of 0.05.

4.2.1. Results of Testing of the First Main Problem

The first main problem P1: What is the effect of visual treatment on sixth grade students' spatial ability, spatial orientation and spatial visualization?

The first sub-problem of the first main problem is: "Is there a statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)?"

For the first sub-problem the following hypotheses is stated:

$H_0$1.1 "There is no statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)?"

To test this hypothesis, one-way repeated measures ANOVA is used. One of the main assumptions is the normality assumption. The normality assumption for SAT is determined by Kolmogorov-Smirnov statistics. The significance values were found .099 for PRESAT scores, .200 for POSTSAT scores and .138 for RETSAT scores. This means that the normality assumption is satisfied because Pallant (2001) stated that "a non-significant result (Sig value more than .05) indicates normality" (p.58).

• One-way repeated measure ANOVA was used as a method. The other assumptions for this analysis are listed below by using guidelines of Matulsky (1999).

Effectiveness of matching: Variables are measured across three time periods (pre-treatment, post treatment and retention). Moreover, the P value is low (p=.000), so matching is effective.

Independence of subjects: Subjects were independent; I had 21 rows of data obtained from 21 students. There was no duplicate measurement in each student.

Only one factor: Research aim was to compare groups defined by one factor which was visual treatment.

Fixed factor rather than random: This test for differences among the means of the particular groups I have collected data from. In other words, the factor fixed rather than random.

Gaussian assumption: Gaussian assumption is about the distribution of the overall population of values by taking into account the scatter of data it was understood that Gaussian assumption was satisfied.

Table 4.2 Results of one-way repeated measures ANOVA for SAT scores with respect to time

Effect	Value	F	Sig.	Partial Eta Squared	Observed Power
Wilks' lambda	.147	55.217	.000	.853	1.000

To test hypothesis, one-way repeated measures ANOVA was performed. After testing hypothesis it was found that there was a significant effect for time (Wilk's lambda= .000, F (2, 19) =55,217, p= .005). The partial eta-squared is found as 0.85. This result suggests very large effect size by utilizing guidelines

proposed by Cohen (1988). To find out which pairs of time periods caused the mean difference scores of spatial ability, least significant difference (LSD) comparisons were used. The results were given in Table 4.3.

Table 4.3 Pairwise Comparisons of SAT scores of students

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-55.429	5.505	.000	-66.911	-43.946
	3	-27.571	4.436	.000	-36.825	-18.318
2	1	55.429	5.505	.000	43.946	66.911
	3	27.857	3.069	.000	21.455	34.260
3	1	27.571	4.436	.000	18.318	36.825
	2	-27.857	3.069	.000	-34.260	-21.455

All three means were significantly different from each other. Mean score of the SAT was significantly higher immediately after the visual treatment (M = 119.05, SD=31.00) than before the treatment (M = 63.62, SD=15.46). The mean performance score one month later was significantly lower (M = 91.19, SD=26.04) than that immediately after the treatment, but significantly higher than the mean performance before the treatment.

This hypothesis was also tested by using the Friedman test and Wilcoxon test because "Use parametric and nonparametric techniques to analyze data. When the results are consistent, interpretation will thereby be strengthened" (Fraenkel & Wallen, 1996, p.237). After testing the hypothesis, it is found that there is a statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention) ($p<0.05$). In other words, there are significant mean rank differences in the spatial ability sores across the three time periods. The mean rank of PRESAT, POSTSAT and RETSAT scores are 1.05, 3.00 and 1.95 respectively. To determine which mean ranks of the test scores cause this difference, the Wilcoxon test is used. The results are given in Table 4.4.

Table 4.4 Wilcoxon signed Rank Test results for SAT scores of students

Tests	Type of Ranks	n	Mean Rank	Sum of Ranks	Sig.
POSTSAT - PRESAT	Negative Ranks	0	.00	.00	0.00
	Positive Ranks	21	11.00	231.00	
RETSAT - POSTSAT	Negative Ranks	21	11.00	231.00	0.00
	Positive Ranks	0	.00	.00	
RETSAT - PRESAT	Negative Ranks	1	1.00	1.00	0.00
	Positive Ranks	20	11.50	230.00	

The Table 4.4 shows that there is a significant difference between mean ranks of the POSTSAT scores and the PRESAT scores ($p < 0.05$). The mean rank of POSTSAT scores is statistically significantly greater than their mean rank of PRESAT scores (Mean $Rank_{postsat}$= 3.00 and Mean $Rank_{presat}$ =1.05). In addition, the mean rank of RETSAT scores is statistically significantly less than their mean rank of POSTSAT scores (Mean $Rank_{retsat}$ =1.95, Mean $Rank_{postsat}$= 3.00). Lastly, the mean rank of RETSAT scores is statistically significantly greater than their mean rank of PRESAT scores (Mean $Rank_{retsat}$ =1.95, Mean $Rank_{presat}$= 1.05).

The second sub-problem of the first main problem is: "Is there a statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention)?"

For the second sub-problem the following hypotheses is stated:

$H_0$1.2 "There is no statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention)?"

To test this hypothesis, one-way repeated measures ANOVA is used. One of the main assumptions is the normality assumption. The normality assumption for SOAT is determined by Kolmogorov-Smirnov statistics. Since the sig. values

were found .200 for PRESOAT scores, .200 for POSTSOAT scores and .200 for RETSOAT scores the normality assumption is satisfied. ($p > 0.05$).

Table 4.5 Results of one-way repeated measures ANOVA for SAT scores with respect to time

Effect	Value	F	Sig.	Partial Eta Squared	Observed Power
Wilks' lambda	.169	46.739	.000	.831	1.000

To test hypothesis, one-way repeated measures ANOVA was performed. After testing hypothesis it was found that there was a significant effect for time (Wilk's lambda= .000, F (2, 19) =46,739, p= .005). The partial eta-squared is found as 0.83. This result suggests very large effect size by utilizing guidelines proposed by Cohen (1988). To find out which pairs of time periods caused the mean difference scores of spatial ability, LSD comparisons were used. The results were given in Table 4.6.

Table 4.6 Pairwise Comparisons of SOAT scores of students

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-43.381	4.710	.000	-53.207	-33.555
	3	-20.762	3.940	.000	-28.981	-12.543
2	1	43.381	4.710	.000	33.555	53.207
	3	22.619	2.779	.000	16.823	28.415
3	1	20.762	3.940	.000	12.543	28.981
	2	-22.619	2.779	.000	-28.415	-16.823

All three means were significantly different from each other. Mean spatial orientation score was significantly higher immediately after the visual treatment (M = 89.95, SD=23.09) than before the treatment (M = 46.57, SD=13.01). The mean performance score one month later was significantly lower (M = 67.33,

SD=18.14) than that immediately after the treatment, but significantly higher than the mean performance before the treatment

It is by Friedman Test at the significance level 0.05. After testing the hypothesis, it is found that there is a statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention) ($p<0.05$). In other words, there are significant mean rank differences in the spatial orientation sores across the three time periods. The mean rank of PRESOAT, POSTSOAT and RETSOAT scores are 1.00, 3.00 and 2.00 respectively. To determine which mean ranks of the test scores cause this difference, the Wilcoxon test is used. The results are given in Table 4.7

Table 4.7 Wilcoxon signed Rank Test results for SOAT scores of students

Tests	Type of Ranks	n	Mean Rank	Sum of Ranks	Sig.
POSTSAT – PRESOAT	Negative Ranks	0	.00	.00	0.00
	Positive Ranks	21	11.00	231.00	
RETSAT - POSTSOAT	Negative Ranks	21	11.00	231.00	0.00
	Positive Ranks	0	.00	.00	
RETSAT - PRESOAT	Negative Ranks	0	.00	.00	0.00
	Positive Ranks	21	11.0	231.00	

The Table 4.7 shows that there is a significant difference between mean ranks of the POSTSOAT scores and the PRESOAT scores ($p < 0.05$). The mean rank of POSTSOAT scores is statistically significantly greater than their mean rank of PRESAT scores (Mean $Rank_{postsoat}$= 3.00 and Mean $Rank_{presoat}$ =1.00). In addition, the mean rank of RETSAT scores is statistically significantly less than their mean rank of POSTSAT scores (Mean $Rank_{retsoat}$ =2.00, Mean $Rank_{postsoat}$= 3.00). Lastly, the mean rank of RETSOAT scores is statistically significantly greater than their mean rank of PRESOAT scores (Mean $Rank_{retsoat}$ =2.00, Mean $Rank_{presoat}$= 1.00).

The third sub-problem of the first main problem is: "Is there a statistically significant change in students' spatial visualization scores across three time periods (pre-treatment, post treatment and retention)?"

For the third sub-problem the following hypotheses is stated:

$H_0$1.3 "There is no statistically significant change in students' spatial visualization scores across three time periods (pre-treatment, post treatment and retention)?"

To test this hypothesis, one-way repeated measures ANOVA is used. One of the main assumptions is the normality assumption. The normality assumption for SVAT is determined by Kolmogorov-Smirnov statistics. Since the sig. valuees were .200 for PRESVAT scores, .200 for POATSVAT scores and .076 for RETSVAT scores the normality assumption is satisfied. ($p > 0.05$)

Table 4.8 Results of one-way repeated measures ANOVA for SAT scores with respect to time

Effect	Value	F	Sig.	Partial Eta Squared	Observed Power
Wilks' lambda	.242	29.778	.000	.758	1.000

To test hypothesis, one-way repeated measures ANOVA was performed. After testing hypothesis it was found that there was a significant effect for time (Wilk's lambda= .000, F (2, 19) =29,778, p= .005). The partial eta-squared is found as 0.76. This result suggests very large effect size by utilizing guidelines proposed by Cohen (1988). To find out which pairs of time periods caused the mean difference scores of spatial ability, LSD comparisons were used. The results were given in Table 4.9

Table 4.9 Pairwise Comparisons of SAT scores of students

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-12.048	1.567	.000	-15.316	-8.779
	3	-6.810	1.417	.000	-9.765	-3.854
2	1	12.048	1.567	.000	8.779	15.316
	3	5.238	1.002	.000	3.148	7.329
3	1	6.810	1.417	.000	3.854	9.765
	2	5.238	1.002	.000	-7.329	-3.148

All three means were significantly different from each other. Mean spatial visualization score was significantly higher immediately after the visual treatment (M = 29.10, SD=10.81) than before the treatment (M=17.05, SD=6.71). The mean performance score one month later was significantly lower (M = 23.86, SD=10.38) than that immediately after the treatment, but significantly higher than the mean performance before the treatment.

It is by Friedman Test at the significance level 0.05. After testing the hypothesis, it is found that there is a statistically significant change in students' spatial visualization scores across three time periods (pre-treatment, post treatment and retention) ($p<0.05$). In other words, there are significant mean rank differences in the spatial visualization sores across the three time periods. The mean rank of PRESVAT, POSTSVAT and RETSVAT scores are 1.12, 2.88 and 2.00 respectively. To determine which mean ranks of the test scores cause this difference, the Wilcoxon test is used. The results are given in Table 4.10

Table 4.10 Wilcoxon signed Rank Test results for SAT scores of student

Tests	Type of Ranks	n	Mean Rank	Sum of Ranks	Sig.
POSTSAT – PRESOAT	Negative Ranks	0	.00	.00	0.00
	Positive Ranks	21	11.00	231.00	
RETSAT - POSTSVAT	Negative Ranks	18	11.28	203.00	0.00
	Positive Ranks	2	3.50	7.00	
	Ties	1			
RETSAT - PRESOAT	Negative Ranks	2	3.75	7.50	0.00
	Positive Ranks	18	11.25	202.50	
	Ties	1			

The Table 4.10, shows that there is a significant difference between mean ranks of the POSTSAT scores and the PRESVAT scores ($p < 0.05$). The mean rank of POSTSVAT scores is statistically significantly greater than their mean rank of PRESVAT scores (Mean $Rank_{postsvat}$= 2.88 and Mean $Rank_{presvat}$ =1.12). In addition, the mean rank of RETSVAT scores is statistically significantly less than their mean rank of POSTSVAT scores (Mean $Rank_{retsvat}$ =2.00, Mean $Rank_{postsvat}$= 2.88). Lastly, the mean rank of RETSVAT scores is statistically significantly greater than their mean rank of PRESVAT scores (Mean $Rank_{retsvat}$ =2.00, Mean $Rank_{presvat}$= 1.12).

4.3. The results of the second main problem

4.3.1. The results of the interview related to thinking process in the visual treatment

Researcher analyzed each interview by using phenomenographic method to summarize findings about each question. A phenomenographic analysis seeks a "description, analysis, and understanding of experiences" (Marton, 1981, p. 180). Students' speech was categorized with respect to their meaning and then students' excerpted answers were fit in these categories. Tables for each question include

students' opinion about visual treatment in terms of cognitive process and feelings. Each table was designed to have one column for each cognitive process and feelings category.

Table 1 demonstrated that the categories for the question "which solution methods did you use for solving questions for the first time?" The purpose of this question was to investigate the methods that students used before taking spatial ability activities.

Table 4.11 The Results of First Interview Question

Answer Categories	Students' Explanations
Imagining. (Sts.1,2.3.4.6.7,8.9)	I tried to imagine in my mind (st1) I tried to construct shapes in my mind (st2) For example, I tried to imagine the cubes in my mind in the cube comparison questions. I usually tried to find the symmetry of the shapes in my mind. I tried such kind of methods in the card rotation questions. (st3) I tried to imagine the shapes in my mind. I dreamed and solved questions by using this method. (st4) I tried different solving methods, while solving the questions. I tried to solve questions by Imagination in the mind. I tried to find the shapes on unseen faces. I imagined shapes in my mind. (st6)

Table 4.11 (continued)

Answer Categories	Students' Explanations
	I say that "if I turn the shapes in my mind, it would turn into such condition." I solved it by means of using this way. (st7) I made an effort to find the answer by imagining the shapes, while solving the questions. (st8) I made an effort to solve the questions by imagination. I sometimes rotated the question paper. (st9)
Seeking a pattern. (st1)	I made an effort to seek a pattern for solving questions. (st1)
Looking at sample solutions. (Sts.2,5)	I examined the sample solutions and tried to understand the logic while solving the questions. (st2) While solving the questions, I examined the sample solutions. I made an effort to find a suitable method for me. (st5)
Estimating. (st.7)	I tried to solve questions by imagination. I said if I turned the shape, it would be something like that and solved them by using this method (st7)

As it is seen in the table, students' solving methods were categorized into 4 subgroups which were; imagining, seeking a pattern, looking at sample solution, and estimating. When the students' answers were analyzed, a similar tendency was observed to select imagining method. Related to the interview question,

almost all students stated that they tried to imagine the geometric shapes in their mind and tried to solve questions by selecting appropriate transformation movements. For example st6 used mental picture to found drawings on unseen faces in card rotation question and expressed his thoughts as:

> "I tried different solving methods, while solving the questions. I tried to solve questions by imagination in the mind. I tried to find the shapes on unseen faces."

Moreover, st.1 stated that he used combination of seeking a pattern and imagining together.

Sts. 2 and 5 attempted looking at sample solution to conclude the right answers. In my opinion which was gained from the interview with these students, they just only used sample question solving method to got an idea about which solving method could be used but they had same trouble with express their thinking

As it understood from the table estimating was not the only method used by st7. He used the combination of estimating and imagining of the shapes in mind.

In general imagine the geometric shapes in mind was used by nine students expect st5. Seeking a pattern was used by one student, examine the sample question solving was used by two students and estimating method was used by only one student.

Table 4.12, displayed that the categories for the question "Did your solving methods show changes respect to question types in spatial ability tests?" The purpose of this question was to investigate whether students' problem solving method show changes within test types

Table 4.12 the Results of Second Interview Question

Answer Categories	Students' Explanations
Didn't show change (Sts.1,2,4,5,6,7,8,9)	I used the same methods for the tests. I didn't use different methods. I made an effort to imagine in my mind.(st1) No, my solving methods didn't show any difference. I solved all of these questions by using these methods. These methods are imagining and rotating shapes in the mind (st2) I generally used the same methods. I tried to solve all of the questions by imagining in my mind. (st4) Generally, I used same methods. I tried to solve the questions by looking at sample questions while solving the first tests. (st5) I used the same methods while solving the questions again. I tried to solve them by imagining. (st6) No, it didn't show any change. I tried to solve the tests by imagining. (st7) That's to say, I answered all the questions using the same method. I didn't use any other methods. (st8) No, I always used the same method. My method didn't show any change with respect to the question types. (st9)

Table 4.12 (continued)

Answer Categories	Students' Explanations
Show changes (st3)	Sometimes I did. For example, I solved he card rotation questions by using symmetry and rotating in the mind methods. (st3)

As it is seen in the table, students' solving methods were categorized into 2 subgroups which were: didn't show changes and show changes

Almost all students expect st3 explained that he/she did not use another method different than he/she used in the first test. St2 who used imagination as a problem solving method expressed his thoughts as;

> "No, my solving methods didn't show any difference. I solved all of these questions by using these methods. These methods are imagining and rotating shapes in the mind."

Different than the other student, st3 expressed that he/she used finding symmetry and imagine in mind together for solving questions and expressed his thoughts as;

> "Sometimes I did. For example, I solved he card rotation questions by using symmetry and rotating in the mind methods."

It is definitely understood from the students' responses that problem solving methods did not show changes within spatial ability tests. In other words, problem solving methods given in the table 4.11 were used in all; cube comparison, card rotation, surface development and paper folding tests without feel necessity of any other solving method.

Table 4.13 showed the categories for the question “Did your solving methods show changes after activities? For example, how had you solved questions before the activities, how did you solve questions after the activities? What kind of solving method did you develop for solving cube comparison questions?” The purpose of this question was to got investigate the changes in methods and effects of activities on it

Table 4.13 The Results of Third Interview Questions

Answer Categories	Students’ Explanations
Seeking a pattern (Sts.1,7)	When I made the cube comparison questions, I tried to seek a pattern on the shapes. I tried to understand which shapes would come after which shape.(st1) I was solving questions by imagination before the activities but I tried to rotate I tried to perform cube comparison questions by imagining while solving the first tests. Afterwards, I tried to solve the again by seeking a pattern.(st7)
Imagination in the mind (Sts. 2,8,9)	I made an effort to solve the cube comparison questions by imagining them in my mind.(st2) I used the imagination method. I tried to guess which shape to come after the shape on the surface of the cube. If the shapes match one another, this means that cubes were the same if not they weren’t. Imagination was clearer after doing the activities. (st8) In the beginning, I didn’t know how to handle questions. However after the activities, I tried to answer the questions by imagining. I tried to find which shapes would come after which movement. (st9)

Table 4.13 (continued)

Answer Categories	Students' Explanations
Perception of surface (st3)	Perceiving the front and back faces of the cubes become easier after doing the activities. I solved those questions faster. At the first activity, I had got more undone questions, but after the activities the number of undone questions gradually reduced. (st3)
Turning in the mind (Sts. 4,6)	shapes in my mind and I gave attention to shapes which come to the front surfaces after the activities. (st4) I firstly thought how I could found the shapes that were on unseen surfaces of the cubes. I rotated shapes in my mind for finding these shapes. (st6)
Giving numbers to surface of the shapes (st5)	While I was solving the questions again, I gave numbers for the shapes on the cubes. I compared the shapes with numbers. I understood that I could remember the numbers more easily than remembering the shapes. (st5)

As it is seen in the table, students' problem solving methods were categorized into 5 subgroups which were; seeking a pattern, imagination in the mind, perception of surface, turning in the mind, and giving number to surface of the shapes.

Sts.1 and 7 stated that they used seeking a pattern as a problem solving method in the second application of cube comparison test. St1 explained that his problem solving method did not show change with respect to first application. However, method used in the second application was more successful than the first one. He tried to find shapes alternately on the cubes. Although, the st7 used guessing as a solving method in the first cube comparison test, he used seeking a

pattern in the second application.

According to information had from sts. 2, 8 and 9 it was understood that their problem solving method did not show changes in respect of first and second cube comparison test application. They used imagination in mind as a problem solving method. St8 manifested that appearing image in the mind was clearer and moving it was easier in the second application with respect to first one.

St3 denoted that it was easy to perceive the faces of cubes in the second application and expressed his thoughts as;

> "Perceiving the front and back faces of the cubes become easier after doing the activities. I solved those questions faster. At the first activity, I had got more undone questions, but after the activities the number of undone questions gradually reduced."

Sts. 4 and 6 explained that they used rotation in the mind as a problem solving method. Their problem solving method showed a change with a small difference.

St5 defined that he gave numbers to the cube faces and match them with shapes. The reason giving numbers to the face of the shapes was being easy to remember numbers than remembering shapes.

Table 4.14 showed the categories for the question "Which solving method did you use for solving card rotation questions after the activities?" The purpose of this question was to investigate the changes in methods used in card rotation questions and effects of activities on it.

Table 4.14 The Results of Fourth Interview Questions

Answer Categories	Students' Explanations
Turning in the mind (Sts. 1,2,7,8,9)	I tried to solve the card rotation questions by turning the shapes in my mind.(st1) I also tried to solve the card rotation questions by turning the shapes in my mind.(st2) I tried to turn the shapes in my mind and my decision was based on this movement.(st7) In the beginning, I tried to solve these questions again by turning the paper. Afterwards, I tried to make a decision for whether the shapes were the same or not by turning shapes in my mind(st9) Firstly, I looked at the first shape and then asked shape. I tried to rotate the shapes in the asked questions for making a decision about whether the asked and given shapes were the same. (st8)
Looking at the previous shape (Sts. 3,6)	At the first activity I was solving the card rotation questions consistently by looking at the initial shape, but after the activities I made a decision by looking at the previous

Table 4.14 (continued)

Answer Categories	Students' Explanations
	shapes. That is to say if the initial and the first asked shapes were the same, and also, the first asked and the second asked shapes were the same, that meant the initial and the second asked shapes were the same. (st3) While answering the card rotation questions, I always made decisions by considering the initial shape. But after the activities I tried to make a decision by looking at previous shapes. (st6)
By controlling symmetry (Sts 4,9)	At first, I tried to rotate shapes in my mind but then, I gave attention to whether the shapes were symmetrical or not. I realized that if the shapes were symmetrical they were not the same. (st4) I gave attention to whether the shapes were symmetrical or not. I realized that two symmetrical shapes cannot be the same. (st9)
Giving the letter to the shapes (st5)	I named each corner of the shapes by a letter for solving the card rotation questions. After I turned the shapes, I tried to find the new places of the letters. My decision was based on this logic. (st5)

As it is seen in the table, students' problem solving methods were categorized into 4 subgroups which were Turning in the mind, Looking at the previous shape, By controlling symmetry, Giving the letter to the shapes;. When the answers of students were analyzed, it was seen that students' problem solving method showed changes and their thinking style got more deeply into spatial ability problems when comparing with first application.

Sts. 1, 2, 7 and 9 stated that rotation in the mind was used as a solving method for card rotation questions.

Sts. 3 and 6 denoted that they tried to solve questions by looking at previous shape and getting it as a reference. They determined whether the asked shape same, by rotating leading shape in the first application. However, their solving method had showed changes after the activities. They started took up previous shape as a reference instead of leading shape and st6 explained the method as follows;

> "While answering the card rotation questions, I always made decisions by considering the initial shape. But after the activities I tried to make a decision by looking at previous shapes."

Controlling symmetries was the method used by sts.4 and 9. Their solving method was based on determining whether the asked shape was symmetrical with leading shape or not. If the shape was symmetrical with leading shape they understood that shapes were not the same if not vice versa.

Giving letters to the corners of the shapes was another method used by st5. He/she stated that decision was depending on the position of letters on the shape. If the letters brought into correct line after the rotation, this means that shapes were same if not vice versa.

St8 stated that he looked at the leading shape, and then tried to rotate leading shape to obtain the asked shape. If he obtained the asked shape by rotating leading shape this means that shapes were the same, if not they weren't.

Table 4.15 showed that the categories for the question "'which problem solving methods did you used for paper folding?" The purpose of this question was to got investigate the changes in methods used in paper folding questions and effects of activities on it

Table 4.15 The Results of Fifth Interview Questions

Answer categories	Students' Explanations
Folding in the mind (Sts.1,3,4,7,8,9)	I tried to solve questions by folding paper in my mind. I tried to find where the hole was. (st1) In the beginning, I wasn't able to solve the paper folding questions but after the activities I could fold and open papers in my mind. (st3) While folding the paper, I tried to understand where the hole could be. I tried to understand the place of hole by folding and opening shapes in my mind. (st4) While solving the paper folding questions, I tried to find the place of hole in my mind. I was eliminating irrelevant choices and I was pointing the most logical one(st7) I tried to find the answers of paper folding questions by folding and opening shapes in my mind(st8)

Table 4.15 (continued)

Answer categories	Students' Explanations
	Before the activities, I tried to find the place and number of the holes by eliminating choices. After the activities, I could find the number and place of the holes in questions with less folding but I still had trouble about questions with more folding. I tried to find the place of holes by opening shapes in my mind. (st9)
Estimating (Sts. 2,5)	While solving the paper folding questions, I tried to estimate where the holes could be. (st2) That is to say, I paid the attention to place the folding lines of the paper. I tried to estimate the place of the hole with respect to this place. For example, If the folding line was near the middle, the holes had to be near. If those lines were near the corner, the holes had to be distant. (st5)
Imagination (st6)	For the first time, I had trouble in the paper folding questions. Afterwards, I started to enjoy them. While I was solving the questions again, I used the imagining method. I tried to find where be holes could be by imagining. (st6)

As it is seen in the table, students' problem solving methods were categorized into 3 subgroups which were; folding in the mind, estimating and imagination

Almost all students expect sts. 2, 5 and 6 explained that folding in the mind was the problem solving method that they used in the second paper folding test application. Moreover st7 student used elimination of irrelevant choices and folding in the mind as a problem together. Although elimination of irrelevant choices had been used in the first application of test, folding in the mind was selected as a problem solving method in the second application by st9. However he thought that questions with high number of folding was still very difficult for him to fold and open in mind

Sts. 2 and 5 expressed that guessing was the problem solving method used in second paper folding application. They used guessing for finding correct places of dots. If folding paper was pierced from place near center, dots formed closely, if pierced place near to corners dots formed apart from each other.

St6 stated that paper folding questions were the most difficult questions that he dealt in the first application expressed his thoughts as follows:

> "For the first time, I had trouble in the paper folding questions. Afterwards, I started to enjoy them. While I was solving the questions again, I used the imagining method. I tried to find where be holes could be by imagining."

Table 4.16 demonstrated that the categories for the question "'what kind of method did you follow for finding number of hole on folding papers?" The purpose of this question was to investigate the strategy that students used.

Table 4.16 The Results of Sixth Interview Questions

Answer Categories	Students' Explanations
Giving attention to number of folding (Sts. 1,2,3,4,5,6,7,8)	In order to find the number of holes, I tried to pay attention to how many sheets I folded. That is to say, the numbers of the holes and folding sheets were increasing together. For example, when we folded the paper twice two holes appeared. When we fold twice again four holes appeared(st1) I tried to find the number of the holes, by thinking of the number of folding sheets. (st2) In order to find the number of holes, I counted the folding sheets. If I folded the paper twice, two holes appeared; if I folded again four holes appeared. (st3) I paid attention to the number of folding sheets, when I tried to find the number of holes. That is to say, when we folded the paper twice, two holes appeared. (st4) I paid attention to the places where the paper was folded. (st5)

Table 4.16 (continued)

Answer Categories	Students' Explanations
	For example, while I was solving such questions for the first time, I supposed that there would be one hole on the paper. After the activities, I realized that after one folding two holes appeared on the paper. (st6) I had difficulty in finding the number of holes in the beginning, but then I realized that the number of holes was increasing together with the number of folding. (st7) It was very difficult for me to find the number of the holes. Then, I understood that the number of the holes was increasing along with the number of the folding. (st8)
Folding shapes in the mind (st9)	I tried to imagine the shapes of the folded paper in my mind and also to open those shapes in my mind. I counted the number of holes during this opening process. (st9)

As it is seen in the table, students' problem solving methods were categorized into 2 subgroups which were; giving attention to folding number of folding and Folding shapes in the mind

Almost all students except st9 specified that they found the number of holes on the paper by giving attention to number of folding. Students stated that there was a directional proportion with the number of holes and folding number. Students discovered that if the paper was folded once, two holes were appearing. If the same paper was folded once again, the hole number got twice and this logarithmic increase continued with the number of folding. Sts 7 and 8 discovered that number of holes was increasing with the folding. However, finding the exact number of hole was still a problem for them. St. 6 expressed his thoughts as follows;

> "For example, while I was solving such questions for the first time, I supposed that there would be one hole on the paper. After the activities, I realized that after one folding two holes appeared on the paper."

St9 explained that he counted the number of holes appearing on the paper by opening folded shapes in the mind. This solving method was similar to the method used by other students. However, st9 emphasized on the usage of imagining in the mind method much more than the other students.

Table 4.17 showed the categories for the question "Which lectures were related with activities? Could you please explain it with examples?" The purpose of this question was to understand whether or not students put connection between spatial ability activities and lectures.

Table 4.17 The Results of Seventh Interview Questions

Answer Categories	Students' Explanations
Mathematics (Sts.1,2,3,4,5,7,9)	For example, the questions that, were asked to solve perspective drawing of shapes from different point of view in mathematics lecture were similar to the activities.(st1)

Table 4.17 (continued)

Answer Categories	Students' Explanations
	Activities and the geometry subjects resembled to one another. For example the subject, drawing perspective drawing of geometric shapes.(st2) The subject drawing the opened form of different geometric shapes performed in mathematics lecture resembled to the activities. (st3) I was unsuccessful at drawing opened form of three dimensional geometric shapes in mathematics lecture. However, after the activities, I achieved to solve these types of questions more easily. (st4) In my opinion, the subject finding symmetries of shapes in mathematics lecture resembled to the activities. (st5) I think that finding symmetries of geometric shapes and drawing them were related with activities. (st7) Activities helped me to solve the questions that were asked to draw views of cubes from different angles such as front, top and behind. That is why I believed that activities were mostly related with mathematics. (st9)

Table 4.17 (continued)

Answer Categories	Students' Explanations
Technology and design (Sts.(6,8,9)	Our technology and design lecture teacher requested from us to construct a structure by using the plastic glasses. I constructed a shape without bases in turning form .The most admired project was mine. This project resembled to the activities (st6) Our technology and design lecture teacher requested from us to construct different models by combining different geometric shapes. Pentominoes activity was related with this construction. (st8) Our mathematics teacher requested from us to find a geometric shape which has not invited yet. I tried to find different shapes by using knowledge gained from origami. (st9)

As it is seen in the table, students' problem solving methods were categorized into 2 subgroups which were; mathematics and technology-design lectures

Most of the students stated that activities were related with mathematics. For example, orthographic drawing was one of the activities that was related with mathematics. The reason for giving this example by the students was the similarity of activity and math subject. St9 expressed that orthographic drawings

were performed better than the days before activities. Because of that reason, he thought that activities were related with mathematics.

Sts. 3 and 4 stated that finding the open frame of three-dimensional geometric shapes in mathematics lecture was similar to activity we performed. Because of that reason they believed that activities were related with mathematics.

Sts. 5 and 7 expressed that they found a relation between shading reflection activity and finding the symmetry of a figure subject in mathematics lecture. Thence the idea activities were relevant with mathematics appeared.

Sts. 6, 8 and 9 denoted that activities were mostly related with technology and design lecture. St6 explained that gaining acquired from activities helped him to construct a building design made up of plastic glasses without any attachment. Number St8 believed that activities were related with technology and design lecture because; pentaminoes facilitated him to constitute a picture by connecting different geometric shapes in a manner. St9 tried to find an unknown geometric shape as a technology-design lecture' project by using techniques acquired from origami activities and expressed himself as;

> "Our mathematics teacher requested from us to find a geometric shape which has not invited yet. I tried to find different shapes by using knowledge that is gained from origami."

Table 4.18 showed that the categories for the question " Do you think that the time passing between second and third application period had positive or negative effects on you in solving third application questions?" The purpose of this question was to have opinion about students thinking process about the time-break given to the students for four weeks after the post-treatment.

Table 4.18 The Results of Eight Interview Questions

Answer Categories	Students' Explanations
Negative effect (Sts. 1,2,3,4,5,6,7,8,9)	In my opinion, this time interval caused negative effect on me. It was more difficult for me to solve third application question when comparing with second application. That's to say we didn't perform the activity hence I forgot how to solve questions. (st1) I found questions a bit difficult in third application. I had difficulty in solving questions. Probable reason was the time interval experienced without any activity. (st2) Solving third application questions was easier than first application. I think that giving a break to the activities caused to decrease my spatial knowledge. Therefore, I think that time without any activity affected me in negative manner. (st3). I believe that this time break caused a negative affect on me. After I left to perform activities, solving questions got more difficult for me. (st4)

Table 4.18 (continued)

Answer Categories	Students' Explanations
	I found questions more difficult, after we left to deal with activities. As we didn't perform activities, I forgot how to solve questions. (st5)
	It caused negative affect on me. Solving thesis questions was more difficult for me after we left to solve activity questions. (st6)
	I found questions a bit strange. Because we didn't solve activity questions for a long time, I forgot the methods that I use for solve questions. (st7)
	This experienced time without performing activities caused to forget knowledge gained from the activities. (st8)
	In my opinion, It caused negative effect on me; After I left to perform the activities, I had difficult in solving third application questions(st9)

All students stated that time interval that experienced without any visual treatment affected their spatial knowledge ability negatively. Almost all students stated that they forgot how to handle spatial ability problems and had some difficulty in solving questions. Sts. 1 and 3 stated that solving third application

questions were more difficult when comparing with second application. However, st3 explained that solving third application questions were easier than first application questions and expressed his/her thoughts as follows;

> "Solving third application questions was easier than first application but more difficult than second one. I think that giving a break to the activities caused to decrease my spatial knowledge. Therefore, I think that time without any activity affected me in negative manner."

This explanation showed that giving a break to visual treatment caused to forget knowledge gained from activities but loss of knowledge was limited. Otherwise, it couldn't possible for students to get high score at third application when comparing with first application. This result was consistent with inferential findings of this study.

4.3.2. The results of the interview related to feelings toward the visual treatment

Table 4.19 shows that the categories for the question "What did you feel when you faced with spatial ability questions for the first time?" The purpose of this question was to examine the effects of spatial ability questions on students' feelings.

Table 4.19 The Results of Ninth Interview Questions

Answer Categories	Students' Explanations
Fear (st1)	It was the first time that I faced such kind of questions; I feared that I wouldn't be able to solve the questions. I had never met such types of questions before. (st1)
Being sad (st9)	I said I wouldn't be able to solve questions and I got sad. (st9)

Table 4.19 (continued)

Answer Categories	Students' Explanations
Being tensed (Sts.4,5,7)	I get tensed because I thought that given time to finish test wouldn't be enough for me. (st4) I get tensed since; I thought that I wouldn't have solved the questions. (st5) Since, I had never faced such a thing, I coerced insistently and I got tensed. (st7)
Being worried (st6)	I found questions very worrying. Because I didn't know anything and I hadn't any idea about how questions would be solved. I got a bit worried while I was solving the questions. (st6)
Being nervous (st8)	When I saw the questions, I thought that what I would made and I got nervous (st8)
Enjoyment (Sts.2,3)	I found questions very interesting. Questions were similar to a game. While I was solving the questions, I had difficulty but it's true that I enjoyed myself. (st2) The questions very difficult and I had never faced with such kind of questions

Table 4.19 (continued)

Answer Categories	Students' Explanations
	before. But it was enjoyable to try to solve questions. (st3)
Being excited (Sts.4,5)	It was the first time that I faced with such kind of questions and I got excited (st4) I found questions different and stranger that is why I got excited (st5)

As it is seen in the table students' feelings were categorized into 7 subgroups which were: Fear, being sad, being tensed, being worried, being nervous, enjoyment and being excited. Most of the students' feelings were negative when they faced with spatial ability problems.

St1 said: "I was afraid of not being able to solve spatial ability questions when I faced spatial ability questions for the first time". Moreover he said it was the first time that he dealt with this kind of question types.

Sts. 2 and 3 denoted that they entertained during this forty-minute time that dealing with spatial ability questions. Both of these two students find questions difficult and entertaining.

Students with number 4, 5 and 7 expressed themselves get tensed. Because they thought not being able to solve questions. In addition to this, sts. 4 and 5 were excited different than st7. The reason for those feelings was being the first time that they faced with such kind of questions.

St8 felt affection because, he thought not being able to solve questions when he faced with the questions. St6 was worried about solving method of questions,

with the same reason of st8. The reason was not being able to solve the problems and expressed him as:

> "I found questions very worrying. Because I didn't know anything and I hadn't any idea about how questions would be solved. I got a bit worried while I was solving the questions."

While 5 categories included negative feelings, 2 of them included positive feelings. Four of the students felt negative and positive feelings together when they firstly faced with spatial ability problems.

Table 4.20 presented that the categories for the question "What did you feel when you realize that your solving method failure at the first time?" The purpose of this question was to investigate students' feelings when they had trouble about their problem solving method

Table 4.20 The Results of Tenth Interview Questions

Answer Categories	Students' Explanations
Fear (st1)	The thinking not being able to solve questions caused to get fear and I left these questions undone (st1)
Being demoralized (Sts. 2,3,4,5)	I found questions a bit difficult and felt myself demoralized. I couldn't able to think what I would make and I left answer undone in such questions. (st2) I thought that I wouldn't able to solve the questions, so I become low. However, I said myself that I can solve these questions and I tried to apply different solving methods to the questions. (st3)

Table 4.20 (continued)

Answer Categories	Students' Explanations
	I felt myself demoralized when my solving method was failure. (st4) When I didn't solve the questions, I became low. Although, I found questions very easy at the first page, it became increasingly difficult in the following pages. I thought that I wouldn't able to solve those difficult questions at the last part. (st5)
Disappointment. (st6)	I was disappointed. (st6)
Being nervous (st7)	When I didn't solve the questions I thought that I wouldn't able to solve other questions. In addition to this, given time to solve questions was limited so; I did not finish solving questions. Therefore I felt nervous. (st7)
Being panic (st8)	That's to say, I felt in panic by thinking that I wouldn't able to solve those questions. (st8)
Being angry (st9)	I got angry. I said that myself" I wouldn't solve those questions in no way." I felt angry. (st9)

As it is seen in the table, students' feelings were categorized into 6 subgroups which were; fair, being demoralized, disappointment, being nervous, being panic and Being angry. All students' feelings were negative when their problem solving method of no avail. Students were expected to try other solving methods at that time. However, students selected to leave questions empty.

St1 felt fear when his solving method was up to no good. He left question

blank instead of tried different solving method. Sts. 2, 3, 4 and 5 emphasized that they got bored and depressed when their problem solving method failure. St2 said that:

> "I found questions a bit difficult and felt myself demoralized. I couldn't able to think what I would make and I left answer undone in such questions."

Moreover st5 signified that questions on 2nd pages of spatial ability problem test were much more difficult than the questions on 1st pages. He got bored and depressed especially in these pages.

St6 said that he frustrated when his solving method was of no avail

St7 expressed that he felt affliction while he realized that his solving method was useless. Moreover, he thought that he would not be able to solve any other questions from that point. Another reason for experiencing affliction was the limited time given students to complete spatial ability test. He denoted his conceptions as:

> "When I didn't solve the questions I thought that I wouldn't able to solve other questions. In addition to this, given time to solve questions was limited so; I did not finish solving questions. Therefore I felt nervous."

While the st8 expressed that he felt bad and live panic on account of thinking about the test couldn't be finished on time, st9 stated that he couldn't solve spatial ability question and this bring on feel unstrung

Table 4.21 presented that the categories for the question "What do you think about activities we performed during 10-week? Did you enjoy or get bored what do you feel in general**?**" The purpose of this question was to investigate students' feelings during activities.

Table 4.21 The Results of Eleventh Interview Questions

Answer Categories	Students' Explanations
Enjoyment (Sts 1,2,3,4,6,9)	I got enjoyed in the activities that we construct square and rectangle by using geometric shapes as well as construct geometric shapes by using cubes. (st1) I enjoyed during the computer-based activity, but the others were very difficult. (st2) Well, those activities were generally very funny. I had a good time, when I made an effort to perform the activities. (st3) I found activates very different and enjoyable. I had never performed such kind of activities .So, when I performed it, I had a good time. (st4) I found the activities very enjoyable. Especially, Tetris and origami which required combining and folding shapes were very funny. (St6) After I understood the solving methods, I enjoyed performing activities. (st9)

Table 4.21 (continued)

Answer Categories	Students' Explanations
Boring (Sts.2,5,6,7,8,9)	I found activities very boring. I didn't want to solve the questions. (st2) However; I was in difficult in solving questions that requires perspective drawings. Those activities were very boring. (st5) I was impatient about performing activities but I got bored during difficult activities. (st6) That's to say the questions very difficult, so I found activities very boring. (st7) Namely, the activities were a bit boring. I strike, while I was making the activities. So I can't say that those activities were enjoyable. (st8) I got very bored when I couldn't solve the questions. (st9)

As it is seen in the table, students' feelings about activities were categorized into 2 subgroups which were; enjoyment and boring

Almost all students found activities very entertaining. Two of the students expressed that activities performed with manipulative such as construct cube and pentominoes. They were the most enjoyable ones. St4 stated that it was the first

time that he engaged with such kind of activities, that is why he found activities enjoyable. Although st6 found easy activities enjoyable, he got bored during hard ones and emphasized his thoughts as:

> "I found the activities very enjoyable. Especially, Tetris and origami which required combining and folding shapes were very funny. I was impatient about performing activities but I got bored during difficult activities."

St9 explained that activities were a bit boring during first two weeks. He started to find activities more enjoyable with the adoption to activities and understood how to perform them. He expressed himself as:

> "I got very bored when I couldn't solve the questions. After I understood the solving methods, I enjoyed performing activities."

Sts. 2, 7 and 8 affirmed that spatial ability activities were boring. St1 remarked that activities were very boring and difficult except computer based one. According to my observation st1 get bored very early and tried to find excuses for being absent during activity times. St7 stated that the reason for finding the activities boring was difficulty of questions and had trouble to complete them. St8 said that:

> "Namely, the activities were a bit boring. While I was making the activities, I strike. So that I can't say that those activities were enjoyable."

Table 4.22 presented that the categories for the question "Do you think that activities helped you in solving thesis questions? I mean the questions you got after 10-week period" The purpose of this question was to got vision of students about what do they think about activities, did they put connection with activities and asked questions

Table 4.22 The Results of Twelfth Interview Questions

Answer Categories	Students' Explanations
Usefulness (Sts.1.3.4.5.6.9)	Yes, I think that those activities were very useful. Questions and activities were similar, so solving those questions was very easy for me after the activities.(st1) Yes, activities assist me. Because some of the questions were similar to those questions we dealt in the activities. Therefore, it assisted me. (st3) Yes, I think that activities assisted me. Performing activities provided me a chance to make a practice. (st4) Yes, I think that activities were beneficial for me. I was able to solve the questions faster after the activities. (st5) Yes, activities assisted me. I found questions easier, and I solved the questions faster after the activities. (st6). Yes, I think that activities were beneficial for me. While performing the activities, we were dealing with similar questions. Therefore, solving questions was easy for me. (st9)

Table 4.22 (continued)

Answer Categories	Students' Explanations
Limited benefit (Sts.2,7)	Benefits of the activities were limited. Because, activities and questions were not similar to each other. (st2) Yes, activities were a bit beneficial for us solving questions was easier for me after the activities. I accustomed to solve such questions. (st7)
Being not beneficial (st8)	Those activities weren't beneficial for me. I wasn't able to understand the activities. I had trouble, while I was solving the questions. (st8)

As it is seen in the table, students' feelings about activities were categorized into 3 subgroups which were; usefulness, limited benefit, being not beneficial

Based on this interview question, I began to look across all students' responses in which activities affected students' understanding to the spatial ability questions and problem solving methods. Analysis of students' responses helped me to see how activities affected students' point of view to the questions. It was also understood from the table 4.22 that there was a general inclination to the consideration that activities were beneficial in respect of solving spatial ability test questions

Almost all students except Sts. 2, 7 and 8 specified that activities that were performed for ten weeks assisted to solve spatial ability test questions. Related to helpfulness of the activities, sts 1, 3 and 9 emphasized the similarity of activities and spatial ability test questions. Students believed that this similarity let them to

solve spatial ability test questions more easily. St4 stated that spatial ability activities provided him a chance to practice and defined his thoughts as;

> "Yes, I think that activities assisted me. Performing activities provided me a chance to make a practice."

Sts. 2 and 7 remarked that contribution of activities were limited. St2 stated that activities were different than spatial ability question that is why contribution was limited.

St8 student imported that activities did not provide help to solve spatial ability questions and he expressed his thoughts as;

> "Those activities weren't beneficial for me. I wasn't able to understand the activities. I had trouble, while I was solving the questions."

Table 4.23 presented that the categories for the question "What did you gained from the activities?" The purpose of this question was to got vision of students about what kind of achievements did they gain after 10-activity-week.

Table 4.23 The Results of Thirteenth Interview Questions

Answer Categories	Students' Explanations
Thinking style and ability (Sts.1,6)	I believe that, those activities have improved my intellectual ability.(st1) Activities provided me a different thinking style especially in technology and design lecture. (st6)

Table 4.23 (continued)

Answer Categories	Students' Explanations
Creativity (st3)	I think that, my creativity has improved. I am able to have various thinking about different circumstances. (st3)
Fast problem solving (Sts.3,5,7)	I am good at finding different solving ways to the questions and solving the questions faster after the activities. (st3) Thanks to those activities, I was able to solve spatial ability questions faster. (st5) Owing to the activities, I can solve the questions faster (st7)
Looking situation from different point of view (st4)	Those activities provided me a chance to think better. I can look at the situations from different point of view. (st4)
Solving geometry questions (Sts.4,5)	I was successful in solving geometry questions after the activities. I believe that, Iwill able to solve difficult geometry questions anymore. (st4) Owing to those activities, I can understand geometry concepts and solve

Table 4.23 (continued)

Answer Categories	Students' Explanations
	questions of the three dimensional shapes. (st5)
Drawing plan (st7)	I am getting more successful with activities in drawing plan. (st7)
Imagining shapes in the mind (st9)	I was able to put shapes together and imagine shapes in my mind. (st9)
Being not useful (Sts.2,8)	I don't think that, those activities provided me a lot of usefulness. (st2) Like to my saying, I don't think that those activities provided a lot of usefulness. (st8)

As it is seen in the table, students' feelings about activities were categorized into 7 subgroups which were; thinking ability-thinking style, creativity, fast problem solving, looking situations from different point of view, solving geometry questions, drawing plan , imagining shapes in the mind, being not useful. Most of the students except sts2 and 8 believed that activities they acquired different gaining by the help of activities.

While the students' answers were examined, it was seen that almost each students' opinion about their achievements showed diversity. Sts. 1 and 6 believed that activities caused to change his thinking style and ability. St3 predicated that activities enhanced his/her creativity. Moreover, st3 emphasized that activities let her to solve questions more quickly than in normal times. sts.5 and 7 shared the same thought with st3 about solving questions more quickly

According to st4, activities provided a chance not only to look at situations from different point of view but also to being more successful in solving difficult geometry questions. Moreover st5 thought that understanding and solving geometry questions included three-dimensional geometric shapes were easier after the activities. St9 stated that he could able to solve geometry questions with the ability gained from the activities. He could put shapes together and imagine them in his/her mind better.

St7 student, activities helped him to draw a diagram of a place and stated him as;

> "I am getting more successful with activities in drawing plan."

Sts. 2 and 8 thought that activities did not provide any gaining to them

Table 4.24 showed that the categories for the question "Why do you think that these activities are so important? For example, do these activities were related with daily life?" The purpose of this question was to get vision of students about daily usage of spatial ability activities

Table 4.24 The Results of Fourteenth Interview Questions

Answer Categories	Students' Explanations
Drawing (Sts.1,6,7)	I believe that, it is probable to come on with application of activities in our daily life. For example, I had trouble about how to draw plan before the activities. Nevertheless I can draw the plan easily after the activities. (st1) I believe that, activities are related with our

Table 4.24 (continued)

Answer Categories	Students' Explanations
	daily life. For example, my technology and design teacher requested to construct a house model. I firstly imagined inside and outside of the house in my mind and then drew the model of the house on a paper. (st6) I wasn't able to draw the plan of the roads from our school to my home. After those activities, I closed my eyes and then imagined the roads, houses from sky view in my mind and finally I drew it easily. (st7)
Putting a mouse to a computer case (st3)	Activities are related with our daily life. For example, when I put the mouse input, to the computer port, I found its place easier.(st3)
Decoration of home (st4)	I believe that, activities are related with our daily life. For example, we can use our spatial ability to decorate our furniture in our mind before put it into practice. Activities enhanced my decoration ability. (st4)
Three dimensional thinking (Sts.5, 9)	I like drawing car models. I could only two-dimensional drawings of the car in previous days, but now I can draw three dimensional appearance of the car. (st5)

Table 4.24 (continued)

Answer Categories	Students' Explanations
	I believed that activities are necessary for solving geometry question that required three-dimensional thinking ability. (st9)
Limited usefulness (Sts.2,8)	I don't think that activities provided me a something (st2) As I said before it was not beneficial for me. (st8)

As it is seen in the table, students' thoughts about daily life usage of spatial ability activities were categorized into 7 subgroups which were; drawing, putting the mouse to a computer case, decoration of home, three dimensional thinking, limited usefulness

According to information got from sts. 1 and 7 it was difficult to drawing a plan before spatial ability activities. However, after the activities drawing a plan from a house to the school was performed better than the days before activities. In addition to this st6 stated that he achieved to imagine house model before started to construct it and to draw imagined model to a paper. St6 expressed his/her thoughts as follows;

> "I believe that, activities are related with our daily life. For example, my technology and design teacher requested to construct a house model. I firstly imagined inside and outside of the house in my mind and then drew the model of the house on a paper finally construct the house model in respect of my drawings."

St3 specified that putting the mouse input to the computer port was easy for

her by just only looking at the mouse input, without looking at the computer port. St4 declared that it was easy for her to arrange the furniture of their house in her mind before put it into practice. St5 explained that he was capable of drawing two dimensional car designs before spatial ability activities. However, he was up to design three dimensional car pictures from different point of view after the activities.

Sts 2 and 8 thought that there was no relation between spatial ability activities and daily life. This result was consistent with findings from thirteenth interview question. In that question students were asked to what you gained from activities.

Table 4.25 showed that the categories for the question "'in which ability you felt change after spatial ability activities?" The purpose of this question was to investigate change occurred in students' abilities after spatial ability activities.

Table 4.25 The Results of Fifteenth Interview Questions

Answer Categories	Students' Explanations
Solving the questions with shapes (Sts.1,7)	I didn't want to solve difficult questions and questions with shapes formerly. But now, I can solve those questions. That is to say, I am able to find the different solving methods.(st1) I can combine and imagine the geometric shapes for solving questions with shapes anymore. (st7)
Imagination of shapes in the mind (st2)	I can imagine and open the geometric shapes in my mind. (st2)

Table 4.25 (continued)

Answer Categories	Students' Explanations
Creativity (st3)	My creativity has been improved. I realized that I have different intellectual abilities after the activities. (st3)
Three dimensional thinking ability (st4)	I think that, my three dimensional thinking ability has been improved after the activities. (st4)
Drawing three dimensional objects (st5)	I think that my three dimensional drawing ability has been improved. That's to say I could draw only one side of the car formerly. However, I can draw the different sides of a car anymore. (st5)
Solving questions faster (Sts. 6,9)	I could solve difficult questions faster than the days before activities. (st6) For example, I am able to solve questions that were asked to find perspective drawings of a construction faster than the days before activities. (st9)
No any change (Sts 2,8)	I don't think that the activities improved my any ability. (st2) I don't think that activities helped to enhance my abilities.(st8)

As it is seen in the table, students' problem solving methods were categorized into 8 subgroups which were; Solving the questions with shapes, imagination of shapes in the mind, creativity, three dimensional thinking ability, drawing three dimensional objects, solving questions faster, no any change.

St1 expressed that it was difficult for him to solve difficult geometry questions before activities. However, he stated that he could find different solving methods for these questions after the activities. In addition to this he could scratch assisted geometry drawings after the activities and defined him as;

> "I didn't want to solve difficult questions and questions with shapes formerly. But now, I can solve those questions. That is to say, I am able to find the different solving methods."

St2 explained that activities provided him a chance to imagine 3 dimensional geometric shapes in the mind. Moreover st3 believed that his creativity changed with activities and explained his idea with examples here is the conversation we had:

> T: In which competence you felt change after the activities?
>
> St3: As I said before my creativity has improved after the activities.
>
> T: Could you please give me an example?
>
> St3: For example, our technology and design teacher requested to find a shape that is not found before. I achieved to find different shapes
>
> T: How did you find different kinds of shapes?
>
> St3: I found different kind of shapes by folding papers.
>
> T: Which geometric shapes did you use?
>
> St3: I started with square and then I tried to find different shapes by folding square in different directions

T: Did you remember the name of activity which resemble your solution method

St3: Yes, it was origami

St.4 explained that, three-dimensional thinking ability was developed with the spatial ability activities. St4 specified his thoughts with examples. Here is the conversation we had:

T: In which competence you felt change after the activities?

St4: My three dimensional thinking ability has enhanced after the activities

T: Could you please give me an example?

St4: I had some troubles about constructing three dimensional geometric shapes and drawing the open form of geometric shapes but I solved these kinds of questions easily after the activities.

T: Which geometric shapes for example?

St4: For example, pyramids, prisms and the shapes you were asked to us.

St.5 believed that his three dimensional drawing ability was developed with activities. He explained that although he was capable of drawing car models from one view, he could draw same car models from different point of views which were front side and back

St9 expressed that understanding geometry questions, getting geometry shapes together and imagining geometry shapes were easier than the days before activities.

St6 thought that his time management ability for solving question was developed with activities. He said that solving cube drawing from different point of view in geometry lectures were faster than the days before activities

Sts 7.8 believed that activities did not lead to any change in their abilities

4.4. Conclusions of the study

In the light of the above findings obtained by examining of each hypothesis, the following conclusions can be deduced:

1. There is a statistically significant change in students' spatial ability scores across three time periods (pre-treatment, post treatment and retention)

2. There is a statistically significant change in students' spatial orientation scores across three time periods (pre-treatment, post treatment and retention)

3. There is a statistically significant change in students' spatial visualization scores across three time periods.

As a qualitative finding it was observed that visual treatment has positive effects on students' cognitive process in terms of their three-dimensional thinking ability, creativity, solving spatial ability problems, imagination in the mind and application of spatial ability in daily life. Moreover, visual treatment has positive effects on students' feelings in terms of develop positive attitudes toward both lectures and spatial ability problems.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

This chapter includes discussion and interpretation of the results and some recommendations for further studies. In the first section, restatement of some results and discussion of these results are given. In the second section some recommendations for further research studies are made.

5.1. Discussion of Findings

5.1.1. Discussion of Findings on Students' Thinking Process

Many research studies were conducted in order to investigate the relationship between spatial ability and other sciences such as mathematics, geology, medicine, geology, engineering (Maier, 1996; Trindade, Fiolhais & Almeida, 2002; Battista, Whealthy & Talsma, 1982; Wanzel, Hamstra, Caminiti, Anastakis, Grober & Reznick, 2003; Olkun, Altun & Smith, 2005; Piburn, Reynolds& McAuliffe, 2005). In addition to this, how to develop students' spatial ability by using different visual treatments was another important subject that was investigated by the researchers (Clements & Owens, 1998; Alias, Black & Gray, 2003; Ben-Chaim, Lappan & Houang, 1985, 1988; Trindade, Fiolhais & Almeida, 2002; Waters, Gobet & Leyden, 2002; Ferk & Vratachic, 2003; Black, 2005; Clements, Battista, Sarama & Swaminathan, 1997). However, students' opinions about visual treatment in terms of their feelings and cognitive process were not a common issue handled by the researchers.

In this study, 6th grade elementary school students took nine different activities within the context of visual treatment, which has performed by the researcher for 10 weeks. The aim of the study was to investigate the development of students' spatial ability; spatial visualization and spatial orientation. In addition

to this, nine randomly selected 6th grade elementary school students were interviewed to have students' opinions about the visual treatment in terms of thinking process and feelings.

To test the effects of visual treatment on the students' spatial abilities, one-way repeated measures ANOVA, Friedman and Wilcoxon tests were used. The results showed that there was a statistically significant change in students' spatial ability, spatial visualization and spatial orientation scores across three time periods (pre-treatment, post treatment and retention). Visual treatment activities can be the main reason for this improvement.

It was quite important for researcher to have opinion about the methods used by students to solve spatial ability problems before and after visual treatment. Imagination was the most popular method used by the students before visual treatment. The other methods were; seeking pattern, looking at sample solutions and estimating. According to students' explanations; these methods didn't change with respect to test types. However, methods that were used after the visual treatment show specificity with respect to test types. For example while students used seeking a pattern, perception of surface and giving numbers to surface of shapes as a problem solving method in cube comparison test, they used turning in the mind and controlling symmetry in card rotation questions.

Imagining in the mind was the most common method used by students both before and after visual treatment. However, the number of questions which were done and the number of correct answers were higher after visual treatment. Conversation performed with st3 clarified this issue. He stated that activities helped him to enhance his thinking ability and to imagine geometric shapes in his mind. He explained the difference before and after activity as below;

> T: You said you used imagining in the mind as a problem solving method both before and after the activities. However, the number of undone questions was less in second application than in first application. What was the difference?
> St3. Imagination was more realistic in the second

application. Shapes were appearing bad in the first application

T: What do you mean by “appearing bad”?

St3: I couldn’t imagine the shapes properly.

T: Why do you think that imagination was better after the activities?

St3: I got accustomed to such things after the activities. These activities were very beneficial for me.

T: You mean, although you can’t explain how it happened, your ability to imagine was better after the activities

Caroll (1993) defined spatial ability as mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually. The two sub-skills of spatial ability which were spatial orientation and spatial visualization were defined by Ekstrom et al. (1976). He defined spatial orientation as an ability to visualize and mentally manipulate spatial configurations, to maintain orientation with respect to spatial objects, and to perceive relationships among objects in space and defined spatial visualization ability as the ability to manipulate or transform the image of spatial patterns into other arrangements. The findings of the study were discussed with respect to these definitions.

According to the results of the study, students’ spatial ability improved after the visual treatment. One of the reasons for this improvement might be the activities applied in the present study. For example, pentominoes activity that was used for two weeks might be a reason. This activity was mostly related with spatial orientation ability because it didn’t require manipulating spatial patterns into other arrangements. According to my experience some of the students were aware of the transformation geometry movements such as slide, flip and rotate during the activities. Some also started to use the strategy to combine parts. Moreover, some tried to join parts by rotating mentally.

All students expressed in their interview that Pentominoes provided a help to solve cube comparisons questions. This activity might affect the methods that were used by students to solve cube comparison questions. Students used seeking a pattern, imagination in the mind, perception of the surface, turning in the mind and giving numbers to surface of the shapes as a problem solving method after visual treatment. These methods were different than the methods before activities. The main reason could be tendency to transfer the gaining and methods used in the activities to the test problems. Because students stated there was a similarity between activities and test problems. For example st1 used seeking a pattern instead of imagination in the mind after the visual treatment. He expressed his solving method as below;

> "When I made the cube comparison questions, I tried to seek a pattern on the shapes. I tried to understand which shapes would come after which shape."

Another student who changed his solving method after the activities was st3. Although he used imagination in the mind before the activities, he used perception of surface after the activities. He tried to determine whether the given cubes were same, by perceiving the surface of cubes and solved problems faster. St3 expressed his thoughts as follows;

> "Perceiving the front and back faces of the cubes become easier after doing the activities. I solved those questions faster. At the first activity, I had got more undone questions, but after the activities the number of undone questions gradually reduced."

Tetris game was another activity type applied to students for one week to enhance their spatial ability. Tetris game is a tool that provides a chance to use the combination of these skills in a virtual environment and mostly related with spatial orientation ability. Students were capable of rotating and moving shapes. The observations indicated that Tetris game attributable to students' imagining and rotating ability of geometric shapes in their mind. Since, students were required to determine the correct empty place not only for the present shape but

also for the coming shape by rotating it in a given time. Lisi and Wolford (2002) stated in his study that students' spatial ability has improved after 11 Tetris game playing. In addition to this, students were enthusiastic about performing Tetris activity. Their enthusiasm could effect their motivation so their learning. This opinion is consistent with the findings of Clements et al. (1997) who stated that Tetris game motivated and aided students to improve their spatial ability.

When the students' problem solving methods were examined it was understood that most of the students used turning in the mind as a problem solving method in card rotation questions. Tetris and rotation geometry activities were required to rotate objects in the mind so these activities might help students to enhance their mental rotation ability. St9 expressed his method for solving card rotation questions as follows;

> "In the beginning, I didn't know how to handle questions. However after the activities, I tried to answer the questions by imagining. I tried to find which shapes would come after which movement."

Other problem solving methods were; looking at previous shape, by controlling symmetry and giving letter to the shapes. Students who used controlling symmetry method realized that rotation just only changed the appearance of the shape but symmetry changed the shape itself. They determined whether the shapes were same by comparing two shapes. St4 explained the method he used as fallow;

> "At first, I tried to rotate shapes in my mind but then, I gave attention to whether the shapes were symmetrical or not. I mean, I looked at the initial shape and decided whether the given shape was symmetrical with the initial one. I realized that if the shapes were symmetrical they were not the same."

Another activity was Architectural-type activity which required drawing the different point of views of figures and construct figure by looking at top, front and side views of it. According to my experience the number of students' correct

drawing and construction showed increase in the following days of activities. This pointed to a connection between students' use of concrete materials and their performance in orthographic and isometric projection. However, it was more difficult for students to perform orthographic projection that is representing a three dimensional (3D) objects in two dimensions (2D) than isometric projection that is representing a two dimensional (2D) objects in three dimensions (3D). Students stated that we were responsible to combine three different perspective views to construct the shape, however drawing the view could be performed just only look at the constructed shape nothing else. Moreover, this activity was mostly related with spatial visualization ability because students were required to manipulate or transform the image of spatial patterns into other arrangements.

A Cuisenaire rod pattern was another activity that was performed by using concrete materials. The students need to use the rods in solving problems that the concepts will have concrete foundation. This activity provided valuable spatial problem solving experience to the students. Although students tried to fill spaces with randomly selected rods at the beginning, they started to select appropriate rods to fill given space after a short period of time. In other words students' method of trial and error turned into the method of implication. As no need to manipulate parts during the activity, it was mostly related with spatial orientation. Activities with concrete materials could be the chance of seeing objects instead of imagines it for students. According to Piaget (1963) spatial ideas progressed at two different levels which were level of perception (as learned through the sense of touch and seeing) and level of imagination. Imagination will occur after completing the level of perception. Students' imagination ability that is requiring solving spatial ability problems could be enhanced by means of dealing with concrete materials.

Students found activities performed by using concrete materials more enjoyable than activities without them. As these students at the age of 11-12, games took crucial role in their life, students learnt by playing. The reason for it could be; they allowed for more creativity and less calculations. This result is consistent with findings performed by Drickey (2000). According to my

observations the number of task we performed show increase in the fallowing days when we compare with first days. In addition to this, the number of mistake made by students showed decrease in following days. Ben-Haim, Lappan, Houang (1985) expressed in his study that “concrete experiences with cubes - building, representing in 2-dimensional drawings, and reading such drawings - are helpful in improving students' performance” (p.407).

Another reason can be that, transformation geometry activities help students to imagine shapes in their mind and to learn how to move or rotate objects and shapes in the given direction and finding symmetry of figures. Students stated in their interview that transformational geometry activities were helpful in solving cube comparison and card rotation questions. This result was expected because solution of these two type questions was depending on imagine and move shapes in the mind. St. 3 stated that she determined whether the asked shape was same with given shape in card rotation questions by using symmetry. If the given shape was symmetric with asked shape, this means that shapes were not same. All students expect with number 5 expressed that they used imagine in the mind as a problem solving method after the transformation geometry activities and it assist them to enhance their imagination ability in the mind. In addition to this % 44 of students used imagine in the mind, %22 of students used control of symmetry and % 11 used transform given shape as a problem solving method in cube comparison test after the transformation geometry activities. These solving methods were very crucial because they were learnt after transformation geometry activities. In the study development of students’ spatial thinking in a unit on geometric motions Clements and Battista (1997) found that flip and turn activity help students to enhance their mental rotation ability.

Two different types of paper folding activity performed with students; origami and making shapes. These two types of activities were performed for two weeks. Origami brings extra meaning to a piece of paper by shaping it into a form that has symbolism. It is well established among educators that paper folding could be beneficial as an aid in teaching geometry to children (Geretschlager, 1995). After a short period of time students’ ability to construct shapes,

understand the terms related geometry, speed of constructing shapes showed increase in the following days of activities. They could benefit from origami activities in terms of different features of it. For example, students were required to listen, understand instruction which includes basic geometry terms such as edge, face, angel, corner, diagonal, parallel, perpendicular, and bisector and put it into practice. All these requirements helped students to enhance their imagination, construction and guessing ability. Since the shape of paper was changed into other arrangements after folding, Origami activities were related with spatial visualization ability. Performing activity related with spatial visualization was more difficult than activity related with spatial orientation. The reason for this, spatial visualization requires manipulation or transformation of spatial patterns' image into other arrangements. The specific skills involved in the manifestation of the spatial visualization ability improve with practice (Ben-Haim, Lappan & Houang, 1988).

Similarly, making shape activities had curious properties such as rotate, fold, unfold, twist, and fit together in unexpected ways. Activities gave students a complete nets for all regular stellated polyhedral together with a number of interesting compounds. Moreover, it gave a chance to enhance their ability to imagine shapes' view in their minds after and before folding. %66.6 of students used folding in the mind, %33.3 of students used guessing, %11.1 of students used imagination as a problem solving method in paper folding questions. Students stated in their interview that paper folding activities helped them to solve paper folding and surface development questions. There were two main points in paper folding questions. First one was the place of hole and second one was the number of hole. Students expressed that both place and number were determined by using ability that was gained from paper folding activities.

It was required to imagine shapes after folding or give a decision about which folding movement should be done to get given shape in these two activities. These two activities might help students to enhance their mental folding ability. According to students' answer, most of the students used folding in the mind as problem solving method in paper folding questions. Students used this method to

find the correct place of the hole. They firstly fold paper in their mind and after that open this folded paper to find the correct place of the hole. St4 stated his solving method after the activities as follows;

> "While folding the paper, I tried to understand where the hole could be. I tried to understand the place of hole by folding and opening shapes in my mind."

Different than the other test problems, paper fading questions were required combination of two different abilities. First one was discussed above, finding the place of the hole. The second ability was to find the number of hole appeared on the paper after folding. Students used giving attention to number of folding as a problem solving method. It was good to see that students realized the logarithmic increase in the hole number with folding number. In other words, students discovered that if paper folded once, two holes were appeared. If the same paper folded again, number of hole got twice and so on. However, sts. 7 and 8 had trouble about finding the exact hole number, although they realized that hole number increase with folding number.

Since development of spatial ability in neglected in elementary and secondary school level in our country, it was decided to give great importance to spatial ability concepts (MEB, 2005). Subjects such as orthographic and isometric projection, tessellations, transformation geometry, surface area and volume of prisms were included into new mathematics curriculum. I was their mathematics teacher so; I was able to examine students' performance during mathematics courses which was the part of visual treatment. According to my experience, there was an increase in students' understanding of mathematics subjects especially the subjects that were based on concrete foundation during and after visual treatment practice so; students could be benefit from mathematics lecture includes spatial ability concepts. Students stated that it was easier to learn with concrete materials than just by listening and I observed that students felt confident because of being familiar to such kind of activities.

The last interview question was “do you think that time passing between second and third application period had positive or negative effects on you in solving third application questions?” The aim of this question was to examine retention of visual treatment. All students thought that time passing between second and third application caused a negative affect in solving third application questions. Most of the students stated that solving third application questions was more difficult than second application. One of the reasons could be that, since any visual treatment activity was performed during this period of time, it caused to forget knowledge that was gained from visual treatment. St3 expressed his thoughts about retention of visual treatment as follows;

> “Solving third application questions was easier than first application but more difficult than second one. I think that giving a break to the activities caused to decrease my spatial knowledge. Therefore, I think that time without any activity affected me in negative manner.”

These explanations were consistent with inferential finding of this to research result study. According to research results while students post-test scores of three tests were higher than pre-test scores, their ret-test scores were lower than pos-test scores but ret-test score were higher than pre-test scores.

5.1.2. The Discussion of Findings related to feelings toward visual treatment

According to the results of the interview, most of the students had negative feelings when they firstly faced spatial ability problems. These feelings were fear, sadness, tension, anxiety and anger. The reasons for these negative feelings could be the fact that it was the first time to deal with such kind of questions; that the procedure couldn’t be understood by the students and not being able to solve questions. For example, st1 stated the reason for his fear as below;

> “It was the first time that I faced such kind of questions; I feared that I wouldn't be able to solve the questions. I had never met such types of questions before”.

However, 42% of students tend to reflect a “totally agree” perspective toward spatial ability problems in terms of anxiety after the activities. This result showed that visual treatment has an effect on anxiety in terms of decreasing it.

Another reason for negative feelings could be the limited time that was given to complete test. When I examined the results of students’ test scores, I realized that no one was able to complete whole tests in the first trial. Actually, this result was expected because it was the first time that students faced with such kinds of questions and they had question marks in their mind about the solving method. However, this expected result did not change the reality. St4 stated that;

> “I get tensed because I thought that given time to finish test wouldn't be enough for me.”

While most of the students had negative feelings towards spatial ability problems, few students had positive feelings. The positive feelings of the students could be attributed to the characteristics of the activities. For example, Sts. 2 and 4 enjoyed activities even if they didn’t know how to solve questions.

St2 resembled questions to a game and expressed his thought as follows;

> “I found questions very interesting. Questions were similar to a game. While I was solving the questions, I had difficulty but it's true that I enjoyed myself.”

Another finding can be stated that all students’ feelings were negative when they could not solve the problem. These feelings were fear, sad, tensed, worry and nervous. It was understood from the students’ explanations that couldn’t be able to solve questions was the main reason for the negative feelings. St6 stated his thoughts as follows;

> "I found questions very worrying. Because I didn't know anything and I hadn't any idea about how questions would be solved. I got a bit worried while I was solving the questions."

St6 tends to reflect a "tend to agree" perspective toward spatial ability problems in terms of anxiety even after the activities.

In another interview question, students were asked to state their feelings when their solving method of no avail. Different than the feelings stated in the first interview question, all students' feelings were negative in that question. There was a small difference between first and fourth interview questions. In the first interview question students were asked to state their feelings before they started to questions but in the fourth interview question students' feelings were asked after they start to solve questions. Students' feelings were; fear, demoralization, disappointment, nervousness, angry and panic. Most of the students thought that they couldn't be able to solve questions after the failure of their solving method. The reason for these feelings could be because of not being able to find alternative problem solving method. It was an expected result because; students' spatial knowledge was limited to find an alternative solving method. As a conclusion, students didn't find alternative solving method and left question undone. St7 stated that;

> "When I didn't solve the questions I thought that I wouldn't able to solve other questions. In addition to this, given time to solve questions was limited so; I did not finish solving questions. Therefore I felt nervous."

Another reason for negative feelings could be the lack of self-confidence about solving spatial ability problems. Students' attitude toward spatial ability problem was getting more positive after visual treatment. Most of the students stated that they enjoyed during visual treatment. Students found activities enjoyable especially performed with manipulative such as pentominoes, orthographic projection and computer based. The reasons could be stated as; became familiar with spatial ability problems with activities, understood spatial

problem solving strategies, found different solving method for solving questions; found activities interesting and being the first time that they engaged with such kind of questions. St4 stated that;

> "I found activates very different and enjoyable. I had never performed such kind of activities .So, when I performed it, I had a good time."

Some of the students get bored during the visual treatment. The main reason for negative feelings was not being able to solve questions. The same students found Tetris activity funny because they could perform it. St2 stated his opinion as follows;

> "I found activities very boring. I didn't want to solve the questions."

There was a consensus about the usefulness of the activities among students' opinion. 66% of students stated that activities were helpful in solving spatial ability questions, 22% of students believed that activities were helpful but limited, 11% of students stated that activities didn't help him to solve questions. The reason for usefulness of the activities could be the similarity between problems asked in tests and activities. Moreover activities provide a chance deal with spatial ability problems that students didn't faced with before and also students believed that activities helped them to solve spatial ability problems faster. St2 thought different than other students that activity problems were not similar to the test problems. That is why he thought that benefit of activities was limited. The aim of the activities was to enhance students' ability to solve spatial ability problems. St2 may not put the relation between activities and spatial ability problems

The question "what did you gain from the activities" was asked in three different forms to get clear explanation from students. According to students' answers to the interview question; sts 1, 2, 4 and 9 believed that activities helped them to develop spatial thinking ability such as three dimensional thinking ability and ability to think geometric objects in the mind. Activities were designed to perform by using spatial ability so this could be the reason for this thought. In other words, each activity was required different spatial ability such as

imagination, transformation and guessing. Results of this study showed that visual treatment has a positive effect on spatial ability. That is why it was normal for students to thought as activities helped them to develop spatial thinking ability. Sts9 tend to reflect an "agree" perspective toward spatial ability problems in terms of usefulness and expressed his thoughts as follows;

> "I was able to put shapes together and imagine shapes in my mind."

Other students focused on the sub-dimensional usefulness of the activities such as creativity, faster problem solving ability, looking problem and situations from different point of view. These results were not directly related with spatial abilities. However Just only two students didn't believe the usefulness of the activities.

Moreover students were successful in put relation between visual treatment and daily life usage of spatial gaining. One of the main aims of the study was to help students to realize the connection between spatial ability and reflection of it to the daily life. According to students' explanations, spatial ability could be used in; drawing plan of somewhere, attaching mouse to the computer case without looking it, decorating furniture in the mind before put it into practice, drawing three dimensional models of cars, preparing a model of house and solving mathematics questions. St4 gave the example below;

> "I believe that, activities are related with our daily life. For example, we can use our spatial ability to decorate our furniture in our mind before put it into practice. Activities enhanced my decoration ability."

And st5 gave the example below;

> "I like drawing car models. I could only two-dimensional drawings of the car in previous days, but now I can draw three dimensional appearance of the car."

These two students tend to reflect an "totally agree" perspective toward spatial ability problems in terms of usefulness

The reason for students to put this relation easily was related with; spatial ability's wide spread usage and occupying an important role in our daily life. Spatial relations were everywhere. Since we are living in a three dimensional world we are required spatial ability in every field in our life. These activities provide a chance to students to enhance their awareness about spatial ability and usefulness of it. When the students' answers were examined it was understood that, examples were given from students' own life

5.2. Implications

In this section recommendations are stated for teachers, curriculum developers, teacher educators and researchers in order to develop students' spatial abilities.

The findings of this research revealed that visual treatment has a potential to enhance students' spatial ability. Moreover, students' attitudes towards spatial ability problems became more positive after the activities within visual treatment. In addition to this, this research showed that visual treatment provides students a chance to examine their thinking processes which they experienced while being engaged with spatial ability problems.

Teachers:

Based on the findings of this research study and other studies, it can be suggested that the use of visual treatment will improve students' spatial ability (Clements & Owens, 1998; Olkun, 2003; Trindade, 2002). Different kinds of visual treatment activities that serve the same purpose were applied to students during the 10-weeks period. This study suggests that teachers will able to reach students who have different learning potentials and interests by using different visual treatment activities. And also one of the advantages of the activities is that their shortcomings can be eliminated by another activity that has not the same shortcomings. Development of spatial ability can be achieved over a period of time. That is why teachers should be aware of the importance of spatial ability and

make the students be aware of the importance. In addition to this activities were performed for ten weeks and five days a week. It was suggested that visual treatment that aims to enhance spatial ability should be applied for a long time without given any break. Virtual environment and concrete materials are proved to improve students' spatial ability (Gabrielli, Rogers & Scaife, 2000; Lisi & Wolford 2002; Passig & Eden, 2001; Keller, Moses & Hart, 2002; Olkun, Altun & Smith, 2005) Teachers should perform their activities by using concrete materials. Another important point that teachers should be careful is the cognitive level of students. This study was applied with sixth grade elementary level students and activities were selected with respect to their cognitive level, it is suggested that selection of the activities should be appropriate with students' cognitive level. Another suggestion that could be drawn from the study is that classroom observations and interviews performed with students would provide beneficial information about students' feelings and their cognitive process. Information gathered from interviews will be helpful in preparing activities with respect to interest and level of students.

Curriculum developers:

Since, the spatial ability is accepted as an important concept for students both in their academic and work life; it should be handled by curriculum developers and should be included in text books from elementary level to university level. Analyze and synthesize of the spatial ability and its dimensions such as spatial visualization, spatial orientation, spatial perception should be done and should be adapted to elementary and secondary curriculum. The new mathematics curriculum has been performed since 2005-2006 academic year in elementary level but curriculum performed in secondary level is still old. Students graduate from elementary level will have forgotten the spatial ability knowledge during secondary education. Because, it was found that the spatial ability scores of the students decreased after giving a 1 month period without visual treatment in this research. Curriculum developers should be focused on improves spatial ability rather than teaching spatial ability by making authors provide concrete

activities in textbooks. Moreover, attitude scales should be provided for both students and teachers to examine their feelings and cognitive process in textbooks.

Teacher educators:

Teacher educators are one of the most important parts in spatial development process. They are responsible for giving continuation education to pre-service teachers. In other words teachers' occupational characteristics get shape in teacher educators' hand. That is why teacher educators should have pre-service teachers be aware of the importance of spatial ability and should have pre-service teachers qualified on how to develop spatial ability.

Recommendation for further studies:

The sample in the study is predominantly elementary middle class families in a small suburban elementary school. The findings may or may not be applicable to other situations. Additional research using other elementary schools in other locations or cities, sample sizes and participants are recommended. In addition to this study performed with sixth grade elementary school students; research on students in other grades is clearly called for. The sample population for this study was small because of using purposive sampling and effect of gender differences on students' spatial ability did not examine. In the further research a large population can be used and effect of gender can be examined. Interviews in the current research performed with students whose socio-economic level is low so the students' ability to express their feelings and thoughts was a bit problematic. Study with students from different socio-economic level and selecting talkative students are recommended. Moreover effects of spatial ability on students' mathematics and geometry achievement can be examined in further researches. Another important issue that should be handled is the way that teachers use to introduce and improve spatial ability. Teacher way of introduce spatial ability and effect of it in improving spatial ability can be examined in further research.

REFERENCES

Alias, M., Black, T.R. & Gray, D.E. (2001). Spatial Visualization Ability and Problem Solving in Structural Design, *Jurnal Pendidikan Teknikal*, 1(1), 65-76.

Alias, M., Black, T. R., & Gray, D. E. (2002). Attitudes Towards Sketching and Drawing and the Relationship with Spatial Visualization Ability in Engineering Students, *International Education Journal,* 3(3), 1-12

Battista, M. T., Wheatley, G. H., & Talsma, G. (1989). Spatial Visualization, Formal Reasoning and Geometric Problem-Solving Strategies of Pre-service Elementary Teachers, *Focus on Learning Problems in Mathematics*, 11(4), 17-30

Ben-Haim, D., Lappan, G., &. Houang, R. T. (1985). Visualizing Rectangular Solids Made of Small Cubes: Analyzing and Effecting Students' Performance, *Educational Studies in Mathematics,* 16 (4), 389-409.

Ben-Chaim, D., Lappan, G., &. Houang, R. T.(1988). The Effect of Instruction on Spatial Visualization Skills of Middle School Boys and Girls, *American Educational Research Journal,* 25 (1), 51-71.

Bishop, A. J. (1983). *Spatial Abilities and Mathematicsal thinking*, in Zweng, M. et al. (eds.) *Proceedings at the IV I.C.M.E.* (Birhauser: Boston, USA), 176-178.

Booth, R.D.L., Thomas, M.O.J., (2000). Visualization in Mathematics Learning: Arithmetic Problem-solving and Student Difficulties, *Journal of Mathematic Behaviour*, 18(2), 169-190.

Brandt, M.G., Davies, E.T., (2006). Visual-Spatial Ability, Learning Modality and Surgical Knot Tying, C*anadian Journal of Surgery*, 49(6), 412-416

Clements, D., H., Battista, M., T., Sarama, J., & Swaminathan, S. (1997). Development of Students' Spatial Thinking in a Unit on Geometric Motions and Area, *The Elementary School Journal*, 98(2), 171-186.

Davidson, P.S., Willcutt, R.E. (1997). Spatial Problem Solving with Cuisenaire® Rods, *Addison Wesley Publishing Company New York*, p.40

Davidson, P.S., Willcutt, R.E. (1997). Spatial Problem Solving with Cuisenaire® Rods, *Addison Wesley Publishing Company New York*, p.44

Ekstrorn, R. B., French, J. W., & Harman, H. H. (1976). *Manual for kit of factor-referenced cognitive tests*. Princeton, NJ: Educational Testing Service.

Erbilgin, E. (2003). Effects of Spatial Visualization and Achievements' On Students' Use of Multiple Representations, *Unpublished Master's Thesis, The Florida State University*

Fennema, E., & Sherman, J. (1997). Sex-Related Differences in Mathematics Achievement, Spatial Visualization and Affective Factors, *American Educational Research Journal*, vol.14, 51-71

Ferk, V., Vrtacnik, M., Blejec, A., & Gril, A., (2003). Students' Understanding of Molecular Structure Representations, *International Journal of Science Education,* 25(10), 1227–1245

Frankel, J. R., & Wallen, N. E., (1996). *How to Design and Evaluate Research in Education*, New York: Mc Graw-Hill, Inc.

Gabrielli, S., Rogers, Y., Scaife, M., (2000). Young Children's Spatial Representations Developed Through Exploration of a Desktop Virtual Reality Scene, *Education and Information Technologies*, 5(4), 251-262.

Geretschlager, R. (1995). Euclidean Constructions and the Geometry of Origami, *Mathematics Magazine,* 68(5), 357-371

Guay, R.B., McDaniel, E. D., (1977). The Relationship Between Mathematics Achievement and Spatial Abilities Among Elementary School Children, *Journal for Research in Mathematics Education*, 8(3), 211–215

Hirschhorn, D. (2001). Try it! pentominoes. illinois: Learning resources. Intelligence, 32(2), 175-191.

Hodgson, T. (1996). Students' Ability to Visualize Set Expressions: An Initial Investigation, *Educational Studies in Mathematics,* 30, 159- 178.

Humphreys, L.G., Taber, T., (1973). Ability Factors as a Function of Advantaged and Disadvantaged Groups. *Journal of Educational Measurement*, 10(2), 107-115

Isaacs, N. (1965). Some Aspects of Piaget's Work, 8th ed., London: National Frobel Foundation, 30-31

Ives, D. L. (2003). The Development of Seventh Graders' Conceptual Understanding of Geometry and Spatial Visualization Abilities Using Mathematical Representation with Dynamic Models, *Unpublished Master's Thesis, Montclair State University*.

Kayhan, B. (2005). Investigation of High School Students' Spatial Ability, *Unpublished Master's Thesis, Middle East Technical University.*

Keenher, M., Lıppa, Y., Montello, D.R., Tendick, F., Hegarty, M., (2006). Learning a Spatial Skill for Surgery: How the Contributions of Abilities Change with Practice, *Applied Cognitive Psychology*, 20: 487–503

Keller, B.,Wasburn-Moses, J., & Hart.E., (2002). Improving Students' Spatial Visualization Skills and Teachers' Pedagogical Content Knowledge by Using On-Line Curriculum-Embedded Applets, *Overview of a Research and Development Project,* 1-21.

Kozhevnikov, M., & Thornton, R., (2006). Real-Time Data Display, Spatial Visualization Ability and Learning Force and Motion Concepts, *Journal of Science Education and Technology,* 15(1), 111-132.

Kroner, L.R. (1994). Slides, Flips and Turns, *Pearson Education Inc. Parsippany, NJ*, p.14

Kroner, L.R. (1994). Slides, Flips and Turns, *Pearson Education Inc. Parsippany, NJ*, p.54

Linn, M.C., Petersen, A.C., (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis, *Society for Research in Child Development,* 56(6), 1479–1498

Lohman, D.F. (1979). Spatial Ability: A Review and Re-analysis of the Correlational Literature (Tech. Rep. No. 8). *Stanford, CA: Aptitude Research Project, School of Education, Stanford University*.

Lohman, D. F. (1996). Spatial Ability and g. In I. Dennis & P. Tapsfield (Eds.), Human Abilities: Their Nature and Measurement (pp. 97-116). Mahwah, NJ: Erlbaum.

Lowrie, T. & Kay, R. (2001). Relationship between Visual and Nonvisual Solution Methods and Difficulty in Elementary Mathematics, *Journal of Educational Research*, 94(4), 248 – 255.

Maier, P.H., Spatial Geometry And Spatial Ability – How To Make Solid Geometry Solid? In Elmar Cohors-Fresenborg, K. Reiss, G. Toener, and H.-G. Weigand, editors, *Selected Papers from the Annual Conference of Didactics of Mathematics 1996, Osnabrueck* (1998), 63–75

Marton, F. (1981). Phenomenography - Describing Conceptions of the World Around Us, *Instructional Science*, 10(1981), 177-200.

McGee, M. G., (1979). Human Spatial Abilities: Psychometric Studies and Environmental, Genetic, Hormonal and Neurological Influences. *American Psychological Association*, 86(5), 889-918

Piaget, J. (1953). How Children Develop Mathematical Concepts, *Scientific American*, p.74

Piaget, J., Inhelder, B., Szeminska, A., The Child's Conception of Geometry. *New York: Basic Books*, 1960, p. VII. London: Routledge and Kegan Paul.

Piaget, J. (1964). Development and Learning, *Journal of Research in Science Teaching*, 2(3), 121-141

Olkun, S. (2003) Making Connections: Improving Spatial Abilities with Engineering Drawing Activities, *International Journal of Mathematics Teaching and Learning*, 1-10.

Olkun, S., Altun, A., & Smith, G., (2005). Computers and 2D Geometric Learning of Turkish Fourth and Fifth Graders, *British Journal of Educational Technology,* 36(2), 317-326

Osberg, K. M. (1997). *Spatial Cognition in the Virtual Environment, Technical* R-97-18. Seattle: HIT Lab,

Owens, K. D., & Clements, M.A. (1998). Representations in Spatial Problem Solving in the Classroom, *Journal of Mathematical Behavior,* 17 (2), 197-218.

Passig, G., Eden, S., (2001). Virtual Reality as a Tool for Improving Spatial Rotation Among Deaf and Hard-of-Hearing Children, *Cyberpsychology & Behavior, Mary Ann Liebert, Inc*., 4(6), 681-686.

Piburn, M.D., Reynolds, S.J., McAuliffe, C., Leedy, D.E., Birk, J.P., & Johnson, J.K., (2005). The Role of Visualization in Learning from Computer-Based Images, *International Journal of Science Education*, 27(5), 513-527

Rafi, A., Anuar, K., Samad, A., Hayat, M., & Mahadzi, M., (2005). Improving Spatial Ability Using a Web-Based Virtual Environment (WbVE). Automation in Construction, 14, 707-715

Tai, D. W. S., Yu, C. H., Lai, L. C. & Lin, S. J. (2003). *World Transactions on Engineering and Technology Education UICEE,* 2(2), 251-268.

Tartre, L. A. (1990). Spatial Orientation Skill and Mathematical Problem Solving. *Journal for Research in Mathematics Education,* 21(3), 216- 229.

Towle, E., Mann, J., Kinsey, B., "Assessing the Self Efficacy and Spatial Ability of Engineering Students from Multiple Disciplines" Submitted to Frontiers in Education Conference, 2005.

Trindade, J., Fiolhais, C., & Almeida, L. (2002). Science Learning in Virtual Environments: A Descriptive Study, *British Journal of Educational Technology*, 33 (4), 471-488

Thurstone, L. L., (1938; 1969). Primary Mental Abilities, Chicago: University of Chicago Press. Reiss, K. (1999). Spatial Ability and Declarative Knowledge in a Geometry Problem Solving Context. In O. Zaslavsky (Ed.). Proceedings of the 23rd International Conference for the Psychology of Mathematics Education, 1, 303). Haifa (Israel): Technion.

Voyer, D., Voyer, S., Bryden, M.P., (1995). Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables. *American Psychological Association*, 117(2), 250-270

Walter, M. (1996). The Mirror Puzzle Boks, *Tarquin Publications Stratbroke,* p.5

Wanzel, K. R., Hamstra, S.J Anastakis, D. J., Matsumoto, E.D., Cusimano, M.D. *Lancet* 2002; 359: 230–231

Wanzel, K. R., Hamstra, S.J., Caminiti, M.F.,Anastakis, D. J., Grober, E.D., Reznick, R.K., (2003). Visual-Spatial Ability Correlates with Efficiency of Hand Motion and Successful Surgical Performance, *Surgery 2003*; 134(5), 750-757

Waters, A. J.,Gobet, F., & Leyden, G. (2002). Visuospatial Abilities of Chess Players, *British Journal of Psychology*, 93, 557–565.

Yakimanskaya, I. S. (1991). *The Development of Spatial Thinking in School Children* ("Soviet Studies in Mathematics Education"vol.3). (N.T.C.M.: Reston, USA). (From Gutierrez, A. (1989) Visualization in 3-Dimensional Geometry: In Search of a Framework.).

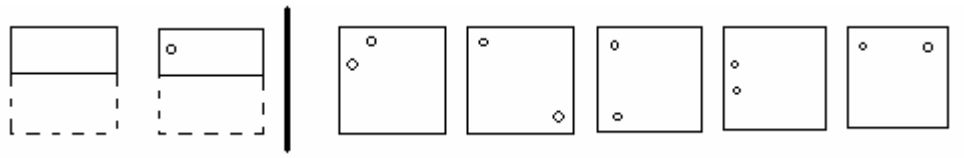
APPENDICES

APPENDIX A

SAMPLE QUESTIONS OF SAT

Paper Folding Test

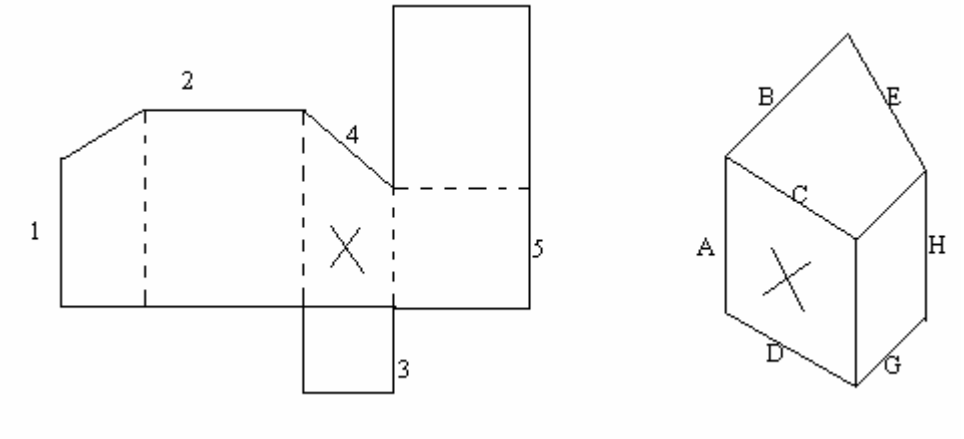
The square shaped paper on the left side of the vertical line is folded and then a hole is made. After unfolding the paper, which one of the shapes in the right side of the vertical line will appear?



Surface Development Test

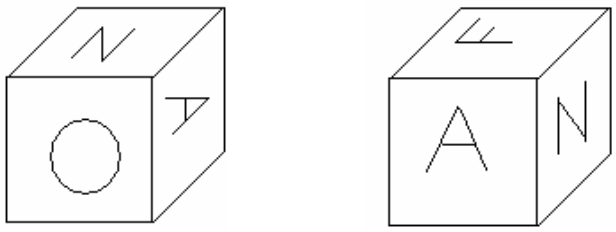
When the paper is folded from the dotted lines, the subject on the right will be formed. By imagining the folding of the paper, match the numbered edges to the letters.

p.c. the surface marked by X on unfolded paper on the left and on the subject on the right shows the same surfaces.



Cube Comparison Test

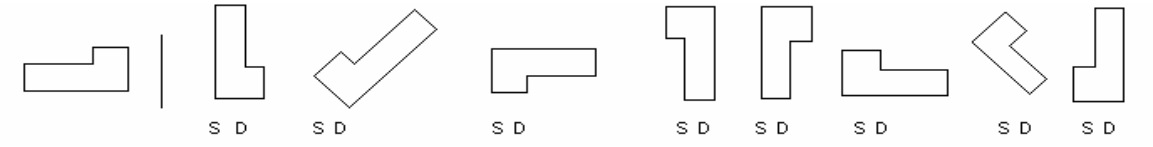
In the following cubes all the numbers, figures and letters appears onlyonce on each cube, but it can be in an unseen position. Then, find out whether the cubes on the left and the right are the same. If the cubes are the same then mark S (Same), otherwise mark D (Different).



Card Rotation Test

This test requires comparing the shape on the left side of the vertical line with the eight shapes on the right side of the vertical line. Find out whether the shapes on the right side can be determined by rotating the shape on the left side of the

vertical line, in other words examine whether the shapes are the same or different. If the shapes are the same as the shape on the left side of the vertical line then mark S (Same), otherwise mark D (Different).



APPENDIX B

INTERVIEW QUESTIONS AND PURPOSE OF THE QUESTIONS

Questions	Purpose(s) of the Questions
What did you feel when you faced with spatial ability questions for the first time?	To examine the effects of spatial ability questions on students' feelings
Which solution methods did you use for solving questions for the first time?	To investigate the methods that students used before taking spatial ability activities
Did your solving methods show changes according to question types in spatial ability tests?	To investigate whether or not students' problem solving method show changes within test types
What did you think about the spatial ability activities? In generally did you got enjoyed or got bored during the activities?.	To investigate students' feelings about activities.
Do you think that activities were beneficial for you to solve spatial ability questions?	To got vision of students about what do they think about activities, did they put connection with activities and asked questions
What did you gained from the activities was asked to the students?	To got vision of students about what kind of achievements did they gain after 10-activity-week

Questions	Purpose(s) of the Questions
Why did you think that spatial ability activities were so important, do you think that you will use this information in your daily life?	To got vision of students about daily usage of spatial ability activities
Did your problem solving methods show changes after the activities? I mean which problem solving methods had you used at the first application and which problem solving method did you used at the second application?	To got investigate the changes in methods
Which problem solving methods did you used for card rotation?	To got investigate the changes in methods used in card rotation questions and effects of activities on it
Which problem solving methods did you used for paper folding?	To got investigate the changes in methods used in paper folding questions and effects of activities on it
What kind of method did you follow for finding number of hole on folding papers?	To investigate the strategy that students used.
In which ability you felt change after spatial activities?	To investigate change occurred in students' abilities after spatial ability activities
Which lectures were related with activities could you please explain it with examples?	To understood whether or not students put connection between spatial ability

Questions	Purpose(s) of the Questions
In which ability you have feels change or improvement before and after the activities in general?	To understood whether or not students put connection between spatial ability activities and lectures
Do you think that the time passing between second and third application period had positive or negative effects on you in solving third application questions?	To have opinion about students thinking process about the time-break given to the students for four weeks after the post-treatment.

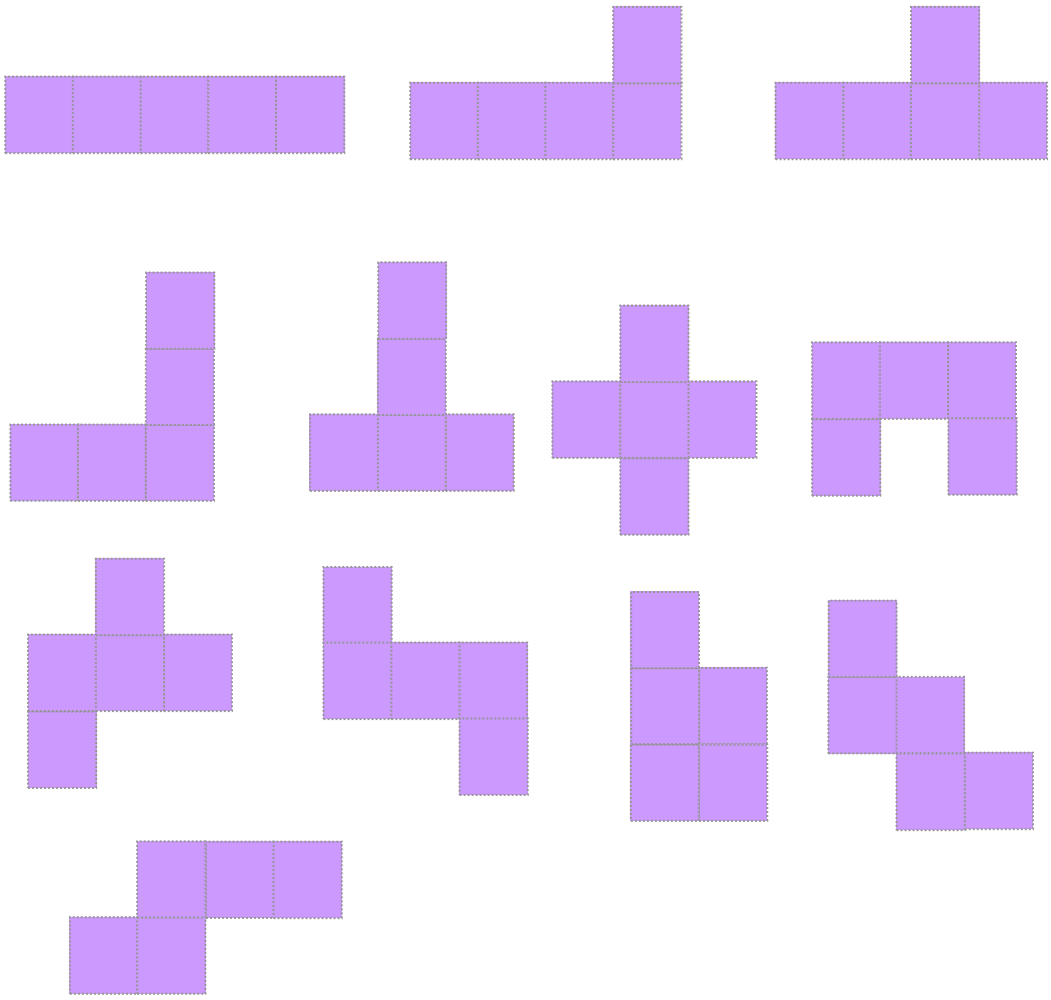
APPENDIX C

SAMPLE VISUAL TREATMENT ACTIVITY SHEETS

PENTOMINOES ACTIVITY SHEET

Verilen beş kareliler setinden istenenleri kullanarak 3 x 10 Dikdörtgensel bölgeleri oluşturunuz.

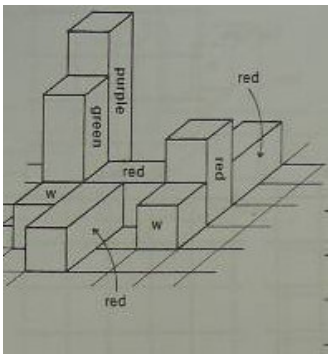
A) 2, 4, 5, 7, 11, 12
B) 1, 2, 3, 4, 5, 11
C) 3, 7, 8, 10, 11, 12
D) 2, 3, 4, 10, 11, 12



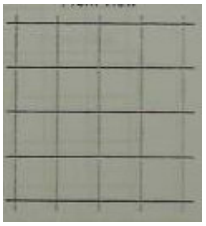
[Note: This activity was utilized from the study of Duby (2001, p.8)]

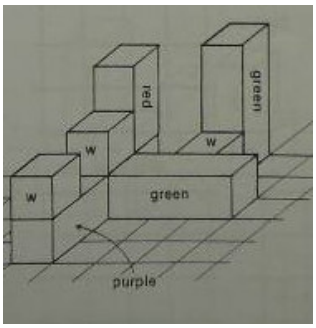
ARCHITECTURAL-TYPE ACTIVITY SHEET

Aşağıda birim küpler kullanılarak oluşturulan yapıların önden, üstten ve yandan görünüşlerini iki boyutlu olarak çiziniz.

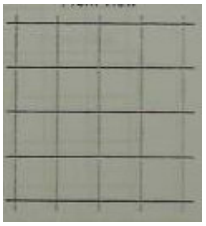


üstten önden yandan

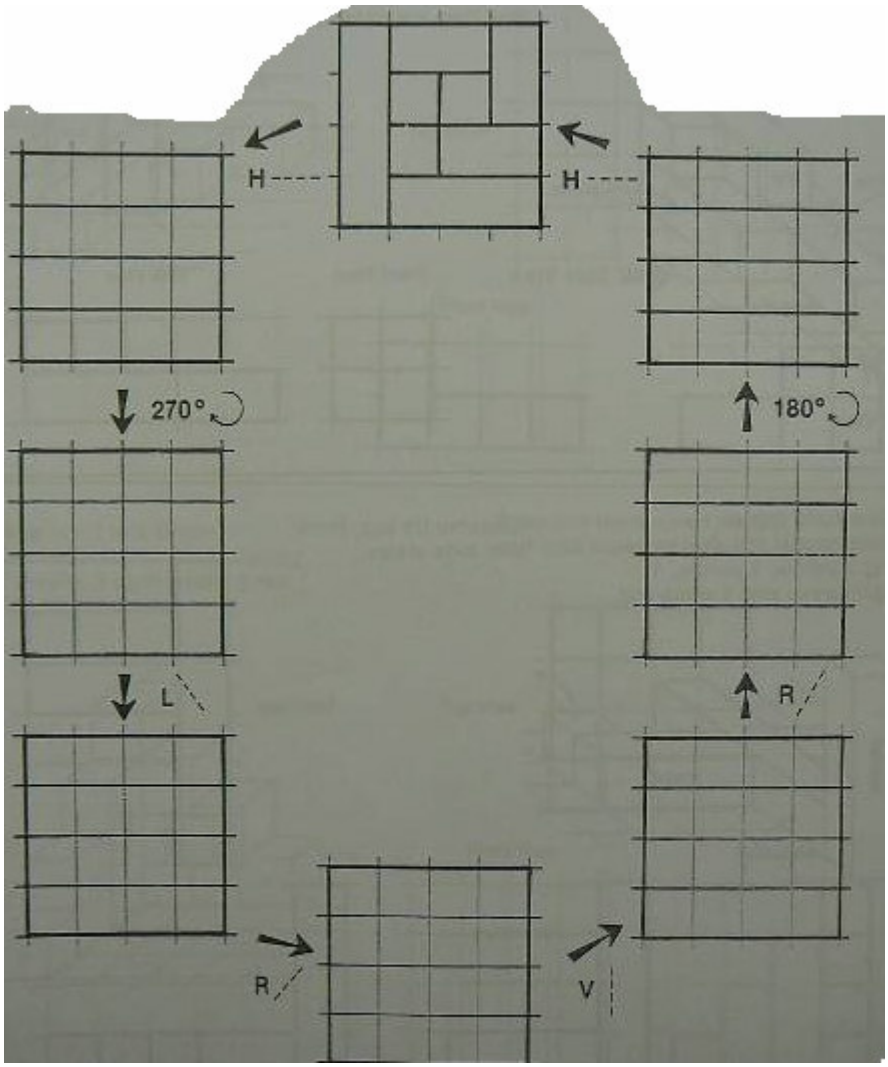
üstten önden yandan


[Note: This activity was utilized from the study of Davidson & Willcutt (1997, p.44)]

ROTATION AND REFLECTION ACTIVITY SHEET

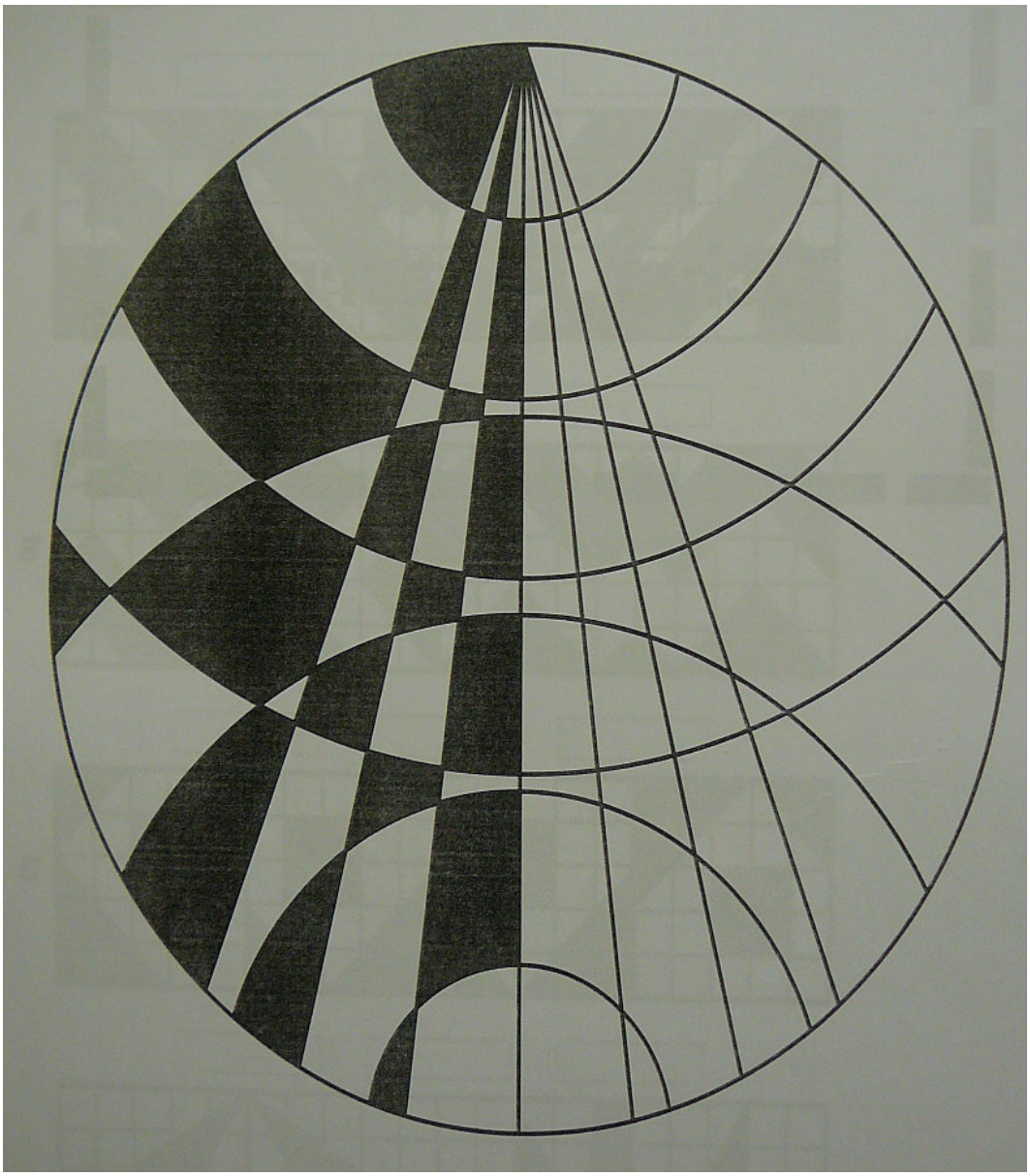
Aktivite kâğıdın en üstünde verilen şekli geometrik çubukları kullanarak oluşturunuz ve şekle uygulanan yansıma ve dönme hareketleri sonrası görüntüsünü verilen yerlere çiziniz.



[Note: This activity was utilized from the study of Davidson & Willcutt (1997, p.40)]

SYMMETRY SHADING ACTIVITY SHEET

Aşağıda verilen şekli simetrik olacak şekilde tarayınız.

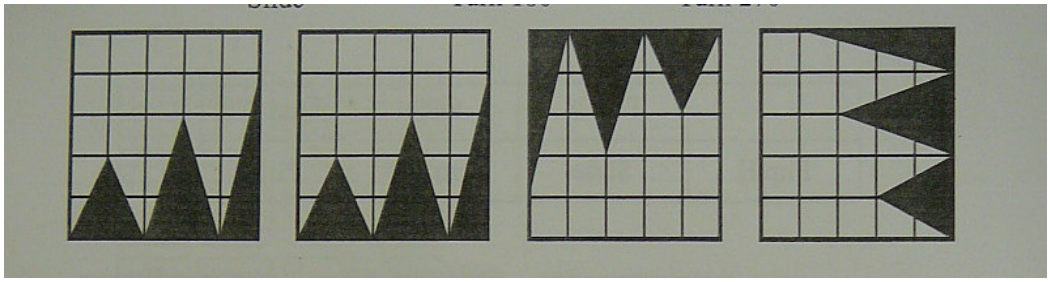


[Note: This activity was utilized from the study of Kroner (1994, p.54)]

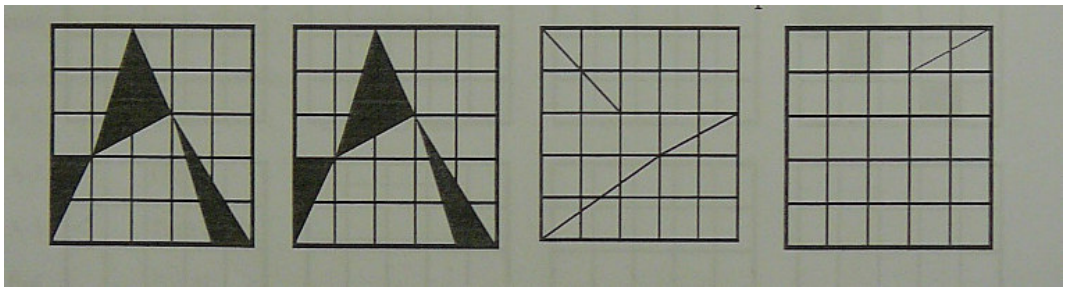
SLIDES, FLIP AND TURN ACTIVITY SHEET

Aşağıdaki şekle uygulanması gereken taşıma geometrisi hareketleri şekillerin üzerine yazılmıştır. Şeklin hareket sonrası oluşacak görüntüsünü verilen yerlere örneğe uygun olarak çiziniz.

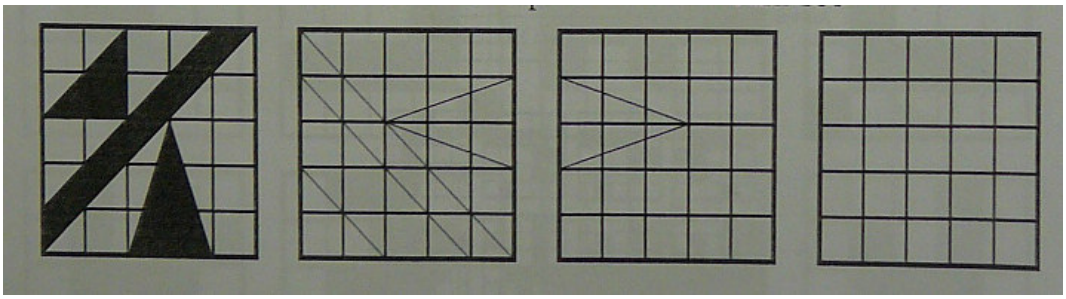
180 derece döndür. 270 derece döndür.



90 derece döndür. Dikey simetrisini al.



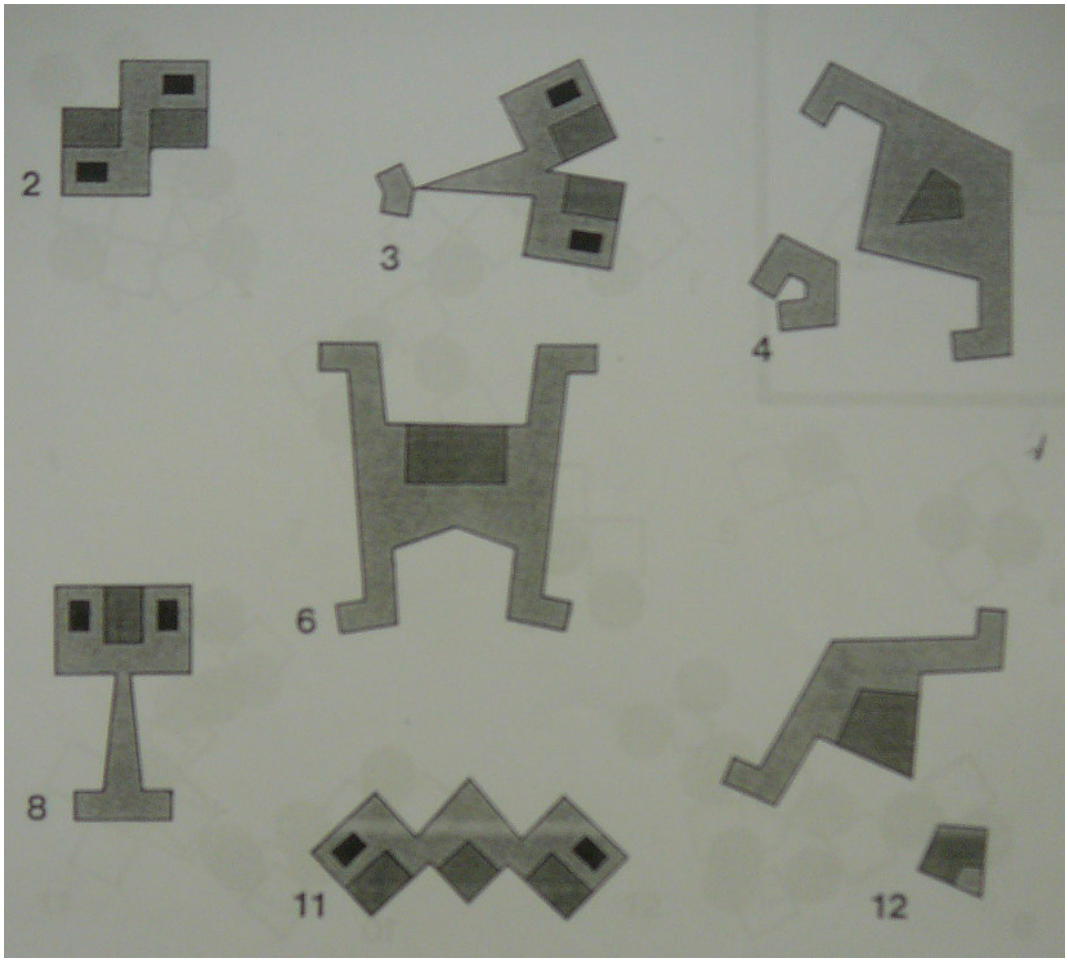
180 derece döndür. Yatay simetrisini al. 270 derece döndür.



[Note: This activity was utilized from the study of Kroner (1994, p.14)]

MIRROR PUZZLE ACTIVITY SHEET

Elinizde bulunan aynayı aşağıdaki şekillerin üzerine yerleştirerek referans olarak verilen şekli elde ediniz ve bulduğunuz yöntemleri gurup arkadaşlarınız ile tartışınız.



[Note: This activity was utilized from the study of Walter (1996, pp.5-6)]