AN INVESTIGATION OF THE EFFECT OF ORIGAMI-BASED INSTRUCTION ON ELEMENTARY STUDENTS' SPATIAL ABILITY IN MATHEMATICS

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SEDANUR ÇAKMAK

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Prof. Dr. Sencer AYATA

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Hamide ERTEPINAR

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Mine IŞIKSAL

Supervisor

Examining Committee Members

Assoc. Prof. Dr. Safure BULUT	(METU, SSME)	
Assist. Prof. Dr. Mine IŞIKSAL	(METU, ELE)	
Assist. Prof. Dr. Çiğdem HASER	(METU, ELE)	

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Name, Last name: Sedanur ÇAKMAK

Signature :

ABSTRACT

AN INVESTIGATION OF THE EFFECT OF ORIGAMI-BASED INSTRUCTION ON ELEMENTARY STUDENTS' SPATIAL ABILITY IN MATHEMATICS

Çakmak, Sedanur

M.S., Department of Elementary Science and Mathematics Education
Supervisor: Assist. Prof. Dr. Mine IŞIKSAL

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The main purpose of the study was to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics. More specifically, how origami-based instruction affected students' spatial visualization and spatial orientation ability was examined. In addition, elementary students' self-reported perceptions related to origami-based instruction was investigated. In other words, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcame these difficulties were investigated.

The data was collected from 38 fourth, fifth, and sixth grade students in a private school in Eryaman neighborhood in Ankara. The participants were given a

Spatial Ability Test (SAT) as pretest and posttest in order to assess the effect of origami-based instruction on their spatial ability in terms of spatial visualization and spatial orientation. In addition, the participants were asked to write reflection papers related to origami-based instruction in order to examine their perceptions.

The results indicated that there was a significant positive effect of origami-based instruction on elementary students' both spatial visualization and spatial orientation ability. Moreover, the findings showed that students had positive attitude toward origami-based instruction where they wanted to continue origami-based instruction. Students also thought that origami-based instruction was beneficial for them especially in geometry topics in mathematics, and they have common views that origami-based instruction was directly related with mathematics. Furthermore, results revealed that students were generally encountered with folding and assembling difficulties, and they overcame these difficulties by themselves, by the help of the teacher, and by the help of their friends.

Keywords: Spatial ability, spatial visualization ability, spatial orientation ability, origami-based instruction, elementary students

ÖZ

ORİGAMİ-TABANLI ÖĞRETİMİN İLKÖĞRETİM ÖĞRENCİLERİNİN MATEMATİKTEKİ UZAMSAL YETENEKLERİ ÜZERİNE ETKİSİNİN İNCELENMESİ

Çakmak, Sedanur

Yüksek Lisans, İlköğretim Fen ve Matematik Alanları Eğitimi Bölümü
Tez Danışmanı: Yard. Doç. Dr. Mine IŞIKSAL

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Bu çalışmanın amacı, origami-tabanlı öğretimin ilköğretim dördüncü, beşinci ve altıncı sınıf öğrencilerinin uzamsal yetenekleri üzerine etkilerini incelemektir. Daha detaylı belirtmek gerekirse, origami-tabanlı öğretimin öğrencilerin uzamsal görselleştirme ve uzamsal yönelim yeteneklerini nasıl etkilediği incelenmiştir. Buna ek olarak, bu çalışmada ilköğretim öğrencilerinin origami-tabanlı öğretim ile ilgili algıları da incelenmiştir. Diğer bir ifadeyle, öğrencilerin origami-tabanlı öğretime yönelik tutumları, origami-tabanlı öğretimin yararları ve matematikle bağlantısı hakkındaki görüşleri ile origami yaparken karşılaştıkları zorluklar ve bu zorlukların üstesinden kimin yardımıyla geldikleri incelenmiştir.

Bu çalışmanın verileri Ankara'nın Eryaman ilçesindeki bir özel okulda öğrenim gören 38 dördüncü, beşinci ve altıncı sınıf öğrencisinden toplanmıştır.

Origami-tabanlı öğretimin uzamsal görselleştirme ve uzamsal yönelim açısından öğrencilerin uzamsal yetenekleri üzerine etkisini değerlendirmek için katılımcılara öntest ve sontest olarak Uzamsal Yetenek Testi uygulanmıştır. Buna ek olarak, katılımcıların origami-tabanlı öğretim ile ilgili algılarını incelemek amacıyla görüşlerini belirten yazı yazmaları istenmiştir.

Çalışma sonuçları, origami-tabanlı öğretimin ilköğretim öğrencilerinin hem uzamsal görselleştirme yetenekleri hem de uzamsal yönelim yetenekleri üzerine anlamlı ve pozitif bir etkiye sahip olduğunu göstermektedir. Bunun yanı sıra, bulgular öğrencilerin origami-tabanlı öğretime yönelik olumlu tutum geliştirdiklerini ve origami-tabanlı öğretime devam etmek istediklerini göstermektedir. Bulgular ayrıca, öğrencilerin origami-tabanlı öğretimin özellikle geometri konularında kendileri için faydalı olduğunu düşündüklerini ve origami-tabanlı öğretimin matematikle doğrudan ilişkili olduğunu belirtiklerini ortaya koymuştur. Buna ek olarak, veri analiz sonuçları öğrencilerin genellikle katlarken ve parçaları birleştirirken zorluk yaşadıklarını ve bu zorlukların üstesinden kendi kendilerine ve öğretmen ile arkadaşlarının yardımlarıyla geldiklerini göstermektedir.

Anahtar Kelimeler: Uzamsal yetenek, uzamsal görselleştirme yeteneği, uzamsal yönelim yeteneği, origami-tabanlı öğretim, ilköğretim öğrencileri

To My Mother and Father

Asiye & Zeki ÇAKMAK

Who have always shown their trust in me

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LIST OF ABBREVIATIONS

CEFT: Children's Embedded Figures Test

METU: Middle East Technical University

MGMP: Middle Grades Mathematics Project

MNE: Ministry of National Education

NCTM: National Council of Teachers of Mathematics

PFT: Paper Folding Test

SAT: Spatial Ability Test

TJCC: Turkish – Japanese Communication Club

TSV: Test of Spatial Visualization in 2D Geometry

CHAPTER 1

INTRODUCTION

As stated by Bishop (1983) "Geometry is the mathematics of the space" (p. 175). By this way, mathematics educators are interested in making students more knowledgeable and skillful in mathematical understanding in geometry. It was mentioned that geometrical thinking was an important skill in learning other areas of mathematics (National Council of Teachers of Mathematics [NCTM], 1989, 2000). The importance of geometry was also highlighted in the new elementary mathematics program which was based on the reform movements in Turkish education system in 2003 (Ministry of National Education [MNE], 2005, 2006).

It was mentioned that spatial thinking skills came into prominence in solving geometry problems (Battista, 2007; Clements & Battista, 1992; Hershkowitz, 1998). Also, Battista (2007) stated that geometrical thinking was based on spatial reasoning, and emphasized on the importance of developing spatial abilities for geometry learning. Clements and Battista (1992) indicated that geometry and spatial skills were interrelated. Similarly, the studies showed that there was a positive relationship between mathematics and spatial ability (Battista, 1990; Casey, Nuttall, Pezaris, & Benbow, 1995; Clements, 1998; Fennema & Sherman, 1977; Guay & McDaniel, 1977; Olkun & Knaupp, 1999; Seng & Chan, 2000; Smith, Olkun, & Middleton, 2003; van Garderen, 2006). Furthermore, NCTM (2000) mentioned that spatial abilities needed to be comprehended and appraised the geometry, and its standards focus on spatial ability. Therefore, it can be inferred that geometry lessons provides an environment to improve spatial skills. In addition, as mentioned before, there was a change in mathematics programs which put emphasis on problem solving, reasoning, communication and making connection processes. By the changes in the elementary mathematics programs in Turkey, topics about spatial ability became a prevalent and important issue in mathematics education (MNE, 2005, 2006). The development of the spatial ability is considered that geometry lessons had great important role in developing it.

Olkun and Knaupp (1999) also mentioned that providing learning experience to students, beginning with the concrete and pictorial stages, and then the abstract stage, made them learn mathematics meaningfully. They stated that students could learn geometry by using manipulative or some other thing. It was also supported by Clements (1998). He stated that many of the studies showed that using varied manipulative was beneficial and improved students' geometric and spatial thinking. Providing leaning activities, in which students have opportunities to draw, visualize and compare the shapes, will help enhancing spatial abilities (NCTM, 2000). In this context, origami can be an important manipulative to improve spatial abilities of students, since students discover geometric shapes, transformations, and geometrical relations by folding two dimensional paper into three dimensional model. Moreover, it was pointed out that origami could be used as an instructional tool in education (Boakes, 2008, 2009; Chen, 2006; Coad, 2006; Cornelius, 2002; Cornelius & Tubis, 2002; Erktin, Özkan, & Balcı, n.d.; Kavici, 2005; Levenson, 1995; Phibbs, 1991; Pope, 2002; Sze, 2005a, 2005d; Tuğrul & Kavici, 2002). By means of the new mathematics program, spatial ability gain importance and become prevalent in mathematics. In order to improve spatial ability, the new program provided some activities. Origami was one of these new activities which were introduced to us with new elementary school mathematics textbooks. Thus, spatial ability has an important role in mathematics education especially in geometry education. There were few research studies performed related to spatial ability in Turkey. Similarly, origami had a part in elementary school mathematics textbooks, but there was not any study which investigated its effects in mathematics, specifically spatial ability in mathematics. Since the importance of spatial ability in elementary mathematics education emphasized on new mathematics program and the provided origami activities in elementary school mathematics textbooks, it was important to investigate the effect of origami-based instruction on elementary students' spatial ability in mathematics.

1.1. Purpose of the Study

The main purpose of the study was to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics. Another purpose of this study was to investigate students' self-reported perceptions related to origami-based instruction. In other words, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcome these difficulties were investigated.

1.2. Research Questions and Hypothesis

The following research questions will be investigated in this study and hypotheses are formulated for this study as followed by research questions:

1. Is there a significant change in fourth, fifth, and sixth grade students' SAT (Spatial Ability Test) scores following participation in origami-based instruction?

    - Is there a significant change in fourth, fifth, and sixth grade students' spatial visualization scores following participation in origami-based instruction?

    H_o: There is no significant change in fourth, fifth, and sixth grade students' spatial visualization scores following participation in origami-based instruction.

- Is there a significant change in fourth, fifth, and sixth grade students' spatial orientation scores following participation in origami-based instruction?

  H_o: There is no significant change in fourth, fifth, and sixth grade students' spatial orientation scores following participation in origami-based instruction.

2. What are the students' self-reported perceptions related to origami-based instruction?

   - What are the students' attitudes towards origami-based instruction?
   - What are the students' views about benefits of the origami-based instruction and its connection to mathematics?
   - What are the difficulties that students encounter with and with whom they overcome these difficulties?

1.3. Definitions of the Important Terms

Research questions and hypothesis were presented in the previous section. In order to understand those research questions and hypothesis, constitutive and operational definitions of important terms of this study were given in the following list.

Spatial Ability is defined as "the mental manipulation of objects and their parts in 2D and 3D space" (Olkun, 2003c, p. 8).

Spatial Visualization is defined as the "ability to manipulate or transform the image of spatial patterns into other arrangements or the mental rotation of a spatial configuration in short term memory" (Ekstrom, French, Harman, &

Derman, 1976 as cited in McGee, 1979, p. 891). In this study, spatial visualization ability score refers to the sum of Spatial Task, Spatial-numeric Task, Informal Area Measurement Task, and Paper Folding Task Test scores.

Spatial Orientation is defined as the “ability to perceive spatial patterns or to maintain orientation with respect to objects in space” (Ekstrom et al., 1976 as cited in McGee, 1979, p. 891). In this study, spatial orientation ability score refers to the sum of Mental Rotation Task Test scores.

Origami: Origami is commonly known word in Japanese. “Ori” means to fold, and “kami” means paper. Generally origami is known as Japanese art of paper folding.

Origami-Based Instruction: In the present study origami-based instruction refers to a mathematics instruction in which origami activities are used to teach mathematics and geometry concepts through paper folding.

1.4. Significance of the Study

Spatial ability has an important role for students in learning mathematics (Clements, 1998), more specifically in learning geometry (Battista, Wheatley, & Talsma, 1982). The importance of the spatial ability in mathematics was also emphasized in the new elementary mathematics program. When the objectives in the learning area of geometry were examined it was seen that spatial skills were increased. In other words, enhancing spatial skills in mathematics classes became an important issue. In this context, there are many research studies which investigate the effect of treatment on spatial ability and its factors (Allias, Black, & Gray 2002; Battista et al., 1982; Bayrak, 2008; Ben-Chaim, Lappan, & Houang, 1988; Brinkmann, 1966; Connor, Schackman, & Serbin, 1978; De Lisi

& Wolford, 2002; McGee, 1978; Olkun, 2003c; Rafi, Anuar, Samad, Hayati, & Mahadzir, 2005; Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990). Those research studies have revealed that spatial ability and its factors can be enhanced if the appropriate treatment is provided. In those studies provided treatments varies from technical drawing to visual methods.

Moreover, Olkun and Knaupp (1999) and Clements (1998) mentioned that to improve students' geometric and spatial thinking, using manipulative in mathematics and geometry classes was an effective way. Also, it was emphasized that that origami could be used as an instructional tool in mathematics education (Boakes, 2008, 2009; Chen, 2006; Coad, 2006; Erktin et al., n.d.; Higginson & Colgan, 2001; Kavici, 2005; Levenson, 1995; Pope, 2002; Sze, 2005a, 2005b, 2005d; Tuğrul & Kavici, 2002), since students discovered geometric shapes, transformations and geometrical relations by folding two dimensional paper into three dimensional figure. In this context, origami can be used as manipulative to improve spatial abilities of students. In addition, with the changes in mathematics curriculum, origami became a current issue in mathematics classes. The elementary school mathematics textbooks from 1st grades to 5th grades, published by Ministry of National Education in 2005, had origami activities at the end of the each chapter aiming to teach geometrical shapes, their classifications, three dimensional geometrical figures, and symmetry concept. In other words, to improve spatial abilities of students, the new elementary school mathematics textbooks provided origami activities. Although there were several studies related with origami in general, research studies directly related with the use of origami in mathematics were limited (Boakes, 2009; Erktin et al., n.d.; Yuzawa & Bart, 2002; Yuzawa, Bart, Kinne, Sukemune, & Kataoka, 1999). Especially, the number of the studies done in Turkey was insufficient while origami activities included in elementary school mathematics textbooks. In other words, both origami and spatial ability became an important issue in mathematics education with the reform movements in 2005 in Turkey, but there is not any study related with the use of origami in mathematics, especially spatial ability in mathematics. Hence, it is believed that this study contributes to the literature about the effect of origami-based instruction on enhancing spatial ability. In addition, the findings of this study are expected to provide useful information for mathematics educators in planning learning activities.

1.5. My Motivation for the Study

I started my undergraduate study at the Middle East Technical University (METU) in 2001 and I graduated in 2006. During the first year of my study, I attended to origami classes to learn how to make different origami models in Turkish – Japanese Communication Club (TJCC) in METU. Then I began to teach origami to university students in TJCC and to elementary student as a volunteer teacher in some other student clubs in METU. Moreover, during my education, I gained extensive knowledge about mathematics teaching including how to teach mathematics concepts and how to get students involved. During my education in elementary mathematics education department and as being an origami instructor in TJCC, I always have some questions in my mind. These questions were “Can we use origami in mathematics classes or not? If yes, how?”, and “Can we use origami to evaluate students learning in mathematics classes or not? If yes, how?”. By means of this thesis, I hope to find answers to these questions. Moreover, I believe that this study will make contribution to my teaching profession.

This thesis is includes five chapters. In the first chapter, introduction and significance of this study are provided. In the second chapter, definition of spatial ability and its factors in the literature, the importance of spatial ability in other countries and in Turkey, research studies related to spatial ability, the definition of the origami, the importance of origami, and research studies related with origami are given. The third chapter is about the description of methodology including research design, population and sample, data collection instruments, reliability and validity of the study, data collection procedure, analyses of data, assumptions and limitations, and lastly the internal and external validity of the study. Fourth chapter includes the results of research questions. The summary and discussion of the major findings and the recommendations for future research studies are given in the last chapter.

CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this study is to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics, and to examine students' self-reported perceptions related to origami-based instruction. In accordance with the purpose, this chapter is devoted to the information about the present literature related to spatial ability and origami. More specifically, this chapter mainly consists of two sections; literature review on spatial ability and literature review on origami.

2.1. Spatial Ability

In this section, how spatial ability and its factors are defined in the literature will be discussed. Moreover, the importance of spatial ability in other countries and in Turkey will be mentioned, and finally research studies related to spatial ability will be given.

2.1.1. Definition of Spatial Ability

Although the amount of the studies in literature related to spatial ability is considerable, there is not a consensus on the terms used for spatial ability and the related factors of spatial ability. In the literature, different terms were used like spatial thinking, spatial visualization, spatial orientation, spatial relations, spatial sense, spatial reasoning, visuo-spatial ability, and spatial intelligence to indicate spatial ability.

Lean and Clement (1981) defined spatial ability as "the ability to formulate mental images and manipulative these images in the mind" (p. 267). Linn and Petersen (1985) defined it as the "skill in representing, transforming, generating, and recalling symbolic, nonlinguistic information" (p. 1482). In addition, Olkun (2003c) stated that spatial ability was generally used to indicate the abilities related to the space. He generally defines spatial ability as "the mental manipulation of objects and their parts in 2D and 3D space" (p. 8). As seen from the literature, definition of spatial ability was changing according to researchers. In other words, there were different definitions existed in literature for the same term but we could say that spatial ability is perceived as mental manipulation of the images.

In the literature, some of the researchers used spatial ability and spatial visualization ability interchangeable (Battista, 1990; Battista et al., 1982). In addition, some researchers use spatial visualization as a factor of spatial ability (Allias et al., 2002; Ben-Chaim et al., 1988; van Gardener, 2006). Most of them used McGee (1979)'s definition of spatial visualization in their study; "the ability to mentally manipulate, rotate, or invert a pictorially presented stimulus object" (p. 893). In the literature it was emphasized that the most common term was spatial ability but the literature review showed that researchers generally studied on spatial visualization. For instance, Salthouse et al. (1990) defined spatial visualization as "the mental manipulation of spatial information to determine how a given spatial configuration would appear if portions of that configuration were to be rotated, folded, repositioned, or otherwise transformed" (p. 128). On the other hand, Smith et al. (2003) defined spatial visualization as "the ability to solve multi-step problems involving configurations of spatial elements" (p. 3). In this definition they focused on problem solving ability in spatial context, they did not highlight the nature of the configurations. Furthermore, Brinkmann (1966) defined spatial visualization as visual space relations in his study. This definition indicated a general situation.

In order to better understand the nature of the spatial ability, factor-analytic studies were conducted (McGee, 1979; Michael, Guilford, Fruchter & Zimmerman, 1957; Linn & Peterson, 1985). For instance, Michael and his colleagues stated that Army Air Force [AAF] studies factorized spatial ability into three groups as spatial relation (SR), visualization (Vz) and kinesthetic (S). The SR is defined by AAF as “involving relating different stimuli to different responses, either stimuli or responses being arranged in spatial order.” (as cited in Michael et al., 1957, p. 188). On the other hand, Vz is defined as “the ability to imagine the rotation of depicted objects, folding or unfolding flat patterns, the relative changes of position of objects in space, the motion of machinery.” (as cited in Michael et al., 1957, p. 188). Lastly, S was identified as “a spatial factor restricted to a few tests. An appreciation of right-hand, left-hand discrimination may be an important aspect of the factor” (as cited Michael et al., 1957, p. 189).

On the other hand, it was mentioned that Thurstone identified four factors for spatial ability which were symbolized as S_1, S_2, S_3, and K (as cited in Michael et al., 1957). S_1 is defined as the “ability to recognize identity of an object when it is seen from different angles” or “ability to visualize a rigid configuration when it is moved into different position” (as cited in Michael et al., 1957, p. 188). S_2 was defined by Thurstone as the “ability to visualize a configuration in which there is a movement or displacement among the parts of configuration” and S_3 as the “ability to think about those relations in which the body orientation of the observer is an essential part of the problem” (as cited in Michael et al., 1957, p. 188). Thurstone stated that K – kinesthetic factor showed the kinesthetic imaginary and related with right-left hand separation (as cited in Michael et al., 1957).

Similarly, French categorized factors into three groups and used different symbols as S for space, SO for spatial orientation, and Vi for visualization (as cited Michael et al., 1957). French defined S (space) as the “ability to perceive spatial patterns accurately and compare them with each other”, SO (spatial orientation) as the “ability to remain unconfused by varying orientations in which a spatial pattern may be presented" and finally Vi (visualization) as the "ability to comprehend imaginary movements in 3 dimensional space or the ability to manipulate objects in the imagination" (as cited in Michael et al., 1957, p. 188).

In short, basing on the previous factor analytic studies Michael and his colleagues categorized spatial ability into three parts as spatial relations and orientation (SR-O), visualization(Vz), and kinesthetic imaginary (K). According to factor analytic studies discussed in Michael et al. (1957), SR-O factor included spatial relations (SR) factor defined by AAF study, S_1 and S_3 factors defined by Thurstone, and space (S) and spatial orientation (SO) factors defined by French. Visualization (Vz) factor was identical with Vz factor defined by AAF, and matching Vi factor defined by French, and S_2 factor defined by Thurstone. Kinesthetic imaginary (K) factor included S factor defined by AAF, K (kinesthetic) factor defined by Thurstone.

Additionally, with regard to previous factor analytic on spatial abilities studies ranged from 1925 to 1976, McGee (1979) mentioned that studies on mechanical and practical abilities were the bases of the factor analytic studies for spatial ability. In his study, he mainly reviewed the factor analytic studies which were also reviewed by Michael et al. (1957) and the study of Ekstrom, French, and Harman which was conducted in 1976. McGee (1979) mentioned that in addition to other researchers, Ekstrom et al. (1976) factorized spatial ability into two components as visualization and orientation. VZ – Visualization was defined as the "ability to manipulate or transform the image of spatial patterns into other arrangements" (Ekstrom et al., 1976 as cited in McGee, 1979, p. 891). S – Orientation was defined as the "ability to perceive spatial patterns or to maintain orientation with respect to objects in space" (Ekstrom et al., 1976 as cited in McGee, 1979, p. 891). In other words, spatial visualization requires mentally reconstitute of a figure by manipulating or rotating its pieces mentally. On the other hand, in spatial orientation the object should be accepted as a whole.

Similar to Ekstrom et al., McGee (1979) concluded that the research about factor analytic studies on 70's had showed that there are at least two distinct spatial abilities as visualization and orientation. In addition he defined both spatial visualization and spatial orientation very similar to Ekstrom (as cited in McGee, 1979).

Apart from McGee (1979) and Michael et al. (1957), a different categorization of the spatial factors was identified by Linn and Peterson (1985) as spatial perception, mental rotation, and spatial visualization. They defined spatial perception as “to determine spatial relationships with respect to the orientation of their own bodies” (p. 1482), mental rotation as “ability to rotate a two or three dimensional figure rapidly and accurately” (p. 1483), and spatial visualization as “spatial task that involve complicated, multistep manipulations of spatially presented information” (p. 1484). Linn and Peterson (1985) factorized spatial ability into three parts, this was the main difference from McGee (1979), when the definitions of the spatial visualization and spatial orientation considered there was a little differences in generally.

In summary, there were different factorizations of spatial ability which caused various definitions of spatial ability and of its factors. With the purpose of investigating the effect of origami-based instruction on elementary students’ spatial ability in mathematics, definitions of spatial visualization and spatial orientation defined by Ekstrom et al. (1976 as cited in McGee,1979) was accepted for this study.

2.1.2. Importance of Spatial Ability in Mathematics

In learning many topics of mathematics, spatial ability has an important role (Clements, 1998), especially in learning geometry (Battista et al., 1982). Moreover, Friedman (1992) mentioned that there were spatial prerequisites for many of elementary mathematical tasks. For example, to calculate the surface area of a cube, visualizing would be helpful if there was not any cube around.

In the literature many researchers found that there was a relation between mathematics and spatial ability (Battista, 1990; Casey et al., 1995; Clements, 1998; Fennema & Sherman, 1977; Guay & McDaniel, 1977; Olkun & Knaupp, 1999; Seng & Chan, 2000; Smith et al., 2003; van Garderen, 2006). For instance, Clements (1998) stated that spatial ability and mathematics achievement were interrelated, and spatial ability had an importance in learning many topics of mathematics especially in geometry. In addition, Fennema & Sherman (1977) stated that there was a positive correlation between spatial ability and mathematical performance involving geometry and they mentioned that spatial visualization skills had major effect in mathematics learning. Furthermore, Battista (1990) stated significant relationship between spatial visualization and geometry achievement and also mentioned that solving geometry problems was significantly related to spatial visualization.

Similarly, Olkun and Knaupp (1999) studied children's understanding of rectangular solids made of small cubes as they engaged in enumeration tasks and to stimulate their understanding through equal sharing activities involving cube building. They mentioned that spatial ability was accepted as an important topic by mathematics educators since there was a strong correlation between mathematical achievement and spatial ability. In another research study, Guay and McDaniel (1977) investigated the relationship between mathematics achievement and the spatial ability of elementary school students. They mentioned that students who had higher scores in mathematics achievement test had high level spatial ability, whereas, students who had lower scores in mathematics achievement test had low level spatial ability. Similarly, in her study, van Garderen (2006) found a significant and positive correlation between spatial visualization and mathematical problem solving. In addition, she stated the significant correlation between spatial visualization and achievement. Seng and Chan (2000) also stated the significant relationship between spatial ability and mathematical performance. They mentioned that spatial ability had a big importance in constructing and using mathematical concept, if visual representations were used in mathematics and geometry lectures, students' understanding would be affected strongly by their spatial ability. Therefore in elementary grades, inadequate spatial ability can cause inability to understand basic mathematical ideas.

In another research study with fifth grade students, Smith et al. (2003) investigated how learning situations affect the spatial visualizations of the students at different levels of ability. With this purpose, thirty-two 5^{th} grade boy students participated in the study. First of all, students were classified according to their ability levels by using Space Relations Subset of Differential Aptitude Test. Participants had the treatment in pairs; namely, while one solved computer-based polyomino puzzles, and his pair observed his work. In order to find out the difference between two learning situations, pretest and posttest including spatial visualization problems with polyominos was administered. The researcher concluded that there was not any significant difference between the two learning situations and solving geometric puzzle positively affected the students' geometric thinking.

In her study, Kayhan (2005) investigated the effect of the type of high school on spatial ability, and the relationships among mathematics achievement, logical thinking ability and spatial ability. In addition, she investigated the effect of technical drawing course on the development of spatial ability. Results revealed strong positive relationship between the students' spatial ability and mathematics achievement, students' spatial ability and logical thinking ability, and industrial vocational high school students' spatial ability and their technical drawing achievement. Furthermore, significant relationship between mental rotation and mathematics achievement was explored by Casey et al. (1995). Based on the previous studies, Seng and Chan (2000) indicated that spatial thinking should be integrated into mathematics curriculum. On the other hand, there were some studies which did not find any positive relation between spatial ability and mathematics or geometry. One of these studies was the Friedman's Meta-analysis (1992) which showed that there was not any relation between spatial ability and mathematical tasks. Similarly, Battista (1981) stated that he could not find any significant positive correlation between spatial ability and mathematics, but he also indicated that results could be caused by the short duration of experimental treatment. Although there were counter examples, most of the research indicated a significant positive relationship between spatial ability and mathematics. The researchers indicated that spatial ability had an important role in mathematics. Moreover, it was seen that in solving geometry problems, spatial ability played an important role (Battista, 2007; Clements & Battista, 1992; Hershkowitz, 1998).

2.1.2.1. Importance of Spatial Ability in Mathematics Curriculum

When the mathematics curricula in the United States and Turkey were examined, it was seen that spatial ability was prevalent in mathematics education, especially in geometry. For instance, when the NCTM standards of USA were examined, it was seen that many geometry standards focus on spatial ability. Some of those standards are given:

- Analyze characterizes and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships,
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems,
- Apply all transformations and use symmetry to analyze mathematical situations,
- Use visualization, spatial reasoning, and geometric modeling to solve problems (NCTM, 2000, p. 41).

Similarly, when the mathematics curriculum was examined in Turkey, it was also seen that spatial skills were important. To state clearly, in the last years there was a change in the Turkish education system. Koc, Isiksal, and Bulut (2007) mentioned that the curriculum reform started in elementary education was made in five subject matter areas: mathematics, science, social science, life science and Turkish.

The reform movements in Turkish Education system began in 2003. The first level of elementary schools (grade 1 to grade 5) have used the new curriculum since 2004-2005 academic year, and the second level of elementary schools (grade 6 to grade 8) have used it since 2005-2006 academic year. Elementary mathematics programs also changed with this reform movement. More specifically, in new mathematics program, mathematics was divided into four learning areas for the grades 1^{st} to 5^{th} as numbers, geometry, measurement, and data analysis. On the other hand, it was divided into five learning areas; numbers, geometry, measurement, probability and statistics, and algebra for grades 6^{th} to 8^{th}. Apart from these learning areas, new mathematics curriculum put emphasis on problem solving, reasoning, communication, and making connection processes. By the changes in the elementary mathematics curriculum in Turkey, topics about spatial ability become a prevalent and important issue in mathematics education (MNE, 2005, 2006).

Reforms in mathematics curriculum in Turkey pointed out the importance of spatial ability. When the objectives in the learning area of geometry were examined it was seen that spatial skills took over. For instance, percentages of the objectives related with spatial skills in the geometry learning area were as the following: 57% for 1^{st} grades, 20% for 2^{nd} grades, 21% for 3^{rd} grades, 18% for 4^{th} grades, 35% for 5^{th} grades, 41% for 6^{th} grades, 35% for 7^{th} grades, and finally 52% for 8^{th} grades (MNE, 2005, 2006). The percentages of objectives related with spatial skills illustrated the importance of spatial skills in mathematics. Some of the objectives from the new program were given below:

- Students should be able to determine and draw the line of symmetry,
- Students should be able to explain rotation,
- Students should be able to explain reflection,

- Students should be able to identify the symmetry of the 3D shapes (MNE, 2005, 2006).

In this section, the studies which emphasized on the importance of spatial ability in mathematics were discussed. Moreover, importance of spatial ability in mathematics and mathematics curriculum were given. In the next section, research studies related with the development of spatial ability will be given.

2.1.3. Related Studies with Improvement of Spatial Ability

In literature, there are lots of studies related to spatial ability and how to improve it. Some of those studies examined the younger children aged between 6 to 10 (Connor et al., 1978; De Lisi & Wolford, 2002), some investigated school age students (Bayrak, 2008; Ben-Chaim et al., 1988; Boulter, 1992; Boyraz, 2008; Brinkmann, 1966; Olkun, 2003c), some others conducted research on university students (Allias et al. 2002; Battista et al., 1982; Ferrini-Mundy, 1987; McGee, 1978; Rafi et al., 2005), and finally some of them studied adults (Salthouse et al., 1990) in order to improve spatial ability through training. Most of these research studies indicated that treatment had positive effect on spatial ability.

Connor et al. (1978) conducted a study with younger children. Ninety-three 1st grade students aged in 6-7 were randomly divided into two groups as an experimental and a control group. Both of the groups were asked to take half of the Children's Embedded Figures Test (CEFT) as a pretest and the remaining half of the test as a posttest. In the study experimental group was trained by activities of embedded figures during four days. The results indicated that training developed the performance of children on CEFT. Similarly, De Lisi, and Wolford (2002) conducted a study to investigate the relationship between computer game playing and mental rotation. Forty-seven 3rd grade students participated in this study for 11 learning hour for 1 month. The experimental group played Tetris game which required mental rotation skill, and control group played Carmen Sandiego game which did not require mental rotation skill. As a result, the authors found that mean scores of students who were in the experimental group significantly increased.

In addition to studies done with early elementary school students aged between 6 and 10, there were a lot of studies performed with elementary school students. Brinkmann (1966) was one of the researchers who firstly studied the effect of training on spatial ability. In the study, the effect of programmed instruction, designed to teach the visualization of space relations in terms of improvement of spatial visualization, was examined. Approximately sixty 8^{th} grade students participated in this study. Half of them were randomly assigned to 3 week length instructional program as an experimental group. Others did not have any training as a control group. Space relations of the Differential Aptitude Test were administered to both of the groups as a pretest and posttest. The analysis showed that two groups pretest mean scores were very similar which was evidence as the experimental and the control group were at the same level. On the other hand, posttest mean score of the experimental group was higher than that of the control group's. The analysis of the gained scores indicated that there was a significant difference between two groups which was concluded as spatial visualization which could be improved by instructional program.

Likewise, Ben-Chaim et al. (1988) conducted a study to investigate the effects of the instruction on spatial visualization skills of 5 to 8 graders. In this study, a unit of instruction on spatial visualization developed by Middle Grades Mathematics Projects (MGMP) was used as a treatment. Approximately 1000 students from different backgrounds participated in the activities which were done with small cubes. To find out the effect of the instruction program, Spatial Visualization Test developed by MGMP was used as pretest, posttest and retention. The authors indicated that 3 week instruction on spatial visualization significantly increased the spatial ability of the 5^{th}, 6^{th}, 7^{th}, and 8^{th} grade students.

Furthermore, Bayrak (2008) conducted a research study to investigate the effect of visual treatment on elementary school students' spatial ability. In this study, extra curricular activities such as transformation, computer-based, manipulative, and origami activities were used as a treatment. Twenty-one 6th grades students in Turkey participated in the activities for one hour in a week and it continued for 10 weeks. In order to find the effect of visual treatment, spatial ability test developed by Ekstrom et al. (1976) was used. The researcher indicated that visual treatment had a significant positive effect on spatial ability, spatial orientation, and spatial visualization.

Additionally, Olkun (2003c) stated that base of engineering drawing was founded on spatial thinking and transformation geometry. Obviously, engineering drawing applications required transformations of 2D and 3D shapes, and it also included orthographic views and perspectives. Hence, Olkun (2003c) provided some activities designed to improve spatial ability for elementary school students which included engineering drawings.

There were also studies in which the treatment effect on undergraduate students' spatial abilities was investigated. Firstly, McGee (1978) carried out a study with 347 undergraduate students to examine the effect of training on mental rotation test. The entire participants had a class on spatial ability as a treatment. Before and after the training session, subjects were asked to take a mental rotation test as pretest and posttest. The results indicated that training increased significantly mean scores of the undergraduate students.

Another study was conducted by Battista et al. (1982) to find out the effect of the instruction on spatial visualization. Totally 82 pre-service elementary teachers who were taking geometry course participated four sections of geometry course which included spatial activities. Both at the beginning and at the end of the instruction students were asked to take Purdue Spatial Visualization Test as pretest and posttest. Researcher investigated that students' spatial visualization skills were significantly improved by spatial activities used in geometry course.

Moreover, Allias et al. (2002) used a group of civil engineering students to explore the impact of manipulative and sketching activities on spatial visualization. Twenty nine students participated as an experimental group and 28 students were participated as a control group in the study. At the beginning of the instruction, both groups were asked to take spatial visualization ability test as a pretest. For the experimental group, structural design courses constituted spatial activities for one week, in the same time control group carried out normal structural design courses. In the activities which were hold by the experimental group, students used building blocks in constructions, made sketching of the construction made by building blocks. At the end of the treatment both groups took spatial visualization test again as a posttest. The spatial visualization test used in the study included three spatial tasks as, cube construction, engineering drawing and mental rotation. Analysis of the pretest and posttest scores showed that there was a significant difference between the mean of the gained scores of the experimental group and the control group. Allias et al. (2002) concluded that spatial visualization skills could be developed with the activities which included spatial tasks.

In another research, Rafi et al. (2005) studied with 98 preservice teachers who took Computer Aided-Design courses. All of the participants took a spatial ability test as a pretest and posttest. Forty-nine of the preservice teachers participated in learning activity with using a Web-based Virtual Environment as an experimental group for five weeks. The authors concluded that there was a significant increase in spatial ability scores of experimental group.

Apart from these studies, adults participated in research studies which investigated the effect of training on spatial ability. Following study was conducted with older adults aged between 60 and 78 by Salthouse et al. (1990). The experimental group included selected participants who were active or retired architects; on the other hand, participants in the control group were adults who did not have any spatial experience. In order to investigate the spatial visualization abilities, all participants took spatial visualization test consisted of Form Board, Paper Folding, Surface Development, and Cube Comparison Tests. On the basis of the study, the authors stated that architects had more ability in spatial visualization than unselected adults.

In literature, there were many studies which indicated that spatial ability or its factors could be developed by spatial related training. On the other hand, some of the reviewed studies indicated that there was not any significant effect of treatment on spatial ability. For instance, Boulter (1992) conducted a study with forty-four 7th and 8th grade students to examine the effects of instruction in transformational geometry on spatial ability. Students in the control group took a traditional instruction and students in the experimental group received an instruction which consisted object manipulation and visual imaginary approaches during two weeks. In order to measure the effect of instruction, both control and experimental groups took a spatial ability test consisting card rotation test, hidden pattern test, and surface development test developed by Ekstrom et al. (1976) as pre and posttest. The results indicated that there was not any significant effect of instruction in transformational geometry on students' spatial ability.

Similarly, Boyraz (2008) carried out a study with fifty-seven 7th grade students in Turkey, in order to investigate the effects of computer based instruction on students' spatial ability. As a treatment, computer based instruction was used for 14 hours during two weeks. The results indicated that computer-based instruction did not have any significant effect on spatial ability of students. Moreover, Ferrini-Mundy (1987) conducted a study with university students to examine the effect of spatial training on students who were enrolled in a calculus class. In that study, the control group had standard classes, contrary to this, the treatment groups had six week spatial training module consisted spatial visualization and orientation tasks; namely, 2D and 3D spatial tasks, rotations from 2D into 3D space, area estimation, development of 3D images from 2D representations. Results of the study revealed that there was no treatment effect on spatial visualization ability.

In brief to sum up, most of the studies which were examined indicated that spatial ability or its factors could be developed through treatment (Allias et al., 2002; Battista et al., 1982; Bayrak, 2008; Ben-Chaim et al., 1988; Brinkmann, 1966; Connor et al., 1978; De Lisi & Wolford, 2002; McGee, 1978; Olkun, 2003c; Rafi et al., 2005; Salthouse et al., 1990). These studies could be accepted as evidence that spatial ability could be improved by spatial training. On the other hand, some of the studies indicated that there was not any significant effect of treatment on spatial ability (Boulter, 1992; Boyraz, 2008; Ferrini-Mundy, 1987). This review showed that generally there were a lot of studies related with improvement of spatial ability in different age groups, but the number of the studies done in Turkey was limited.

In this section, the studies which emphasized on the improvement of spatial ability were discussed. In the next section, research studies related with the origami will be given.

2.2. Origami

In this section, the definition of the origami will be mentioned. Furthermore, the importance of origami will be discussed, and finally research studies related with origami will be given.

Origami is commonly known word in Japanese. "*ori*" means "to fold", and "*kami*" means "paper". Generally origami is known as Japanese art of paper folding. The more precise definition was done in 1999 by Joseph Wu who was an origami designer; he defined origami as a "form of visual / sculptural representation that is defined primarily by the folding of the medium – usually paper. In literature, origami and paper folding used interchangeable.

In general, origami is divided into two categories, which are classical origami and modular origami. In classical origami, one piece of paper is used to make a figure of an animal or a flower. On the other hand, modular origami consists of congruent small modules and requires different combination of these modules to form a figure. Generally, these figures made by modular origami are three dimensional geometric figures (Tuğrul & Kavici, 2002).

2.2.1. Origami in Education

Many researcher and authors pointed out that origami can be used as an instructional tool in education (Boakes, 2008, 2009 Chen, 2006; Coad, 2006; Cornelius, 2003; Cornelius & Tubis, 2003; Erktin et al., n.d.; Kavici, 2005; Levenson, 1995; Phibbs, 1991; Pope, 2002; Sze, 2005a, 2005d; Tuğrul & Kavici, 2002), since origami is an innovational movement for improving important skills. Moreover it had many educational benefits, such as; behavioral skills, cooperative learning, cognitive development, multicultural awareness, community building, and mathematical skills (Levenson, 1995; Tuğrul & Kavici, 2002). In this context, repeated actions in origami provided schematic learning. Moreover, in order to make neat and accurate origami models, students must listen and watch the instructions carefully (Levenson, 1995; Phibbs, 1991; Sze, 2005a, 2005b). In other words, Phibbs (1991) stated that she used origami to teach her students to listen. In order to make origami, students began to listen the sequentially given instruction. By this way students learn to listen other instructions apart from origami; and it provided improvement in students' scores. In another study, Tuğrul and Kavici (2002) introduced origami and emphasized the effect of origami on the development of children's learning skills. They stated that origami should be used in the education of humans and origami was an activity based method which was related with cooperative learning, project base learning, creative learning, active learning and brain based learning.

Origami is also used in education of disabled children. For instance, Chen (2006) aimed to provide an overview of the origami using in mathematics lectures of students who had hearing problems. It was stated that origami activities gave opportunities functional, interesting mathematical lessons which made the mathematics concepts more visual. Similarly, Sze (2005c) provides an overview about the effect of origami construction on children with disabilities.

2.2.1.1. Importance of Origami in Mathematics Education

Besides of the educational benefits, there are also mathematical benefits of origami. Based on their origami teaching experience, some researchers expressed that origami activities give opportunities to use and learn mathematical skills (Higginson & Colgan, 2001; Pope, 2002). Also, authors and researchers mentioned that some topics in mathematics especially in geometry could be taught by using origami activities (Chen, 2006; Coad, 2006; Levenson, 1995). Generally these topics were classified as spatial visualization, intersecting planes, congruence, similarity, classification of polygons, area and volume, and mirror images. Furthermore, paper folding activities were used in illustrations of some concepts in mathematics such as motion, transformation, and geometry could be made by using paper folding. Olson (1998) and Johnson (1999) emphasized on the relationship between lines and angles which could be demonstrated by folding creases in a piece of papers which indicated straight lines. Similarly, Yoshioka (1963) provided some paper folding activities related with construction of geometric shapes and their areas. He also emphasized on relation of mathematics in terms of algebra with geometry by paper folding activities which showed folding an algebraic equation. These studies showed how origami and paper folding activities were used in mathematics and geometry.

Furthermore, with origami integrated mathematics activities, students were able to develop mathematical skills and had an opportunity to learn and use mathematics concepts (Chen, 2006; Levenson, 1995; Sze, 2005b). Students were able to create geometric shapes and students transformed a paper from two dimensions to a three dimensional origami model which provided improving experience in spatial reasoning of students. In addition, students were able to learn symmetry by using origami; because, many of the origami models had symmetry in it, in other words in origami every fold was done for each side of the paper. While folding origami in mathematics students not only had to use their hand to make folding in a sequence to finalize the origami model but also had to use their brains (Chen, 2006; Levenson, 1995; Sze, 2005b). In other words, students participated in learning process both physically and mentally.

In her origami book, Franco (1999) presented origami activities which provided teachers and students to discuss the geometrical concepts during the folding and assembling process. Also, she gave some tips about how to use origami in mathematics classes. Similarly, Linde (2004) emphasized on identifying right angles in geometric figures in her origami book. Furthermore, there were some other origami books which pointed out the geometry in models. Montroll (2002) mentioned that folding polyhedrons combines the art and mathematics and gave instructions of five platonic solids and their sunken versions. In the same manner, researchers emphasized the three dimensional geometrics figures and polyhedrons which were made by paper folding (Gurkewitz & Arnstein, 1995, 2003; Kawamura, 2001; Mitchell, 2005).

Moreover, the elementary school mathematics textbooks from 1st grades to 5th grades published by Ministry of National Education in 2005 had origami activities at the end of the each chapter. There were 5 activities for each grade from 1st to 4th and 6 activities for 5th grades. Generally, these activities aimed to teach geometrical shapes, their classifications, three dimensional geometrical figures and symmetry concept.

In this section the use of origami in different areas and specifically in mathematics was discussed, in the following section research studies related with origami and mathematics will be given.

2.2.2. Research Studies on Origami in Mathematics

There are lots of magazines and papers which discuss the benefits of origami in different areas including mathematics, but there are few research studies performed related to origami and mathematics education.

A research study was carried out to investigate the effect of origami on size comparison strategy of young American and Japanese children by Yuzawa et al. (1999). Forty-six Japanese and forty-eight American children who were aged between 4 to 6 years participated to the study. Children from each country were separated into three groups: a special treatment group, a general treatment group, and a control group. All students were taken a pretest which was asked them to compare the size of 7 pairs of triangle. After the treatment, all children were asked to compare the size of 7 pairs of triangles and 3 pairs of quadrilaterals as a posttest. Children in special treatment group folded origami triangles and superimpose the triangles; children in general treatment group folded traditional origami models. On the other hand, children in control group did not fold any origami; they only made conservation with the researcher. The treatment lasted consecutive five days. As a result, the researcher found that origami practice improved size comparison strategies of both American and Japanese children. Moreover, Yuzawa and Bart (2002) conducted another research study related with origami practice and size comparison strategies. Totally, twenty-four 5 and 6 year old children participated to the study. All students were asked to complete the size comparison task which was the same with the pervious study. After the pretest, half of the children received origami exercises as an experimental group; and took the same size comparison task as a posttest. On the other hand, the remaining half of the children as control group only completed the size comparison task as pretest and posttest. The researchers stated that origami practice developed the children's preciseness of size comparison; but this development was not significant. Moreover, they discussed children's uses of some strategies, such as; one-on-another and general shape were increased.

Carter and Ferruci (2002) conducted a survey related with mathematics education and geometry to investigate the nature and extent of the origami applications in 10 popular mathematics textbooks for pre-service elementary school teachers. In this survey, 137 instances of origami those are, paper folding activities, paper folding examples, and paper folding exercises were examined. Researchers indicated that nature of the origami and paper folding opportunities included: angles, properties of triangles, three dimensional figures, perpendicular segments, polygons, symmetry, fractions, linear measurement, parallel lines, the Pythagorean Theorem, segments and spatial visualization topics in mathematics.

A recent research study which emphasized the effect of origami lessons on 7th grade students' spatial visualization skill was conducted by Boakes (2009). Boakes (2009) performed a research to explore the effect of origami-mathematics lessons on students' spatial visualization skills. Fifty-six 7th grade students were participated in the study. Twenty-five of the students constituted the experimental group and take origami lessons in addition to traditional instruction, on the other hand, remaining thirty-one students constituted the control group and took only traditional instruction during one month geometry unit. Card rotation test, paper folding test, and surface development test developed by Ekstrom et al. (1976) were used as pretest and posttest before and after the treatment for all students. Results revealed significant interaction effect between group and gender in card rotation test, but there was not any significant effect on students spatial visualization skill measured by card rotation test for method of instruction and gender. Moreover, method of instruction and gender had no significant effect on students' spatial visualization skills measured by paper folding test and surface development test. Also, results showed that there was no significant interaction effect between group and gender in paper folding test and surface development test. In addition to those findings, Boakes (2009) mentioned that some informal qualitative data was gathered from students at the end of the study. She asked students to write one word about origami-mathematics courses. As a result, most of the students responded with a positive statement like: fun, helpful, enjoyable, and awesome. Moreover, students were asked to fill a likert scale to investigate whether origami-mathematics lessons helped them to understand geometry or not. The results showed that the mean of the responses was 4.36 in which 5 indicated the strongest agreement.

The reviewed studies showed that there were few studies specifically related with origami and mathematics education. Also the number of studies done in Turkey was very limited. For instance, Kavici (2005), in his master thesis, carried out a research study to investigate the effect of origami instruction on preschool students' visual perception, fine motor skills, and mathematics abilities. There were thirty-six participants which were at age of 5-6 in the study. Half of the students constituted experimental group and participated one hour origami practice in each week of 11 weeks; the other half of the students constituted control group and did not receive any origami-based instruction. In order to determine the effect of origami, fine motor skills part of peabody developmental motor scale, frosting developmental scale of visual perception, and mathematical ability scale were used as pretest and posttest in both experimental and control groups. The results revealed that there was a significant effect of origami on children's visual perception, fine motor skills, and mathematics abilities.

Moreover, as discussed in previous section, Bayrak (2008) conducted a research study to investigate the effect of visual treatment on elementary school students' spatial ability. Origami activities constituted some parts of the visual treatment used in the study. The researcher indicated that visual treatment had a significant positive effect on spatial ability, spatial orientation, and spatial visualization.

Another study was conducted with 1^{st} to 6^{th} grade elementary school students by Erktin et al. (n.d.). In this study, project-based learning method was used in mathematics lessons. Approximately 120 students were given a project homework related with origami which lasted for two weeks. Students were asked to make a research about origami, learn some origami models, and explain the folding steps of their origami model by using mathematical terms. Students made a presentation about their work after making search about origami and learned some origami models. Observations and interviews were made in the first step of the evaluation. The results were revealed that both students and their teachers had positive attitude toward the project work. In the second step of the evaluation a questionnaire was administered to 4^{th} grade students after three months. The results showed that students used some mathematical terms, such as: square, triangle, rectangle, mid-point, vertices, parallel, and edge. Moreover, 60% of the students stated that origami was enjoyable or very enjoyable and 80% of them wanted to continue origami project. Also, they said that origami was beneficial for them. At the second stage of the project 4th grade students continue to origami project in mathematics lessons. In the second stage of the study, the researchers transformed the previous origami topics to origami-mathematics lessons.

In summary, studies showed that origami activities had many educational benefits, specifically in learning mathematics; and it could be used as an instructional tool in education. The research studies also indicated that origami had positive effects in learning mathematic, specifically in geometry. In spite of the benefits of origami, research studies were recently published and number of them was not sufficient. Moreover, origami activities were involved in the new mathematics curriculum but the research studies done in Turkey was very limited.

2.3. Summary

In summary, at the beginning of this chapter, definition spatial ability and its factor were given. The studies related with spatial ability showed that there was not a consensus on the terms used for spatial ability and the related factors of spatial ability. McGee (1979) concluded that the research about factor analytic studies showed that there were at least two distinct factors of spatial abilities as visualization and orientation. Then, importance of spatial ability in mathematics was discussed. The research studies indicated that in learning many topics of mathematics, spatial ability had an important role, especially in learning geometry. Also, importance of spatial ability in mathematics curriculum was given. The mathematics curriculum in Turkey and other countries illustrated that the percentages of objectives related with spatial skills were high and, indicated the importance of spatial skills in mathematics learning. In brief, most of the research studies which were examined in this chapter related with improvement of spatial ability indicated that spatial ability or its factors could be developed through treatment. The second part of this chapter included origami which could though as an instructional method to improve spatial ability. As mentioned before, origami had several benefits in education especially in mathematics education; and many researchers and authors emphasized on the mathematics side of origami. Also, the research studies related with origami and mathematics education indicated that origami had positive effects in learning mathematics, specifically in geometry, and students had positive attitudes toward origami which was used in mathematics classes. The reviewed literature indicated that origami could be an instructional tool to develop spatial ability. Besides, the new mathematics curriculum in Turkey emphasized on the importance of developing spatial ability. In this manner, new mathematics curriculum provided origami activities. Yet, the number of the studies in Turkey was so few. In this aspect, this study conducted to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics and to examine students' self-reported perceptions related to origami-based instruction.

CHAPTER 3

METHODOLOGY

This chapter is devoted to information about the research design, population and sample, data collection instruments, reliability and validity of the study, data collection procedure, analyses of data, assumptions and limitations, and lastly the internal and external validity of the study.

3.1. Design of the Study

The purpose of the research study was to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics. In addition, students' self-reported perceptions related to origami-based instruction were investigated. In this study, both quantitative and qualitative methods were used to examine the research questions. For the quantitative part, one group pretest-posttest design was used. In this research design, a single group was measured before and after the treatment (Fraenkel & Wallen, 2006). The second research question was examined through reflection papers as qualitative part of this study.

3.2. Population and Sample

All fourth, fifth, and sixth grade students in Etimesgut district of Ankara were identified as a target population of this study. The accessible population of this study was determined as all 4^{th}, 5^{th}, and 6^{th} grade students in Eryaman neighborhood of Etimesgut district where the results of the study will be generalized.

Purposive sampling was used to obtain a representative sample of the population. Participants were chosen from 4th, 5th, and 6th grade students of a private school purposively. There were two criteria taken into consideration when selecting students. The first and the most important one was the existence of the two additional mathematics class hours for each grade besides the regular mathematics lessons. In these additional mathematics hours students played mathematical games, solved puzzles, and learned how to use mathematical tools like manipulative. As a result, students were familiar to perform activities like origami. Moreover, one of the additional hours for each grade was reserved for the implementation of this research study. The second criterion was the small class sizes of each grade. There were fifteen 4th grade students, nine 5th grade students, and fourteen 6th grade students in the school. During the implementation of the origami-based instruction in mathematics class, researcher should pay attention to every student one to one. For this reason, smallest class size was important for this research study.

The participants of this study consisted of 38 elementary school students from a private school in Eryaman neighborhood. Table 3.1 shows the number of students from each grade level where 15 (39.5%) students were from fourth grade, 9 (23.7%) students were from fifth grade, and 14 (36.8%) were sixth grade students. In terms of gender, 24 (63.2%) male and 14 (36.8%) female students participated in the study.

Table 3.1 Participants Demographics by Gender and Grade Level

Grade	Female	Male	Total (N)
4th grade	3	12	15
5th grade	2	7	9
6th grade	9	5	14
Total (N)	14	24	38

The table above illustrates all the participants of the study, and also the number of all students in 4^{th}, 5^{th}, and 6^{th} grades. The next section gives detailed information about the data collection instruments.

3.3. Instruments

The purpose of this study was to investigate the effects of origami-based instruction on the fourth, fifth, and sixth grade students' spatial ability in mathematics, and students' self-reported perceptions related to origami-based instruction. To gather the data two sources; namely, spatial ability test and reflection papers were used.

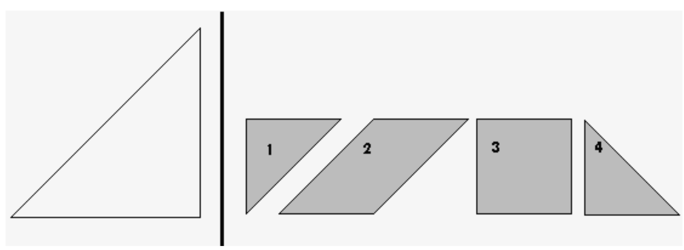
3.3.1. Spatial Ability Test

The Spatial Ability Test (SAT) was used to measure students' ability in manipulating objects and their parts mentally in two and three dimensional space. The SAT used in this study consisted of 35 multiple-choice items and was generated by combination of "Test of Spatial Visualization in 2D Geometry" (TSV) and "Paper Folding Test" (PFT).

TSV was developed by Olkun (2003b) and involves 29 multiple-choice items having four choice alternatives and related to 2D geometry. Olkun (2003b) calculated Cronbach alpha as .78 for the TSV. All of the items in TSV were used in SAT. Since the treatment used in this study was origami-based instruction, and "spatial visualization ability involves the folding and unfolding of patterns" (McGee, 1979, p. 893); items from PFT was used in addition to TSV in this study. PFT was developed by Ekstrom et al. (1976) and was translated into Turkish by Delialioğlu (1996) originally consisted of 20 multiple-choice items having five alternative choices. For the reliability, Delialioğlu (1996) calculated Cronbach alpha as .84 for PFT. Only 6 of the PFT items were chosen by the researcher from the test of Delialioğlu (1996) and added to SAT. While choosing the items their difficulty levels were considered. In one of the questions students are supposed to imagine one fold, in other three of questions, students are supposed to imagine two consecutive folds and in the final two of the questions students are supposed to imagine three consecutive folds.

Olkun (2003a) and Olkun and Altun (2003) categorized the TSV items into four groups according to their types as follows: spatial, spatio-numeric, mental rotation, and informal area measurement. Spatial tasks require visual reasoning on forming a geometric shape by using other geometric shapes. The questions in SAT which were numbered as 1, 2, 3, 4, 5, 6, 7, and 8 are spatial tasks. Figure 3.1 illustrates one of the questions in spatial tasks.

Which of the gray shapes we should use to cover the shape on the left?



A) 1, 3 and 4

B) 1 and 3

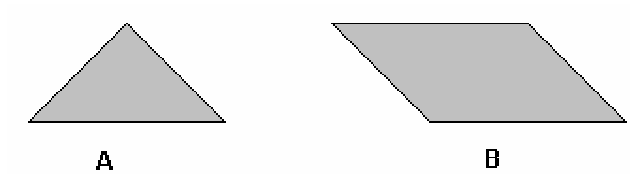
C) 1 and 2

D) 3 and 4

Figure 3.1 Sample Question of Spatial Task

Whereas spatial-numeric tasks not only require visual reasoning but also numerical reasoning depends on dimensions of the geometric shapes. The SAT contains 8 Spatial-numeric tasks. They were the questions numbered as 8, 9, 10, 11, 12, 13, 14, 15, and 16. The figure 3.2 is an example of spatial-numeric tasks.

I have a geometric shape. I use 6 of the shape A to cover that shape. How many of the shape B would I need to cover the same shape?



A) 1

B) 3

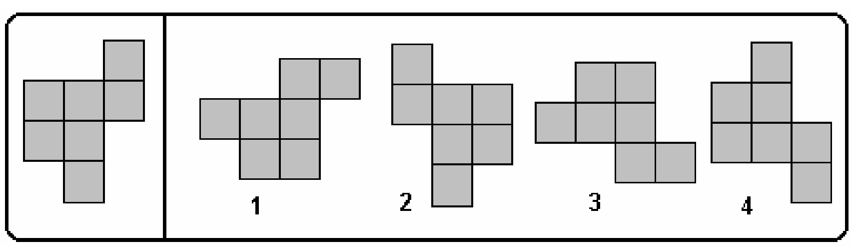
C) 5

D) 7

Figure 3.2 Sample Question of Spatial-numeric Task

Mental rotation tasks require rotating polyomino parts mentally. The questions in SAT, as numbered 17, 18, 19, 20, 21, 22, 23, and 24 are mental rotation tasks. Figure 3.3 illustrates one of the questions in mental rotation task.

Which one of the shapes can be obtained by rotating the figure on the left in clock-wise direction?



A) 1

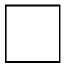
B) 2

C) 3

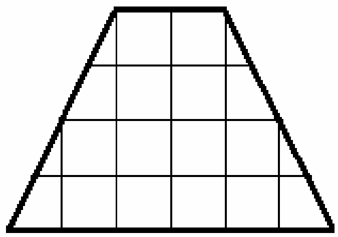
D) 4

Figure 3.3 Sample Question of Mental Rotation Task

Informal area measurement tasks require finding the number of unit square in geometric shapes. There were totally 5 informal measurement tasks in SAT. They were the questions numbered as 25, 26, 27, 28, and 29. The figure 3.4 is an example of informal area measurement tasks.



This is a unit (small) square. How many unit (small) square are there in each of the shapes below.



a) 20

b) 18

c) 16

d) 14

Figure 3.4 Informal Area Measurement Task

The last 6 question were the paper folding tasks which require imagining folding and unfolding a piece of paper. Figure 3.5 illustrates one of the questions in paper folding task.

Square shaped paper is folded as given below and a hole is punched. After unfolding the paper completely which one of the shapes will appear?

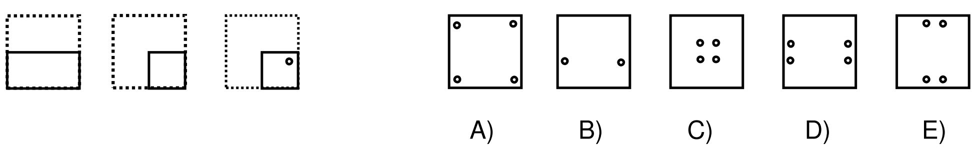


Figure 3.5 Paper Folding Task

All of the questions in the instrument are given in Appendix A.

3.3.1.1. Pilot Study of the Spatial Ability Test

A pilot study was conducted for the final version of SAT defined above (combination of TSV and PFT). A pilot study for SAT was conducted with 413 elementary students from 4^{th}, 5^{th}, and 6^{th} grades. Participants of the pilot study were chosen from four different cities and seven different elementary schools in Turkey. Distribution of the number of students according to grade levels, school type, and location is given in Table 3.2. As shown in the table, number of participants in the pilot study varies according to cities and districts.

Table 3.2 Number of Students' According to Grade Levels, School Type, and Location

Location	School type	4^{th} grade	5^{th} grade	6^{th} grade	Total (N)
Afyonkarahisar (Şuhut district)	Public School	28	15	26	69
Afyonkarahisar (Şuhut district)	Public Elementary Boarding School	10	36	71	117
Bursa	Private School	-	-	18	18
Eskişehir (Alpu district)	Public School	-	-	19	19
Kütahya	Public School	-	1	47	48
Kütahya	Private School	17	26	28	71
Kütahya	Private School	22	23	26	71
Total (N)		77	101	235	413

During the pilot study of SAT, students' answer was coded as "1" if they answered the question correctly. Otherwise, it was coded as "0". Crocker and Algina (1986) mentioned that Kuder-Richardson formulas can be used to find the coefficient alpha merely with items dichotomously scored. Since the items in SAT were dichotomously scored and it was assumed that all of the items had equal difficulty, Kuder-Richardson 21 formula was used to estimate the reliability coefficient. Reliability coefficient was computed as .85 by using the formula below (Crocker & Algina, 1986, p. 139).

$$KR-21=\frac{k}{k-1}\left[1-\frac{\mu(k-\mu)}{k\sigma_x^2}\right] \qquad (3.1)$$

Thus, the SAT was used in this study without any change after the pilot study.

3.3.1.2. Reliability and Validity Issues

Reliability is consistent result of assessments (Linn & Miller, 2005). Kuder Richerdson formulas provide estimation about internal consistency of the tests which were dichotomously scored (Crocker & Algina, 1986). As SAT items were dichotomously scored and it was assumed that all of items had equal difficulty, Kuder-Richardson 21 formula was used. The reliability of pretest and posttest scores were computed as .71 and .86 respectively. Fraenkel and Wallen (2006) mentioned that reliability values above .70 can be accepted as relatively high in social sciences. Thus, it can be said that reliability of both pretest and posttest of SAT scores were high.

Validity is adequate and appropriate interpretations of any measurement (Linn & Miller, 2005). Namely, it is about the aim of the test and what it measures. TSV developed by Olkun (2003b) and PFT developed by Ekstrom et al. (1976) were previously used and their validity studies were done by their developers. Since combination of TSV and PFT constituted SAT, it was a valid test.

Olkun (2003a) and Olkun and Altun (2003) stated that spatial task items are similar to items in standard spatial visualization tests of Minnesota Form Board, spatial-numeric task items are similar to the items in The Third International Mathematics and Science Study, mental rotation task items are similar to the items in Wheatley Spatial Ability Test, and informal area measurement task items are important for learning geometry and learning concepts. Also, "Spatial visualization ability involves the folding and unfolding of patterns" (McGee, 1979, p. 893).

Thus, SAT used in this study was a reliable and valid test.

3.3.2. Reflection Paper

Main purpose of the study was to investigate the effect of origami-based instruction on students' spatial ability in mathematics. In order to achieve this purpose, quantitative techniques were used. Additionally, to reveal the students' self-reported perceptions related to origami-based instruction, qualitative method was used. For this reason, in addition to SAT, reflection papers were used in order to obtain information about what are the self-reported perceptions of participants in origami-based instruction. In other words, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcome these difficulties were investigated. Reflection papers had some questions about origami-based instruction, origami, and the relationship between origami and some concepts in mathematics (see Appendix B). Students also wrote reflections for specific origami-based mathematics class to reflect what they learned from that lesson related to mathematical concepts.

3.3.2.1. Reliability and Validity Issues

In the qualitative part of this study, I analyzed all of the 38 participants' reflection papers with a second coder, a Master of Science student in Elementary Mathematics and Science Education Program in the Faculty of Education at METU. Comparison of the codes also gave evidence for inter reliability. There was a % 99 correlation between the codes in the beginning, and then it increased to %100 after discussing the codes. I also used member checking. I had participants examined their reflection papers and we talked about their reflections to get more detailed reflections and provide the accuracy. In other words, I gave reflection papers to participants again, and I asked them whether they agreed with what they wrote or there was anything that they wanted to change or add. Any of the students did not change the answers that they wrote in reflection papers, but most of the students gave more detailed information during the member check. Furthermore, I tried to use participants' wordings and verbatim while reporting the analysis of the research findings. In reporting, RP-S1 and MR-S1 were used as abbreviation to identify the student and the nature of analyzed document. In other words, RP refers to Reflection Paper, MR refers to Meeting Report, and S1 refers to Student1.

This section provided detailed information about the data collection instruments, and the following section gives information about the data collection and the implementation procedures.

3.4. Data Collection Procedure

The purpose of this study was to investigate the effects of origami-based instruction on the fourth, fifth, and sixth grade students' spatial ability in mathematics, and students' self-reported perceptions related to origami-based instruction.

In the Fall semester of academic year 2007-2008, the participant school was visited and the purpose and the procedure of the study were explained to administrators and mathematics teacher by the researcher. Then, the official permissions were taken from Middle East Technical University Human Subjects Ethics Committee and Ministry of National Education, respectively.

At the beginning of the Spring semester of the academic year 2007-2008, the time schedule for origami-mathematics lessons was planned with the school administrator and mathematics teacher. As mentioned above, in this school, there were two additional mathematics lesson hours besides the regular mathematics lessons. During these two hours, which is also named as mathematics club hours, students play mathematical games, solve puzzles, and learn how to use mathematical tools like manipulative. During the implementation, one of the mathematics club hours for each grade was reserved to the researcher for origami-based instruction.

In the first lesson after talking about the purpose of the study and giving brief information about origami-based instruction, researcher administered the SAT to all of the 4th, 5th, and 6th grade students in the school as a pretest. In total, 30 minutes was given to the students for completing the test. During the pretest, fourth grade students needed extra 5 minutes in order to complete the test. In the following week, implementation of origami-based instruction began for all participants and continued for 10 weeks for all grades. During origami-based instruction different origami figures were taught by the researcher in each week. In consequence of the school program in some weeks sequence of the origami model (a finished origami figure) was changed. At the end of the implementation, students in all grade levels made the same 10 origami model. After implementation of origami-based instructions for all grade levels, SAT was administered again as posttest. Then, students were asked to write reflection papers about the origami-based instruction, origami, and the relationship between origami and some concepts in mathematics. In writing reflections, students did not give much importance to reflection papers, they write very short answers to the questions. Since their grade level was low, it was thought that they were not able to write exactly what they thought. To get detailed reflection from participants, researcher asked the questions face to face again and noted the students' answers to their reflection papers. In these face to face meetings the answers were also recorded.

3.4.1. Origami-Based Instruction

A time schedule for the data collection and implementation procedure, and name of activities during origami-based instruction are given in Table 3.3.

Table 3.3 Time Schedule of the Data Collection and Implementation of Activities

Week	Date	4th grade	5th grade	6th grade
1st	February 11–February 15	School visit	School visit	School visit
2nd	February 18–February 22	Pretest	Pretest	Pretest
3rd	February 25–February 29	Crane	Crane	Crane
4th	March 3 – March 7	Jumping frog	Jumping frog	Jumping frog
5th	March 10 – March 14	Magic star	Magic star	Magic star
6th	March 17 – March 21	Water bomb	Water bomb	Water bomb
7th	March 24 – March 28	Fish & Hat	Fish & Hat	Fish & Hat
8th	March 31 – April 4	-	Cube	Cube
9th	April 7 – April 11	Spinner	Spinner	Spinner
10th	April 28 – May 2	Cube	-	Box
11th	May 5 – May 9	Box	Box	Star box

Table 3.3 (Continued)

12th	May 12 – May 16	Heart	Heart	Heart
13th	May 19 – May 23	Star box	Star box	-
14th	May 26 – May 30	Posttest	Posttest	Posttest
15th	June 2 – June 6	Reflection Paper	Reflection Paper	Reflection Paper
16th	June 9 – June 12	Reflection Paper	Reflection Paper	Reflection Paper

Origami-based instruction were implemented by the researcher and lasted to 10 weeks. As shown in Table 3.3, all of the grades had 10 weeks origami-based instruction during the semester.

In total, ten different origami-based mathematics lessons were prepared by the researcher. Sample activity plans can be seen in Appendix C. During the preparation of activities, related research studies in the literature were reviewed related to different origami models (Baicker, 2004; Beech, 2003a, 2003b; Franco, 1999; Fuse, 1990; Gurkewitz & Arnstein, 1995, 2003; Harbin, 1997; Kasahara, 2006; Kasahara & Takahama, 1987; Kawamura, 2001; Kenneway, 1987; Mitchell, 2005; Montroll, 2002; Smith, 2003; Soong, 2001). In addition, while preparing activity plans, origami models in mathematics textbooks published by Ministry of National Education were used.

Each of the origami-based mathematics lesson lasted in 40 minutes. According to the type of the origami model, students worked in a group or individually to complete the model. During the instruction, students were always encouraged to help each other if they have difficulties. Folding directions were given in mathematics language (for example; fold the square into half from its diagonal etc.) and each folding step of the origami model was illustrated by the researcher by using larger sized paper. Researcher always followed and controlled students' folding, and if students failed or did not understand the folding step researcher explained and showed it again. After each folding step the formed shapes and their properties were discussed. During the origami-based instruction questioning and discussion were frequently used. Throughout the origami-based instruction, regular mathematics teacher was always in the classroom and assist the students if they needed. After students completed the origami model, researcher and students summarized the geometrical concepts and mathematical terms that they encountered while making origami models. At the end of the lesson, students wrote what they learned from that lesson and its relationship to mathematics concept that they know. The following Table 3.4 indicates the aim of each origami-based instruction as weeks.

Table 3.4 Mathematical Aim of the Origami Models

Crane	Square, rectangle, pentagon, triangle, quadrilateral, diamond, area, symmetry, diagonals, line of symmetry, perpendicular lines.
Jumping frog	Parallel and perpendicular lines, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), rectangle, isosceles triangle, isosceles right triangle, pentagon.
Magic star	Square, rectangle, trapezoid, pentagon, parallelogram, octagon, rotation, fractions, lines of symmetry, diagonals, symmetry.
Water bomb	Square, rectangle, triangle, hexagon, cube, diagonals, line of symmetry, perpendicular lines, concurrency, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), ratio, fractions, symmetry.
Fish & Hat	Square, diagonals, triangles (isosceles right triangle, obtuse triangle), trapezoid, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), parallel and perpendicular lines, symmetry.
Spinner	Perpendicular lines, line of symmetry, diagonals, triangles, square, fractions, three dimensional shapes, symmetry.
Cube	Square, triangles, rectangle, trapezoid, parallelogram, cube, edge, parallel lines, symmetry, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), volume,
Box	Parallel lines, perpendicular lines, diagonals, fractions, three dimensional shapes, edge.

Table 3.4 (continued)

Heart	Rectangle, square, triangle, pentagon, perpendicular and parallel lines, lines of symmetry, diagonals, fractions, symmetry, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles).
Star box	Square, triangle, angles, lines of symmetry, diagonals, perpendicular lines, symmetry.

As seen in the table above shapes (square, rectangle, pentagon, triangle, quadrilateral, diamond, parallelogram, octagon, hexagon, isosceles triangle, isosceles right triangle, obtuse triangle), angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), three dimensional shapes, cube, edge, area, rotation, fractions, ratio, concurrency, symmetry, perpendicular and parallel lines, diagonals, and line of symmetry were covered in origami-based instruction, at the end of each implementation, students were summarized those terms which they learned during the origami-based instruction Furthermore, the detailed sample of origami-based instruction is given below.

In the activity named as magic star, students worked in pairs. Firstly, the colored square papers were distributed. After each group received their paper, every student took one piece of paper. Before folding the paper, the shape of the paper was asked. All of the students answered as “it was a square”. It was discussed why its shape was a square. Some of the students said it also had four equal sides, and some other said it had also four equal angles which were right angles. Then, it was shown that it was a square having four equal sides and four angles by folding the paper. The properties of the square were written on the board.

Each student took a piece of paper and began to make a module of magic star according to the researcher’s directions. Researcher used mathematical wording by giving directions and also used big sized paper to illustrate the folding steps. Firstly, the square sheet was folded into half up to down. The name of the formed shape was asked. Students answered as a rectangle, since it had four right angles, opposite sides had equal length and also they were parallel.

The folded paper was unfolded and it was rotated 90^{o} to the right and folded half up to down. It was unfolded again. The formed shape was asked again and its properties. Students answered as there were four small squares in the big square. Their areas were compared to the big square. In the previous two folding, two folding lines were formed. Properties of these lines were asked to the classroom. In each question different students took the floor. Here students explained these lines were two of the lines of symmetry. They also added there were two more lines of symmetry in a square which were diagonals.

Then the upper corners were folded into the center point of original square paper. In here the whole of a formed shape was a pentagon but most of the students called it a house firstly. When the researcher made an emphasis on it geometrical shape, they stated that it was a pentagon but it was not a regular one. This pentagon consisted of a triangle and a rectangle. Firstly, students were questioned about the properties of the triangle which was on the upper part of the pentagon. They discovered that it was an isosceles right triangle. Then, the ratio of the pentagon to the original square paper was discussed.

In the following folding step, the pentagon folded and unfolded into half right to left. Here a trapezoid was formed (It was asked only in 6^{th} grades). After that, for the small square in the left bottom side of the paper, a diagonal which is from center point to the left corner of the paper was folded, and it was unfolded again. Then the symmetric folding was done for the right side of the paper. Simultaneously, previous two foldings were done again. The formed shape was a parallelogram. Students stated that its sides were parallel. They tried to find out its ratio to the original square and its angles. That parallelogram was a one module of the origami model. Each group made eight of these modules to make the whole model.

The way of assembling first two modules was illustrated by the researcher. Then the other modules were assembled as the first two ones. In assembling the modules, the researcher assisted all groups one by one. Also, students helped each other in the assembling procedure. After finishing the assembling eight of the module students were discussed the formed shaped, octagon. Then, the pieces of the octagon were slided together to form an eight pointed star. The model was completed with that operation.

Finally, the whole lesson was discussed by the students and the concepts related with mathematics and geometry was summarized by the teacher.

The following figures consist of photographs taken in the classroom during the origami-based instruction.

Figure 3.6 Students Work on Assembling Modules

Figure 3.7 Researcher Shows Assembling Modules

Figure 3.8 Students Works on Magic Star

In this section, the data collection procedure and origami-based instruction were explained in detail, and the following section will give information about analysis of the data.

3.5. Data Analysis

In this study, both quantitative and qualitative research methodologies were used. In order to answer first and second research question quantitative data analysis, to answer third research question qualitative data analysis methods were utilized.

In quantitative data analysis, both descriptive and inferential statistics were used. All statistical analysis was carried out by using SPSS 11.5 windows program. In terms of descriptive statistics mean, standard deviation, skewness and kurtosis values of pretest and posttest of SAT were calculated. In addition, frequency and percentages were used to describe the demographics of the data. In order to examine the effect of the origami-based instruction on elementary students' spatial ability in mathematics, paired samples t-test was performed as inferential statistics. Moreover, Eta Square was calculated to find out the effect size that shows the practical significance of the results (Pallant, 2001). Furthermore, when t- test is performed, Type 1 and Type 2 errors have possibility to occur. Type 1 error occurs when the null hypothesis is rejected, but, in fact it is true (Pallant, 2001).

In order to answer second research question content analysis was used. More specifically, qualitative data obtained from reflection papers were read and then categories were formulated according to the responses. Example of the codes obtained by two coders can be seen in Appendix D.

This section gave information about the data analysis, and the next section will give information about assumptions and limitations of the study.

3.6. Assumptions and Limitations

In this section, the basic assumptions and limitations of the research study were discussed. First of all, it was assumed that all of the participants answer the questions in SAT, and reflection papers, and interviews seriously and accurately.

It was observed that most of the students answer to the questions in a given time. Also, it was assumed that difference scores were independent of each other.

In this study, the school was not selected by using random sampling procedures. In addition, the study was performed in a private school, thus, the sample did not consist of participants from public schools. Similarly, this study was one-group pretest-posttest design with no control group. Thus, those might limit the generalizability of the research findings to broader samples. Moreover, only 4^{th}, 5^{th}, and 6^{th} grades participated in the study and the small class sizes were limiting the comparison among grade levels.

Assumptions and limitations of the study were explained in this section; in the following and the final section of this chapter the validity of this study will be given.

3.7. Internal and External Validity of the Study

Both internal validity threats and external validity for this study were discussed in the last part of the methodology chapter.

3.7.1. Internal Validity

Internal validity of the study refers to the degree to which observed differences on dependent variable affected by the independent variable directly, not any other variables (Fraenkel & Wallen, 2006). In experimental studies, the possible internal validity threats are changed with respect to the research design. Subject characteristics, mortality, location, instrumentation (instrument decay, data collector bias, data collector characteristics), testing, history, maturation, attitude of subjects, regression, and implementation are the general internal validity threats for experimental research designs (Fraenkel & Wallen, 2006).

In this study one-group pretest-posttest design was used. Fraenkel and Wallen (2006) stated that in this experimental research design nine internal validity threats are present. These are history, maturation, instrument decay, data collector characteristics, data collector bias, testing, statistical regression, attitude of subjects, and implementation threats.

History was an important internal validity threat for this study. If some unexpected situations occurred during the study, the responses of the participant to the tests might be affected from this unwanted event. During this study any unexpected event did not occur. The passing time during the treatment could be a treat for maturation but in this study there are 13 weeks between pretest and posttest. Thus, maturation was not a threat for this study. If the scoring of an instrument is changing according to scorers or time to time, it could be a threat for instrument decay but multiple-choice items were used in this study to control this threat. Data collector characteristic could also be a possible treat for this research design, but there is only one group and only the researcher collected all the data from the participants. Most important internal validity threat was researcher bias in this study. In a study data collectors or scorers might unconsciously distort the data in an intended way so the outcomes support the hypothesis (Fraenkel & Wallen, 2006). In this study, the treatment was implemented by the researcher. Both pretest and posttest were administered in the classroom by the researcher. Since the researcher knows the purpose of the study, occurrence of the researcher bias is possible. In this study researcher was involved in the whole process, but also she was an outside observer. To control this bias, during the tests researcher gave importance to answering students' questions without giving any clues about the test questions or their answers. Furthermore, testing was another important threat to internal validity for the weak designs. Effect of pretest on the results of posttest could be a treat for testing, but to control this threat, the possible longest time interval, 13 week, was given between the intervention of pretest and posttest in this study. Moreover, if the participant were chosen according to their previous very high or very low scores, it could be a treat for statistical regression, but all 4^{th}, 5^{th}, and 6^{th} grade students were included in the study to control this internal validity threat. In a study if there were both control and experimental group participants, the experimental group can increase their interest since they are selected for a study. On the other hand, participant in the control group can be demoralized. These situations affect their performance which could be a threat for the attitude of subjects, but in this study all students in 4^{th} to 6^{th} grades participated as an experimental group.

Finally, implementation threat might occur if different people implemented (different) treatments differently, the objectivity of the tests was negatively affected. Moreover, if the implementer had personal bias for one of the treatments to another one, implementation threat might also have occurred. Implementation was not an internal validity threat for this study, since there was only one group, one method, and one implementer.

3.7.2. External Validity

External validity of the study refers to "the extent to which the results of a study can be generalized from a sample to a population" (Fraenkel & Wallen, 2006, p. 108). Target population of this study was determined as all 4^{th}, 5^{th}, and 6th grade students in Etimesgut district of Ankara. The accessible population of this study was determined as all 4^{th}, 5^{th}, and 6^{th} grade students in Eryaman neighborhood of Etimesgut district. The participants in this study were selected from one of private the schools in Eryaman neighborhood of Etimesgut district by using purposive sampling. Thus, the selected sample size did not provide population generalizability, which is generalizing results of the study to the intended population (Fraenkel & Wallen, 2006). However, the study was conducted in a private school and results could be generalized to the students in public schools. In other words, research study opens doors for ecological generalizability, which is generalizing results of the study to other conditions and settings (Fraenkel & Wallen, 2006).

CHAPTER 4

RESULTS

With the purpose of investigate the effect of origami-based instruction on elementary students' spatial ability in mathematics and examine students' self-reported perceptions related to origami-based instruction, this chapter aims to present the results in three main sections. The first section includes the descriptive statistics of pretest, posttest, and gained scores. The second section contains the inferential statistics of the quantitative analysis and the final section deals with the qualitative analyses.

4.1. Descriptive Statistics

In this section, descriptive statistics on pretest and posttest scores of SAT, pretest and posttest scores for each category of SAT and pretest and posttest scores for each factor of SAT will be given.

Thirty-eight elementary students responded to SAT generated by combination of TSV and PFT. Table 4.1 illustrates descriptive statistics for both pretest and posttest scores of SAT.

Table 4.1 Descriptive Statistics for Pretest and Posttest Scores of SAT

	Pretest (out of 35)	Posttest (out of 35)
N	38	38
Minimum	8.00	12.00
Maximum	34.00	34.00
Mean	22.21	25.03
Std. Deviation	5.09	6.53

Table 4.1 indicates that while 4th, 5th, and 6th grade elementary students had a mean score of 22.21 (*SD* = 5.09) on the pretest of SAT, and their mean scores in the posttest of SAT was 25.03 (*SD* = 6.53) out of 35. In addition to total scores obtained from SAT, Table 4.2, presents the descriptive statistics for pretest and posttest scores of each categories of SAT.

Table 4.2 Descriptive Statistics for Pretest and Posttest Scores for each Categories of SAT

		Pretest	Posttest
Spatial Task (out of 8)	N	38	38
	Minimum	4.00	3.00
	Maximum	8.00	8.00
	Mean	6.55	6.63
	Std. Deviation	1.25	1.13
Spatial Numerical Task (out of 8)	Minimum	1.00	1.00
	Maximum	8.00	8.00
	Mean	5.24	5.95
	Std. Deviation	1.84	1.97
Mental Rotation Task (out of 8)	Minimum	0.00	0.00
	Maximum	8.00	8.00
	Mean	3.47	4.79
	Std. Deviation	2.49	2.59
Informal Area Measurement Task (out of 5)	Minimum	0.00	0.00
	Maximum	5.00	5.00
	Mean	4.10	4.08
	Std. Deviation	1.47	1.36

Table 4.2 (Continued)

	Minimum	0.00	0.00
Paper Folding Task	Maximum	6.00	6.00
(out of 6)	Mean	2.84	3.58
	Std. Deviation	1.58	1.90

As shown in Table 4.2, elementary school students' pretest mean scores in the Spatial Task which was 6.55 (*SD* = 1.25) increased to 6.63 (*SD* = 1.13) in posttest. According to the table pretest mean scores in the Spatial-numerical Task which was 5.24 (*SD* = 1.84) increased to 5.95 (*SD* = 1.97) in posttest. Similarly, mean scores in Mental Rotation Task was increased from 3.47 (*SD* = 2.49) to 4.79 (*SD* = 2.59) in posttest. On the other hand, mean scores in Informal Area Measurement Task was decreased from 4.10 (*SD* = 1.47) to 4.08 (*SD* = 1.36) in posttest. Finally, pretest mean score in the Paper Folding Task was 2.84 (*SD* = 1.58) where it is 3.58 (*SD* = 1.90) in posttest.

As a result, the greatest increase from pretest to posttest was in Mental Rotation Task. The increase in the mean scores was 1.32 which constitutes 16.50 % of 8 which is the possible highest score in Mental Rotation Task. On the other hand, in Area Measurement Task mean score was decreasing from pretest to posttest. The decrease in the mean scores was 0.02 which constitutes 0.4 % of 5, which is the possible highest score in Area Measurement Task

Table 4.3 presents the descriptive statistics for pretest, posttest, and gained scores for two factors of spatial ability test namely, spatial visualization and spatial orientation. Spatial visualization included combination of Spatial Task, Spatial-numeric Task, Informal Area Measurement Task, and Paper Folding Task tests, whereas spatial orientation included only Mental Rotation Task test.

Table 4.3 Descriptive Statistics for Pretest, Posttest, and Gain Scores for Spatial Visualization and Spatial Orientation factors of SAT

		Pretest	Posttest	Gain (Posttest–Pretest)
Spatial Visualization (out of 27)	N	38	38	38
	Minimum	8.00	8.00	-11.00
	Maximum	26.00	26.00	12.00
	Mean	18.73	20.23	1.50
	Std. Deviation	3.98	4.92	4.49
Spatial Orientation (out of 8)	Minimum	.00	.00	-4.00
	Maximum	8.00	8.00	6.00
	Mean	3.47	4.79	1.32
	Std. Deviation	2.49	2.59	2.07

Table 4.3 indicates that while elementary students had a mean score of 18.73 (*SD* = 3.98) on the pretest of Spatial Visualization Test, their mean scores in the posttest of Spatial Visualization Test was 20.23 (*SD* = 4.92). In addition, the mean of gain score was 1.50 (*SD* = 4.49) which shows that there is an increase in elementary students' Spatial Visualization Test scores after the treatment. The gain score on Spatial Visualization Test constituted 5.59 % of 27, which was the highest possible score in Spatial Visualization Test.

Based on the results presented in the table, there is an increase in the mean scores of spatial orientation from pretest 3.47 (*SD* = 2.49) to posttest 4.79 (*SD* = 2.59) where, the average mean score was 1.32 (*SD* = 2.07). The gain score on spatial orientation constituted 16.5 % of 8, which is the highest possible score in Spatial Orientation Test.

4.2. Inferential Statistics

In the previous section, descriptive statistics on SAT, factors of SAT, and categories of SAT were mentioned. In this section inferential statistics will be given.

In this research study, there were two dependent and one independent variables. In this situation, conducting MANOVA is appropriate. Yet, Pallant (2001) mentioned that MANOVA works better only for moderately correlated dependent variables. Thus, Pearson product-moment correlation between gain scores of Spatial Visualization and Spatial Orientation Tests are given in Table 4.4.

Table 4.4 Result of Bivariate Correlations for Gain Scores in Spatial Visualization and Spatial Orientation Tests

		Spatial Visualization Gain	Spatial Orientation Gain
Spatial Visualization Gain	Pearson Correlation		0.24
	Sig. (2-tailed)		0.14
	N		38
Spatial Orientation Gain	Pearson Correlation	0.24	
	Sig. (2-tailed)	0.14	
	N	38	

As illustrated in Table 4.4, there was a small positive correlation between gain scores of spatial visualization and spatial orientation scores [$r = .24$, $n = 38$, $p > .05$]. In other words, the results of Pearson product-moment correlation between gain scores of spatial visualization and spatial orientation revealed that spatial visualization and spatial orientation had low correlation. Furthermore, Pallant (2001) suggested running univaritate analysis of variance separately for the dependent variables if two dependent variables had a low correlation. Thus, since the design of the present study was one group pretest-posttest design, running paired sample t-tests for each dependent variable is more appropriate than conducting repeated one-way ANOVA separately for dependent variables. Hence, in order to investigate the research hypotheses, paired sample t-tests were performed as inferential statistics.

4.2.1. The Effect of Origami-Based Instruction on Elementary Students' Spatial Ability

To investigate whether there is significant effect of origami-based instruction on elementary students' Spatial Ability Test (SAT) scores, paired sample t-tests were run for two factors of Spatial Ability; namely, spatial visualization and spatial orientation.

4.2.1.1. Assumptions of Paired Samples t-test

Before conducting the analysis, two assumptions of paired samples t-test stated by Green and Salkind (2005) were checked. To check normal distribution of the gain scores, Kolmogorov-Simirnov statistics was run. Table 4.5 presents the test of normality results.

Table 4.5 Results of Kolmogorov-Simirnov Test

	Statistic	df	Sig.
Spatial Visualization – Gain score	0.13	38	0.09
Spatial Orientation – Gain score	0.17	38	0.01

As shown in Table 4.5, significance value of gain scores of spatial visualization was 0.09 indicating the normality. On the other hand, significance value of gain scores of spatial orientation was 0.01 which indicates the violation of normality assumption. However, Central Limit Theorem stated that the distribution can be accepted as normal if the sample size is larger or equal to 30 (Gravetter & Wallnau, 2004). Thus, depending on central limit theorem the distribution can be accepted as normal. The following evidences also verified the normality of the distribution of the gain scores. Table 4.6 illustrates the skewness and kurtosis values for spatial visualization and spatial orientation scores.

Table 4.6 Skewness and Kurtosis Values of Spatial Visualization and Spatial Orientation Test scores

		Pretest	Posttest	Gain (Posttest - Pretest)
	N	38	38	38
Spatial Visualization (out of 27)	Skewness	-0.26	-0.76	-0.37
	Kurtosis	0.35	-0.12	1.43
Spatial Orientation (out of 8)	Skewness	0.54	-0.01	0.02
	Kurtosis	-0.82	-1.47	0.46

Table 4.6 shows the skewness and kurtosis values for pretest, posttest, and gain scores for the spatial visualization and spatial orientation test scores. These values changes between -1.47 and 1.43 indicating that the distribution of pretest, posttest, and gain scores of both dimensions of spatial ability test were normally distributed (George & Mallery, 2003).

In addition to evidences for normality mentioned above, histograms of gain scores of spatial visualization and orientation are represented in Figure 4.1 and Figure 4.2 respectively.

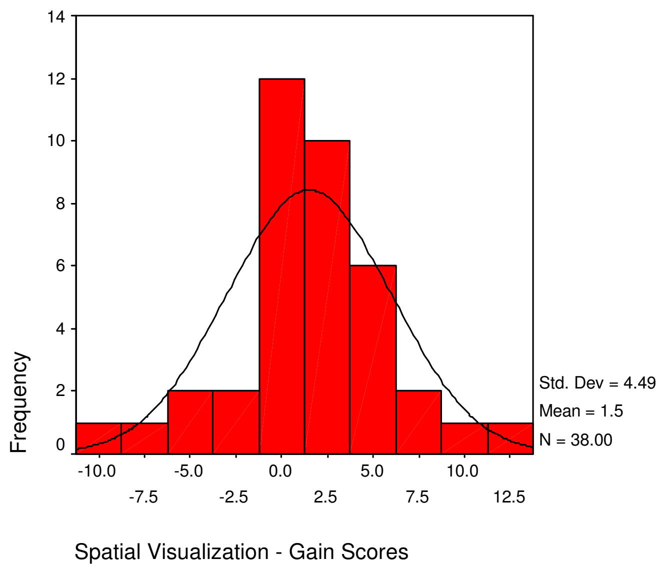


Figure 4.1 Histogram of Gain Scores of Spatial Visualization Test Scores

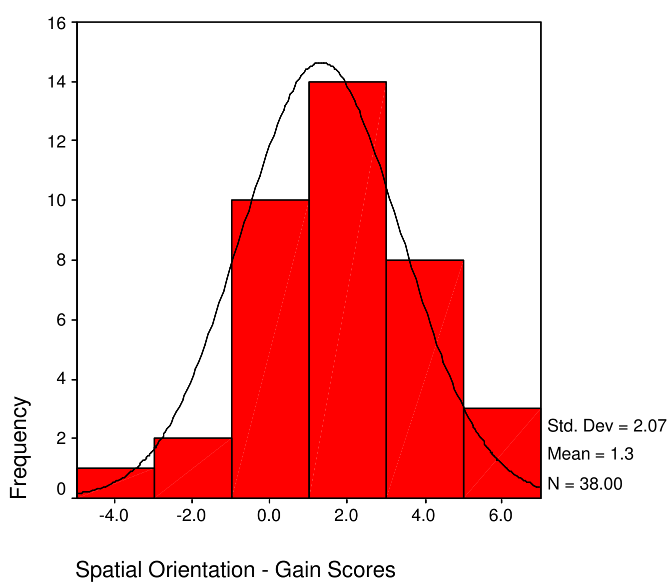


Figure 4.2 Histogram of Gain Scores of Spatial Orientation Tests Scores

The histograms with normal curves also provide additional evidence for the normality of gain scores of both spatial visualization and spatial orientation test scores. Normal Q-Q plots of gain scores of spatial visualization and orientation are also represented in Figure 4.3 and Figure 4.4, respectively.

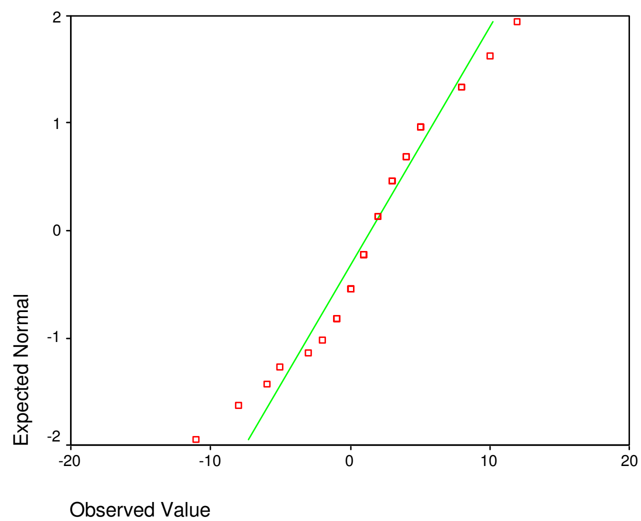


Figure 4.3 Normal Q-Q Plots of Gain Scores of Spatial Visualization

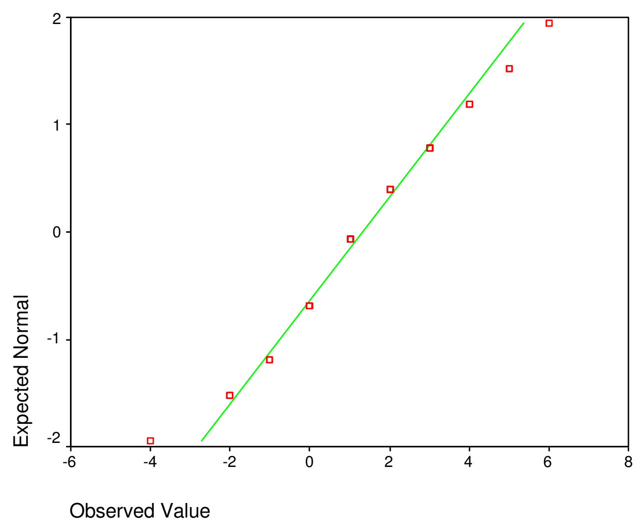


Figure 4.4 Normal Q-Q Plots of Gain Scores of Spatial Orientation

When Normal Q-Q Plots of gain scores of both spatial visualization and spatial orientation were examined, almost straight lines were observed suggesting a normal distribution.

The second assumption for paired samples t-test indicates that "The cases represent a random sample from the population, and the difference scores are independent of each other" (Gravetter & Wallanu, 2004, p. 162). In this study it was assumed that difference scores were independent of each other.

4.2.1.2. Investigation of Research Problems

As mentioned above**,** to investigate whether there is significant effect of origami-based instruction on elementary students' Spatial Ability Test (SAT) scores, dependent variables were taken into account separately.

Is there a significant change in fourth, fifth, and sixth grade students' spatial visualization scores following participation in origami-based instruction?

A paired samples t-test was conducted to evaluate the impact of the origami-based instruction on elementary students' spatial visualization ability. The results were presented in Table 4.7.

Table 4.7 Paired Samples t-test for Spatial Visualization

		Mean difference	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Spatial Visualization Pretest Score - Spatial Visualization Posttest Score	-1.50	4.49	-2.06	37	0.046

Results revealed that there was a statistically significant effect of origami-based instruction on elementary students' spatial visualization scores ($t(37) = -2.06$, $p < .05$). The mean difference (posttest score in spatial visualization – pretest score in Spatial visualization) was 1.50.

The effect size is evaluated by eta squared statistic computed by formula given below (Pallant, 2001, p. 184).

$$\text{Eta squared} = \frac{t^2}{t^2 + N - 1} \qquad (4.1)$$

According to the Cohen's (1977) guidelines for paired samples t-test, the eta squared statistics calculated as 0.10. Thus, 10% of the variance in the difference scores was explained by the effect of origami-based instruction. The calculated effect size referred to a medium effect size indicating practical significance in addition to statistical significance.

Is there a significant change in fourth, fifth, and sixth grade students' spatial orientation following participation in origami-based instruction?

Similarly, a paired samples t-test was conducted to interpret the impact of the origami-based instruction on elementary students' spatial orientation ability. The results were presented in Table 4.8.

Table 4.8 Paired Samples t-test for Spatial Orientation

		Mean difference	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Spatial Orientation Pretest Score - Spatial Orientation Posttest Score	-1.32	2.07	-3.92	37	0.000

Results revealed that there was a statistically significant effect of origami-based instruction on elementary students' spatial orientation scores ($t(37) = -3.92$, $p < .05$). The mean difference (posttest score in spatial orientation – pretest score in spatial orientation) was 1.32. The eta squared statistics was calculated as 0.29 which meant 29% of the variance in the difference scores was explained by the effect of origami-based instruction. According to Cohen's (1977) guidelines, 0.29 indicated a large effect size. Similarly, the large effect size verified that there was practical significance in addition to statistical significance.

One of the purposes of this study was to investigate the effect of origami-based instruction on elementary students' spatial ability in mathematics. In this section, to investigate the effect of origami-based instruction on elementary students' spatial ability in mathematics, first two research questions were answered by using quantitative methods. As a result, there is a significant positive effect of origami-based instruction on elementary students' spatial visualization and spatial orientation scores. Another purpose of this was to examine students' self-reported perceptions related to origami-based instruction. In the next section of analysis, the qualitative analysis results of the third research question will be given.

4.3. Self-reported Perceptions of Students related to Origami-Based Instruction

Reflection papers were administered and face to face meeting were done to disclose students' self-reported perceptions related to origami-based instruction. In other words, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcome these difficulties were investigated. In this section, analysis based on the topics mentioned above will be presented.

4.3.1. Students' Attitudes toward Origami-Based Instruction

Analysis of students' reflection papers and their face to face meeting reports show that nearly all of the students had a positive attitude toward origami-based instruction. More specifically, thirty-seven (97.4%) students had positive thoughts about origami-based instruction. Remaining student did not point out his opinion related to origami-based instruction. Students indicated their positive attitudes by using the following adjectives: entertaining, enjoyable, good, and beautiful. The thirty two students (84.2%) mentioned that origami-based instruction was entertaining and enjoyable where 21 (55.3%) students stated that origami-based instruction was good and beautiful. For instance:

Student 8: “Origami was very entertaining. Sometimes I can not do it but I am trying to do it. Generally we are having fun so much in origami courses (MR-S8).”

Student 27: “We had a good time in origami classes. In every origami class we learnt new things. Anyway every class was very entertaining. When mathematics classes bored us, passing to origami was very entertaining” (MR-S27).

Another student said that:

Student 13: “I think that origami classes are very good. One of my friends made origami before and I was so curious about how she did it. After origami classes were started I began to learn slowly how to make origami models, and I am enjoying making origami” (MR-S13).

Similarly, following students thought that it was enjoyable:

Student 14: “Origami was enjoyable. We had some difficulties in folding some parts but at the end good things came out” (MR-S14).

Student 23: “It was so enjoyable. In my opinion, we had a good time in origami courses. I made lots of figures by folding. It was so enjoyable for me” (MR-S23).

Parallel to this view, another student mentioned the followings:

Student 29: “I think origami classes are good, for example, we are learning things which we do not know. Since it was an entertaining course I like it. We are learning a lot of thing in origami courses. I enjoy what we learn and I have a good time” (MR-S29).

Furthermore, Thirty six (94.7%) students stated that they want to continue origami-based instruction in the following years. For instance:

Student 4: “I want to continue making origami activities. I show my origami models to my family, they are proud of my success (RP-S4).” “I want to continue making origami. I taught few origami models to my mother. My sister also likes it. We are planning to make origami together in the summer. My mother will buy colored papers and we will make them together” (MR-S4).

Other students mentioned that:

Student 11: “I want to continue origami since it is an enjoyable course. Before origami classes, we went to mathematics club but we did not do anything, we only play games. But after origami lesson I can take something to my parents, I can make different origami models. Also, I am learning mathematics; it helps in mathematics” (MR-S11).

Similarly, the following student wanted to continue origami activities:

Student 17: “I want to continue origami, because making origami is really enjoyable. ı think that making origami as a lesson is good” (MR-S17).

Student 25: “I want to continue origami for everyday” (RP-S25).

Student 37: “I want to continue origami, because origami classes are so enjoyable and entertaining” (RP-S37).

On the other hand, one of the students stated that sometimes he got bored during origami-based instruction. For instance:

Student 6: “Origami classes are enjoyable but beginning of the classes are enjoyable, in the middle of the classes I began to get bored” (MR-S6).

In this section, students’ attitudes toward origami-based instruction were analyzed by using qualitative methods. The results showed that 97.4% of the students had positive attitude toward origami-based instruction. They generally mentioned that origami classes were entertaining, enjoyable, good and beautiful. Also, students indicated their positive attitude toward origami-based instruction by their own wishes and to continue these classes. In the next section, students' views about the origami-based instruction and its connection to mathematics will be given.

4.3.2. Students' Views about the Benefits of Origami-Based Instruction and its Connection to Mathematics

Analysis of students' reflection papers and their face to face meeting reports showed that all of the students have common views that origami-based instruction was directly related to mathematics. More specifically, this relation can be categorized into three groups as (i) using mathematical terms, (ii) thinking that it is beneficial for mathematics and geometry, and (iii) thinking that it helps to understand the subject which they have difficulty with. All of the students (100%) mentioned that they used terms related with mathematics during the origami-based instruction. Those were the examples of terms that were stated by students during origami-based instruction: triangle, square, rectangle, angles, diagonal, pentagon, trapezoid, sides, quadrilateral, symmetry, hexagon, parallelogram, geometrical object, fractions, rhombus, deltoid, area, length, line, and rotation. For instance:

> Student 20: "While making samurai hat, we talked about the trapezoid, isosceles triangle, equilateral triangle, and scalene triangle. We also emphasized that the top and bottom bases of the trapezoid were parallel to each other. We fold the angles 45^o and $22,5^o$" (RP-20).

Similarly another student mentioned that the used terms were related with mathematics:

Student 24: "At the beginning of every origami lesson the paper was square. There were triangle and rhombus in the origami models as cube, box, and bird. We made origami by rotating 90^o and 180^o angles. We also use the fractional expressions as $\frac{3}{4}$ and $\frac{8}{16}$. We always use geometrical objects. We also go over the terms like right triangle, acute triangle. Sometimes we encountered some shapes like parallelogram" (RP-S24).

Moreover, thirty-six (94.7%) students thought that origami-based instruction is beneficial for mathematics and geometry lessons. For instance:

Student 9: "Origami is beneficial for us in terms of mathematics and geometry, because origami came out from mathematics (RP-S9). For example, as I said before origami is helping me to understand the subjects which I have difficulty with" (MR-S9).

Parallel to this view other students mentioned that:

Student 18: "Origami is beneficial for us in terms of mathematics and geometry, because while making origami we are using mathematical terms. This helps to reinforce the subjects which we learn in mathematics courses" (RP-S18).

Student 17: "I think that origami is beneficial for us in terms of mathematics and geometry. While making origami, you are creating the geometry and symmetry by yourself, by this way you can comprehend mathematics sooner" (MR-S17).

Furthermore, twenty-nine (76.3%) student stated that origami-based instruction helped them to understand the subjects which they had difficulty with. Angles, geometrical shapes, area, and fractions are the examples in which students stated that they began to understand them more clearly after origami-based instruction. For instance:

> Student 10: "For example; I had a difficulty in angles but now I learned it better. For example; if we rotate the right triangle, it looks like an acute triangle, but it is still right triangle. I understand it better" (MR-S10).

Similarly, following students had some difficulties in mathematics but they overcame it in origami classes.

> Student 19: "I did not know the numbers of edges of a cube but after studying origami I know it" (MR-S19).

> Student 26: "During mathematics classes I did not understand how to measure the area of informal areas, but when we made shapes and found its area in origami, I understand it better" (MR-S26).

Another student mentioned that she discovered new things in those classes, for instance:

> Student 4: "I did not know that the diagonals of pentagon constitute a five-point star, but I folded the diagonals of a pentagon accidentally then I realized that it was five-point star. I liked it" (MR-S4).

The students thought that origami-based instruction has other benefits for instance; eight (21.1%) students mentioned that their handcraft has been developing, five (13.2%) students stated that origami improved their imagination and creativity, two (5.3%) students said that it improved their intelligence, and one (2.6%) student thought that it made them relax. For instance:

> Student 4: "Origami is very enjoyable and also improves my imagination and intelligence" (MR-4).

Similarly,

> Student 21: "Origami is beneficial for us since it improves the handcraft. Also our imagination improves" (MR-21).

> Student 20: "My handcraft was not good before, but in origami classes it developed" (RP-20).

In this section, students' views about the origami-based instruction and its connection to mathematics were analyzed by using qualitative methods. The results indicated that all of the students (100%) mentioned that they used terms related with mathematics during the origami-based instruction. Moreover, thirty-six (94.7%) students thought that origami-based instruction is beneficial for mathematics and geometry lessons. Furthermore, twenty-nine (76.3%) students stated that origami-based instruction helped them to understand the subjects which they had difficulty with. Also, eight (21.1%) students mentioned that their handcraft has been developing, five (13.2%) students stated that origami improved their imagination and creativity, two (5.3%) students said that it improved their intelligence, and one (2.6%) student thought that it made them relax. In the next section, the difficulties that students were encountered during origami-based instruction and by whom they overcome these difficulties will be given.

4.3.3. Difficulties that Students Were Encountered During Origami-Based Instruction and by Whom They Overcome these Difficulties

Finally, analysis of students' reflection papers and their face to face meeting reports showed that thirty-six (94.7%) of the students encountered difficulties during origami-based instruction. Difficulties that students encountered could be categorized into three general groups as (i) folding difficulties, (ii) assembling difficulties, and (iii) technical difficulties. The results revealed that thirty-five (92.1%) students had difficulties in folding. Indeed, folding difficulties could be categorized into three groups as not folding properly, not understanding how to fold, and folding wrongly. Twelve students (31.6%)

stated that they had difficulty since they could not fold origami models properly. In other words, those students obtained the intended origami model badly because of the not making neat foldings in some steps. For instance:

> Student 1: “I had difficulties in folding, for example, while I was folding triangle, it was overflowed so I couldn’t fold it” (MR-S1).

> Student 31: “I couldn’t fold some parts. Also, I can not fold completely fine since it is not matching” (RP-S31).

In addition, nine (23.7%) students mentioned that they could not fold because they did not understand how to fold in some steps. For instance:

> Student 9: “During the origami activities, I usually do not understand where I should fold. There is not any other difficulty in origami” (MR-S9).

> Student 34: “I could not fold some models, to illustrate, when we folded we got some shapes, but sometimes I was not able to do it. I can not understand where I should fold it to get the correct figure” (MR-S34).

Also, seven (18.4%) students expressed that they had difficulty in folding since they folded the figures wrongly. In other words, those did not obtain the intended origami model because of the wrong folding. For instance:

> Student 7: “Sometimes I folded inversely, for this reason the figures came out inversely. There is not any other difficulty” (MR-S7).

> Student 27: “I did not encounter any difficulty but sometimes I folded wrongly” (MR-S27).

As mentioned before students generally had difficulties in folding, in assembling, and some technical difficulties. Seven (18.4%) student stated that they had difficulty in assembling modules in modular origami. For instance:

> Student 18: "Sometimes assembling modules in modular origami is very difficult but classic origami is so entertaining and very easy" (RP-S18).

> Student 28: "For example, when we made something related with assembling, it was difficult to assemble it" (MR-S28).

Finally, three (7.9%) students had technical difficulties. In other words, students stated that some origami models were torn or jumping frog (one of the origami model) was not jumping. For instance:

> Student 4: "While I was making a crane, I had torn the wings of the crane. Wings of the crane could be torn since it was flapping its wings. I made it again because it was torn" (MR-S4).

> Student 6: "I encountered some difficulties, such as, tearing. Also, I made a frog but it was not jumping; then I made it again. The new frog was jumping" (MR-S6).

> Student 16: "While I was making some origami models, for example, folding a bird, we had to open its wings. While I was opening the wings, it was torn. I had such difficulties like this" (MR-S16).

In addition to difficulties discussed above, 18 (47.4%) students stated that they could overcome the difficulties that they encountered during origami-based instruction. More specifically; 14 (36.8%) students mentioned that they overcame the difficulties by the help of the teacher, 8 (21.1%) students mentioned that they overcame the difficulties by the help of their friends, and 7 (18.4%) students by themselves. For instance, Student 10: “I got assistance from my teacher, sometimes when you were busy; I received help from my friends” (MR-S10).

Student 17: “At the beginning, folding was a bit difficult, I could not make folding properly, but I improved myself, now I am folding properly” (MR-S17).

In this section, the difficulties that students were encountered during origami-based instruction and by whom they overcome these difficulties were analyzed. The results indicated that thirty-six (94.7%) of the students encountered difficulties during origami-based instruction, which was categorized into three groups as folding difficulties, assembling difficulties, and technical difficulties. Moreover, 18 (47.4%) students stated that they could overcome the difficulties that they encountered during origami-based instruction. The students overcome those difficulties by themselves, by the help of the teacher, and by the help of their friends.

In the qualitative part of the analyses students' self-reported perceptions related to origami-based instruction were examined. More specifically, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami, and as well as by whom they overcome these difficulties were investigated.

These results will be discussed in the next chapter.

CHAPTER 5

DISCUSSION, IMPLICATIONS AND RECOMENDATIONS

The main purpose of the study was to investigate the effect of origami-based instruction on fourth, fifth, and sixth grade students' spatial ability in mathematics. Another purpose of this study was to investigate students' self-reported perceptions related to origami-based instruction. In other words, students' attitude towards origami-based instruction, their views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcame these difficulties were investigated.

In this chapter findings will be discussed in line with the previous research studies. In addition, implications and recommendations for the future research studies will be presented.

5.1. The Effect of Origami-Based Instruction on Spatial Ability

In this study to investigate whether there is a significant effect of origami-based instruction on elementary students' spatial ability scores, dependent variables were taken into account separately. Paired sample t-test results indicated that there was a statistically significant effect of origami-based instruction on both spatial visualization scores and spatial orientation scores.

Results indicated that origami-based instruction had a positive impact on elementary students' spatial ability. In other words, students took advantage of the spatial training. Although there were few studies which indicated non significant results about the effects of spatial training on spatial visualization, many studies discussed that spatial visualization ability could be developed by training (Allias et al., 2002; Battista et al., 1982; Ben-Chaim et al., 1988; Brinkmann, 1966; Connor et al., 1978; Olkun, 2003c; Rafi et al., 2005; Salthouse et al., 1990). Similarly, the studies related with spatial orientation also indicated that training might be resulted in the development of spatial orientation (Bayrak, 2008; De Lisi & Wolford, 2002; McGee, 1978). More specifically, in this study the results revealed that spatial visualization ability and spatial orientation ability could be improved separately by spatial related treatment. This conclusion can be interpreted as origami-based instruction has an impact on students' spatial abilities. In other words, origami-based instruction could be regarded as one of the appropriate instructional methods which can be used to improve spatial ability of students.

Researchers mentioned that the used treatments in their studies were spatial in nature. In other words, those treatments included activities which emphasized on visual methods, technical drawings, and visualization topics. This could be the reason of the improvement in spatial ability. When the nature of the instruction (origami-based instruction) was considered, many authors and researchers mentioned that origami could be used in teaching topics in mathematics especially related with spatial visualization (Bayrak, 2008; Carter & Ferruci, 2002; Chan, 2006; Coad, 2006; Kavici, 2005; Levenson, 1995; Sze, 2005b). This can be resulted from the nature of content of the origami-base instruction. In origami-based instruction students see everything visually and they transform the two dimensional paper into three dimensional shape by themselves. In other words, they have a chance to learn the concepts while they were actively involved in the process. Thus, it could be deduced that actively involvement into the process and creating 3D figures by folding papers could be an important factor in developing students' spatial visualization and orientation.

On the other hand, as mentioned above there were few studies which indicated no significant effect of instruction on spatial ability and spatial visualization (Boakes, 2009; Boulter, 1992; Boyraz, 2008; Ferrini-Mundy, 1987). Common point of these studies was the limited duration of the treatment which could be the reason of the non significant results of the studies. In other words, duration of the implementation could be an important factor in developing spatial ability with respect to spatial visualization and spatial orientation ability. Thus, another reason for the improvement of spatial ability in this research study could be the 10 week duration of the treatment.

Another aspect of this study was investigating the self-reported perceptions of students' related to origami-based instruction. The qualitative results revealed that students' self-reported perceptions related to origami-based instruction can be grouped into three main categories; students' attitude towards origami-based instruction, students' views about the benefits of origami-based instruction and its connection to mathematics, and the difficulties that students encountered while making origami as well as by whom they overcome these difficulties.

The results related with the attitudes of students toward origami-based instruction revealed that nearly all of the students had positive attitudes. Students indicated their positive thoughts about origami-based instruction by using the following words 'entertaining, enjoyable, good, and beautiful'. These results were supported by Boakes (2009) where in her study; students showed their attitudes by positive statements like: fun, helpful, enjoyable, and awesome. Also, most of the students want to continue origami-based instruction in the following years which can be an indicator of students' positive attitudes. During the origami-based instruction, students made origami with their friends by involving the process actively. This could be the reason of their positive attitude toward origami-based instruction. Moreover, students did not use classical methods to learn concepts in mathematics; they learned them by origami which was new for them. This new method could draw their attention and affect their positive attitude toward origami-based instruction. In addition, students' positive attitudes toward origami-based instruction could be a reason to enhance their spatial abilities as mentioned above. Since, students were always interested in origami classes, and followed the folding directions which were given by using mathematical terminology.

Furthermore, results revealed that students have common views that origami-based instruction was directly related to mathematics. More specifically, all of the students mentioned that they used terms related with mathematics during the origami-based instruction. These terms were triangle, square, rectangle, angles, diagonal, pentagon, trapezoid, sides, quadrilateral, symmetry, hexagon, parallelogram, geometrical object, fractions, rhombus, deltoid, area, length, line, and rotation. Many researchers and authors mentioned that origami activities give opportunities to use and learn mathematical skills (Chen, 2006; Coad, 2006; Levenson, 1995; Higginson & Colgan, 2001; Pope, 2002). Consistent with these studies, students emphasized the usage of mathematical terms during origami-based instruction in this research study also. Furthermore, students highlighted that origami-based instruction helped them to understand the concepts which they had difficulty with; such as, angle, geometrical shapes, area, and fractions. In this context, the results concur with the findings of Boakes (2009) which indicated that students have positive views on the benefits of origami in mathematics. In addition, students had the view that origami-based instruction develop handcraft, improve imagination, creativity and intelligence, make them relax which were consistent with the previously research studies (Levenson, 1995; Tuğrul & Kavici, 2002).

Finally, the result revealed that most of the students encountered difficulties during origami-based instruction, such as in folding, assembling and some technical difficulties. In this research students were acquainted with the origami-based instruction which was new for them. Thus, this could be the reason of the difficulties they encountered during the instruction. Some of the students overcome those difficulties by themselves, by the help of the teacher, and by the help of their friends. During origami-based instruction students had a chance to request assistance from the teacher who is the researcher when they had difficulty in making origami models. In addition, they were always working their friends, and they have chance to ask for help from their friends when they needed. In addition, it can be inferred that working coordinately with friends and teachers could have a positive effect on students' attitudes. In the reviewed literature there is not any evidence related with the difficulties or how they overcome it. Therefore this study contributes to the literature in this context.

All of the results revealed that spatial ability and its factors can be developed by origami-based instruction; and students' self-reported perceptions related to origami-based instruction were positive. Therefore, as mentioned above students' positive self-reported perceptions related to origami-based instruction could also have an effect on students' spatial ability in terms of spatial visualization and spatial orientation ability.

5.2. Implications and Recommendations

This study is mainly focused on the effects of origami-based instruction on elementary students' spatial abilities in terms of spatial visualization and spatial orientation abilities. In addition, it emphasized students' self-reported perceptions related to origami-based instruction. Based on the analysis of the data, some recommendation for further research studies can be proposed.

The design of this study was one group pretest and posttest design. There is only experimental group in this study. A similar research study might be replicated with control group to identify the effect of origami-based instruction on spatial ability.

Furthermore, this study analyzed the only data collected from 4^{th}, 5^{th}, and 6^{th} grade students in a private school. It did not investigate the effect of grade level, school type and gender, since the class sizes were very small. A similar study might be conducted with other grades in both public and private schools; and the effect of grade level, type of school and gender might be included in the analyses.

Moreover, similar research study might be replicated to investigate the effect of origami-based instruction on students' achievement or the relationship between spatial ability and achievement. In addition, the relationship between self efficacy of students in origami and spatial ability can be investigated in the further studies.

In addition, this study might be conducted by using origami-based instruction in a different way. For instance, using videos of origami models and using origami diagrams.

Finally, there are some implications for mathematics teachers, mathematics teacher educators, and curriculum developers. As mentioned before origami was included in the new elementary mathematics program and this research study investigated the effect of origami-based instruction on elementary students' spatial ability in mathematics. The results revealed origami-based instruction used in mathematics classes had both statistically and practically significant effect on spatial abilities of students. Therefore, mathematics teachers and mathematics teacher educator should be informed about the origami-based instruction. In other words, seminars related with teaching origami in mathematics lessons should be planned for mathematics teachers and mathematics teacher educators. In addition, in order to make mathematics teachers more sufficient in this context, courses related with origami teaching in mathematics for preservice teachers should be offered or these topics should be mentioned in mathematics education courses.

During the origami-based instruction, it was observed that students asked every steps of folding procedure they performed to confirm the correctness of the origami model which they completed. Since, this study was conducted in small size classes it did not constitute any problem for origami-based instruction. However, in order to use origami-based activities in crowded classrooms, teachers should either use group work or give origami diagrams before the origami-based instruction.

Furthermore, in present study, the difficulties that student encountered while making origami was investigated. Therefore, these findings should be shared with both mathematics teachers and mathematics teacher educators in order to remove. Furthermore, suggestion for how overcome the encountered difficulties should be given to mathematics teachers.

Moreover, this study revealed that origami-based instruction could be used as an instructional tool in mathematics classes to improve students' spatial abilities. Therefore, curriculum developers should make authors include more origami activities in mathematics textbooks. Also, there should be origami books for both students and teachers which included mathematics activities. For instance, the book for students should contain activity sheets about the mathematical concepts which were emphasized by the origami activities. And the book for teachers should be a guide which includes how origami activities were performed by emphasizing the mathematical concepts.

5.3. Reflections about my Future Profession

As I mentioned before, during my education in elementary mathematics education department and as being an origami instructor in TJCC, I always have some questions in my mind. These questions were "Can we use origami in mathematics classes or not? If yes, how?", and "Can we use origami to evaluate students learning in mathematics classes or not? If yes, how?". In this context, this study revealed that origami could be used as an instructional tool in mathematics classes. The results of this study also revealed that students had positive attitudes toward origami-based instruction, and they willing to make origami activities in mathematics classes. I believe that I will use origami-based instruction in my mathematics classes in my future profession as a mathematics teacher.

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APPENDICES

APPENDIX A

Spatial Ability Test

Sevgili öğrenciler:

Bu testin amacı sizlerin uzamsal yeteneklerinizi ölçmektir. Testin sonuçları sadece bilimsel bilgi edinmek amacıyla kullanılacaktır. Herhangi bir şekilde not ile değerlendirme amacıyla kullanılmayacaktır. Bu amaçla:

1. Aşağıda size ait bilgileri eksiksiz olarak doldurunuz.
2. Sayfayı çevirdikten sonra göreceğiniz soruları okuyarak size en uygun gelen seçeneği işaretleyiniz.
3. Bilmediğiniz soruyu geçiniz.
4. Testi tamamlamak için 30 dakika süreniz vardır.

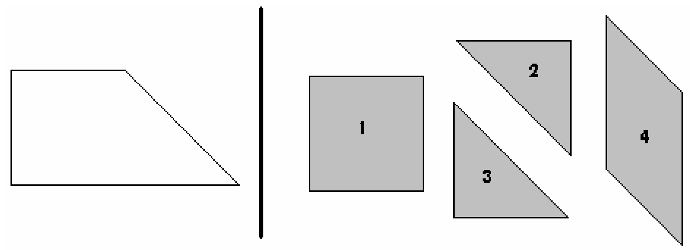
Teşekkürler.

Sedanur Çakmak
Yüksek Lisans Öğrencisi
ODTÜ Eğitim Fakültesi
sedanurcakmak@gmail.com

ADI SOYADI : ....

SINIFI : ..../......

1. Aşağıdaki gri şekillerden hangileri ile soldaki şekil <u>kaplanamaz</u>?



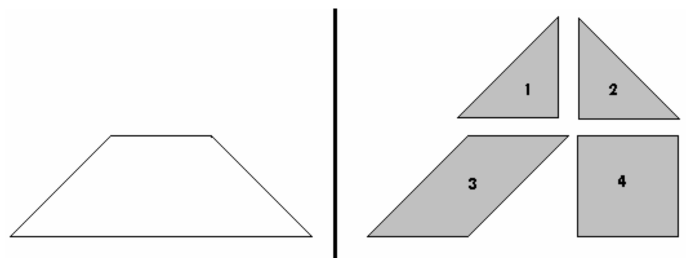
A) 1 ve 2

B) 1 ve 3

C) 3 ve 4

D) 1 ve 4

2. Soldaki şekli kaplamak için sağdaki numaralı şekillerden hangilerini kullanmak gerekir?



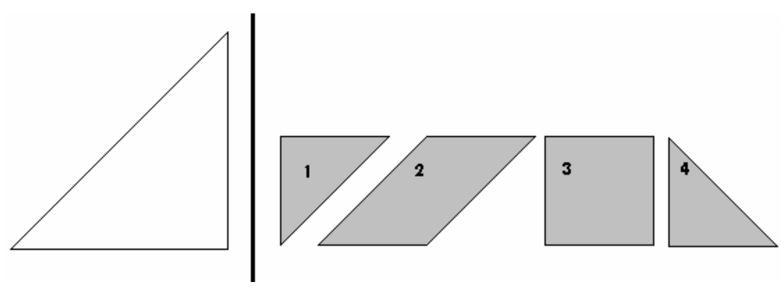
A) 1 ve 2

B) 1 ve 3

C) 1, 2 ve 4

D) 3 ve 4

3. Soldaki şekli kaplamak için sağdaki numaralı şekillerden hangilerini kullanmak gerekir?



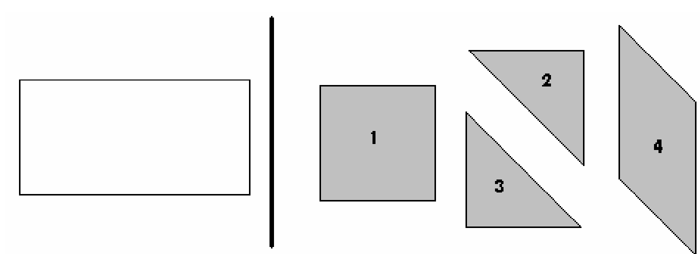
A) 1, 3 ve 4

B) 1 ve 3

C) 1 ve 2

D) 3 ve 4

4. Soldaki şekli kaplamak için sağdaki numaralı şekillerden hangilerini kullanmak gerekir?



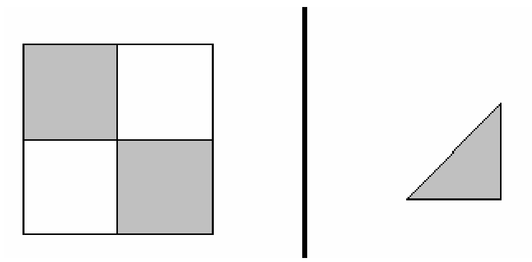
A) 1 ve 2

B) 1, 2 ve 3

C) 1, 2 ve 4

D) 3 ve 4

5. Soldaki şekilde boş bırakılan yerleri kaplamak için sağdaki gri üçgenden kaç tane kullanmak gerekir?



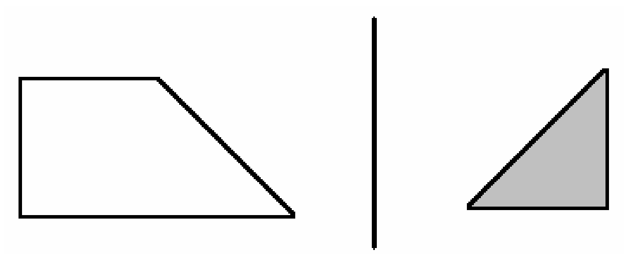
A) 2

B) 4

C) 6

D) 8

6. Soldaki şekli kaplamak için sağdaki gri üçgenden kaç tane kullanmak gerekir?



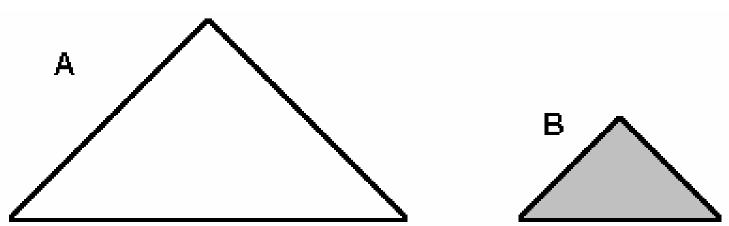
A) 3

B) 4

C) 5

D) 6

7. Aşağıda solda bulunan A üçgenini kaplamak için sağda bulunan gri B üçgeninden kaç tane kullanmak gerekir?



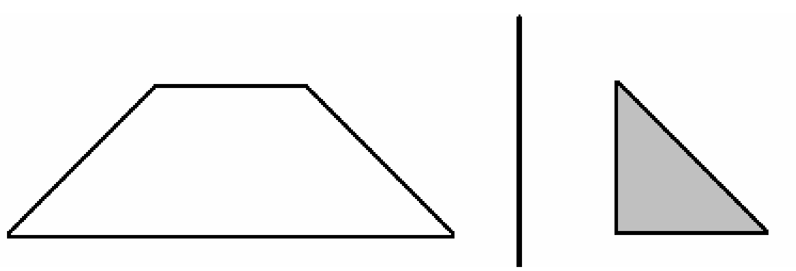
A) 2

B) 3

C) 4

D) 5

8. Aşağıda solda bulunan şekli kaplamak için sağda bulunan gri üçgenden kaç tane kullanmak gerekir?



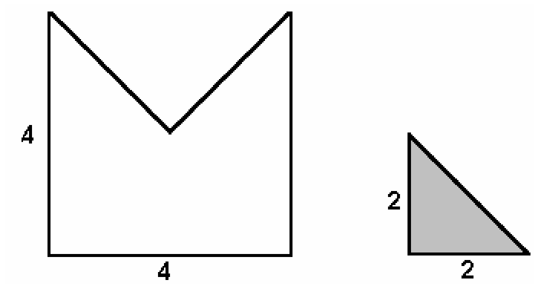
A) 2

B) 3

C) 4

D) 5

9. Aşağıda solda bulunan geometrik şekli kaplamak için sağda bulunan gri üçgenden kaç tane kullanmak gerekir?



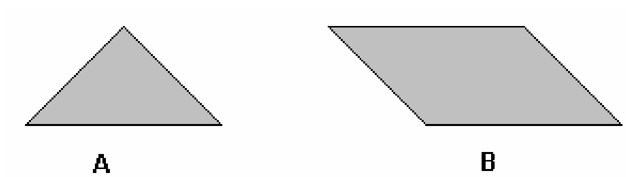
A) 3

B) 4

C) 5

D) 6

10. Elimde bir geometrik şekil var. Bu şekli kaplamak için aşağıdaki A şeklinden 6 tane kullanmam gerekmektedir. Aynı şekli kaplamak için B şeklinden kaç taneye ihtiyacım olurdu?



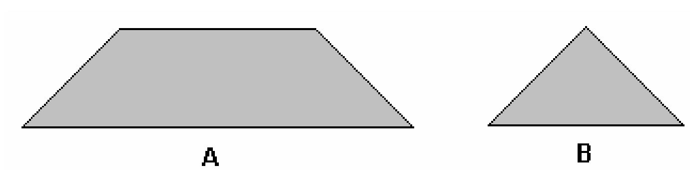
A) 1

B) 3

C) 5

D) 7

11. Elimde bir geometrik şekil var. Bu şekli kaplamak için aşağıdaki A şeklinden 2 tane kullanmam gerekmektedir. Aynı şekli kaplamak için B şeklinden kaç taneye ihtiyacım olurdu?



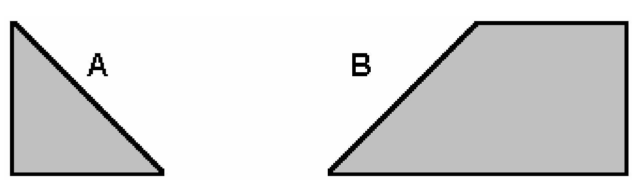
A) 3

B) 4

C) 5

D) 6

12. Elimde bir geometrik şekil var. Bu şekli kaplamak için aşağıdaki A şeklinden 6 tane kullanmam gerekmektedir. Aynı şekli kaplamak için B şeklinden kaç taneye ihtiyacım olurdu?



A) 2

B) 3

C) 4

D) 5

13. Elimde bir geometrik şekil var. Bu şekli kaplamak için aşağıdaki A şeklinden 3 tane kullanmam gerekmektedir. Aynı şekli kaplamak için B şeklinden kaç taneye ihtiyacım olurdu?

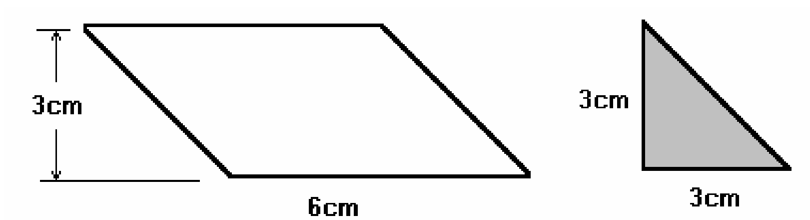
A) 4

B) 5

C) 6

D) 7

14. Aşağıda, solda görülen paralelkenarı kaplamak için sağda görülen gri üçgenden kaç tane kullanmak gerekir?



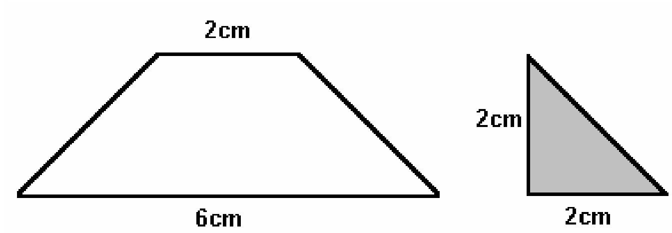
A) 7

B) 6

C) 5

D) 4

15. Aşağıda, solda görülen ikizkenar yamuğu kaplamak için sağda görülen gri üçgenden kaç tane kullanmak gerekir?



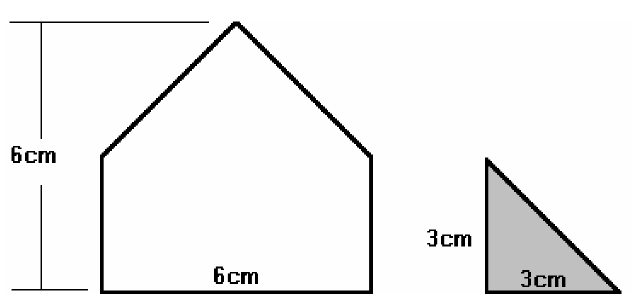
A) 3

B) 4

C) 5

D) 6

16. Aşağıda, solda görülen beşgeni kaplamak için sağda görülen gri üçgenden kaç tane kullanmak gerekir?



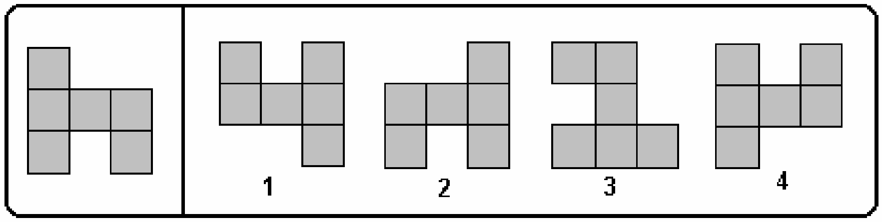
A) 3

B) 4

C) 5

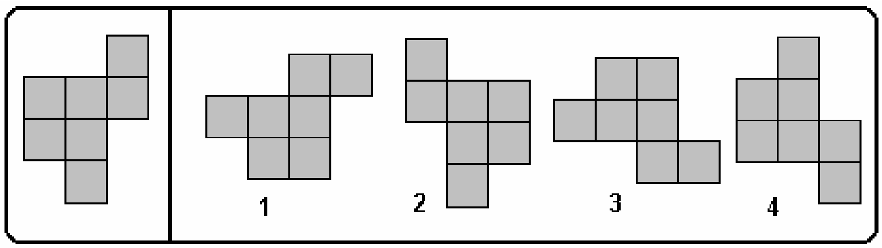
D) 6

17. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



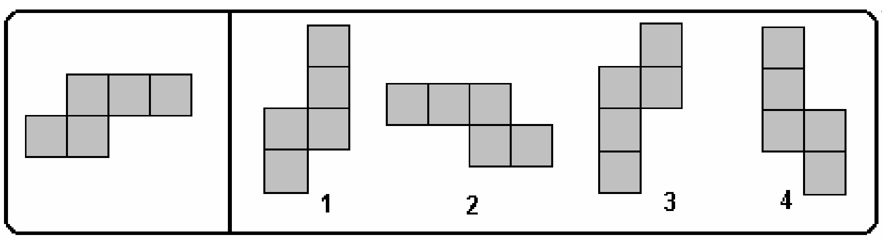
A) 1
B) 2
C) 3
D) 4

18. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



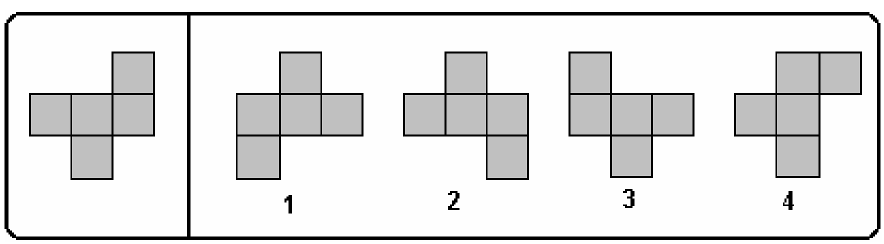
A) 1
B) 2
C) 3
D) 4

19. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



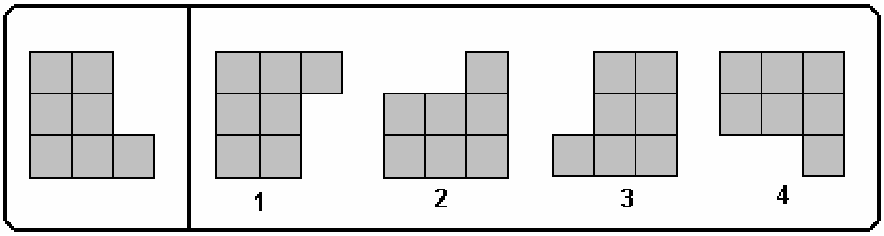
A) 1
B) 2
C) 3
D) 4

20. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



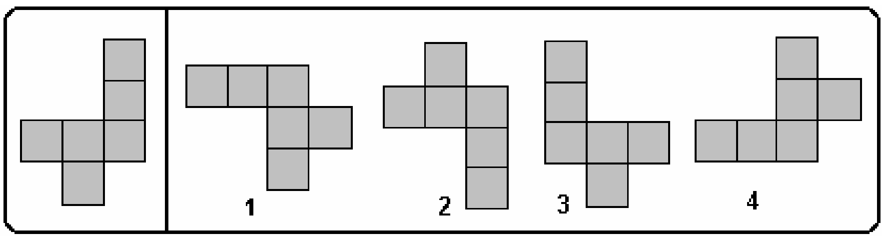
A) 1
B) 2
C) 3
D) 4

21. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



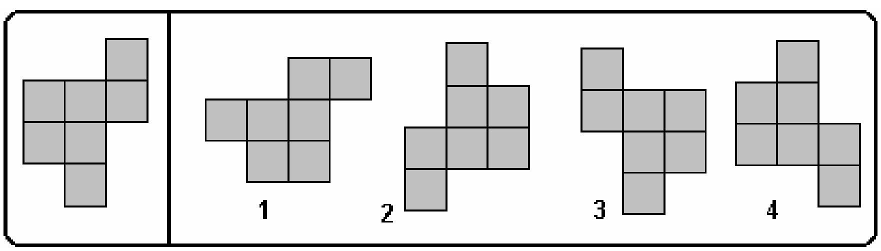
A) 1
B) 2
C) 3
D) 4

22. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?



A) 1
B) 2
C) 3
D) 4

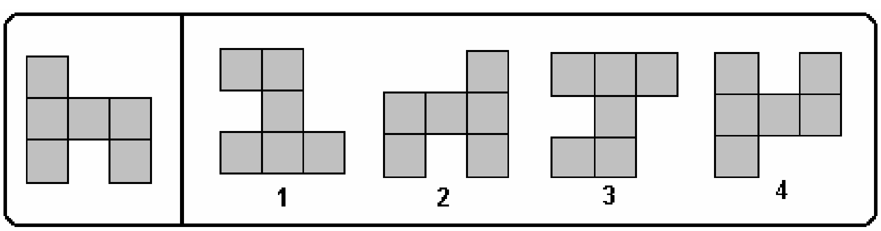
23. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?

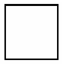


A) 1
B) 2
C) 3
D) 4

24. Aşağıda, solda görülen şekil saat yönünde döndürülerek sağdakilerden hangisi elde edilebilir?

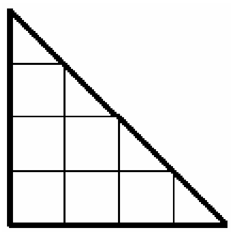
A) 1
B) 2
C) 3
D) 4





Yandaki şekil bir birim karedir. Aşağıdaki şekillerin her birinin içinde bu birim karelerden toplam kaçar tane olduğunu bularak belirtilen yerlere yazınız.

25.



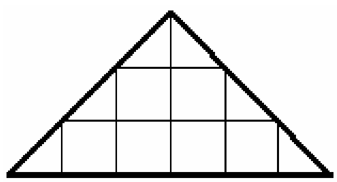
A) 7

B) 8

C) 9

D) 10

26.



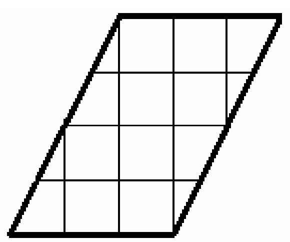
A) 9

B) 10

C) 11

D) 12

27.



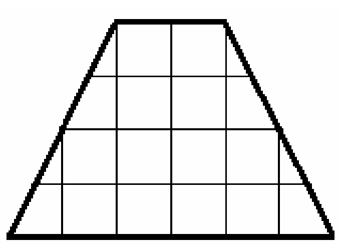
A) 10

B) 11

C) 12

D) 13

28.



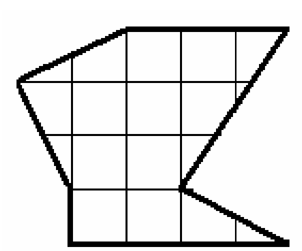
A) 20

B) 18

C) 16

D) 14

29.



A) 16

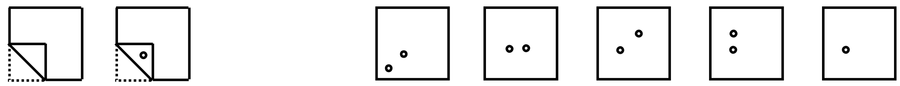
B) 15

C) 14

D) 13

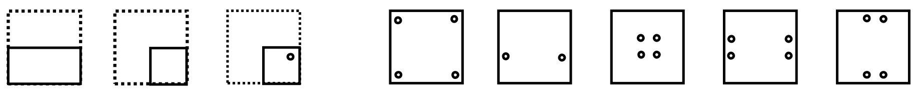
Aşağıdaki sorularda bir parça kağıdın katlanıp açılmasını hayal etmeniz gerekmektedir.

30. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



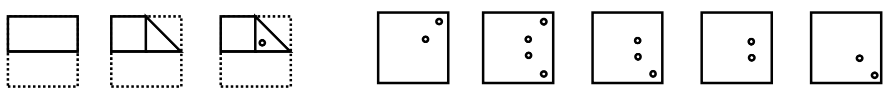
A) B) C) D) E)

31. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



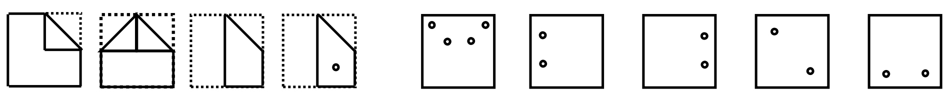
A) B) C) D) E)

32. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



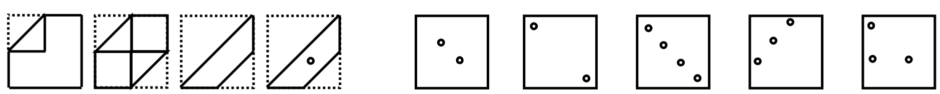
A) B) C) D) E)

33. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



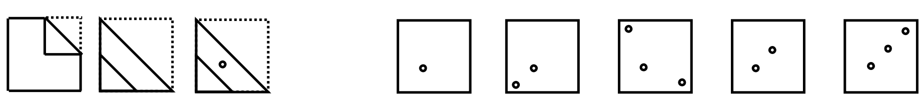
A) B) C) D) E)

34. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



A) B) C) D) E)

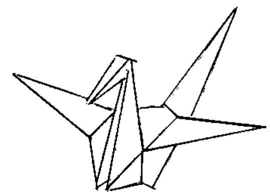
35. Verilen kare şeklindeki kağıt aşağıdaki gibi katlanıp bir noktadan deliniyor, kağıt açıldıktan sonra hangi şeklin oluşacağını bulunuz.



A) B) C) D) E)

APPENDIX B

Reflection Paper



Adı - Soyadı:

1. Origami nedir?

2. Dersler sırasında neler yapmayı öğrendiniz?

3. Origami etkinlikleri sırasında ne gibi zorluklarla karşılaştınız?

4. Origami etkinlikleri sırasında hangi matematiksel terimleri kullandınız? Örnekler vererek açıklayınız.

5. Bu etkinlikler daha önce anlamakta zorlandığınız bir konuyu anlamanıza yardımcı oldu mu?

6. Origami etkinliklerinin matemetik ve geometri açısından sizin için yararlı olduğunu düşünüyor musunuz? Neden?

7. Origami çalışmalarına devam etmek ister misiniz?

APPENDIX C

Sample Activity Plans

Activity Plan 1: Magic Star

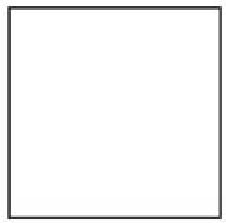
Teaching Methods: Questioning and Discussion, Cooperative learning
Materials: 8 sheets of square paper for each group
Duration: 40 minutes
Mathematical concepts: Square, rectangle, trapezoid, pentagon, parallelogram, octagon, rotation, fractions, lines of symmetry, diagonals, symmetry.

Procedure:

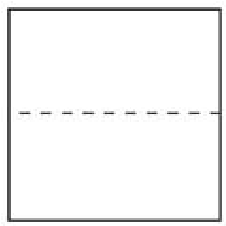
- At the beginning of the lesson students were grouped in to pairs, then 8 sheets of square paper distributed for each group.
- According to diagrams origami model is made by emphasizing the mathematical concepts.
- Students make origami model according to given direction in 30 minutes.
- Students were encouraged to discuss the mathematical concepts.

Evaluation:

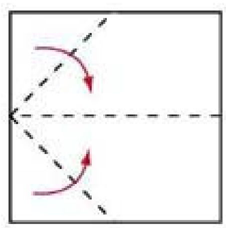
At the end of the lesson, 8 sheets of square paper for each group and students asked to make origami models again.



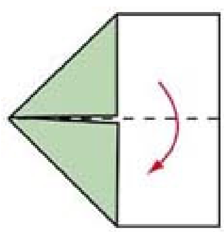
Start with a square



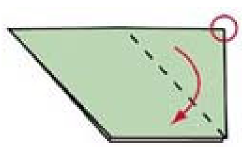
Fold the square horizontally in half and bring it back to its original position, so that you have two visible rectangles



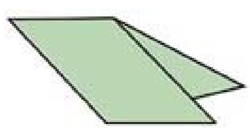
Bring the upper left corner toward the center of the crease and fold. Do the same to the lower left crease.



Fold the top portion over to the bottom by folding it at the center crease

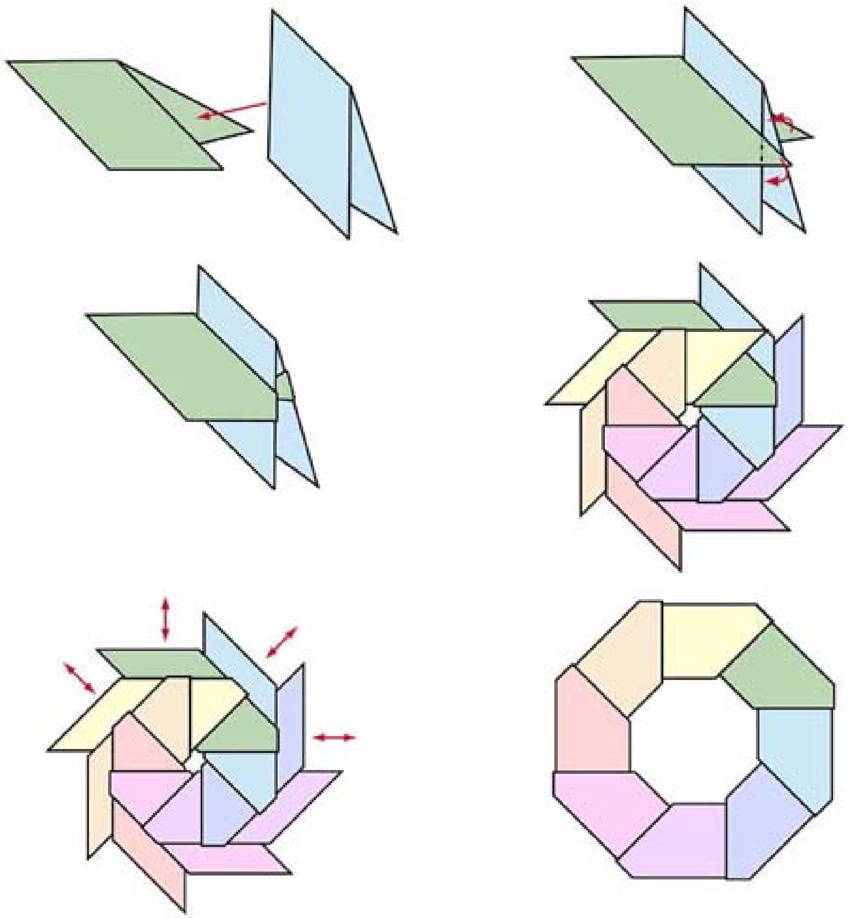


Push the fold to the inside so that paralelogram is formed



This is one of the units for magic star. Now make seven more units.

Assembling



Source: http://www.opane.com/ufo.html

Activity Plan 2: Jumping Frog

Teaching Methods: Questioning and Discussion, Cooperative learning

Materials: 2 sheets of square paper for each student

Duration: 40 minutes

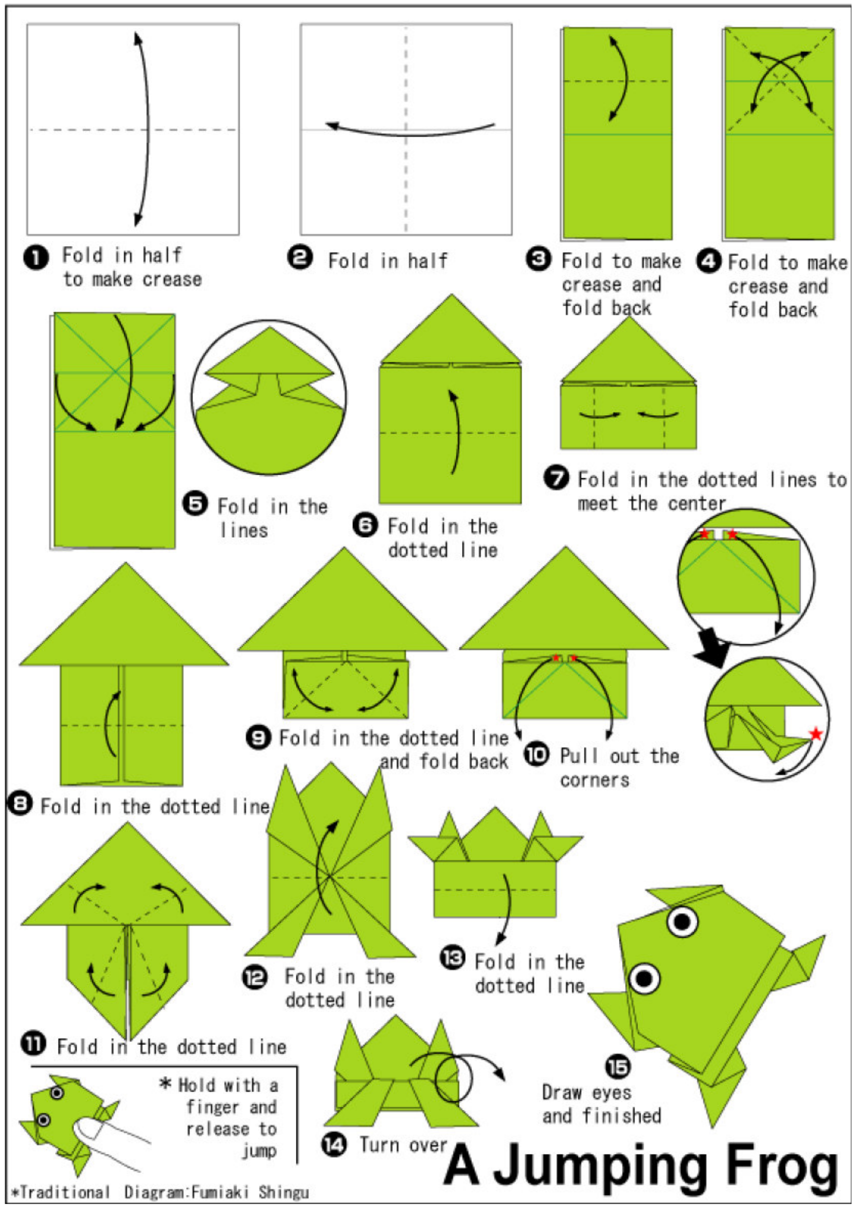
Mathematical concepts: Parallel and perpendicular lines, angles (acute, right angle and opposite, adjacent, supplementary, complementary angles), rectangle, isosceles triangle, isosceles right triangle, pentagon.

Procedure:

- At the beginning of the lesson students were given 2 sheets of big square paper for each student.
- According to diagrams origami model is made by emphasizing the mathematical concepts.
- Students make origami model according to given direction in 30 minutes.
- Students were encouraged to discuss the mathematical concepts.

Evaluation:

At the end of the lesson, students asked to make origami models again with the second sheet of paper.



Source: http://www.origami-club.com

Activity Plan 3: Crane

Teaching Methods: Questioning and Discussion, Cooperative learning

Materials: 2 sheets of square paper for each student

Duration: 40 minutes

Mathematical concepts: Square, rectangle, pentagon, triangle, quadrilateral, diamond, area, symmetry, diagonals, line of symmetry, perpendicular lines.

Procedure:

- At the beginning of the lesson students were given 2 sheets of big square paper for each student.
- According to diagrams origami model is made by emphasizing the mathematical concepts.
- Students make origami model according to given direction in 30 minutes.
- Students were encouraged to discuss the mathematical concepts.

Evaluation:

At the end of the lesson, students asked to make origami models again with the second sheet of paper.

Make your own origami crane!

Begin with a square piece of paper - ideally one side coloured and the other plain. Place the coloured side face up on the table. In all diagrams, the shaded part represents the coloured side.

1. Fold diagonally to form a triangle. Be sure the points line up. Use your thumbnail to make all creases very sharp.
Now **unfold** the paper

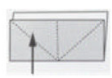
2. Now fold the paper diagonally in the opposite direction, forming a new triangle.

Unfold the paper and turn it over so the white side is up. The dotted lines in the diagram are creases you have already made.

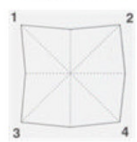
3. Fold the paper in half to the **right** to form a tall rectangle.

Unfold the paper.

4. Fold the paper in half, bringing the bottom up to the top and form a wide rectangle.



Unfold the rectangle, but don't flatten it out. Your paper will have the creases shown by the dotted lines in the figure on the right.

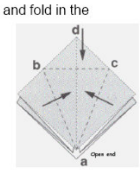


5. Bring all four corners of the paper together, one at a time. This will fold the paper into the flat square shown on the right. This square has an open end where all four corners of the paper come together. It also has **two flaps on the right and two flaps on the left.**

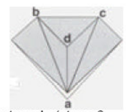
6. Lift the **upper right flap**, and fold in the direction of the arrow. Crease along line a-c.

7. Lift the upper left flap and fold in the direction of the arrow. Crease along the line a-b.

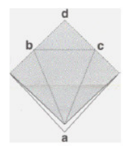
8. Lift the paper at point d (in the upper right diagram) and fold down into the triangle b-a-c.



Crease along the line b-c.

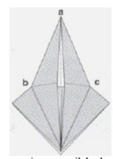


Undo the three folds you just made (steps 6, 7, and 8), and your paper will have the crease lines shown on the right.



9. Lift just the top layer of the paper at point a.

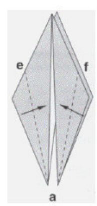
Think of this as opening a crane's beak. Open it up and back to line b-c where the beak would hinge. Crease the line b-c inside the "beak."



Press on points b and c to reverse the folds along lines a-b and a-c. The trick is to get the paper to lie flat in the long diamond shape shown on the right. At first it will seem impossible but with some patience you will get the hang of it!

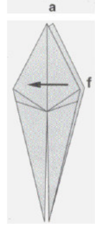
10. - 13. Turn the paper over. **Repeat** Steps 6 to 9 on this side. When you have finished, your paper will look like the diamond below with two "legs" at the bottom.

14. - 15. Taper the diamond at its legs by folding the top layer of each side in the direction of the arrows along lines a-f and a-e so that they meet at the center line.



16. - 17. Flip the paper over. Repeat steps 14 and 15 on this side to complete the tapering of the two legs.

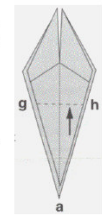
18. The figure on the right has two skinny legs. Lift the **right upper flap** at point f and fold it over in the direction of the arrow - as if turning the page of a book. This is called a "book fold."



Flip the entire piece over.

19. Repeat this "book fold" (step 18) on this side. Be sure to fold over only the upper flap.

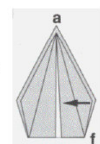
20. Now imagine this image is what you would see if you were looking straight down, at the top of a crane's head. The two points at the top of the picture are the back of the crane's head, and its pointy beak is at the bottom. Open the upper layer of the beak at point a, and crease it along line g-h so that the tip of the beak touches the back of its head (ouch!)



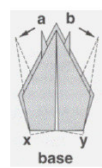
21. **Turn the figure over.** Repeat step 20 on this side so that all four points touch.

22. Your paper should look like this image on the right. Next another "book fold." Lift the top layer on the right (at point f), and fold it in the direction of the arrow to the middle. Be sure to crease the fold.

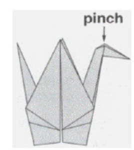
23. Flip the entire figure over. Repeat the "book fold" (step 22) on this side.



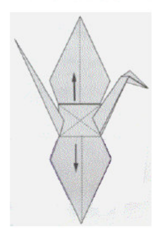
24. - 25. There are two points, a and b, below the upper flap. Pull out each one, in the direction of the arrows, as far as the dotted lines. Press down along the base (at points x and y) to make them stay in place.



26. Take the end of one of the points, and bend it down to make the head of the crane. Using your thumbnail, reverse the crease in the head, and pinch it to form the beak. The other point becomes the tail.



Open the body by blowing into the hole underneath the crane, and then gently pulling out the wings.



Why not use a black and red crayon or marker and give your origami crane the features of a Whooping Crane?

Made possible through the Wild Birds Unlimited Pathways To Nature® Conservation Fund.

Source: http://www.operationmigration.org/Origami.pdf

APPENDIX D

An Example of Coding Obtained from two Coders

Student no	Difficulties which they encountered	Attitudes toward origami	Benefits of origami and its connection to mathematics	Others…
10	• Bazı yerlerde katlayamadım.	• Dersler keyifli geçiyor. • Origamiyi sevdim. • Devam etmek istiyorum.	• Matematik ve geometri açısından yaralı; anlayamadığım şeylere yardımcı oluyor, daha iyi öğreniyorum. • Açılarda zorlanıyordum, şimdi daha iyi öğrenmiş oldum. • Açılar, üçgen, kare, dikdörtgen, beşgen, simetrik özellikler,. • "Dik açılı üçgen çevirdiğimizde dar açılı gibi gözüküyor ama o hala dik üçgen, bunu daha iyi anladım."	• Sizden yardım aldım.

Student no	Difficulties which they encountered	Attitudes toward origami	Benefits of origami and its connection to mathematics	Others…
4	• Katlama ve iz çıkartmada • Katlarken tam eşit olmuyor, yamuk oluyor. • Turna yaparken yırtılmıştı.	• Origami çalışmalarına devam etmek istiyorum. • Zevkli ve eğlenceli geçiyor. • Anneme de öğrettim. Kardeşimde seviyor. Yazın renkli kağıt alıp yapacağız.	• Yıldızın köşelerinin beşgen oldugunu keşfettim. • Yararlı çünkü hem eğleniyorum hem öğreniyorum. • Hayal gücüm ve zekam gelişiyor. • Origami yaparken birçok terim kullandık: kare, dikdörtgen, beşgen,simetri ekseni. • Karenin tek köşegenini katlayınce simetrik ve birbiriyle aynı oldu.	

Student no	Difficulties which they encountered	Attitudes toward origami	Benefits of origami and its connection to mathematics	Others…
24	• içe veya dışa katlarken zorlandım.	• Çok eğlenceli hemde öğretici. • Bir daha sene yine origami dersi olsun.	• Yararlı, matematiği daha eğlenceli buldum. • Metemetiği daha iyi kavramama yardımcı oldu. • Kare, üçgen, köşegen, yamuk, 22.5^{o}, eşkenar dörtgen, açılar, kesirli ifadeler, geometrik cisimler, paralelkenar, deltoid.	
28	• Bazı katlamalarda zorlandım. • Birleştirmek zordu.	• Eğlenceliydi • Devam etmek istiyorum.	• Kare, dikdörtgen, üçgen, yamuk, açılar geometrik şekiller, geometrik cisimler • Origami ile daha eğlenceli şekilde ve rahat öğreniyorum. • El becerim gelişiyor.	• Arkadaş-larından ve öğretmenimden yardım aldım.