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# The Effects of Using Google SketchUp on the Mental Rotation Skills of Eighth Grade Students*

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**Abstract**

The aim of this study is to investigate the effectiveness of Google SketchUp, which is a computer aided design (CAD) software, on the Mental Rotation Skills of eighth grade students. For this purpose, in the spring semester of the 2011-2012 academic year, a treatment was conducted with 62 students comprised of 8A and 8B classes in the GSD Education Foundation Bahçelievler Primary School during the six weeks. The study was carried out in accordance with a quasi-experimental research with pretest and posttest design. The "Vandenberg Mental Rotation Test" was used to determine mental rotation skills of the students, participating the research study, as a pretest and posttest. When pretest results examined with independent samples t-test, a significant difference was found in favor of the class 8B ($\bar{x}_{8A} = 5.42$ $\bar{x}_{8B} = 8.45$ $t(60)=3.62$, $p<.01$). During the four weeks, the students in the control group tried to draw the different view of unit cube models developed by researchers on an isometric paper. In the same duration, the students in the experimental group tried to draw same models with the help of Google SketchUp software. At the end of the four weeks, the Mental Rotation Test was re-conducted for participants as a posttest. Although the increase in the mean scores of mental rotation test is higher in the experimental group, the ANCOVA results revealed that, there is no significant difference between the mean scores of the Mental Rotation Test of the experimental and control groups ($F_{(1-59)}=.309$, $p>.05$).

**Key Words**

Spatial Ability, Mental Rotation, Google Sketchup, Concrete Objects, Manipulative.

Understanding the positions and the relationships between the objects, and reposition and visualize the views from different angles of these objects mentally is an extremely important skill for human being. Although this skill is referred to the various names in literature, it is commonly called as "Spatial Skill". Spatial skills are highly essential to solve various issues in our daily life, from organizing furniture to parking a car, from landscaping garden to taking photos.

There are many different definitions of spatial skill

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or spatial ability in the literature. Linn and Petersen (1985) defined spatial ability as a general skill for representing, transforming, generating and recalling the symbolic, non-linguistic information. According to the Tartre (1990) spatial skills are mental skills concerned with understanding, manipulating, re-organizing or interpreting the relations visually. Spatial ability may be defined as the ability to generate, retain, retrieve, and transform well-structured visual images (Lohman, 1996). Spatial ability divides three factors: [1] spatial perception, the ability to determine spatial relations with respect to the orientation of their own bodies [2] mental rotation, the ability to rotate a two or three dimensional shape rapidly and accurately, and [3] spatial visualization, the ability to manipulation of spatially presented information (Linn & Petersen). Spatial ability is one of the reasoning skills that is a capability of visualization the three dimensional objects, imagine different perspectives, and comprehend the relations between objects (Erkoç & Erkoç, 2012). Spatial abilities are valuable in our everyday life (driving, taking photos, playing computer games, etc.), in many professions (architecture, engineering, music, piloting, etc.) and in the scientific branches (mathematics, chemistry, biology, physics, etc.) (Kurtuluş, 2011; Yurt & Sünbül, 2012).

Many studies have shown that spatial skills can be improved by training and learning with appropriate materials and activities (Burnett & Lane, 1980; Ben-Chaim, Lappan, & Houang, 1988; Olkun, 2003; Rafi, Samsudin, & Ismail, 2006; Rafi, Samsudin, & Said, 2008; Kurtuluş, 2011; Yıldız & Tüzün, 2011). Improving the spatial skills of students is one of the roles of geometry course activities (Olkun). The National Council of Teachers of Mathematics (NCTM) recommends that geometry instruction should include the study of three-dimensional geometry and provide students opportunities to use spatial skills to solve problems (Güven & Kösa, 2008). Also, the latest educational program of Turkish Ministry of National Education (TME / MEB), published in 2009, recommends the improving spatial skills in geometry courses. One of the objectives of geometry learning domain in the 6-8 grade mathematics education program of TME, "Improves the spatial abilities using multi-cube" purposes the training spatial ability directly. Other acquisitions in the mathematics program, "Draws the various perspectives of structures created with unit cubes" and "Draws perspectives of a cube or prism from a distance" concerning spatial skills. Manipulatives can be used in geometry courses for providing an interesting, enjoyable, and an understandable instructional environment and improving the spatial skills.

Manipulatives can be defined as physical objects, such as base-ten blocks, algebra tiles, unit cubes, Cuisenaire rods, fraction pieces, pattern blocks and geometric solids that can make abstract ideas and symbols more meaningful and understandable to students (Durmuş & Karakırık, 2006). Students are motivated to learn when activities are presented in a dynamic hands-on engaging manner (Furner & Marinas, 2007). As a result of recent advances in computer and software technologies, a new approach called virtual manipulatives, as well as new capabilities, or toolkits, for computer programs that use visual representations has been used instead of physical manipulatives (Erkoç & Erkoç, 2012). Clements and McMillan (1996) define the virtual manipulatives as computer programs that allow the user to manipulate representations of concrete objects, such as base-ten blocks or geoboards, on a computer screen. Both the physical and virtual manipulatives have been used to develop the students' perceptions and capabilities of mathematics. In addition, teachers may impact the students' lives positively creating good attitudes toward mathematics and developing substantial mathematical content knowledge through the use of virtual manipulatives as a technological tool (Furner & Marinas).

In this study, particularly, we focused on the improving the Mental Rotation (MR) which is a sub-dimension of spatial ability. Mental Rotation is a skill which a person visualizes the new perspective of a two- or three-dimensional object after it has been turned around a specified axis a given number of degrees (De Lisi & Wolford, 2002). Mental Rotation skills have an important role in many occupations, such as engineering, medical professions and other job required creativity (Hegarty & Waller, 2005) and linked to the mathematics performance (Hegarty & Kozhevnikov, 1999; Heil & Jansen-Osmann, 2008). When related literature is examined, it is possible to see many studies in which the mental rotation was the main theme of the studies. A study by Heil and colleagues showed mental rotation improvements restricted to practice trial settings, after four sessions of training (Heil, Rösler, Link, & Bajric, 1998).

Another study conducted by Roberts and Stephans (1999) of three geometry classes in an urban high school, looked at the results from a motivational and learning perspective. Researchers were interested in whether the use of dynamic geometry software increased the interest and enjoyment of the students. The results of the study showed that the use of the software improved student interest and participation in geometry. De Lisi and Wolford (2002) investigate the relationship between the mental rotation skill and game playing experiences. For this purpose, a pretest posttest control group design was used. The two-dimensional mental rotation test was carried out to control and experimental groups, before and after the implementation, respectively. According to the results of the study, a significant difference between the experimental group playing games required mental rotation skills and control group was found. The researchers stated that the computer-aided activities can be used to improve the mental rotation skills of the students.

Yıldız and Tüzün (2011) investigate the effect of using three dimensional virtual environments and concrete materials on spatial visualization and mental rotation skills. To this end, three dimensional virtual unit cube simulation created by researchers was used in the experimental group and also, concrete unit cubes were used in the control group. At the before and after the study, "Spatial Visualization Test" and "Mental Rotation Test" were carried out to groups by the researchers. As a result of the research, a significant increment in the results of the both tests of the control group was seen, and while a significant increment in the results of the Spatial Visualization Test of the experimental group was found, no significant increment in the results of the Mental Rotation Test was determined.

Baki, Kösa, and Güven (2011) compared the effectiveness of the Dynamic Geometry Software and physical manipulatives on Spatial Visualization Skills of the teacher candidates. In the study, Purdue Spatial Visualization Test including questions related to mental rotation was used in order to collect research data. In the first experimental group Cabri 3D software was used as a virtual manipulative, in the second experimental group physical manipulatives were used and control group continued the traditional methods. According to research results, the use of Dynamic Geometry Software and physical manipulatives were more effective on the improving the mental rotation skills of the teacher candidates.

Google SketchUp is a dynamic software program that allows the users to compose, edit and share three dimensional structures or constructions quickly. It was developed for drawing three dimensional models in the domains of architecture and engineering by Last Software Company in 2000. Although it did not develop to serve as a virtual manipulative, because of its user friendly interface it can be used for teaching and learning of space geometry concepts. The Google SketchUp is a revolutionary, interactive software providing an active learning environment and creative experiences for learners. One of the most significant advantage of Google SketchUp is being free to users and accessible anywhere without licensing restrictions.

All SketchUp models consist only of edges and faces. Edges are straight lines which can create a two dimensional face by combined properly. It takes very short time to learn how to draw lines and faces. Two dimensional surfaces can be converted three dimensional models quickly and easily. For example, two dimensional square can be converted a three dimensional cube by SketchUp "Expand" tool. In this way, users can construct, edit and share their three dimensional models through Google SketchUp. It allows students not only to compose, edit and share three dimensional models or constructions, but also explore different views of models and constructions by means of manipulating the models by dragging and rotating. However, many studies focused on the positive impact of dynamic geometry software such as Geometer's Sketchpad, Cabri 3D, Geometry 3D Shapes in improving the spatial skills and mental rotation, there are a limited number of studies (Kurtulus & Uygan, 2010; La Ferla et al., 2009; Martin-Dorta, Saorin, & Contero, 2008) on the effectiveness of the Google SketchUp.

We believe that Google SketchUp can be used in improving the mental rotation skills as a virtual manipulative, although, it was not specially developed for instructional activities. In this study, we aimed to investigate the impact of Google SketchUp on the improving the mental rotation skills of eighth grade students. A screenshot of Google SketchUp is shown in Figure 1.

## Method

The main objective of the study is to investigate the effectiveness of using Google SketchUp in improving eighth grade students' Mental Rotation Skills through a quasi-experimental research with pretest and posttest design. This study was carried out for six weeks during the spring semester of the 2011-2012 academic year. During the experimental implementation, in the control group, concrete cube models created with lego pieces were shown to the students and were asked to draw on isometric paper. In the experimental group, students were asked to draw same models with the Google SketchUp software.

The dependent variable of the study is students'

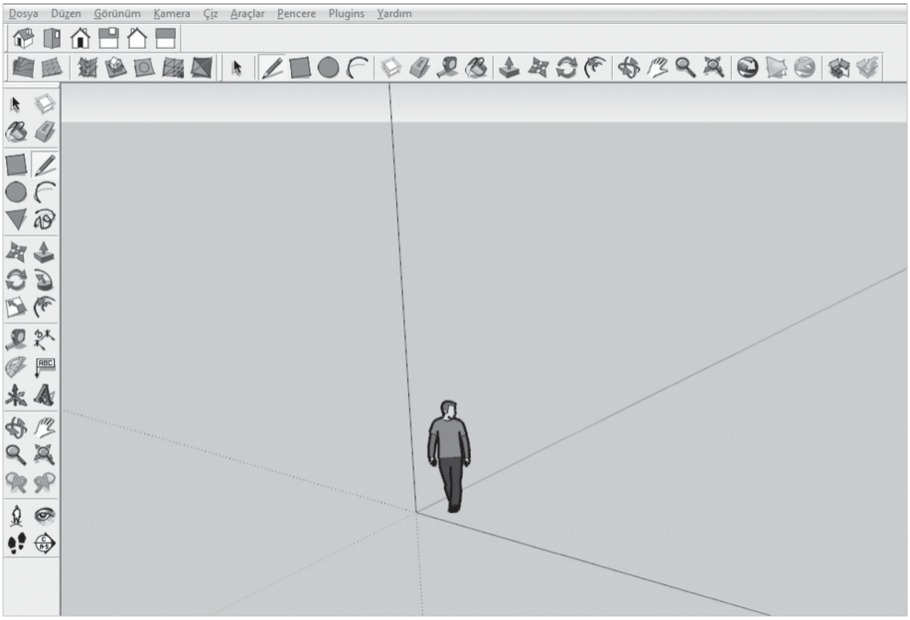



**Figure 1.**
*A Screenshot from Google SketchUp*

Mental Rotation Skills and the independent variables are the methods carried out using Google SketchUp and isometric papers. Within the framework of the main objective, we tried to find answers to the following questions;

1. Is there a significant difference between the control group students' pretest and posttest scores of Mental Rotation Test?
2. Is there a significant difference between the experimental group students' pretest and posttest scores of Mental Rotation Test?
3. Is there a significant difference between the posttest scores of the control group and experimental group students of Mental Rotation Test, controlling for the effects of pretest scores of the groups?

### Participants

This research was carried out with 62 eighth grade students in two classes (8A and 8B) of GSD Education Foundation Bahcelievler Primary School in Istanbul during the spring semester of the 2011-2012 academic year. One of these classes was assigned as control group (8B, N=31) and the other class was assigned as the experimental group (8A, N=31) randomly. When students in the control group drew the concrete models created with the lego pieces on the isometric paper, the others assigned as the experimental group drew with the help of Google SketchUp software during the experimental process.

### Materials and Data Collection Tools

The "Vandenberg Mental Rotation Test" (Peters et al., 1995) was used to determine mental rotation skills of the students as a pretest and posttest. The Mental Rotation Test was re-developed by Peters and colleagues in 1995, and adapted to Turkish by Yıldız in 2009. The test consists of 24 multiple-choice questions. A sample of Mental Rotation Test which was solved by the student given in Appendix 1. A model created with unit cubes is given in each question, and view of different directions and different angles of this model are given in each option. Two of these four options are correct and others are incorrect. If both the correct choices are marked by participants, the question is accepted as right. If one of the correct answers isn't marked, the question is accepted as wrong. Figure 1 shows a sample question of Mental Rotation Test.

Reliability of the test was calculated .712 (N=161) before the implementation, and reliability of the test was calculated .661 (N=108) after the implementation by Yıldız (2009). The cube models created with lego pieces and worksheets were prepared and expert opinions of mathematic teachers were taken by researchers each week during the implementation process.

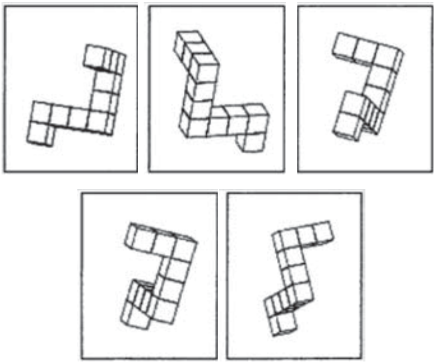


**Figure 2.**
*A Sample Question of Mental Rotation Test*

## Procedure

The implementation process of this study took a total of six weeks. In the first week of implementation, the Mental Rotation test was carried out to control and experimental groups as a pretest. During the next four weeks, the students in the control group tried to draw the different view of unit cube models developed by researchers on an isometric paper (Figure 3). In the same duration, the students in the experimental group tried to draw same models with the help of Google SketchUp software (Figure 4). Before the implementation, students in the experimental groups were trained in using Google SketchUp for three hours. The activities that were done by the students in both groups can be seen in both Figure 3 and 4.

Participants drew at least four different models every week. At the end of the four weeks, the Mental Rotation Test was re-conducted to participants as a posttest. Figure 5 summarizes the implementation process of the study.

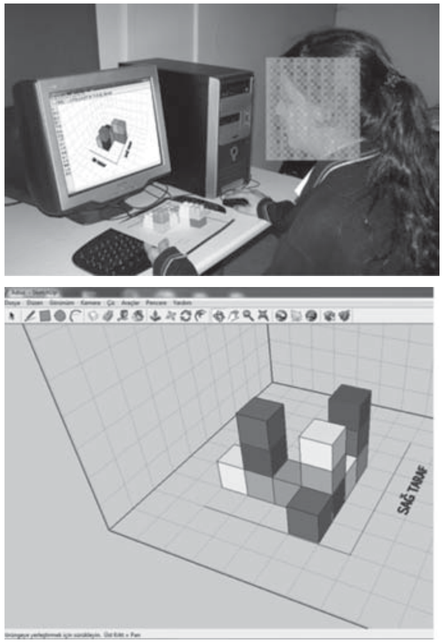



**Figure 4.**
*Student in the Experimental Group and her Activity with Google SketchUp*

## Data Analysis

SPSS 16.0 package program was used to analyze the obtained data in the study. The Mental Rotation Test pretest scores of control and experimental groups were analyzed using independent samples t-test. Because of the significant difference between the pretest scores of experimental and control groups, covariance analysis (ANCOVA) was used to exam-

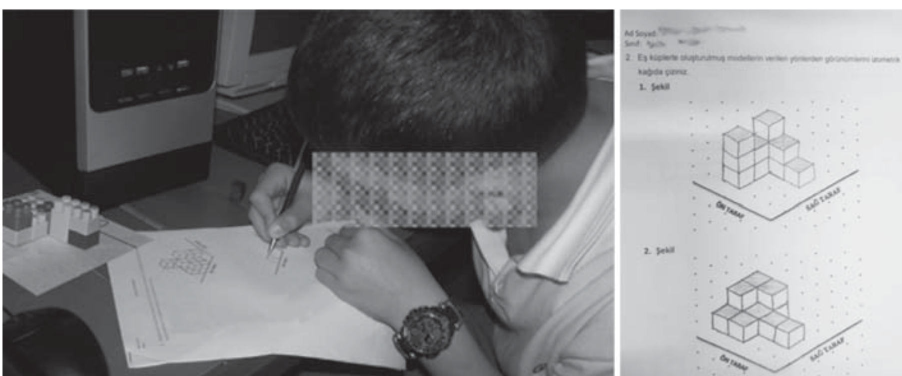



**Figure 3.**
*Student in the Control Group and his Activities on Isometric Paper*

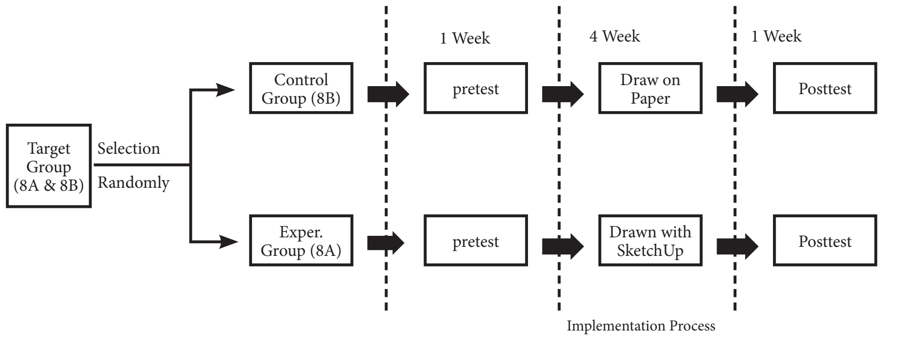



**Figure 5.**
*The Implementation Process of Study*

ine the relations between the pretest and posttest scores of the groups, with the pretest scores as covariate variable. According to Büyüköztürk (2004), covariance analysis eliminates the external factors, cannot be controlled with research design, by means of a linear regression method, and makes it possible to determine the real effects of the treatment. Finally, the data acquired from the groups was analyzed using paired samples t-test in order to determine the relations between the pretest and posttest scores of the control and experimental groups.

## Results

In order to identify whether there is a significant difference between the pretest scores of the control and experimental groups students, independent samples t-test analysis was carried out. Table 1 represents the results of independent samples t-test analysis of the Mental Rotation Test pretest scores of the control and experimental groups.

The analysis showed that there is a significant difference between the pretest scores of the Mental Rotation Test ($t_{(60)}$=3.62, $p$<.01). According to these results, it is observed that the Mental Rotation Test scores of the control group is higher than the experimental group. The aim of the study is to investigate the effects of the experimental implementation, therefore the significant difference between the pretest scores of groups is an undesirable result. In order to eliminate this negative impact, the pretest scores were used as covariate variable while analyzing posttest scores.

**Table 1.**
*The Independent Samples t-test Analysis Results of MRT Scores of Experimental and Control Groups*

| Groups | N | $\bar{x}$ | S | df | t |
|---|---|---|---|---|---|
| Experimental Group (8A) | 31 | 5.42 | 3.18 | 60 | 3.62 |
| Control Group (8B) | 31 | 8.45 | 3.40 | | |

Table 2 summarizes the analysis of paired samples t-test in order to determine whether or not there is a significant difference between the pretest and posttest scores of the experimental group for the Mental Rotation Test.

**Table 2.**
*The Paired Samples t-test Results of Pretest and Posttest of Experimental Groups*

| Mental Rotation Test | N | $\bar{x}$ | S | df | t |
|---|---|---|---|---|---|
| Pretest | 31 | 5.42 | 3.18 | 30 | 13.86 |
| Posttest | 31 | 14.03 | 3.16 | | |

According to the results of the analysis, there is a significant difference between the pretest and posttest scores of the experimental group ($t_{(30)}$=13.86, $p$<.01). While the average score of the Mental Rotation Test for the participants was $\bar{x}$=5.42 before of the treatment period, it was increased to $\bar{x}$=14.03 with the treatment. These finding shows that the activities involved building the structures with the help of Google SketchUp increase the Mental Rotation skills of the students. The paired sample t-test results of the control group can be seen in the Table 3.

**Table 3.**
*The Paired Samples t-test Results of Pretest and Posttest of Control Groups*

| Mental Rotation Test | N | $\bar{x}$ | S | df | t |
|---|---|---|---|---|---|
| Pretest | 31 | 8.45 | 3.40 | 30 | 11.58 |
| Posttest | 31 | 15.81 | 3.40 | | |

As can be seen in the table 3, the results indicate that there is a significant difference between the pretest and posttest mean scores of the students in the control group ($t_{(30)}$=11.58, $p$<.01). Before the implementation process, while the mean of the Mental Rotation Test scores of the control group was $\bar{x}$=8.45, after the implementation process mean of the test scores increased to the $\bar{x}$=15.81. It is observed that there is a significant difference between the pretest and posttest mean scores of students in the control group. According to these findings, we can say that the drawing activities using concrete objects, pencils and isometric papers increase the Mental Rotation skills of the eighth grade students.

Covariance analysis (ANCOVA) was carried out to examine the difference between the mean of Mental Rotation Test posttest scores of the experimental group and the control group, controlling the pretest scores as covariate variable. Assumptions of the ANCOVA must be met before the covariance analysis. The first of these assumptions is the homogeneity of the variance. Therefore, Levene test was carried out to determine whether or not there is homogeneity of variance. The Levene test results are shown in table 4.

**Table 4.**
*The Levene Test Results of the Homogeneity of Variance.*

| Dependent variable | F | df1 | df2 |
|---|---|---|---|
| Mental Rotation Test | .005 | 1 | 60 |

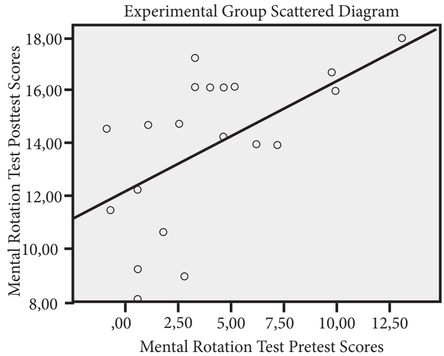
According to analysis shown in table 4, variances are homogeneous for the posttest scores of participants ($F_{(1,60)}$=.005, $p$>.05). Analysis of covariance has an additional assumption of the linear relation between the dependent variable and covariate variable in all groups. For this purpose, the relationships between the dependent variable and covariate variable were examined by scatter diagrams in each group. Figure 6 represents the scatter diagram of the pretest and posttest scores of the study groups.

For both groups, linear relation between the dependent variable and covariate variable can be seen in figure 4. Then, the results of the descriptive statistics of the posttest scores of experimental and control groups were examined. The arithmetic mean and standard deviation of the posttest scores are presented in table 5.

**Table 5.**
*The Results of Descriptive Statistics of Posttest Scores*

| Group | $\bar{X}$ | S | N |
|---|---|---|---|
| Experimental Group | 14.03 | 3.16 | 31 |
| Control Group | 15.81 | 3.40 | 31 |
| Total | 14.92 | 3.37 | 62 |

The Benferroni's pairwise comparison test was used to determine the direction of the difference between the posttest scores of the groups. Table 6 represents the results of the ANCOVA in order to determine whether there is a significant difference between the posttest scores of the experimental and control groups, with the pretest scores as covariate variable.



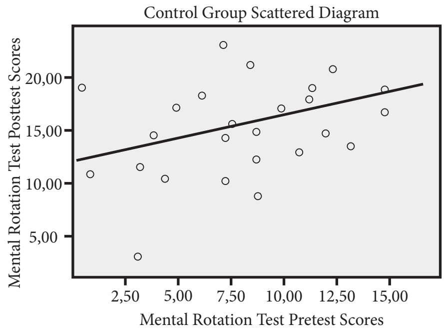




**Figure 6.**
*Scatter Diagram of the Pretest and Posttest Scores of Groups*

According to the results of the ANCOVA analysis, there is no significant difference between the mean scores of the Mental Rotation Test of the experimental and control groups, controlling for the effects of pretest scores of the groups ($F_{(1-59)}$=.309, $p$>.05). For the experimental group, although there is a significant increment in the mean of the posttest scores ($\bar{x}_{pre}$=5.42, $\bar{x}_{post}$=14.03), no significant difference was observed between the mean of the posttest scores of the control and experimental groups.

**Table 6.**
*Covariance Analysis Results of the Mental Rotation Test Scores of the Groups*

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Pretest (Covariate) | 121.500 | 1 | 121.500 | 13.672 |
| Group | 2.743 | 1 | 2.743 | .309 |
| Error | 524.306 | 59 | 8.887 | |
| Corrected Total | 694.597 | 61 | | |

## Discussion and Conclusion

The aim of the present study was to determine the effects of using Google SketchUp, interactive software program on the mental rotation skills of eighth grade students. For this purpose, we tried to find whether there is a positive effect of using concrete objects and Google SketchUp on mental rotation skills through a quasi-experimental pretest posttest research with a control group. At the beginning of the research, there was a significant difference between the experimental and control groups. While analyzing posttest scores, we used covariance statistic method to eliminate the negative impact of the difference between the pretest scores.

The data gathered with "Vandenberg Mental Rotation Test" was analyzed; the paired sample t-test results showed that the posttest scores of the both experimental and control groups significantly increased when compared to the pretest results. There are many studies indicating that training with appropriate materials and activities increase the spatial skills (Burnett & Lane, 1980; Ben-Chaim, Lappan, & Houang, 1988; Kurtuluş, 2011; Olkun, 2003; Rafi et al., 2006; Rafi et al., 2008; Yıldız & Tüzün, 2011). According to the results of the study, the drawing activities used concrete objects and Google SketchUp is effective as well as the training with concrete objects and isometric paper. This present result supports Yıldız and Tüzün's study which has shown that using unit cube models and isometric papers has a significant effect on students' mental test's scores. On the other hand the finding contradicts the result (Yıldız & Tüzün) that demonstrated that using 3-D virtual environment did not have a significant effect on the scores of the mental rotation test. In addition to this, the current study's results are in contradiction with the studies which suggest the use of dynamic geometry software and computer aided activities to improve the mental skills of learners (Baki et al., 2011; De Lisi & Wolford, 2002).

Furthermore, although the increase in the mean scores of mental rotation test is higher in the experimental group, the ANCOVA results revealed that, there is no significant difference between the mean scores of the Mental Rotation Test of the experimental and control groups, controlling for the effects of pretest scores of the groups. According to this result, whatever the environment in which the instruction was executed, there is no evidence to say that the use of physical and virtual manipulatives develops spatial skills of students. This finding is parallel with the studies (Yıldız & Tüzün, 2011) which stated that there is no significant difference between groups in terms of "Vandenberg Mental Rotation Test" scores.

Mathematics teachers, informally interviewed in the aforementioned school, stated that mathematics covers abstract subjects, but space geometry subjects are the most abstract. Space geometry topics could be a problem not only for pupils but also teachers, especially when they have very limited spatial skills. One of the most significant reasons of this problem might stem from the drawings on the blackboard or paper which could not be constructed in students' minds. Therefore, teachers need various teaching tools and new approaches to embodying geometry concepts.

In conclusion, as it mentioned before, NCTM and TME stressed the importance of geometry instruction that should present three-dimensional geometry activities and improvement of spatial skills of learners. According to the latest mathematics education program, there are several objectives which are related to spatial ability like improving spatial abilities, drawing different perspectives of structures etc. Furthermore, mathematics teachers, informally interviewed in the aforementioned school, stated that mathematics covers abstract subjects, but space geometry subjects are the most abstract. Space geometry topics could be a problem not only for pupils but also teachers, especially when they have very limited spatial skills. One of the most significant reasons of this problem might stem from the drawings on the blackboard or paper which could not be constructed in students' minds. Therefore, teachers need various teaching tools and new approaches to embodying geometry concepts. Manipulatives can be used as a teaching tool to engage learners in mathematics and geometry lessons. As Furner and Marinas (2007) stated, activities that are enriched by dynamic hands-on materials can motivate students to learn abstract geometry subjects and also have positive attitudes toward mathematics and developing substantial mathematical content knowledge. This present study states that the use of physical manipulatives (unit cube models) and virtual manipulatives (dynamic geometry software) may help the improvement of spatial abilities of learners. For the further studies, the effects of using physical manipulatives with virtual manipulatives on learners' spatial skills and mathematics achievements can be investigated. This study might serve several implications for geometry or mathematics teachers, researchers, instructional designers and school administrators. Obviously, the training sessions which took four weeks were not enough to make the students capable in mental rotation skills. In other words, with the help of more practice and longer training process students could be more successful in solving mental rotation problems. Also, this study was conducted with secondary school students, therefore the future studies can investigate the effects of using manipulatives (physical & virtual) on the performance of spatial ability of elementary and high school students.

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## Appendix

*A Sample Mental Rotation Test Paper of a Participant is Shown Below*