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THE INFLUENCE OF 4MAT MODEL ON ACADEMIC ACHIEVEMENT AND RETENTION OF LEARNING IN TRANSFORMATION GEOMETRY

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Abstract
This study investigates the influence of 4MAT model in the teaching of "Transformation Geometry" – a subject included in secondary school seventh grade mathematics curriculum – on students' academic achievement and retention of learning. 4MAT model, which is one of the contemporary educational approaches, is based on perceiving and processing knowledge. 4MAT model was designed by considering all of four learning styles in such a way that all learners could find a timeframe suitable for them. It defends developing student-centered learning environments based on the learning styles of students and making students discover knowledge by themselves. It enables students to use both hemispheres of their brains effectively (McCarthy, 1990). The pretest-posttest control group quasi-experimental design was used in the study. The study took 3 weeks. This teaching period was determined by considering the time recommended in the textbook and the time allocated for activities in other studies on 4MAT model. In this period, experimental group students were taught by lesson plans and activities based on 4MAT model. Control group students were taught by the 7th grade textbook of the Ministry of National Education in the same period. The research sample consisted of 61 seventh grade students living in a northern province of Turkey. The Transformation Geometry Knowledge Test developed by the researcher was used as data collection tool. This test was used in this study as a pre-test at the beginning of the teaching process, as a post-test at the end of the teaching process and as a retention test one month after the teaching process. The present study concluded that there was a significant difference in favor of the experimental group between the experimental group students and the control group students in terms of academic achievement and retention of learning in the learning of transformation geometry subject. It was seen that 4MAT model was more effective in the teaching of transformation geometry in comparison to textbook-based teaching.

Keywords: Mathematics education, 4MAT model, brain hemisphere, learning style, transformation geometry.

INTRODUCTION

As modern educational mentality has emerged, innovations have been introduced to teaching, and many models have started to be used in order to be more productive in education. One of these models is 4MAT model (McCarthy, 1982). McCarthy created 4MAT model through experimental studies carried out in a high school for 6 years (McCarthy, 1987). The 4MAT model has many similarities to Kolb's learning style model in terms of perception and processing of information. In both models, individual's perception of the information ranges from concrete experience to abstract conceptualization and processing of the information ranges from reflective observation to active experimentation, see Figure 1 (McCarthy, 1982, 1990, 2000).

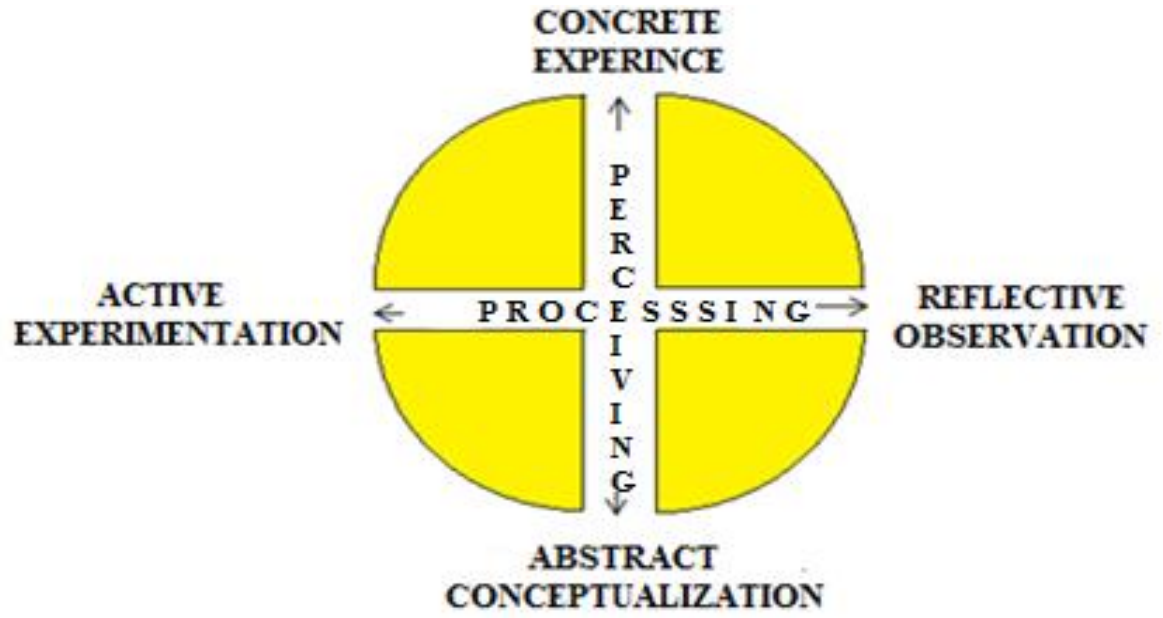

Figure 1: Learning cycle (McCarthy, 1990)

Through experimental studies, McCarthy determined the learning styles as a combination of an individual's perception and processing of the information as follows (see Figure 2):

- type 1 learners (imaginative learners);
- type 2 learners (analytic learners);
- type 3 learners (common-sense learners); and
- type 4 learners (dynamic learners) (McCarthy, 1987, 1990, 1997; Morris & McCarthy, 1999).

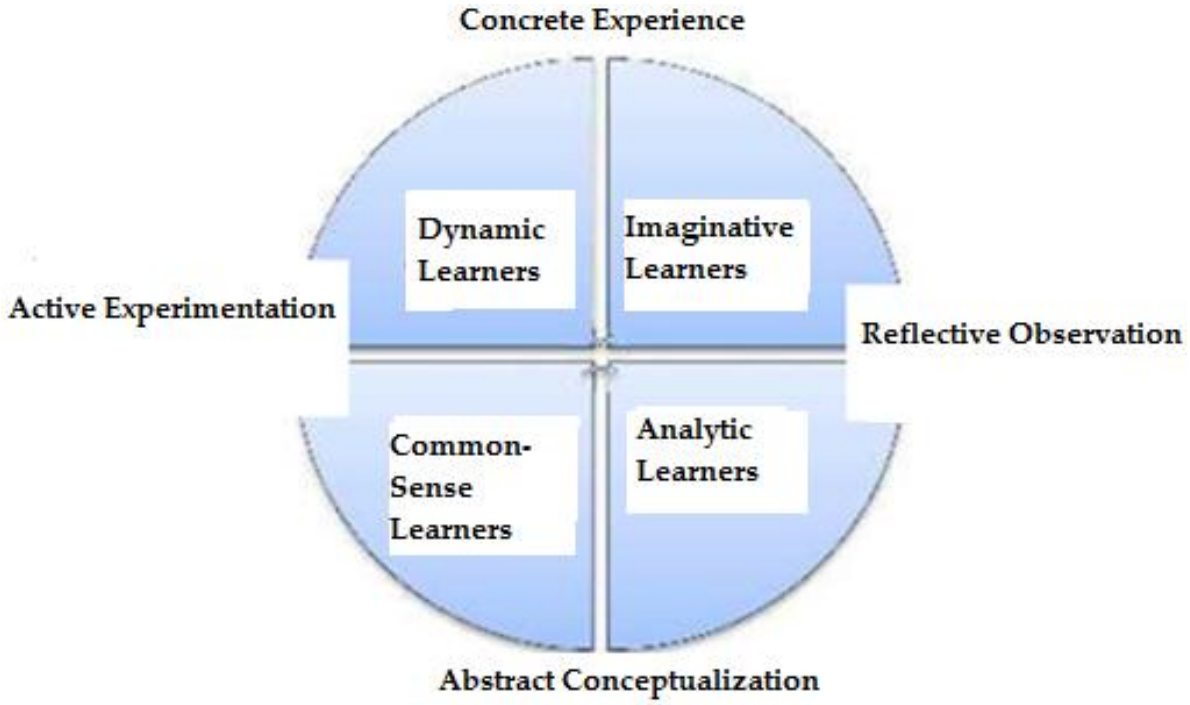

Figure 2: McCarthy's 4MAT model (McCarthy, 1990)

The priorities of the imaginative learners are personal meaning. Teachers need to create a reason for their students and answer "Why?" question. The priorities of the analytic learners are phenomena that will provide conceptual meaning. Teachers should give cases to students to deepen their understanding and answer "What?" question. The priorities of the common-sense learners are to know how things work. Teachers should give their students an opportunity to do this and answer "How?" question. And lastly, the priorities of the dynamic learners are personal exploration and adapt their learning to them. Teachers should give their students an opportunity to provide personal exploration and answer "If?" question (McCarthy, 1997).

Since mathematics is an abstract course, non-use of appropriate methods and techniques may cause students to wrongly feel that mathematics is not used in the daily life, and mathematics is limited to textbooks alone. To prevent that, it must be made clear that mathematics is an enjoyable course that both contributes to the development of individuals and provides them with such skills as questioning and establishing cause and effect relations. That can be achieved by visualizing and concretizing subjects as much as possible, including all students in lessons actively, and implicating the link of mathematics with real life in lessons (Altun, 2006). Besides, one of the main reasons for low mathematics achievement among students is the problems about the way they perceive and process mathematics (Ersoy, 1997). 4MAT model, which is one of the contemporary educational approaches, is based on perceiving and processing knowledge. It defends developing student-centered learning environments based on the learning styles of students and making students discover knowledge by themselves. It enables students to use both hemispheres of their brains effectively (McCarthy, 1990). Thus, it is recommended to be used in mathematics lessons.

4MAT model does not only consist of a cycle that is based on Kolb's experimental learning model. In consideration of neurological studies, McCarthy also stated that the dominant hemisphere used by individuals in the information processing process (i.e. right or left hemisphere) had to be considered (McCarthy, 1990). To achieve meaningful learning, the integrity of new information must be seen and such information must be associated and constructed with the existing information in the mind that has been learned before. That is possible only if brain functions are used as a whole. The research on the functions of right and left hemispheres of brain generally describes left hemisphere as serial, logical, rational, verbal, analytic, and systematic. Analysis and planning strategies are adopted. The result is important and problems are solved by looking at the parts (McCarthy, 1990). The right hemisphere, on the other hand, is visual, universal, and holistic. It can see the connections between pieces. It solves the problem by looking at the big picture (i.e. the whole) and considers the whole more important than all parts (McCarthy, 1990).

4MAT model was designed by considering all of four learning styles in such a way that all learners could find a timeframe suitable for them. Training should be conducted to address all four regions of the learning cycle so that all students can be successful and not only limited to one region but also to improve all learning abilities. Thus, students do not only succeed in their own learning style regions but also learn a lot from each other in other regions of the cycle. To this end, McCarthy developed an eight-step lesson plan (McCarthy, 2000). Each step of this eight-step model addresses a different hemisphere of the brain. Such steps are as indicated in Figure 3 (McCarthy, 1990; Morris & McCarthy, 1999).

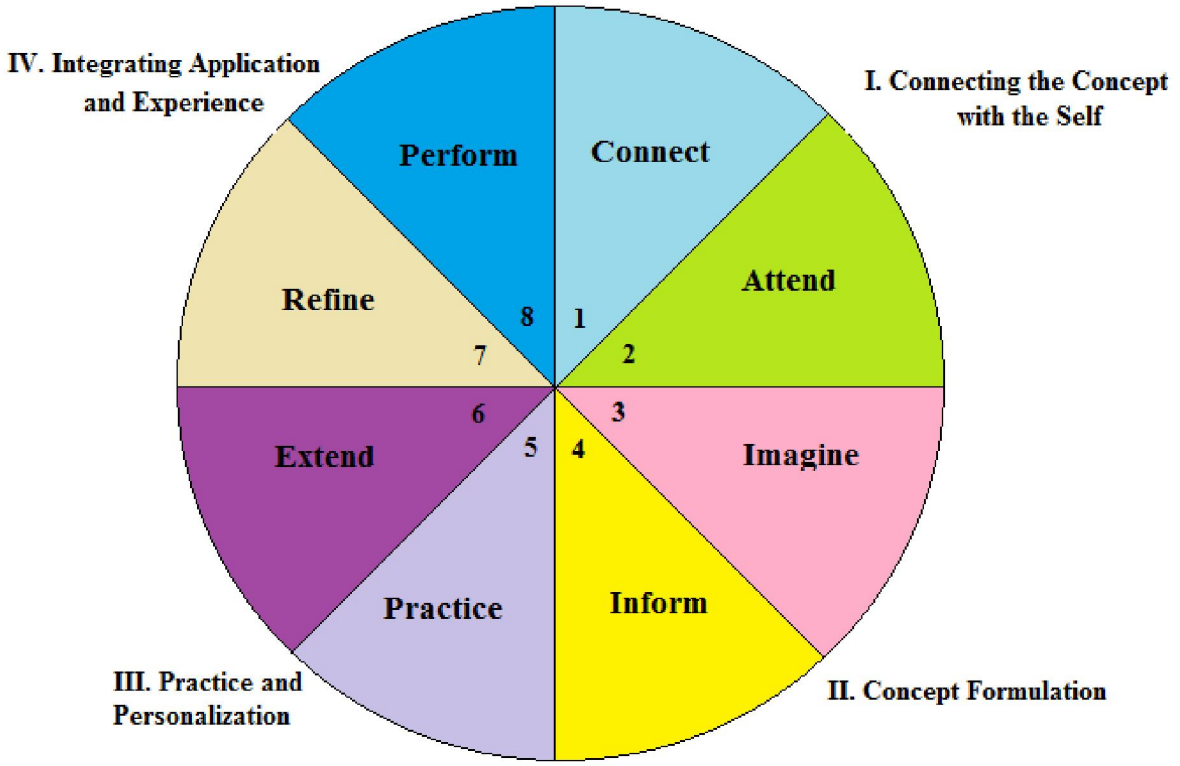

Figure 3: 4MAT model and eight steps (McCarthy, 1990; Morris & McCarthy, 1999)

Transformation geometry is an abstract subject included in the mathematics curriculum with an amendment introduced by the Ministry of National Education in 2005 (MoNE, 2006). Therefore, studies on transformation geometry in Turkey are limited and studies to be done are important. Research on transformation geometry has mostly focused on the computer-supported teaching of this subject and compared traditional teaching with computer-supported teaching. (Dixon, 1995; Glass, 2001; Altın, 2012; Sarı, 2012; Özyaşar, 2013). However, it is thought that attention should also be focused on the teaching of transformation geometry through other contemporary learning approaches, and 4MAT model is one of these approaches. Additionally, when reviewing the "4 MAT 4 geometry teacher book" (McCarthy, 2010), it appears that the 4MAT model is suitable for teaching the subject of transformation geometry. However, there isn't any study about the application of 4MAT model to transformation geometry subject.

In this research, reflection symmetry topic will be investigated from the topics of transformation geometry. The concept of symmetry is an important concept that individuals need to organize things and events in their environment and to develop qualitative perceptions about the outside world (Knuchel, 2004). NCTM (1991) notes that the concept of symmetry is a necessary mental tool for analyzing mathematical situations. There are many reasons why symmetry is important. The first of these is the need for symmetry to recognize the environment we have experienced. The second reason is that the concept of symmetry is included in mathematics curricula at every level from primary education to university. In addition, the information about symmetry has great importance for the teaching of many subjects in the context of analytic geometry, plane and space geometry (Aksoy & Bayazit, 2014). The concept of symmetry also has an interdisciplinary function. Many professions, such as biologists, chemists and physicists use the concept of symmetry (Barry et al., 2002; Whiteley, 2004).

The literature review about 4MAT model shows that most studies compare the effects of traditional teaching methods and those of 4MAT model on student achievement in different lessons. There are studies that examine the impact of 4MAT model on academic success in science lesson (Aktaş, 2011;

Delaney, 2002; Mutlu, 2004), in middle school mathematics lesson (Ardıç, 2013; Dikkartın, 2006, Uysal, 2009), in high school mathematics lesson (Peker, 2003), in geography lesson (Demirkaya, 2003; Kofoğlu, 2014), in physics lesson (Ergin, 2011), in history lesson (Öztürk, 2007), in microbiology lesson (Jackson, 2001). Some researchers, on the other hand, deal with the influence of 4MAT model on the retention of what is learned in addition to academic achievement (Ardıç, 2013; Jackson, 2001; Uysal, 2009).

When looking at the researches done it is seen that fewer studies have been conducted on 4MAT model in Turkey in comparison to those conducted abroad. Moreover, while research on 4MAT model has been conducted abroad for a long time, research on this subject has just started in Turkey. In addition, studies on the 4MAT model in mathematics are few and also there are very few studies examining the impact of the 4MAT model on academic achievement and retention of learning together in mathematics subjects. Therefore, it is thought that the research to be done on this model has great importance.

Research Problem

This study was carried out in order to determine the influence of 4MAT model on the learning of transformation geometry. The problem of the present study is as follows: "Does the use of 4MAT model in teaching 'Transformation Geometry' in the middle school 7th-grade mathematics course have any influence on student achievement and the retention of what is learned?" In this regard, an attempt was made to answer the below-mentioned questions;

1. Is there any significant difference between the influence of teaching by 4MAT model and teaching based on the textbook on students' academic achievement on transformation geometry subject?
2. Is there any significant difference between the influence of teaching by 4MAT model and teaching based on the textbook on the retention of knowledge on transformation geometry subject?

METHOD

Research Model

The pretest-posttest control group quasi-experimental model was employed in the study. The subjects were subjected to measurement both before and after the experimentation. The subjects were divided into two groups: experimental and control group. Because the classes were formed by the school management, it was not possible for the students to be placed on the experimental and control groups randomly. One of the previously formed classes was assigned to the experimental group and the other to the control group.

Sample

The sample of the research consisted of 61 seventh grade students living in a northern province of Turkey. The distribution of the study group is provided in Table 1 given below.

Table 1: The Number of Students in the Experimental and Control Groups

Group	Female	Male	Total
Experimental group	21	11	32
Control group	16	13	29
Total	37	24	61

As is seen in Table 1, the study group consisted of 61 students in total. It was decided that the groups were equal to each other by looking at the mathematics lesson success scores in previous years and the mathematics averages in examinations made by the Ministry of National Education. Additionally, pre-test mean scores obtained by the achievement test were analyzed and it was seen that groups are equivalent.

Application

The lessons were completed in the total of 8-course hours, each of 40 minutes. The duration was determined by considering the recommended duration for this achievement in the secondary school mathematics curriculum and the durations suggested in the lesson plans developed based on the 4MAT model. The teaching experience in both groups was done by two teachers who graduated from Primary Mathematics Education Department. They had the same experience in mathematics teaching and were of the same age. The teacher who is teaching in the experiment group had the knowledge and expertise about the 4MAT model.

Experimental group teaching: Experimental group students were taught by lesson plans and activities based on 4MAT model. Lesson plans based on 4MAT model were prepared by examining the books entitled "4 MAT 4 Algebra" (McCarthy, 2007) and "4 MAT 4 Geometry Activity Book" (McCarthy, 2010) and receiving expert opinions. A sample lesson plan is presented in Appendix 1.

Control group teaching: Control group students were taught by the 7th grade textbook of the Ministry of National Education in the same period. This teaching period was determined by considering the time recommended in the textbook and the time allocated for activities in other studies on 4MAT model. Generally, question-answer, display techniques were used and the teacher was more active than students. First of all, the teacher explained the subject on the board. After doing the teaching, the teacher asked the students various questions about the subject. Some students were able to answer the questions, and some could not answer correctly. The activities in the textbook were done by the students with the guidance of the teacher. Some of the questions in the book were given to students as homework. The next lesson teacher solved the questions students could not solve. Then the teacher taught the new subject similarly.

Data Collection Tools and Data Analysis

The research data were obtained through The Transformation Geometry Knowledge Test. This test was used in this study as a pre-test at the beginning of the teaching process, as a post-test at the end of the teaching process and as a retention test one month after the teaching process. 35 questions were prepared based on previous years' central exam questions and the questions from various sources. To determine its validity and reliability, the test was administered to 118 eighth grade students as a pilot study. Cronbach's Alpha coefficient was used a criterion of reliability. It is considered that a Cronbach's Alpha reliability coefficient which is not less than 0.70 is generally enough for accepting that test scores are reliable (Büyüköztürk, 2008). The Cronbach's Alpha reliability coefficient of The Transformation Geometry Knowledge Test was found to be 0.754.

The validity of the knowledge test and the difficulty of the questions were examined by SPSS (Statistical Package for the Social Sciences). The test was finalized to consist of 30 questions based on reliability, validity, and difficulty criteria as well as expert opinions. Thus, it was ready for administration to both groups as the pre-test, post-test and retention test.

RESULTS

Results Related To First Sub-Problem

An ANCOVA test was used for determine is there any significant difference between the influence of teaching by 4MAT model and teaching based on the textbook on students' academic achievement on transformation geometry subject. ANCOVA hypotheses were examined for achievement test in the first place. Since all ANCOVA hypotheses were confirmed, whether or not there was any significant difference between the posttest scores of the groups adjusted based on the pretest scores was analyzed through the ANCOVA test. The analysis results are given in Table 2.

Table 2: The Adjusted Scores of the Experimental and Control Groups

Group		Original Mean	Adjusted Mean
Experimental	Pretest	14.16	14.90
Control		15.72	14.90
Experimental	Posttest	21.22	21.70
Control		18.55	18.02

As is seen in Table 2, while the original pretest score of the experimental group was 14.16, that of the control group was 15.72. On the other hand, while the original posttest score of the experimental group was 21.22, that of the control group was 18.55. The adjusted means indicated that the pretest scores became equal at 14.90, and the posttest scores were recalculated to be 21.70 for the experimental group and 18.02 for the control group. Figure 4 presents the pretest and the posttest scores of the experimental and control groups.

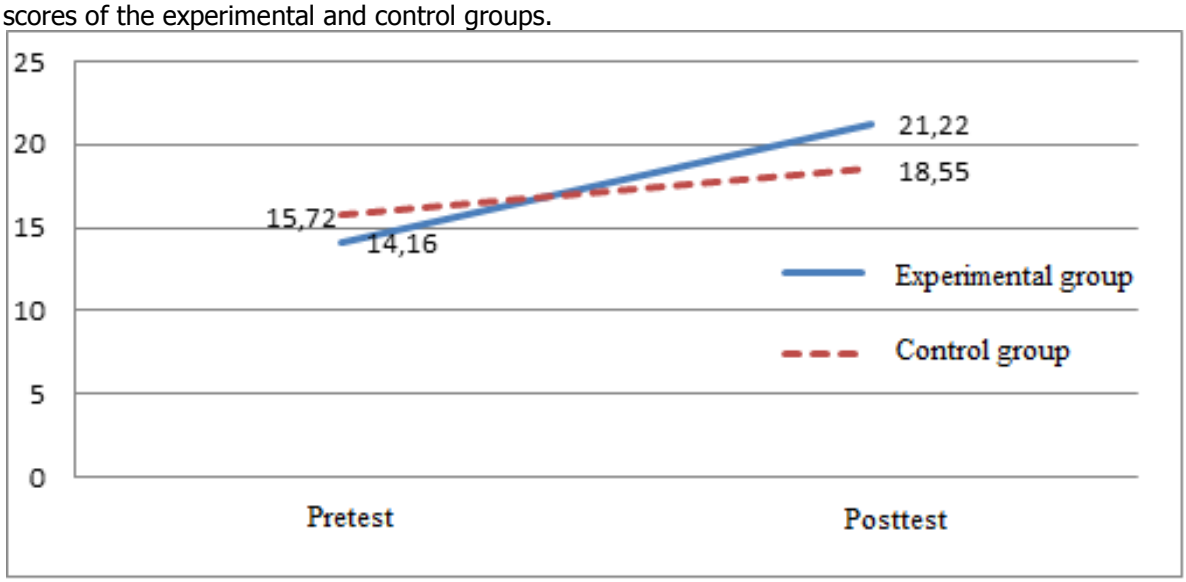

Figure 4: The pretest and the posttest scores of the experimental and control groups

Table 3 shows the ANCOVA results of the posttest scores adjusted based on the pretest scores by groups.

Table 3: The Ancova Results of the Posttest Scores Adjusted based on the Pretest Scores by Groups

Group	Sum of Squares	sd	Mean Square	F	P
Pretest	512.213	1	512.213	37.302	.000
Group	199.496	1	199.496	14.528	**.000**
Error	796.428	58	13.732		
Total	25697.000	61			

As is seen in Table 3, the ANCOVA results showed that there was a significant difference in favor of the experimental group between the posttest average scores of the experimental and control groups students adjusted based on the pretest scores **[F(1.58)=14.528, p<.05].** The results demonstrated that the experimental group students have a higher-level academic achievement in

comparison to the control-group students. Based on these results, it can be said that teaching involving 4MAT model is more effective than teaching based on the textbook.

Results Related To Second Sub-Problem

An ANCOVA test was used for determine is there any significant difference between the influence of teaching by 4MAT model and teaching based on the textbook on the retention of knowledge on transformation geometry subject. ANCOVA hypotheses were examined for achievement test in the first place. Since all ANCOVA hypotheses were confirmed, whether or not there was any significant difference between the posttest scores of the groups adjusted based on the pretest scores was analyzed through the ANCOVA test. The analysis results are given in Table 4.

Table 4:The Adjusted Scores of the Experimental and Control Groups

Group	Original Mean	Adjusted Mean
Experimental		14.16
14.90		
	Pretest	
Control		15.72
14.90		
Experimental		21.66
22.07		
	Retention test	
Control		18.52
18.06		

As is seen in Table 4, while the original pretest score of the experimental group was 14.16, that of the control group was 15.72. On the other hand, while the original retention test score of the experimental group was 21.66, that of the control group was 18.52. The adjusted means indicated that the pretest scores became equal at 14.90, and the retention test scores were recalculated to be 22.07 for the experimental group and 18.06 for the control group. Figure 5 presents the pretest and the retention test scores of the experimental and control groups.

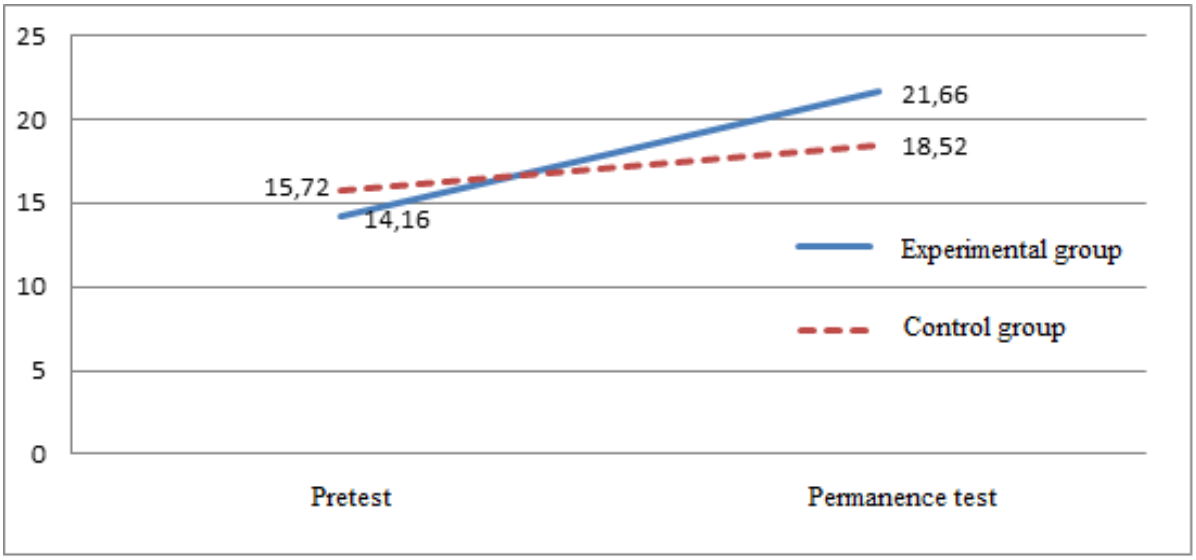

Figure 5: The pretest and the retention test scores of the experimental and control groups

Table 5 shows the ANCOVA results of the posttest scores adjusted based on the pretest scores by groups.

Table 5:The Ancova Results of the Posttest Scores Adjusted based on the Pretest Scores by Groups

Group	Sum of Squares	sd	Mean Square	F	P
Pretest	385.524	1	385.524	23.714	.000
Group	237.923	1	237.923	14.635	**.000**
Error	942.936	58	16.258		
Total	26280.000	61			

As is seen in Table 5, the ANCOVA results showed that there was a significant difference in favor of the experimental group between the retention test average scores of the experimental and control groups students adjusted based on the pretest scores **[F(1.58)=14.635, p<.05].**

When two groups starting to learn in equal conditions are compared at the end of a certain period, the group with a higher average is deemed to have achieved more permanent learning. The results demonstrated that in transformation geometry subject, the experimental-group students taught through 4MAT model have more permanent learning in comparison to the control-group students taught based on the textbook. Based on these results, it can be said that teaching involving 4MAT model is more effective than teaching based on the textbook.

DISCUSSION AND CONCLUSION

The present study concluded that there was a significant difference in favor of the experimental group between the experimental group students and the control group students in terms of academic achievement in the learning of transformation geometry subject. The research result is similar to those of many studies in the literature. As in this study, in many of the researches, subjects taught experimental groups by 4MAT model and control groups by use of textbooks based on traditional lecture and question-answer teaching. In most of the studies, similar to this study, it was seen that experimental groups were significantly more successful than control groups. When we examined according to the lessons, 4MAT model has a significant impact on science achievement (Aktaş, 2011; Mutlu, 2004), on mathematics achievement (Ardıç, 2013; Dikkartın, 2006; Peker, 2003; Uysal, 2009), on geography achievement (Demirkaya, 2003; Kofoğlu, 2014), on physics achievement (Ergin, 2011), on history achievement (Öztürk, 2007) and on microbiology achievement (Jackson, 2001). Contrary to these studies, in the work of Delaney (2002) and Lee (2008) there was no significant difference in academic achievement between the experimental and control group students.

When we look at the research that examines the effect of the 4MAT model on the retention of learned topics, as in this study, it has been seen that teaching based on 4MAT model is more effective than traditional teaching at achieving permanent learning (Ardıç, 2013; Jackson, 2001; Uysal, 2009). Looking at these results, it can be concluded that 4MAT model is effective in practice. Based on these research results, the following suggestions have been made.

- Failure in addressing all students and teaching based on just one method cause us to fail to reach intended success in the mathematics course. Since 4MAT model takes into consideration individual differences and provides the diversity of methods and activities, it may be used in the classroom environment effectively.
- Mathematics teachers may teach transformation geometry subject based on 4MAT model rather than sticking to textbooks alone.
- Prospective teachers should be informed of 4MAT model and other methods based on learning styles in the faculties of education so that they can employ such models in their future professional lives.

- The effect of 4MAT model on academic achievement may be investigated in subjects other than transformation geometry and in grades different from the 7th grade as well as at different levels and in different sub-learning fields.

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Appendix 1. Sample Lesson Plan based on 4MAT Model

Acquisition: Explains reflection
1st Quarter (Connecting the Concept with the Self)
1st Step (Connect)
Studenst are provided with an opportunity to have personal experience so that they can establish a bond with the subject.
Objective: To enable students to establish a bond with the subject by giving examples from daily life.
Activity: Students sit in groups. They are asked to write their opinions on paper together with group members. Then they are told that the opinions noted by them will be discussed in the class.

Photos about reflection are brought to the classroom. Students are requested to examine photos in Figure 6.

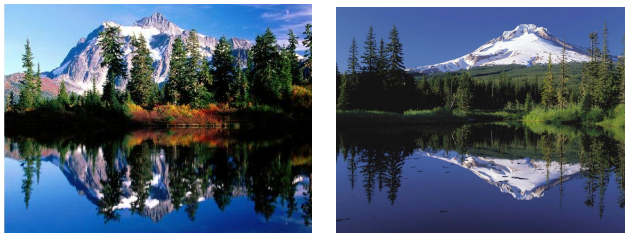

Figure 6: Photos about reflection

The following questions are asked: "What sorts of similarities and differences are there between ourselves and our images in the mirror?" and "What change and what remain unchanged in the reflection?". In addition, the question, "Why is the word 'ambulance' written backwards on ambulances?" is asked. Students write their opinions in groups of 4.

Photos about symmetry in Figure 7 are showed. Students are asked to give examples. The relationship between symmetry and reflection is questioned.

Figure 7: Photos about symmetry

Do you think there is symmetry in daily life?
Students are made to play the mirror game. They are made pairs. One student plays the role of a person looking in the mirror, and the other student plays the role of the image of this person in the mirror. The student looking in the mirror acts in some ways, and the student playing the role of the image tries to act in the same ways by considering the images of such acts in the mirror. For example, when the student looking in the mirror raises his right hand, left hand must be raised by the student playing the role of the image.

Students' attention is attracted by showing games about reflection.

2nd Step (Attend)
The experience created in the previous step is analyzed.

Objective: To enable students to analyze the experience in the first step by discussing.

Activity: Classroom discussion organized by teacher is made.

Students examine photos about reflection and discover that a reflection is the image of a figure with respect to a specific reference point.

It is discovered that our image in the mirror is the same as us, and the difference is that our image in the mirror is our inverse. The image in the mirror is our reflection. Mirrors show written things backwards. So, when the driver of a car followed by an ambulance looks at the ambulance by using the rear-view mirror, reads the word "ambulance", which is written on the ambulance backwards, normally. That is, s/he reads it as "ambulance" and gives way to the ambulance depending on his/her humanity. Students are made to find out why the word "ambulance" is written backwards and understand that reflection is employed on this occasion.

Based on the symmetry photos examined, students are made to find out that reflection is the symmetry of an object with respect to a line. Students are requested to find the lines of symmetry of butterfly and human face.

It is concluded that the student playing the role of image in the mirror does the opposite of the person looking in the mirror as our image in the mirror is the opposite of us.

Students' opinions in regard to the symmetry game in the internet are received.

2nd Quarter (Concept Formulation)
3rd Step (Imagine)
Ideas are conceptualized in this step.

Objective: To enable students to see the relationship between the concepts "symmetry" and "reflection" and visualize the concept "symmetry of figure with respect to a line".

Activity: Students are made to find the symmetries of letters and figures by using the symmetry mirror. Symmetrical and nonsymmetrical letters are drawn. By using the symmetry mirror, it is discussed which letters are symmetrical and which ones are asymmetrical (see Figure 8).

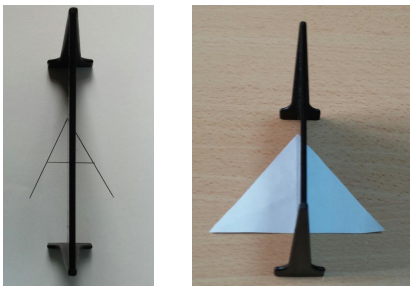

Figure 8: Photos about symmetry mirror

Isometric dot paper is covered with gelatin. The symmetry mirror is put in the middle of it. Figures are made out of multi-squares, and the symmetries of these figures are found by use of the symmetry mirror. In this way, reflection is acquired by regarding the symmetry mirror as the line of symmetry. Triangle, quadrangle, and circle models are drawn, and the concepts "symmetry" and "reflection" are understood by using the symmetry mirror. It is concluded that the image turns down when the symmetry is being taken in the models used and the drawings made. The mirror symmetry is reflection with respect to a line.

The images of the figures, letters, and words in the mirror are examined by putting a symmetry mirror next to and over them. In this way, symmetry is found.

Regular polygons are made by cutting paper, and students are asked to find the number of symmetry axes through folding (see Figure 9).

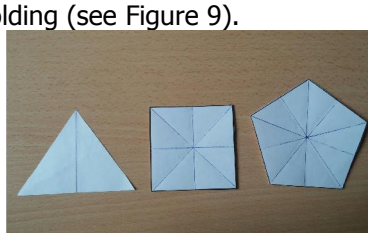

Figure 9: Students' studies about symmetry axes

Every group folds the paper in two. They draw a model and cut it. They open the figure, put a pencil between two sides, and regard it as line of symmetry. In this way, symmetry is understood. The same model is used when explaining how to find the symmetry of a symmetry. In this case, the paper is folded in three (see Figure 10).

Figure 10: Students' studies about reflection over a pair of parallel lines

4th Step (Inform)
Teacher gives information about the subject.

Objective: To define the concept reflection; to find the symmetries of figures and their reflections with respect to a line.

Activity: Teacher conducts the lesson where information about the subject area is to be given.
It is explained that the concepts "mirror symmetry", "reflection", and "symmetry with respect to a line" have the same meaning, that a figure and its reflection are equivalent, and that the form and the size of a figure do not change in reflection, and only the figure becomes reverse and changes place. The concepts "horizontal symmetry" and "vertical symmetry" are explained. Examples can be given from the symmetry axes of letters. The symmetry axes of regular polygons are focused on. It is demonstrated that symmetry with respect to a line is found by determining points on the figure and drawing perpendicular lines from such points to the symmetry axis.

3rd Quarter (Practice and Personalization)
5th Step (Practice)
The defined concepts are practiced.

Objective: To practice upon reflection under the guidance of teacher.

Activity: Isometric paper is reflected on the board by a projector; figures are drawn on it; and students are made to find the symmetries of these figures. Students find such symmetries by drawing the figures on their notebooks. Students are made to solve problems for practice.

Figures are created on the geometry board by use of rubbers. Students are made to find their reflections on the axes. The figures are created on a geometry board. Their symmetric images are obtained on other geometry boards. (see Figure 11).

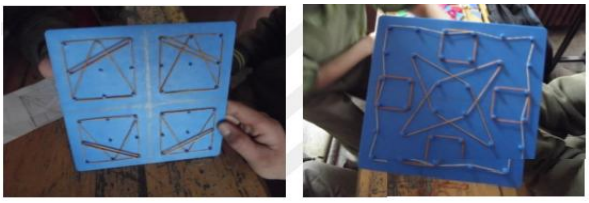

Figure 11: Reflection examples in geometry board

Students are asked to create symmetrical figures on the paper by using colored pencils and to find symmetry lines. Evaluations are made in regard to which ones are symmetrical and which ones are non-symmetrical (see Figure 12).

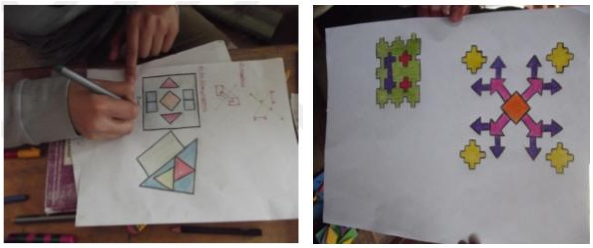

Figure 12: Students' painting activities about symmetrical and non-symmetrical shapes

Simple reflection practices are made by Geogebra program in the computer.

6th Step (Extend)
By using their current knowledge, students add to what have they learned in the previous step.
Objective: To enable students to internalize what they have learned about reflection.

Activity: Students are made to solve higher-level problems for practice.

High-level practices are made in regard to reflection by Geogebra. Billiards games and problems such as those involving shortest distance between cities that require the use of reflection are assigned to 4-person groups as a project (see Figure 13).

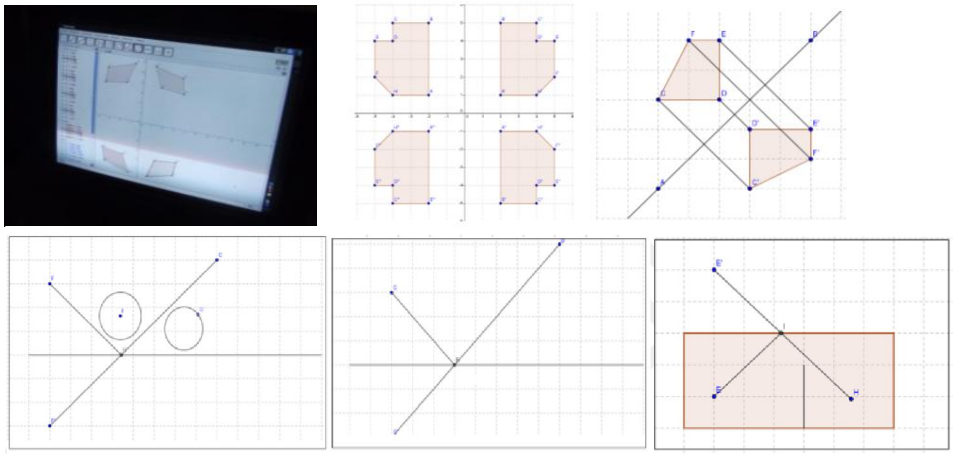

Figure 13: Students' activities on reflection in the geogebra program

4th Quarter (Integrating Application and Experience)
7th Step (Refine)
Practices are analyzed by students.

Objective: To enable students to analyze the practices about reflection.

Activity: Practices in the steps 5 and 6 are analyzed in terms of relevance and usefulness. Every group evaluates the works of other groups. In regard to their projects, they ask questions to one another and receive the opinions of one another.

8th Step (Perform)
Students share what they have learned with their classmates.

Objective: To provide students with an opportunity to explain what they have learned to one another.

Activity: Based on the criticisms, group works are made the best. Teacher evaluates projects according to a rubric. Projects are hung in the classroom. Students present their projects to the classroom. In this way, every student can see all projects. If possible, projects are exhibited in the website.

Students are requested to create a mathematics journal where they will write their opinions about this mathematics lesson.