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The Effects of Teaching Mathematics Creatively on Academic Achievement, Attitudes towards Mathematics, and Mathematics Anxiety

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Abstract

This study was conducted to examine the effects of teaching math creatively on 6th graders' mathematics achievement, attitudes towards mathematics and mathematics anxiety. A pretest-post test with control group quasi-experimental design was used in the study. The sample of the study was composed of 42 6th graders attending public elementary schools. The data have been collected by administering the *Math Achievement Test*, *Mathematics Attitude Scale* and the *Math Anxiety Scale*. "Teaching math creatively" was used in teaching mathematics to the experimental group whereas the control group was taught using the "traditional method". The results of the study showed that employing "teaching math creatively" in 6th grade mathematics can be effective in increasing math achievement, attitudes towards math, and decreasing math anxiety. In addition, when effect size is examined, teaching math creatively has a strong effect on students' mathematics achievement (d= 1.97, η2= .57); moderate effect on attitudes towards mathematics (d= 0.50, η2= .08); and a strong effect on mathematics anxiety (d=1.37, η2= .32).

Introduction

Problem solving has a long tradition in school mathematics. Usually, it has been taught (and is still taught in some schools even today) by the method of "learning from the master": The teacher shows a method, with some examples, which pupils then apply to similar problems. Every now and then, such a teaching style is criticized as formal and schematic, but so far, attempts to shake off formal teaching methods have never been successful (Pehkonen, 1997). Similarly, according to Hirsch (2010), math was often thought of as memorization of facts and algorithms. Many math textbooks, workbooks, and resources reinforced this traditional memorization methodology. It is apparent that radical changes are needed in the teaching of mathematics. In addition, too many adults fear and dislike mathematics- and therefore feel unable to use it in their everyday lives. Innovations in policy and practice have made some improvements but this is not enough (Pound & Lee, 2011). Within this perspective, math teaching should be a subject that needs to be continually questioned, evaluated, and developed (Kocabaş, 2008).

In math class, creative teaching which encourages divergent thinking, provides a supportive and constitutive learning environment (Fasko, 2000-2001), and which is characterized as a good teaching by Kind and Kind (2008) can influence the academic achievement, attitudes toward math, and math anxiety of students in a positive way. However, in math class, among different teaching application seeking, there are very few studies about creative approaches to teaching math, how to apply them, and their effects on different variables. Therefore, it is thought that the findings of the study will contribute to this field both theoretically and practically.

Mathematics course is one of the courses in Turkey that occupies 5 hours of classwork in a week. In secondary school mathematics curricula, besides acquiring mathematical concepts, it is also aimed students to acquire problem solving for learning and using mathematics effectively, developing of mathematical process skills (communication, reasoning, and association), affective skills, psychomotor skills and basic skills such as information and communication technologies. This curriculum covers such learning areas as "numbers and operations", "algebra", "geometry and measuring", "data processing" and "probability". As a teaching and learning approach problem solving, meaningful learning, collaborative learning, using of real learning environments and information and communication technologies effectively are suggested in the curricula. Additionally, in mathematics teaching, students are assessed both outcome and process oriented. (MoNE, 2013).

Theoretical framework

Mathematics and Teaching Creatively

Mathematics is not a fixed body of knowledge to be mastered but rather a fluid domain, the essence of which is the creative applications of mathematical knowledge in the solving of problems (Poincare, 1913; Whitcombe, 1988; cited in Mann, 2005). Unfortunately, some math instruction—always focusing on one correct way to find one correct answer—can rob from math much of its beauty and make it difficult for students to see *links between creativity and mathematics* (Starko, 2005).

In the last decades there has been a change in educational policy around the globe and combining creativity and knowledge of subject matter efforts were seen (Dickhut, 2003). Creative activity is possible in all subjects at school, all domains of knowledge and all areas of life. It is not confined to any particular domain (Allien, 2003). Therefore, creativity should be an intrinsic part of the "mathematics for all" program (Pehkonen, 1997).

Creative teaching may be defined in two ways: firstly, teaching creatively and secondly, teaching for creativity. Teaching creatively might be described as teachers using imaginative approaches to make learning more interesting, engaging, exciting and effective. Teaching for creativity might best be described as using forms of teaching that are intended to develop students' own creative thinking and behavior (Morris, 2006). Teaching math creatively was preferred within the framework of this study. Teaching creatively is an effective pedagogy (Jeffrey & Craft, 2001) and can improve the quality of education, make learning more meaningful and open up more exciting ways of approaching the curriculum (Beetlestone, 1998). Creative approaches to instruction usually entail finding new ways of accomplishing familiar tasks. In creative instruction, the subject matter is organized in a way that facilitates connections, encourages excitement, and makes learning a powerful endeavor. Creative teaching practices are both effective and innovative in promoting the acquisition of skills, knowledge, and understanding. Such practices provide motivation for student learning and often infuse a class with excitement and activity (Ritchhart, 2004). Teaching mathematics

creatively is essential and means teaching with variations and innovations. A creative lesson is interesting, challenging, unconventional, productive, and motivating (Girl, 1998). In order to teach creatively, teachers will use all their creative skills to plan and provide imaginative and stimulating activities, experiences and resources. Creative teaching can encourage pupils to question/challenge what they are offered, to imagine possibilities and make connections with other ideas or areas of learning (Pound & Lee, 2011). Numeracy skills are shown to benefit if teachers adopt a more creative approach to teaching and learning (Beetlestone, 1998).

Creative techniques

Creative teaching is influenced by various components. The first component is related to basic pedagogical skills such as lesson planning, classroom management, communication, and evaluation. The second component refers to the domain specific expertise, creative techniques (Girl, 1998). This study utilizes techniques like "analogy, stories, origami, tangram, drawing, visualization, and brainstorming" within the framework of *Teaching Math Creatively*. Starko (2005) draws attention to creative activities like "drawing, thinking flexibly, trying multiple paths, looking at problems in more than one way, asking questions, and making hypotheses" which can be used in math classes. Fisher (1995) proposes techniques like stories, drawing, and brainstorming which can be used during the creative process. According to Fisher, stories can provide a rich stimulus for divergent thinking (Fisher, 1987; cited in Fisher, 1995). Drawing is a wonderful way of making thinking visible. A child may not find it easy to express thinking in words but can always attempt to express it visually and find it easier to understand something in visual terms. Brainstorming is a useful strategy for generating ideas with children of all ages. Brainstorming helps children to reveal and share the fund of knowledge they bring to the learning situation (Fisher, 1995). Further, Zimmerman (1999; cited in Meissner, 2006) defines creative problem solving in four steps as finding analogies, double representations (visual-perceptual/formal-logical), multiple classifications, and reducing complexity. Hirsh (2010) challenges traditional mathematics instruction and proposes creative practices like arts to be utilized in mathematics classes. These practices include drawing pictures to solve problems, presenting information visually, visual story problems, visual representation of math concepts, and spatial strategies (charts, tessellations, geometrical grids, graphs, logic puzzles, flip charts, origami, information tables, and games) (Wilson 2009; cited in Hirsh, 2010).

Related studies

In mathematics education recent interest in creativity research can be observed. Leikin (2009) analyzed publications from 1999 till 2009 in seven leading research journals in mathematics education and seven leading journals in gifted education, and demonstrated that very few publications in mathematics education were devoted to creativity-related issues while research devoted to creativity within general psychology paid very little attention to mathematical creativity.

Nevertheless, a small number of empirical studies on creativity associated with mathematics have been carried out (cited in Leikin & Pitta-Pantazi, 2013). Bahar and Maker (2011) investigated the relationship between the creative mathematical performance of first to fourth graders and their achievements, and found significant correlations between the two. These results are consistent with those of Sak and Maker (2006), who studied connections among age, grade, mathematical knowledge and creative mathematical thinking for first to fifth grade students. They reported an increasing contribution of mathematical knowledge to children's creative mathematical thinking. Mann (2005) explored the relationship between mathematical

creativity and mathematical achievement of seventh-grade students. He reported that mathematical achievement was the strongest predictor of mathematical creativity (cited in Tabach, Friedlander, 2013). Evans (1964) and Tuli (1980) reported a significant relationship between attitudes towards mathematics and mathematical creativity. Plucker and Renzulli (1999) suggest a positive attitude may be an indicator of creative potential (cited in Mann, 2005). These studies are generally about mathematical creativity.

There are also studies on Teaching Creatively, which is the subject of this study. The research results of Akçam (2007) reveal that creative activities in elementary science classes (story, drawing, poetry, fairy tale, poster, model, etc.) positively affect students' attitudes and achievement. Candar (2009) found that science instruction supported by creative thinking techniques had positive effects on the students' academic achievement, attitudes, and motivations. Emir's study (2001) demonstrated that creative thinking in social sciences instruction created a statistically significant difference in favor of the experiment group regarding achievement, retention, attitude, and creative skill scores. Forseth (1980) evaluated the effects of art-making activities on students' attitudes towards mathematics and mathematics achievement in a study conducted with 30 4th graders in mathematics class. The results of the study indicated improved attitudes towards mathematics and increased elaboration ability. Another study conducted by Saygılı (2008) revealed that the analogy based teaching method was effective on mathematics achievement in secondary school 9th grade mathematics classes. Solomon (1989) studied the creative teaching practices in social sciences classes and concluded that "creativity can foster students' understanding of social issues and aid in the retention of students until graduation.**"**

Consequently, this study aims at analyzing the effects of *teaching math creatively* on academic achievement, attitudes towards math, and math anxiety. Because of the significance of mathematics in social life, problems in mathematics teaching, the need for different, rich approaches to mathematics teaching, and because of the fact that the number of studies on *teaching math creatively* is limited.

Study hypotheses

In order to study the problem, the following hypotheses were formulated:

1. Teaching math creatively increases math achievement.
2. Teaching math creatively improves the attitudes towards math.
3. Teaching math creatively decreases the anxiety of math.

Method

Research design

A pretest-post test control group quasi-experimental design was used in the study. Quasi-experiments do not use random assignment. In practice, it is often impossible in social research to assign subjects randomly to groups, particularly when the groups are pre-constituted (e.g. school classes, work departments, etc.) (Corbetta 2003, pp.107–108). Therefore, rather than randomly allocating, researchers choose a control group that is as similar to the experimental group as possible (Muijs 2004, pp.27). In this pattern, two of the present groups are matched based on specific variables (Büyüköztürk et al. 2008). At the beginning of the experimental trial "Math Achievement Test", "Mathematics Attitude Scale", and "Math Anxiety Scale" were administered in order to determine whether the groups were matching or not and the results of the t-test revealed that there was no significant difference

(p>.05) between the pretest scores of the study groups**.** While teaching math creatively was applied to the study group, the traditional method of teaching was applied to the control group. Finally, measurements related to the dependent variables of both groups were obtained by using the same tools.

Subjects

The study was conducted with 42 (23 females) 6th graders attending a state elementary school in Denizli city's central county, Turkey. Students were aged 11–12 years and enrolled in two classes. An experimental group in which teaching math creatively was employed (n=20) and a control group (n=22) were designated randomly among these subjects.

Data collection tools

Math Achievement Test, The Mathematics Attitude Scale, and Math Anxiety Scale have been used as pre and post-tests in this research. This method is very beneficial in terms of being easy to administer, reducing response shift bias, allowing for participant reflection about program effect on particular topic (Colosi, Dunifon, 2006). On the other hand, pre-test might have an effect on post-test scores because the participant might become familiar to the form and content of the test by means of pre-test due to the application of the same test to the same participants with certain intervals. There is a statistical solution in case of meeting the conditions for removing this threat for the internal validity; namely, covariance (ANCOVA) (Büyüköztürk et al. 2008). Therefore, Analysis of Covariance (ANCOVA) was used in this study. Moreover, expectations of participants and researchers related to experimental conditions might affect the findings of the study in a way of those expectations. It is suggested that in those experiments which have a possibility that can be affected by the expectations, participants should not be informed about experimental conditions and tools that will be applied (Büyüköztürk et al. 2008). In this study, participants have not been informed about experimental conditions and tools with the aim of not differentiating their behaviors on the experimental conditions.

The term mathematics achievement is operationalized as problem solving using polygons and ratio while the term attitude towards the math is operationalized as emotional disposition towards math. Also, the term math anxiety is operationalized as fear towards mathematics, stress, nervousness.

Information on these tools is as follows:

Math achievement test

In this study, the Mathematical Achievement Test covering the polygons and ratio subjects has been developed by the researchers. During the development of this test firstly a table of specifications was formed within the framework of the set objectives (8 objectives) for the polygons and ratio subjects in the Mathematics Course Curriculum for elementary 6th grade students and an experimental test of 50 questions was prepared based on experts' opinion. A total of 115 students attending a different state elementary school were given this test for the pilot study. The material analysis following the pilot study calculated each item's difficulty and discrimination indexes. Subsequently, a mathematics achievement test comprising a total of 38 questions was obtained. The means of the items in the test are between .20 and .87, and the standard deviations are between .34 and .50. The item total correlation coefficient ranges between .24 and .59. The test's KR-20 reliability coefficients were found to be 0.89. The math achievement test scores were organized in such a way that 1 point was given to the correct responses and 0 point for wrong responses.

Some of the questions covered by the mathematics achievement test are as follows:

1. Turkey is between 36º south and 42º north parallels. Find the distance in centimeters between the northern and southern tips of our country in a map drawn in 1:2 000 000 scale (the distance between two parallels of latitude=111 km).
2. A rectangular shaped garden's longer side is 4 meters short of twice the length of its shorter side. If the perimeter of the garden is 100 meters, how long is its longer side?
3. There are 14 female and 21 male guests in a dining room. What is the ratio of the number of female guests to the number of male guests?

Mathematics attitude scale

In this study the "Mathematics Attitude Scale" developed by Baykul (1990) covering a range of students from the elementary fifth grade to high-school seniors was used to assess the students' attitudes towards mathematics. The scale was commonly used by researchers in order to assess attitude towards mathematics in elementary schools in Turkey. The points in this Likert type scale was rated as "Strongly agree," "Generally Agree," "Neither agree nor disagree," "Disagree," and "Strongly disagree." Some of the items in this scale are: "Engaging in mathematics is fun for me", "I fear mathematics classes", "Mathematics is among my favorite subjects" and "I do not like mathematics at all".

According to the results of the factor analysis, which was carried out in order to determine the structural validity of the scale, the variant that can be explained by a single factor was found to be 0.49. The Cronbach alpha value of this attitude scale comprising of a total 30 items –of which 15 reflect positive and 15 reflect negative attitudes- is 0.96. A student may score between 30 and 150 in the scale.

Since the subjects of the study were comprised of 6th graders, another validity and reliability study was conducted. Hence, the scale was applied to 145 6th graders. Then, an item-total analysis of the data obtained from the scale was made and one item with a value under 0.30 was removed from the scale. Principal component analysis with varimax was applied to the remaining items to determine the construct validity of the instrument. According to the results of this application, 21 items remaining on the scale fall into one factor and their factor loadings range between 0.679 and 0.865. Total variance explained by a single factor is 75.087. Since there are 21 items on the scale, the lowest point expected is 21, the highest is 105, and the range is 84. The mean of the scale is 47.82, the median is 49.60, the standard deviation is 1.18, and the skewness coefficient is .209. These values show that the distribution of the scale is very close to normal distribution. The mean of the items on the scale are between 1.82 and 2.85 and their standard deviation is between 1.16 and 1.47. The item-total correlation coefficients of the scale range between 0.30 and 0.60. Cronbach's alpha for the Math Anxiety Scale (21 items) was 0.87.

Math anxiety scale

The Mathematics Anxiety Scale, whose validity and reliability have been proven and developed by Bindak (2005) for 7th graders, was also used in this research. The multidimensional five-point scale where 1=Never and 5=Always is used in the scale. Cronbach's alpha for the Math Anxiety Scale (10 items) was 0.84. The fact that the score is high points out to high levels of math anxiety. The results of the factor analysis that was applied in order to determine the construct validity of the scale show that the factor loadings of the 10 items range between 0.49 and 0.77 and that the items fall into one factor.

Since the subjects of the study were comprised of 6th graders, another validity and reliability study was conducted. Hence, the scale was applied on 137 6th graders. Then, an item-total analysis of the data obtained from the scale was made and one item with a value under 0.30 was removed from the scale. Principal component analysis with varimax was applied to the remaining items to determine the construct validity of the instrument. According to the results of this application, the 9 items remaining on the scale fall into one factor and their factor loadings range between 0.463 and 0.802. The variance (extraction) of this factor is 45.2 % but after varimax rotation; it is 30.7%. Since there are 9 items on the scale, the lowest point expected is 9, the highest is 45, and the range is 36. The mean of the scale is 24.78, the median is 24, the standard deviation is 8.78, and the skewness coefficient is −.184. These values show that the distribution of the scale is very close to normal distribution. The mean of the items on the scale are between 1.84 and 2.80 and their standard deviation is between 1.15 and 1.48. The item-total correlation coefficients of the scale range between 0.55 and 0.80. Cronbach's alpha for the Math Anxiety Scale (9 items) was 0.86. Some of the items in this scale are: I worry that I will always be asked questions in math classes; Math is so much fun for me; I do not fear anything as much as I fear math exams; I am afraid of asking questions in math classes.

Procedure

Math Achievement Test, Mathematics Attitude Scale, and Math Anxiety Scale were administered as pre-tests to the experimental group and to the control group. The tests were given with thirty minute rest intervals. The students were given 40 minutes to complete the mathematics achievement test and 10-15 minutes for the other two tests.

The researchers prepared the lesson plans based on the teaching math creatively. The duration of each class was 40 minutes. The classes in the study and control groups were taught by a mathematics teacher who has 10-year experience in state schools and who is also one of the researchers of this study 4 hours a week totaling 24 hours. The polygons and ratio subjects were taught through teaching math creatively in the experimental group while they were taught through the traditional method (direct instruction) of teaching in the control group. Following the completion of experimental procedures the Math Achievement Test, the Mathematics Attitude Scale, and the Math Anxiety Scale were administered as post-tests to the experimental group and to the control group.

Control group instruction

Teaching through presentation (direct instruction which is the presentation of academic content to students by teachers, such as in a lecture or demonstration) and question and answer method was applied to the control group but no teaching math creatively activities were utilized. The students in the control group were firstly asked to read the given problem silently and to solve the problem on their own in their notebooks. Then the teacher checked the students' answers and the problem was solved by voluntary students on the board. After a student solved the problem on the board, the class discussed the shortcomings and faults and these, if any, were corrected. In control group classes similar examples as with the treatment group were done. However, those examples were given with different ways in both groups. For example in treatment group students were asked to give examples of parallelism and polygons which they could see around. After that, they were provided to build parallels and polygons with origami. In control group, teacher gave examples of parallelism and polygons. Beside that students in treatment group were asked firstly to find ratios of the polygons' carpet and then were asked to calculate the circumference of the polygons. During this process, students were requested to make shapes in a unique way and supported only with

some basic instructions. In control group, students were asked to calculate circumference of the shapes which were drawn on the board by the teacher. Except polygons given, they weren't asked to give examples of extraordinary polygons. In addition, polygon carpet were drawn on the board by teacher and students were asked to take notes as the same of the board. During the study, it was provided that both groups were assessed with the same questions.

Treatment group instruction: Teaching Maths Creatively

Within the framework of teaching math creatively, techniques such as "analogy, origami, tangram, story, drawing, brainstorming, thinking aloud, problem solving by using specific objects (for example toothpicks and paper), naming figures discovered, and tree diagram" were used in the treatment group. The steps taken in the application of these techniques are as follows:

Analogy applications

The analogy technique was used within the framework of the "comprehends parallelism and the intersection of straights lines" objective. In order to achieve this, the teacher offered examples about parallelism and the intersection of straights. Then the students were asked to offer examples from their environment about parallelism and the intersection of straights in order to let them associate this subject with their daily lives. Following the examples, the students defined parallelism and the intersection of straights**.**

Examples of analogy offered by the students on parallelism and the intersection of straights are as follows: *a. Parallelism*: Planes in air show following the same route in the air side by side and rain drops, street lamps, moving vehicles on the highways, right and left wheels of cars. *b. The intersection of straights:* Water supply network of the city and branches of trees, intersections on highways, kite slats.

Both the analogy and drawing techniques were used for the "*forms patterns by using polygons and the identical and similar forms of the polygonal area*" objective. The students were asked to find and draw objects that they observed in their environment and formed similarities pertaining to polygons. The students formed analogies like car, house, garden, and drew pictures of these. Because it is impossible to make it in real dimensions for them, students have proportioned those figures according to their sizes in nature; and, they have concretized the similarities by means of visualizing with their own drawings (see Appendix A for sample student worksheet in study group).

Within the framework of the "*explains ratio and the relationship between directly proportional quantities*" both the analogy and drawing techniques were used. An analogy was formed between the concept of polygons and patterns on a rug. In this activity, the students were given the picture of a rug with geometrical patterns. They were asked to name the polygons on the rug and to explain the ratio among the figures (see Appendix B for sample student worksheet in study group).

Origami application

The origami technique was utilized in line with the "builds polygons" objective. Within the activity the students were asked to fold a blank paper following the directions given and geometrical figures that appeared were discussed. Then the students were asked to fold another blank paper in the way they wished. They unfolded the papers and draw the figures on the paper with a pencil and named these geometrical figures (see Appendix C for sample student worksheet in study group).

Tangram application
The tangram technique was used in line with "*uses ratio in comparing quantities and shows the ratio in different forms*" and "*builds polygons*" objectives. The students were asked to find the relationship among the lengths of the pieces in the tangram set by putting them on top of another. Bigness, smallness, and equality were measured and written down by the students. Then, the students were asked to determine the similar pieces and to find out the proportions between those pieces. In order to make students have fun, they are given tangram pieces with which they can make shapes of whatever. (See Appendix D for sample student worksheet in study group).

The toothpick activity
The toothpick activity was carried out in line with the "*guesses the perimeters of plane figures by using strategies*" objective. Within the scope of this activity, the students have been asked to create hexagons which have a lengthy of two toothpicks (or matches) for the each side of those hexagons. The students were made to find out the perimeters of those hexagons; and, after removing one of two toothpicks from each side, they were also asked to find out the perimeters of those new hexagons, as well. They were ensured to discover the decrease in perimeter by a ratio of ½ based on removal of one of two (half) toothpicks from each side. A student participated in this activity interestingly by bending the papers instead of using toothpicks (see Appendix E for sample student worksheet in study group).

Stories
The students were presented a story about mathematical ratios in line with the "*uses ratio in comparing quantities*" objective. The students brainstormed about which solution to use while solving the problem. They talked about their solutions reached by using different ways and wrote down the solution on the worksheets.

Related Story*:* One of the villagers who made a living by transporting goods by mules had died. He passed 17 mules down to his 3 sons. The will of the villager revealed that he had passed half of his mules to his oldest son, one third of them to his middle son, and one ninth of them to his youngest son. If it were you, how would you share these mules?

The students were presented a story covering the ratio question and were asked to solve this question by visualizing it in line with the "*shows ratio in different forms*" objective.

Related Story*:* There has been a continuous situation among the children of a family. When they get married the first children of the children of this family are always an individual child while their second children are always twins. In this case, if this family does not have any children up to the third generation or no member of it dies, how many members do they have in total? (See Appendix F for sample student worksheet in study group).

Data analysis procedures
The statistical tests that were conducted included: Independent samples t-test and Analysis of Covariance (ANCOVA). The independent samples t-test was used to determine the significance of any observed differences between two pre-test means because of its superior power in detecting differences between two means. ANCOVA was used to detect initial group differences using the students' pre-test scores as covariates so as to adjust for any initial differences in the post-test scores and thereby establish group equivalence statistically**.** When there was a difference, to determine the effect size causing this difference, effect size index Cohen's d and eta square ($\eta 2$) values were calculated. Post hoc comparison was done with

Benforroni's test to identify the location of statistically significant mean differences. Single Sample Kolmogorov-Smirnov (K-S) Test was used in order to test whether the data collected from the scale were conforming to a specific distribution (uniform, normal or poisson).

Results

Data analysis on students' achievements in the Math Achievement Test

The effects of teaching math creatively on students' math achievement was investigated by comparing the post-test scores of students in the experimental group with the post-test scores of students in the control group on the Math Achievement Test (MAT). Single sample K-S test was used to determine which statistical technique should be used in order to point out whether there was a significant difference between the pre-test scores of the students in the study and control groups. The analysis results of the single sample K-S test showed that the pre-test scores of the experimental group (K-S (Z) = .526; p>0.05) and the pre-test scores of the control group (K-S (Z) =.533; p>0.05) were in a normal distribution. Therefore, it was agreed that the t-test for independent samples, which is a parametric test, should be used.

The analysis of pre-test scores for the MAT shows that the study group's MAT pre-test mean score was 14.00 and the standard deviation was 4.21. The control group's MAT pre-test mean score was 13.27 and the standard deviation was 4.23. While the mean scores of the experimental group was slightly higher than the mean scores of the control group, the difference was not statistically significant [$t_{(40)}$= .557, p>.05].

Hypothesis 1 tested in this experiment stated that teaching math creatively increases math achievement. The single sample K-S test was used in order to determine which statistical technique should be used to point of whether there was a significant difference between the students in the study and control groups regarding their final test scores. The analysis of the results of the single sample K-S test revealed that the study group's final test scores (K-S (Z)= .612; p>0.05) and the control group's final test scores (K-S (Z)=.735; p>0.05) were within a normal distribution. Therefore, a one-way analysis of covariance (ANCOVA), which is a parametric test, was used. The independent variable, type of instruction, included two levels: the teaching math creatively, and the traditional method of teaching. The dependent variable was the students' post-test mathematics achievement scores and the covariate was students' pre-test mathematics achievement scores. A preliminary analysis evaluating the homogeneity-of-regression (slopes) assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(1, 38) = .097$, $p = .757$. Table 1 presents the means, adjusted mean scores, and standard deviations for the mathematics achievement scores.

Table 1. Means, adjusted mean scores, and standard deviations for the mathematics achievement scores

	Pretest			Posttest		
Group	N	M	SD	M	Adj.M.	SD
1. Teaching math creatively	20	14.00	4.21	23.100	23.830	4.32
2. The traditional method	22	13.27	4.23	14.409	14.655	4.98

The ANCOVA was significant, $F(1, 39) = 52.32$, $p < 0.05$. When the Eta Squared values investigated, teaching math creatively explains for the 57% variation in the post test scores, independent of the pre-test scores, obtained from Mathematical Achievement Test.

When Cohen's d value is examined, teaching math creatively has a strong effect on students' mathematics achievement (d= 1.97). (See Table 2).

Table 2. Analysis of co-variance for the mathematics achievement scores

Source	*SS*	*df*	*MS*	*F*	*p*	η^2	d
Pre-test	359.184	1	359.184	27.046	.000	.41	1.97
Group	694.777	1	694.777	52.316	.000	.57	
Error	517.934	39	13.280				
Total	16117.000	42					

Follow-up tests were conducted to evaluate pairwise differences among the adjusted means for groups. The Bonferroni procedure was used to control for Type I error. The results showed that the students in the experimental group who had been taught creatively (M = 23.830) had significantly higher mathematics achievement scores, controlling for the effect of their pre-test, than the students in the control group who had received the traditional method of teaching (M = 14.655). Both the observed and adjusted means show that students in the teaching math creatively group performed best. Consequently, Hypothesis 1 was accepted. (See Table 3).

Table 3. Pairwise comparisons in achievement by instruction type

	Mean Difference (I-J)		s.e.
Group	1.	2.	
1. Teaching math creatively	--	8.175*	1.13
2. The traditional method	-8.175*	--	1.13

* $p < .05$

3.2. Data analysis on students' attitudes towards math in the Mathematics Attitude Scale

The effects of teaching math creatively on students' attitudes towards math was investigated by comparing the post-test scores of students in the experimental group with the post-test scores of students in the control group on the Mathematics Attitude Scale (MAtS).

Single sample K-S test was used to determine which statistical technique should be used in order to point out whether there was a significant difference between the pre-test scores of the students in the study and control groups. The analysis results of the single sample K-S test showed that the pre-test scores of the experimental group (K-S (Z) = .564; p>0.05) and the pre-test scores of the control group (K-S (Z) =.988; p>0.05) were in a normal distribution. Therefore, it was agreed that the t-test for independent samples, which is a parametric test, should be used. The analysis of pre-test scores for the MAtS shows that the study group's MAtS pre-test mean score was 65.60 and the standard deviation was 10.20. The control group's MAtS pre-test mean score was 68.95 and the standard deviation was 4.04. While the mean scores of the control group was slightly higher than the mean scores of the study group, the difference was not statistically significant [$t_{(40)}$= 1.425, p>.05].

Hypothesis 2 tested in this experiment stated that teaching math creatively increases the attitudes towards math. The single sample K-S test was used in order to determine which statistical technique should be used to point of whether there was a significant difference between the students in the study and control groups regarding their final test scores. The analysis of the results of the single sample K-S test revealed that the study group's final test scores (K-S (Z) = .786; p>0.05) and the control group's final test scores (K-S (Z)=1.47; p>0.05) were within a normal distribution. Therefore, a one-way analysis of covariance

(ANCOVA), which is a parametric test, was used. The independent variable, type of instruction, included two levels: teaching math creatively, and the traditional method of teaching. The dependent variable was the students' post-test Mathematics Attitude scores and the covariate was students' pre-test Mathematics Attitude scores. A preliminary analysis evaluating the homogeneity-of-regression (slopes) assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(1, 38) = .73$, $p = .398$. Table 4 presents the means, adjusted mean scores, and standard deviations for the mathematics attitude scores.

Table 4. Means, adjusted mean scores, and standard deviations for the mathematics attitude scores

	Pretest			Posttest		
Group	N	M	SD	M	Adj.M.	SD
1. Teaching math creatively	20	65.60	10.20	74.85	74.16	17.87
2. The traditional method	22	68.95	4.04	65.09	65.71	16.13

The ANCOVA was significant, $F(1, 39) = 3.38$, $p < .05$. When the Eta Squared values investigated, teaching math creatively explains for the 8% variation in the post test scores, independent of the pre-test scores, obtained from **"**Mathematics Attitude Scale" (MAtS). When Cohen's d value is examined, teaching math creatively has a moderate effect on attitudes towards mathematics (d= .50). (See Table 5).

Table 5. Analysis of co-variance for the mathematics attitude scores

Source	*SS*	*df*	*MS*	*F*	*p*	η^2	d
Pre-test	355.189	1	355.189	1.687	.202	.04	.50
Group	711.379	1	711.379	3.380	.044	.08	
Error	8209.179	39	210.492				
Total	213825.000	42					

Follow-up tests were conducted to evaluate pairwise differences among the adjusted means for groups. The Bonferroni procedure was used to control for Type I error. The results showed that the students in the experimental group who had received teaching math creatively (M = 74.16) had significantly higher Mathematics Attitude scores, controlling for the effect of their pre-test, than the students in the control group who had received (M = 65.71). Both the observed and adjusted means show that students in the teaching math creatively group had more positive attitudes towards math. Consequently, Hypothesis 2 was accepted. (See Table 6).

Table 6. Pairwise comparisons in mathematics attitude score by instruction type

	Mean Difference (I-J)		s.e.
Group	1.	2.	
1. Teaching math creatively	--	8.447*	4.38
2. The traditional method	-8.447*	--	4.38

* $p < .05$

Data analysis on students' math anxiety in the Math Anxiety Scale

The effects of teaching math creatively on students' math anxiety was investigated by comparing the post-test scores of students in the experimental group with the post-test scores of students in the control group on the "Math Anxiety Scale" (MAnS) Single sample K-S test was used to determine which statistical technique should be used in order to point out whether

there was a significant difference between the pre-test scores of the students in the study and control groups. The analysis results of the single sample K-S test showed that the pre-test scores of the experimental group (K-S (Z) = .759; p>0.05) and the pre-test scores of the control group (K-S (Z) =1.32; p>0.05) were in a normal distribution. Therefore, it was agreed that the t-test for independent samples, which is a parametric test, should be used.

The analysis of pre-test scores for the (MAnS) shows that the study group's MAnS pre-test mean score was 36.85 and the standard deviation was 5.41. The control group's MAnS pre-test mean score was 39.09 and the standard deviation was 7.48. While the mean scores of the control group was slightly higher than the mean scores of the study group, the difference was not statistically significant [$t_{(40)}$= .1.10, p>.05].

Hypothesis 3 tested in this experiment stated that teaching math creatively decreases the anxiety of math. The single sample K-S test was used in order to determine which statistical technique should be used to point of whether there was a significant difference between the students in the study and control groups regarding their final test scores. The analysis of the results of the single sample K-S test revealed that the study group's final test scores (K-S (Z) = .960; p>0.05) and the control group's final test scores (K-S (Z)=.712; p>0.05) were within a normal distribution. Therefore, a one-way analysis of covariance (ANCOVA), which is a parametric test, was used. The independent variable, type of instruction, included two levels: the teaching math creatively, and the traditional method of teaching. The dependent variable was the students' post-test Mathematics Anxiety scores and the covariate was students' pre-test Mathematics Anxiety scores. A preliminary analysis evaluating the homogeneity-of-regression (slopes) assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(1, 38) = .013$, $p = .911$. Table 7 presents the means, adjusted mean scores, and standard deviations for the mathematics anxiety scores.

Table 7. Means, adjusted mean scores, and standard deviations for the mathematics anxiety scores

	Pretest			Posttest		
Group	N	M	SD	M	Adj.M.	SD
1. Teaching math creatively	20	36.85	5.41	21.60	21.64	5.4
2. The traditional method	22	39.09	7.48	28.68	28.64	4.83

The ANCOVA was significant, $F(1, 39) = 18.292$, $p < 0.05$. When the Eta Squared values investigated, teaching math creatively explains for the 32% variation in the post test scores, independent of the pre-test scores, obtained from The Mathematics Anxiety Scale (MAnS). When Cohen's d value is examined, teaching math creatively has a strong effect on decreasing mathematics anxiety (d= 1.37). (See Table 8).

Table 8. Analysis of co-variance for the mathematics anxiety scores

Source	*SS*	*df*	*MS*	*F*	*p*	η^2	d
Pre-test	2.545	1	2.545	.094	.761	.002	1.37
Group	497.649	1	497.649	18.292	.000	.319	
Error	1061.028	39	27.206				
Total	28493.000	42					

Follow-up tests were conducted to evaluate pairwise differences among the adjusted means for groups. The Bonferroni procedure was used to control for Type I error. The results showed

that the students in the control group who had received traditional method of teaching (M = 28.64) had significantly higher mathematics anxiety scores, controlling for the effect of their pre-test, than the students in the experimental group who had received teaching math creatively (M= 21.64). Both the observed and adjusted means show that students in the teaching math creatively group have lesser math anxiety. Consequently, Hypothesis 3 was accepted. (See Table 9).

Table 9. Pairwise comparisons in the mathematics anxiety by instruction type

	Mean Difference (I-J)		s.e.
Group	1.	2.	
1. Teaching math creatively	--	-6.996*	1.63
2. The traditional method	6.996*	--	1.63

* $p < .05$

Discussion and implications

The results of the study show that the application of *teaching math creatively* in the 6th grade mathematics classroom is effective in increasing students' math achievement. The results of this study are similar to those of Akçam (2007), Candar (2009), Emir (2001), Forseth (1980), Saygılı (2008), and Solomon (1989) who found that creative activities were effective in academic achievement. According to Pehkonen (1997), in successful problem solving both hemispheres will be needed. First, the right hemisphere has a leading role as this is where holistic data processing takes place. The left hemisphere is better in logical tasks, therefore it dominates the work in the second stage of problem solving. When the solution has been reached, the solver will again consider the situation in a holistic manner (the right hemisphere) in order to check the reasonableness of the constructed solution. Since teaching math creatively allows both hemispheres to work together, it might have been effective in academic achievement.

Classroom environment is supportive the creative thinking. It allows students to have choices, and create a climate of mutual respect (Feldhusen & Treffinger, 1980; cited in Fasko, 2000-2001). Moreover, teachers in creative teaching classes show empathy, are flexible, do not dismiss student views, and allow children to communicate (Shaheen, 2010). In this study, forming a creative social environment whose characteristics have been indicated might affect academic achievement in a positive way.

The constant emphasis on rules and algorithms which are usually sequential may prevent the development of problem solving skills. Rich and varied learning programs can give pupils possibilities to reach new levels in mathematics (Branthwaite 1986; cited in Pehkonen, 1997). Torrance (1981; cited in Fasko, 2000-2001) also noted several signs that indicate when creative learning occurs, such as improved motivation, alertness, curiosity, concentration, and achievement. Thus, creative teaching can enhance learning**.** A creative mathematics lesson stimulates pupils' thinking, and encourages pupils to discover new knowledge (Girl, 1998). Further, according to Hirsh (2010), integrating the arts (origami, drawing pictures, charts, tessellations, geometrical grids, graphs) into the mathematics classrooms provides students access to content, multiple perspectives on a topic, and invites them to think, apply, understand, create, and participate in their learning. It is in this participation that new ideas emerge and become possible. Teaching creatively increases understanding, retention, and transfer of skills and knowledge of the students. In creative classrooms, students not only enjoy learning, but also tend to learn more. Teaching creatively offers students the

opportunity to put their skills and knowledge to use in a particular context (Ritchhart, 2004). Within the framework of this study, it can be argued that teaching math creatively (origami, tangram, story, drawing, visualization, problem solving with specific objects), which brings about making thinking visible, divergent thinking, and presents rich stimulus, enhances academic achievement. Based on these results, it can be suggested that teaching math creatively can be used in the 6th grade mathematics classroom in increasing their math achievement.

Moreover, the results of this study indicate that the attitude of the experimental group is significantly better than that of the control group. Teaching math creatively is effective in developing students' positive attitude towards mathematics. The studies conducted by Akçam (2007), Candar (2009), Emir (2001), and Forseth (1980), who determined that creative teaching affected attitudes towards the class, support the results of this study. Further, students' attitudes towards mathematics could be enhanced through effective teaching strategies. It has in fact been confirmed that effective teaching strategies can create positive attitude on the students towards school subjects (Beke, 1987; Balogun and Olarewaju, 1992; Akinsola, 1994; Akale, 1997; Olowojaiye, 1999, 2000; cited in Akinsola, Olowojaiye, 2008).

Maat and Zakaria and Vaughan (2010, 2002; cited in Mata, Monteiro, and Peixoto, 2012) identified a significant relationship between learning environment and attitude towards mathematics. Baer (1994; cited in Girl, 1998) in the study conducted with elementary school students used games, puzzles, and quizzes as mathematical activities. The results of Baer's study showed that "learning that brings pleasant experiences is likely to generate satisfaction and when a lesson is interesting and enjoyable, it is likely that pupils develop positive attitudes towards learning". A positive attitude towards mathematics reflects a positive emotional disposition in relation to the subject (Zan, Martino, 2008; cited in Mata, Monteiro, Peixoto, and 2012). Creative classrooms are often places where students are engaged in fun projects and activities that capture their attention and keep them interested. Creative classrooms also foster a joy of learning that provides an internal motivation for learning (Ritchhart, 2004). According to Girl (1998), too, a creative mathematics lesson maintains pupils' learning interests. Informal observations undertaken within the scope of this study revealed that students liked teaching math creatively, acted in an enthusiastic manner in the classes, participated in the class eagerly, and maintained their interest in the math class throughout the study since teaching math creatively activities are amusing, fun, and interesting as opposed to traditional methods. It is therefore suggested that the teacher can use teaching math creatively to increase positive attitude towards mathematics.

Further, the results of the study show that the application of teaching math creatively in the 6th grade mathematics classroom is effective in decreasing students' math anxiety. Teaching methods used in mathematics instruction are one of the main reasons of mathematics anxiety (Baloğlu, 2001). Teachers may create anxiety by applying rote-memory rules and setting out work in the traditional way (Greenwood, 1984). The National Council of Teaching of Mathematics (NCTM) (1995a) suggests teachers to "encourage original thinking instead of rote memorization" in order to decrease or prevent mathematics anxiety. Instructors who are enthusiastic about the subject and really try to make math fun will have more success with student comprehension. Students also find themselves looking forward to math class rather than dreading a dull presentation of mathematical facts. Moreover, motivating the students, focusing on the process rather than a final/single answer alleviates anxiety too. Teachers of mathematics need to learn not only the mathematics that they teach but also interesting methods of delivery and useful applications of mathematical concepts which may alleviate

anxieties and entice the student to pursue mathematical studies (Godbey, 1997, 8-9). According to Morris (2006), teaching with creativity include all the characteristics of good teaching – including high motivation, high expectations, the ability to communicate and listen and the ability to interest, engage and inspire. Flexibility in teaching, such as students were free while carrying out the activities and letting them reach the right answer through different means, was given special attention in this study. Informal observations also revealed that the students had fun during math classes, enjoyed the subject, were enthusiastic about completing tasks, and actively participated in the class. All these conditions might have made teaching math creatively be effective in alleviating math anxiety. Thus, interesting, fun, and flexible practices like teaching math creatively can be used to reduce or control math anxiety.

Despite the fact that most teachers acknowledge the importance of creativity, still many of them do not include it in their teaching. Specifically, teachers identified the following factors which hinder creativity: the use of one right answer, no mistakes, ignored ideas, competition, evaluation, and insufficient knowledge. Other inhibiting characteristics mentioned by teachers include strict discipline, drill work, emphasis on curriculum and lack of time due to various external pressures such as covering the syllabus and helping students succeed in exams (Fleith, 2000; Shriki, 2008). Consequently, teachers tend to emphasize memorization and rote thinking in teaching rather than creativity (cited in Kattou, Kontoyianni, and Christou, 2009). Therefore, teachers should be given the opportunity to use creative teaching practices in class by devising rich and flexible programs for math classes and by forming a creative learning environment in schools. Moreover, the results of this study indicate that *teaching math creatively* is effective in enhancing academic achievement and attitude towards math and in reducing math anxiety. Thus, teaching math creatively can theoretically and practically be included in the programs of teacher education and in-service training.

This study, unlike the other experimental studies conducted in this field, provides a unique contribution to the teaching math creativity literature in terms of using lots of creative techniques together and for the first time. These techniques can be exemplified as origami, tangram, brainstorming, thinking aloud, problem solving by using specific objects (for example toothpicks and paper), naming figures discovered, tree diagram, analogy, story, and drawing. Also, it contributes to the limited literature in this field by showing that, in addition to the other studies' outcomes, creative techniques have an effect on the math anxiety, as well.

This study is limited to the subjects of polygons and ratio, and 6^{th} grade students. Therefore, the findings of this study can be generalized to this grade level and to these subjects. Further studies can offer opportunities to handle teaching math creatively by focusing on different subjects and class levels. Moreover, this study has a geographical and sample size limitation. It is only limited to 42 students studying at elementary schools in Denizli city's central county, Turkey. Future studies can be conducted in other cities in Turkey and abroad with a larger sample group. This study, however, is limited to 28 class hours. The long term effects of teaching math creatively on academic achievement, attitude, and anxiety can be observed by increasing the duration of experimental procedure. Moreover, this study makes use of experimental design. Research designs based on qualitative design (observation, interview) can be used in further studies in order to characterize the changes brought about during the experimental procedures in a more clear and detailed way and in order to collect data in a deeper manner.

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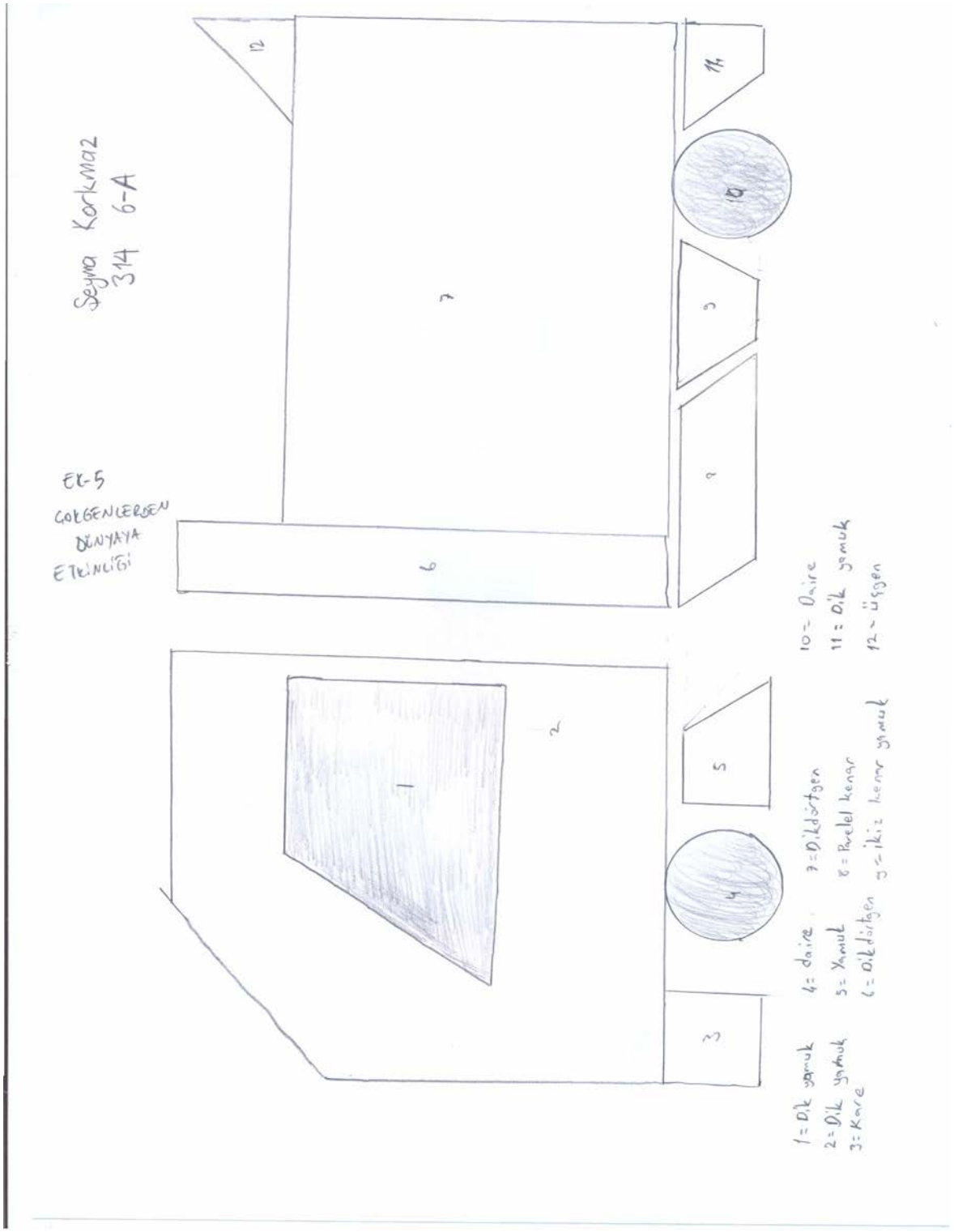
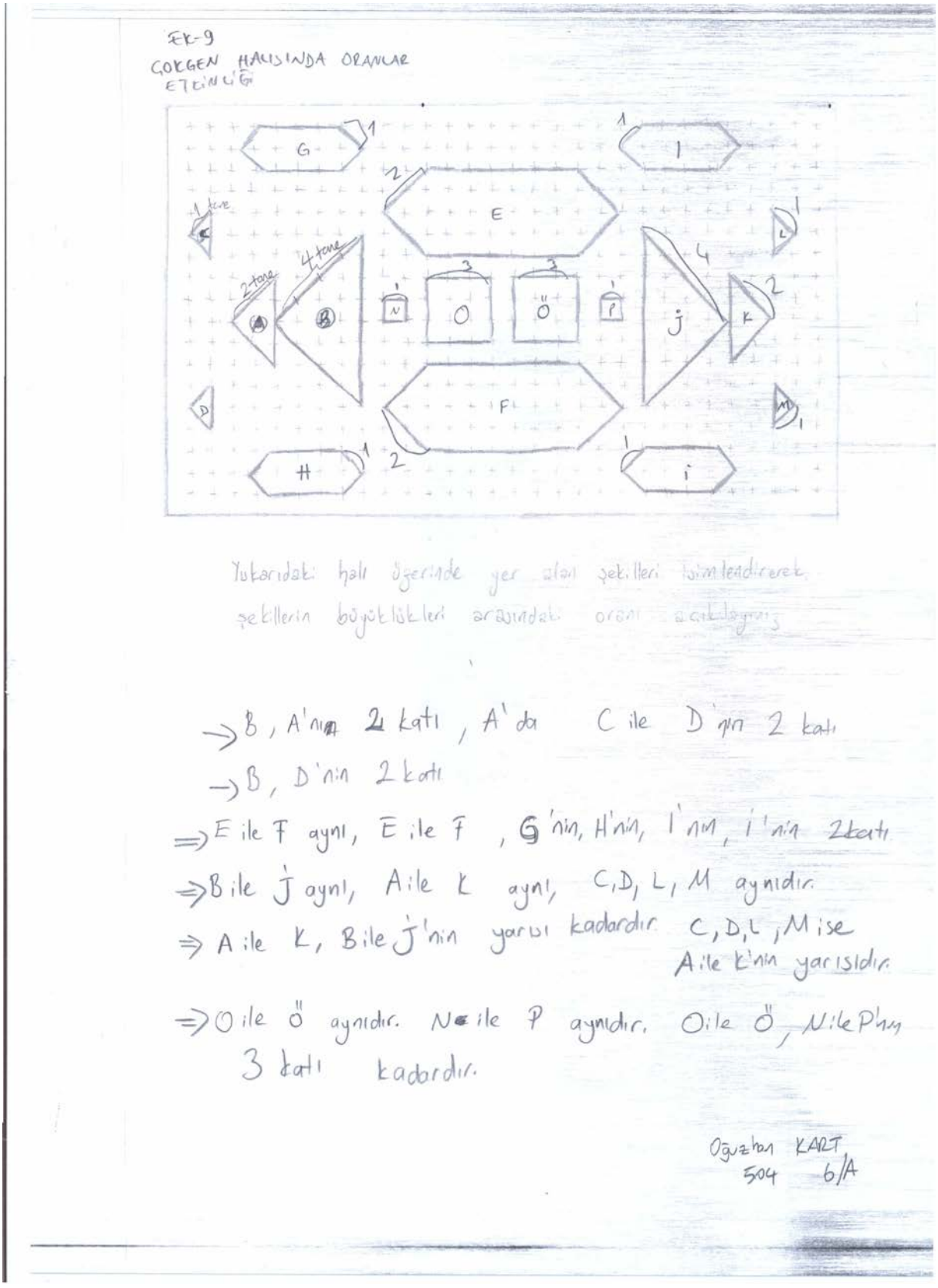
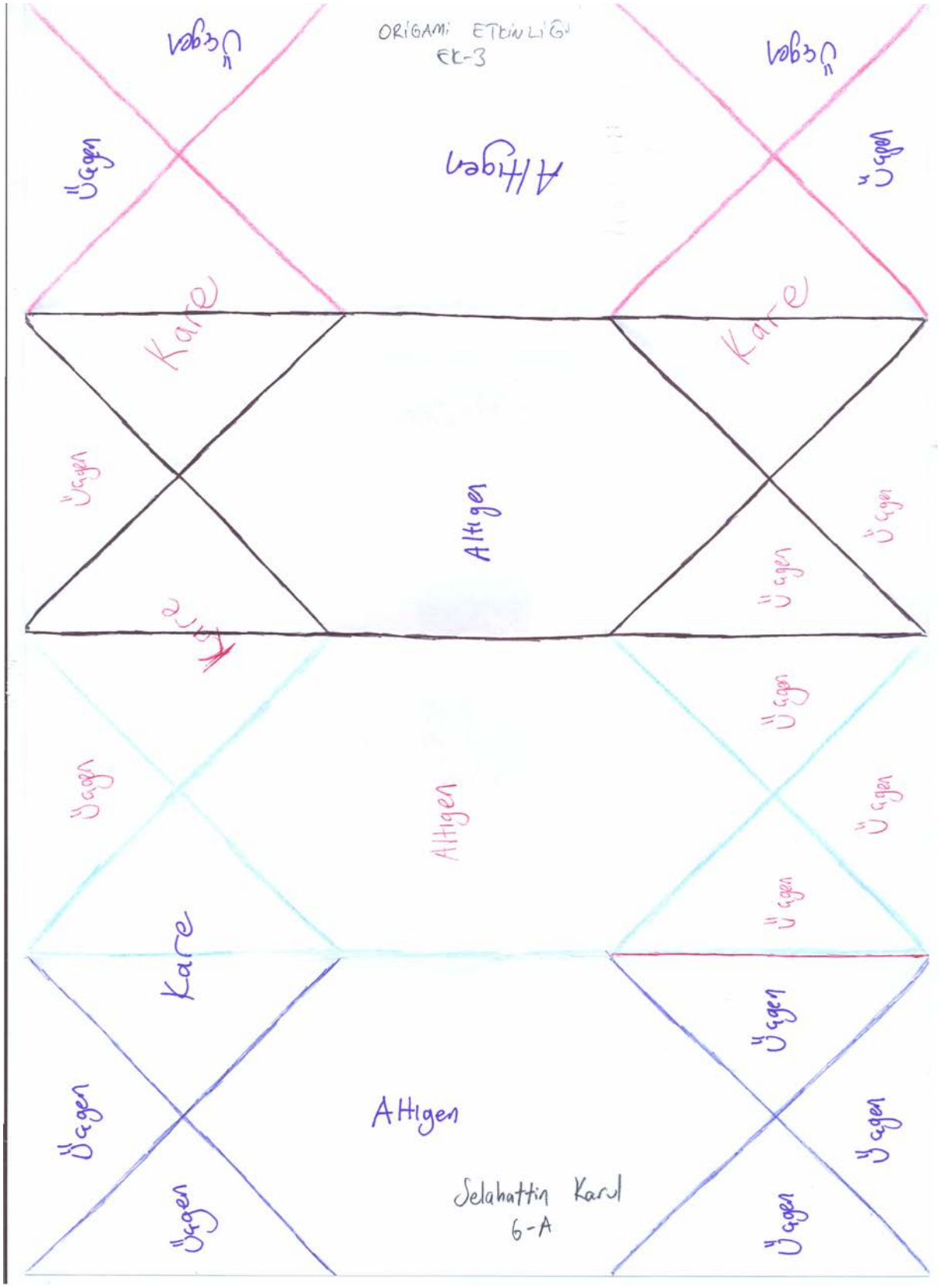
APPENDIX A
Sample Student Worksheet in Study Group



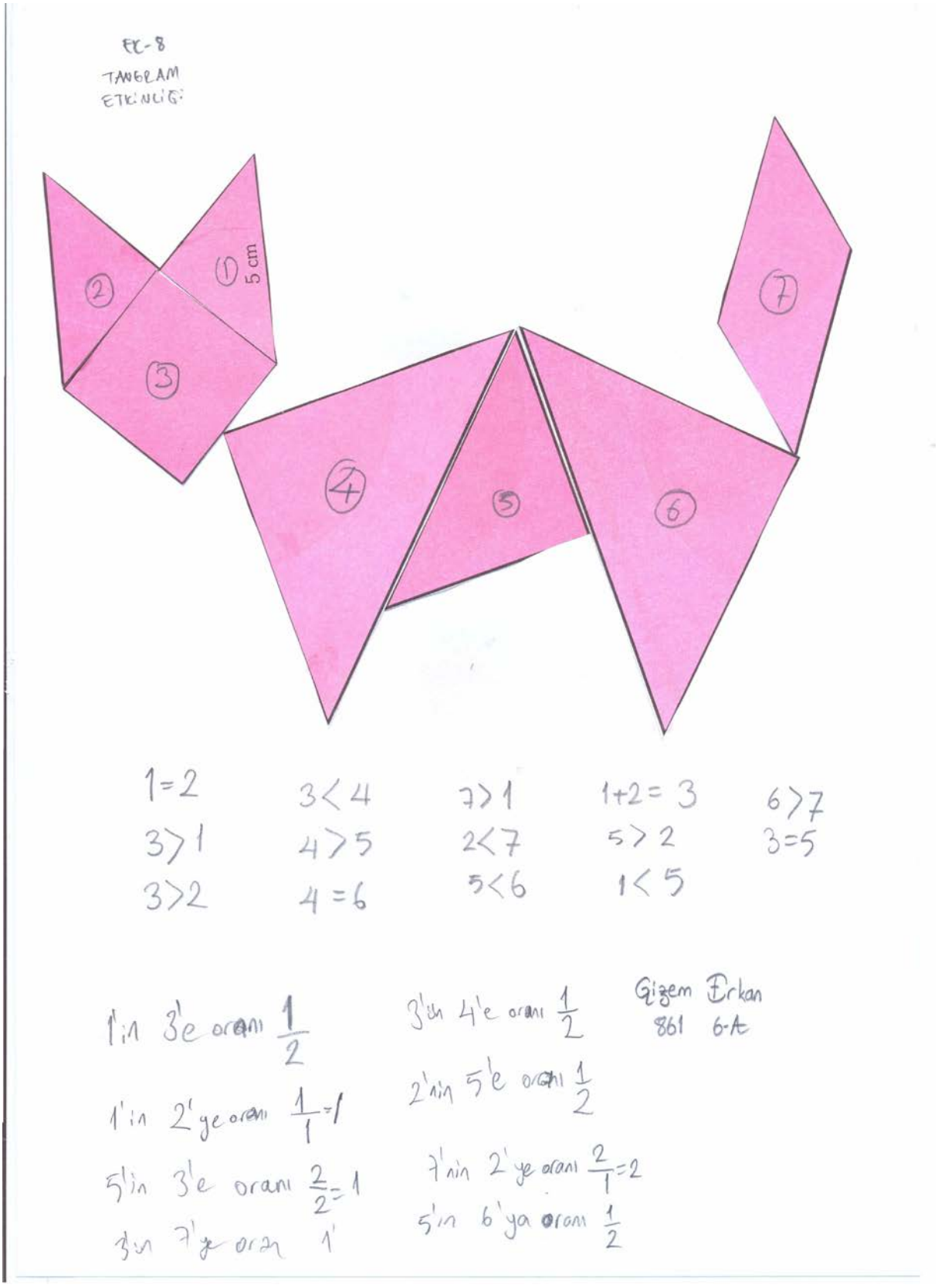
APPENDIX B
Sample Student Worksheet in Study Group



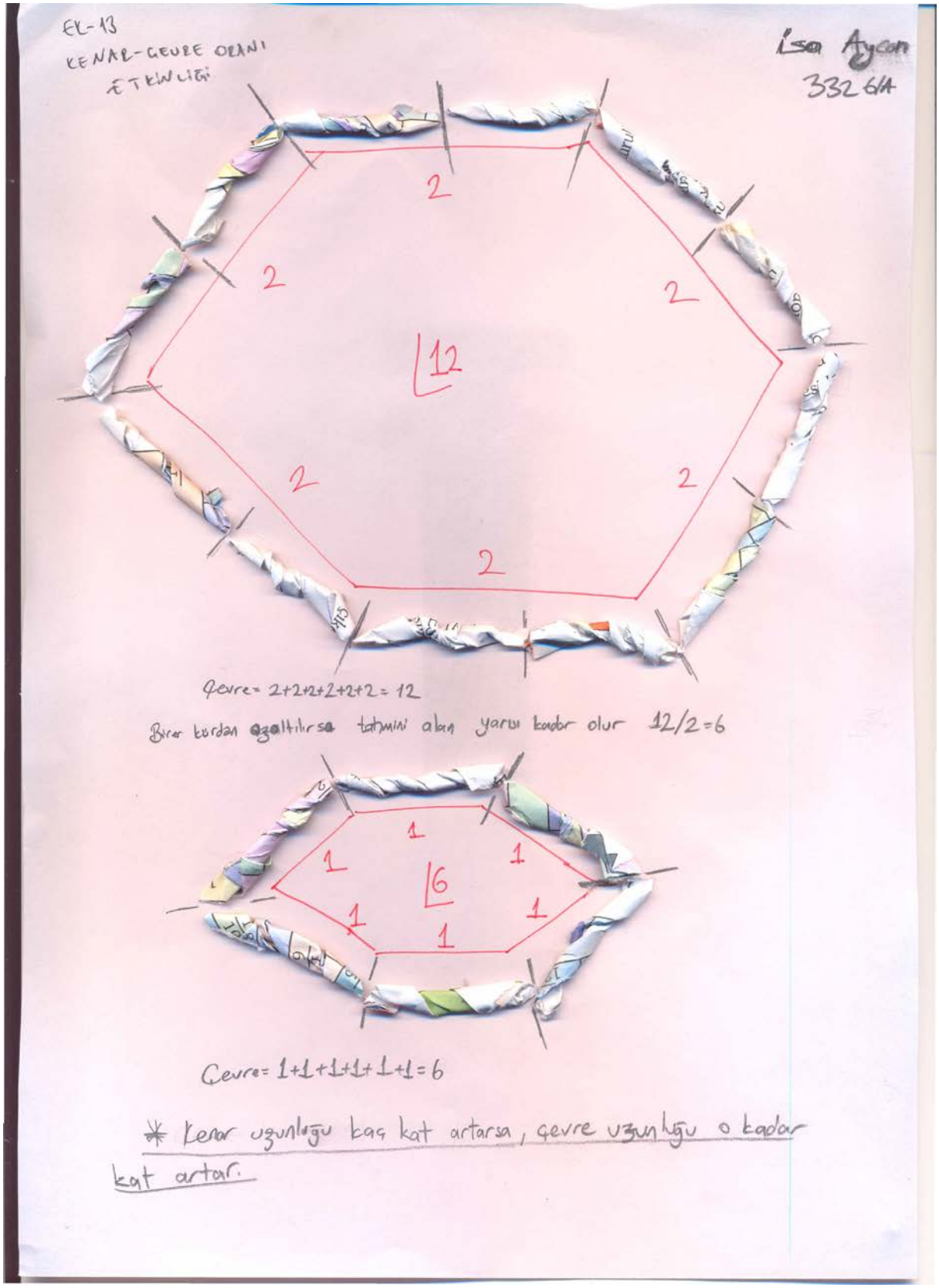
APPENDIX C
Sample Student Worksheet in Study Group



APPENDIX D
Sample Student Worksheet in Study Group



APPENDIX E
Sample Student Worksheet in Study Group



APPENDIX F
Sample Student Worksheet in Study Group