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Original Research

SAGE Open
January-March 2021: 1–17
© The Author(s) 2021
DOI: 10.1177/21582440211003567
journals.sagepub.com/home/sgo
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The Impact of Game-Based, Modeling, and Collaborative Learning Methods on the Achievements, Motivations, and Visual Mathematical Literacy Perceptions

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Abstract

The present study aimed to investigate the effects of geometry instruction activities conducted in nature based on modeling, game-based, and cooperative learning methods on achievement, mathematical motivation, and visual mathematical literacy perceptions of third-grade elementary school students. The present study is a quantitative study conducted with a pre-test/post-test experimental design with a control group. The study was conducted with 61 students (35 students in the experimental group and 26 students in the control group). Modeling-, game-, and collaborative learning-based activities were conducted with the students in the experimental group. It was determined that the achievements of students who were instructed with modeling-based activities in geometry were high when compared to that of the students instructed with collaborative learning- and game-based methods, and those in the control group where no intervention was applied. This group was followed by the game-based and collaborative learning groups. Based on the variable of motivation, the mean motivation of the students in the modeling group was higher when compared to that of the students in the collaborative learning, game-based, and conventional instruction groups. This group was followed by the collaborative and game-based learning groups. Also, based on the visual mathematical literacy perception variable, the mean visual mathematics literacy perception of the students in the collaborative learning group was higher when compared to that of the students in the groups where the modeling, game-based, and conventional instruction methods were used. This group was followed by the modeling and game-based learning groups.

Keywords

mathema modeling, game-based learning, collaborative learning, geometrical achievement, mathematical motivation, visual mathematical literacy perception

Introduction

Teachers' use of games in the classroom environment affects the perspectives of the children on the school and mathematics (Turgut & Temur, 2017). One of the objectives of mathematics instruction with games is to improve the love of the students for mathematics and to allow them to develop positive attitudes toward mathematics. Thus, the active participation of the students who are more interested in and love mathematics would be possible, and their achievements could increase (Biriktir, 2008). The games allow the children to acquire mathematical concepts since the attention, interest, and curiosity of the children increase automatically during gameplay (Aksoy & Çiftçi, 2014). When it is considered that the fear of mathematics starts even before the student starts school, integrating mathematics and games, which is the most popular activity for the primary school children, could be an instrument in overcoming this fear (Aksoy, 2010). Games could change the perception of the students that mathematics is difficult and make them feel comfortable during the learning process (Turgut & Temur, 2017). Tilton (2019) stated that game-based learning has a high experiential learning potential that can create constructive or interactive environments. The game provides an environment for the children to communicate. From a social point of view, it is important for children to talk, to get feedback about their questions, and to communicate with their peers and teachers to learn mathematics (Turgut & Temur, 2017). Schlosser and Balzano (2014) also stated that the professional knowledge and skills of teachers who participate in the game-based learning process improved.

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The elementary school-age children are in the concrete operational stage. Therefore, mainly geometric models and experiences related to their application in life should be instructed in geometry courses (Biriktir, 2008). Models are conceptual systems used to describe, explain, and construct mathematical systems, or to express these using exogenous systems (Lesh & Doer, 2003). Lesh et al. (2006) defined models as conceptual or representative instruments that allow individuals to better understand how they learn, develop, and apply the concepts. Modeling is a complex process that involves several activities (Justi & Gilbert, 2002). Lehrer and Schauble, 2007 referred to the concept of the model as a metaphor that links simply a previously unknown system to a familiar system. Models define our belief in how the world works. In a mathematical model, these beliefs are translated into a mathematical language (Lawson & Marion, 2008). Mathematical modeling can be used for many different reasons. The extent to which a particular target is achieved depends both on the status of the knowledge about the system and how well the model was constructed (Lawson & Marion, 2008). Mathematical modeling provides an alternative and dynamic method that could reduce the gap between mathematics and the real world (Ortiz & Santos, 2011, p. 127). It is important to learn and apply the mathematical modeling process in mathematics education. This means that the words and pictures outside mathematics are not just hollow ornaments. The fact that the involved numbers are true in size and accurate in real life requires to ask real-world questions. It also means which aspects of the real-world facts we consider keeping, and which aspects we would ignore (Consortium for Mathematics and Its Applications, 2012). According to Lehrer and Schauble, 2007, it is the use or co-interpretation of more than one mathematical representation in the process of constructing the mathematical model of an everyday situation. A mathematical model could be considered as a simplification or isolation of a real-world problem or situation in a mathematical form. Then, the mathematical problem could be solved with known mathematical techniques and the solution could be interpreted and transformed into a real-life problem (Ang, 2010; Kertil, 2008).

In collaborative learning, which is one of the instructional methods where the teacher leads and the students actively participate in the teaching-learning processes (Ünlü & Aydıntan, 2011), students work in small groups and help each other to learn in the classroom environment for a common goal (Açıkgöz, 2011, p. 172). In other words, collaborative learning is a method where students learn a topic by working together in heterogeneous small groups for a common objective such as solving a problem or accomplishing a task (Akınoğlu, 2016, p. 172). Collaborative learning utilizes a sitting order and working mode that maximizes the interaction among the students in small groups (Cumhur & Baydar, 2017). In a collaborative group, participants interact and take mutual responsibility as learners and constructors of knowledge based on their experiences, skills, and relationships (Burress & Peters, 2015). The collaborative learning process allows students to be active in the learning process and facilitates their motivation (Güven, 2015, p. 221). The limitations of collaborative learning are as follows: it may be time-consuming, shy students may not participate in group work, disputes may arise within the group, responsibility may be limited to certain individuals, and target achievements might not be realized if the evaluations are not adequate (Sarıtaş, 2016, p. 188). In collaborative learning, individual tests are provided to all students to assess student achievements. The most successful group with the highest score based on individual achievements is rewarded. Furthermore, the students in the group are rewarded based on their contribution to the total group score (Akınoğlu, 2016, p. 170). How the cognitive load of the group is shared in collaborative groups could be determined by asking questions, sharing ideas, and discussing and detailing these ideas (Moore et al., 2019).

One of the requirements for being contemporary lifelong learners is visual literacy (Ev-Çimen & Aygüner, 2018). According to Tekin and Tekin (2004), individuals with visual mathematics literacy could recognize and analyze shape, space, time, and movement-based experiences and the representatives of these concepts using all their senses. Visual mathematics literacy is a concept that combines visual literacy and mathematical literacy and can be considered as an intersection of these literacy clusters (Ev-Çimen & Aygüner, 2018). Visual mathematics literacy perception is defined as the perception, interpretation, evaluation, and utilization of daily life problems visually and spatially and on the contrary, perception, interpretation, evaluation, and utilization of visual or spatial information mathematically (Bekdemir & Duran, 2012). Visual mathematical literacy, in other words, is defined as the process of using intellectual activities in constructing the encountered images with the support of paper, pen, or technology, and using these images for a mathematical discovery or understanding (Çilingir Altıner & Artut, 2017). Duran and Bekdemir (2013) stated that the visual mathematics literacy perceptions of the students affect their visual mathematics achievements and motivations. According to Açıkgöz (2003), one of the most important factors that affect success in mathematics education is the motivation level of the students. It is possible to find studies that measured the impact of motivation on mathematical achievement, researched the mathematical motivation or the effect of different instructional methods on motivation or mathematical achievement in the literature (Aktan & Tezci, 2013; İnam & Ünsal, 2017; Tahiroğlu & Çakır, 2014).

Among the reasons why students do not like geometry courses in mathematics, lack of adequate instruction for the characteristics of the course, attitude and behavior of the teacher, and the high number of rules related to the abstract structure of mathematics could be mentioned. The use of student-centered new instruction methods and techniques in mathematics courses could lead to active, permanent, and entertaining learning and increase achievements. Thus, the

students would be more interested in the courses that they are successful at, their motivation to study this course would improve, and their anxiety levels would be reduced. Three instruction methods where the teacher only leads and the learners play an active role are game-based, modeling, and collaborative learning methods. The use of these student-centered instruction methods in the instruction process was considered to increase the interest in the course and student achievement. The mean mathematics scores of the students in these exams are below 20%. It was observed that Turkish students were at lower competency levels in geometry content knowledge based on mathematics competency levels in international exams such as Program for International Student Assessment (PISA, 2015) and Trends in International Mathematics and Science Study (TIMSS). Thus, the achievements of Turkish students are not satisfactory in mathematics and geometry in international examinations as well. Therefore, the present study aimed to investigate the effect of the implementation of three student-oriented instruction methods that are considered to have a more permanent impact on achievement, motivation, and visual mathematics literacy perception. The inclusion of the latter variable in the study was because the concepts of mathematical literacy and visual mathematics literacy perception were included among the skills that the students should acquire according to the National Council of Teachers of Mathematics (NCTM) as of 2000, and these concepts were introduced by the Ministry of Education in 2017 and 2018 mathematics curricula (MoNE, 2018; NCTM, 2000). The fact that the literature review revealed no studies that analyzed achievement, visual mathematics literacy perception, and mathematical motivation based on the above-mentioned three methodologies underlines the unique character of the present study.

Aim of the Study

The study aimed to investigate the effects of geometry instruction activities in nature conducted with modeling, game-based, and collaborative learning methods on geometry achievements, motivation, and visual mathematics literacy perceptions of elementary school students. Based on this general objective, the following sub-objectives were determined.

In the experimental groups where the geometry was instructed with modeling, game-based, and collaborative learning methods, and in the control group where the geometry was instructed with conventional methods detailed in the current curriculum:

1. Is there a significant difference between the pre-test and post-test achievement scores?
2. Is there a significant difference between the post-test achievement scores when the pre-test achievement scores were controlled?
3. Is there a significant difference between the pre-test and post-test motivation scores?
4. Is there a significant difference between the post-test motivation scores when the pre-test motivation scores were controlled?
5. Is there a significant difference between the pre-test and post-test visual mathematics literacy perception scores?
6. Is there a significant difference between the post-test visual mathematics literacy perception scores when the pre-test visual mathematics literacy perception scores were controlled?

Method

Research Model

The study was designed with the quantitative model that aims to collect and analyze numerical data (Büyüköztürk et al., 2016, p. 251). The study was conducted with a pre-test/post-test experimental design with a control group. In real experimental designs, the subjects are assigned to the groups randomly to ensure maximum control of various variables. Due to the control they provide, they are the most frequently recommended and used designs in experimental research in education (Ary et al., 2010, p. 305). The difference between this design and quasi-experimental designs is the use of more than one group (Baştürk, 2009, p. 38). In the pre-test/post-test experimental design with a control group, the experiment and control groups are initially formed by ransom assignment. Then, the measurements for the dependent variables are conducted for the groups before the application. The experimental process of which effect is tested in the application process is conducted only with the experimental group or groups. Finally, the measurements for the dependent variables are conducted again for the subjects in the groups using the same instrument or a similar form (Büyüköztürk et al., 2016, p. 205). In the present study, the independent variable was the three instruction methods conducted within the context of geometry activities performed in nature, and the dependent variables were the Geometry Achievement Test (GAT), Mathematical Motivation Scale (MMS), and the Visual Mathematical Literacy Perception Scale (VMLPS) scores.

Study Group

The present study group included third-grade students attending three public primary schools located at a lower socio-economic area in Southeast Anatolian Region in Turkey during the 2018–2019 academic year spring semester. After meetings were conducted with the Provincial Directorate of National Education, three primary schools were randomly determined. As a result of the meetings conducted with the principals and classroom teachers in selected schools, 35 third-grade students were randomly assigned to the experimental group and 26 students were randomly

Table 1. Geometry Instruction Activities Conducted in Groups.

Groups	Pre-activity	Activity process (22/24 hr)	Post-activity
Experiment A	Pre-test (GAT+MMS+VMLPS)	Game-based learning	Post-test (GAT+MMS+VMLPS)
Experiment B	Pre-test (GAT+MMS+VMLPS)	Learning by modeling	Post-test (GAT+MMS+VMLPS)
Experiment C	Pre-test (GAT+MMS+VMLPS)	Collaborative learning	Post-test (GAT+MMS+VMLPS)
Control	Pre-test (GAT+MMS+VMLPS)	Current instruction method	Post-test (GAT+MMS+VMLPS)

Note. GAT = Geometry Achievement Test; MMS = Mathematical Motivation Scale; VMLPS = Visual Mathematical Literacy Perception Scale.

assigned to the control group where the instruction method indicated in the current curriculum was implemented. The students in the experimental group were then randomly selected for the modeling (Experiment A = 11), collaborative (Experiment B = 12), and game-based learning (Experiment C = 12) groups. The application processes for geometry instruction activities conducted in the experimental and control groups are presented in Table 1.

As seen in Table 1, GAT, MMS, and VMLPS were applied as the present to the students in the experimental and control groups before the activities. Then, game-based geometry activities were conducted in the Experiment A group, modeling based geometry activities were conducted in the Experiment B group, and collaborative learning-based geometry activities were conducted in the Experiment C group. In the control group, the instruction method indicated in the current curriculum was implemented. In the mathematics curriculum published by MoNE (2018), 22 classes were allocated for 10 achievements in the third-grade fifth unit of the geometry learning area. Thus, the activities in each experimental group were conducted for 24 hr in 6 days. After the activities were conducted, GAT, MMS, and VMLPS were applied as a post-test to the experimental and control groups.

Data Collection Instruments

GAT. This test was developed by the authors to examine the change in geometry achievements due to the geometry instruction activities conducted with the students in nature. The draft test was developed based on the third-grade mathematics curriculum and the textbook published by the MoNE (2018) Board of Education and included 30 multiple-choice questions based on 10 geometry learning achievements. There were three questions for each achievement in the draft test. The views of four academicians and three classroom teachers, who were experts in the fields of mathematics education, geometry, measurement, and evaluation, were obtained to determine the functionality and content validity of the test. Based on these achievements, the required editing was conducted based on expert opinions. The draft test was applied to 256 third-grade students who were not included in the project. After the pilot scheme, the test items were analyzed based on the responses, and the difficulty level and discrimination indices for each item were calculated and the test that included 20 questions was finalized. Furthermore, the KR-20 reliability coefficient was calculated as .779. This test was applied as a pre-test and post-test to the students in the experimental and control groups as part of the project activities.

MMS. The objective of the scale developed by Aktan and Tezci (2013) based on the section related to motivation in the Motivated Strategies for Learning Questionnaire (MSLQ) scale developed by Pintrich et al. (1993) is to determine the mathematical motivation of primary school students. The lowest possible score is 27, and the highest possible score is 135 on the 5-point Likert-type scale. Items are scored as "Strongly disagree" (1), "Disagree" (2), "Neutral" (3), "Agree" (4), and "Strongly agree" (5). Scale items were grouped under the six factors of "Intrinsic Goal Orientation," "Extrinsic Goal Orientation," "topic value and task value," "learning beliefs," "self-efficacy," and "test anxiety." Certain scale items include the following: "I would like to learn the topics I like in the mathematics course although they might be difficult," "studying mathematics makes me happy," "I do my math assignments to learn some stuff, not to get better grades," "if I work hard enough, I can learn the topics in the math course," and "I feel distressed and uncomfortable in math exams." The Cronbach alpha reliability coefficient for the scale was .910. The scale was considered highly reliable since this value was larger than .80 (Kayış, 2005, p. 405).

VMLPS. The objective of the scale, developed by the authors for this project, is to determine the visual math literacy perceptions of primary school students. The draft scale was developed based on the third-grade mathematics curriculum published by the MoNE (2018) Board of Education and included 44 items based on the 10 geometry learning achievements. Each achievement was reflected in four to five items on the draft scale. The views of four academicians and three classroom teachers, who were experts in the fields of mathematics education, geometry, measurement, and evaluation, were obtained to determine the functionality and content validity of the scale. Based on these achievements, the required editing was conducted based on expert opinions. The draft scale was applied to 256 third-grade students who were not included in the project. The lowest possible score is

29 and the highest possible score is 87 in the 3-point Likert-type scale that includes 29 positive statements. The items are scored as "Disagree" (1), "Neutral" (2), and "Agree" (3). The scale items are grouped under four factors of "geometric figure," "geometry in daily life," "nature and geometry," and "induction and geometry," and the total variance explained by these factors is 59.372%. Certain scale items include the following: "I can calculate how many half apples an entire apple includes," "I can calculate the area of a field with a square carton with 1-meter sides," "I can find the directions by observing at the anthills," and "I can guess the time by checking my shadow." The Cronbach alpha reliability coefficient of the scale is .918. The scale is considered reliable since this value was greater than .80 (Kayış, 2005, p. 405).

Data Analysis

The data obtained with GAT, MMS, and VMLPS applied to the students in the study were analyzed with the SPSS 23.0 software. Büyüköztürk (2016, pp. 42–49) stated that the Shapiro–Wilk test could be employed to determine normality. Thus, the Shapiro–Wilk test was preferred to determine the normal distribution of the data. The test results demonstrated GAT ($p = .213$), MMS ($p = .288$), and VMLPS ($p = .199$) in the form of applications ($p > .05$) and exhibited a normal distribution. The differences between the pre-test and post-test scores in the experimental and control groups were analyzed with related samples *t*-test, the significance of the differences between the groups was determined with analysis of covariance (ANCOVA), and the group that showed significant benefits was determined with the Bonferroni test (Büyüköztürk et al., 2016). Thus, the differences between the pre-test and post-test scores in the experimental and control groups, and the differences between the experimental methods, were analyzed based on the GAT, MMS, and VMLPS scores, and the findings are presented in tables.

Application Process

Preparations. During the preparatory phase, project experts were appointed as mentors for each instructor (mentee). Mentors conducted mentorship training meetings with mentees and developed syllabi and course materials. The daily syllabi were developed by the mentees under the guidance of the mentors and based on the activities developed by the authors before the experimental process so that the syllabi would include 24 course-hours in 6 days of instruction for each group. All daily syllabi for the experimental group were developed based on the objectives, content, and evaluation procedures defined in MoNE (2018) mathematics curriculum, only the methods used in the instruction process differed. Attention was paid to the fact that the spaces where the activities were conducted were similar in all groups. The process of syllabi development in the experimental groups is described below.

Development and application of Experiment A group syllabus. The group that was instructed with the game-based learning method included the activities that were developed by the experts in the project team and conducted in nature and historical spaces. Mentorship training was provided for the mentees on the instruction process based on game-based learning. During the activities conducted in this group, the instruction processes conducted with game-based learning that were reported in the literature were implemented. The structure of game-based learning includes knowledge patterns specific to the subject area that help learners to develop their skills. In addition to the capacity of the game-based learning environments to provide students with an opportunity to spend a good time, it could also teach and reinforce through the activities during gameplay. On the other hand, the use of educational games in education makes the instruction process interesting and entertaining by removing the boring environment of the conventional classroom (Akın & Atıcı, 2015). Thus, the activities for the first day were conducted in the Başur recreational area. Students were allowed to trek to find geometric concepts they learned in nature. During the observations conducted in nature, the photographs of the objects that were examples of patterns, squares, rectangles, and triangles were taken. The photographs taken in the nature trek were viewed at the campsite and the students were provided with the necessary feedback. During the activity, the game of cube bowling was played with students. The aim of the cube bowling game was the comprehension of the corners, sides, and number of surfaces in geometric shapes and instruction of similarities and differences between these shapes. The second-day activities were conducted at Gökçebağ Primary School. Students were allowed to take a walk on the school grounds to find geometric concepts they learned about. During the observations, the photographs of objects that were samples of points, lines, beams, and straight-line sections were taken. The educator played games with students at the playground and instructed the concepts of points, lines, beams, and straight-line sections with groups of six, five, and four students. The students then moved to the preselected field to plant seedlings. In this field, using the rope drawn to plant the seedlings on a straight line, the students were allowed to find samples of lines, beams, and straight lines. Students planted the seedlings. The third-day activities were conducted in Hasankeyf and the groups of students visited the historical Hasankeyf bridge and bazaar, Hasankeyf Mosque, the caves, which were ancient settlements, hexagonal nomad tents produced with goat hair and Hasankeyf promenade terrace, and geometrical shapes found in the natural and historical places were observed by the students, and the target achievements were acquired by the students through games. The fourth-day activities were conducted in the Başür recreational area. A field survey was conducted in the recreational area and the students were asked to take photographs of regular and non-regular geometric objects in the environment. In the course of

the activity, the photographs were discussed, and the best examples were selected. With the tower bowling game, the angle of the arm to the body was emphasized and angles and angle types were instructed. Fifth-day activities were conducted in Tillo, and the historic tomb of His Holiness Ibrahim Hakkı, the Great Mosque, and the Tillo Museum were visited. During these visits, the light phenomenon that was designed by His Holiness Ibrahim Hakkı for His Holiness Ismail Fakirullah was explained to the students. Furthermore, the students also observed the geometric models in historical venues and the museum. The tower that is the home of the light phenomenon was visited and the photograph printouts of square, rectangular, and triangular areas and a game developed by the students were put on a canvas and their knowledge on the number of sides and corners of geometric shapes was reinforced. The sixth-day activities were conducted in His Holiness Veysel Karani complex. The students observed the geometric shapes in the complex. The students were gathered by the instructor in an adequate area in the garden of the complex and the game of symmetry was played with the students. During this game, a symmetrical line and the symmetry model were created and the students acquired the required achievements.

Development and application of Experiment B group syllabus. The group that was instructed with the model-based learning method included the activities that were developed by the experts in the project team and conducted in nature and historical spaces. Mentorship training was provided for the mentees on the instruction process with modeling-based learning. During the activities conducted in this group, the instruction processes conducted with modeling-based learning that were reported in the literature were implemented. The mathematical modeling process commences with a real-life situation. To obtain the real model, the case is simplified to construct the mathematical model. During this period, thoughts generate mathematical results that should be reinterpreted for real-life situations. Then, the accuracy of the results is checked (Kaiser & Schwarz, 2006). Developing models in mathematical modeling activities leads to a shared and reusable model (Doruk, 2010). Thus, the first-day activities were conducted in the Başur recreation area, where students discovered the nature and built a geometric nature model using the geometric models they observed in nature. On the second day, tree-planting activities were conducted at of Gökçebağ Primary School garden and the students examined and discussed the geometric models available in nature and created during tree planting and tried to learn these models. The third-day activities were conducted in Hasankeyf and the groups of students visited the historical Hasankeyf bridge and bazaar, Hasankeyf Mosque, ancient settlements in the caves, hexagonal nomad tents produced with goat hair and Hasankeyf promenade terrace, and geometrical models found in nature and historical places were investigated by the students. The fourth-day activities were conducted in the Başur recreation area and the natural geometry model was completed during the nature walks. Furthermore, angle models were drawn on soil, students formed geometric models using the material they found in nature such as branches, and so on. The Fifth-day activities were conducted in Tillo, and the historic tomb of His Holiness Ibrahim Hakkı, the Great Mosque, and the Tillo Museum were visited. During these visits, the light phenomenon that was designed by His Holiness Ibrahim Hakkı for His Holiness Ismail Fakirullah was explained to the students. The geometric models found in this phenomenon were identified. Furthermore, students observed geometric models found in historical spaces and the museum. The tower that is the home of the light phenomenon was visited and the activity was completed with a rediscussion of the geometric models. The sixth-day activities were conducted in His Holiness Veysel Karani complex. The students observed the geometric models in the complex. The students were gathered by the instructor in an adequate area in the garden of the complex and a symmetrical line and symmetrical model were developed with the students. Symmetrical models and other geometric models identified by the students in the complex were discussed.

Development and application of Experiment C group syllabus. The group that was instructed with the collaborative learning method included the activities that were developed by the experts in the project team and conducted in nature and historical spaces. Mentorship training was provided for the mentees on the instruction process with collaborative learning. The learning processes in this group were conducted with the collaborative learning method student team achievement group technique. The reason for the use of this technique was the fact that it is more successful in the retention of mathematical knowledge when compared with other collaborative techniques and it is one of the most frequently used techniques (Arısoy & Tarim, 2013). The student team success group technique developed by Slavin (1994) has five application stages. These are the presentation, teams, exams, individual improvement scores, and team prizes. Information about the application process of this technique was adopted from the books authored by Slavin (1994) and Açıkgöz (1992). Thus, the first-day activities were conducted in the Başur recreation area. The students conducted the activities in three groups of four. The students in the groups walked around the recreation area with their instructors. They were asked to observe the prism and cylinder-like objects such as tree logs, trash cans, bridges, and so on they saw in the environment while walking. After the groups reviewed and evaluated the materials that they identified, the group spokespersons shared these with their peers to ensure the learning of each student. Then, geometric shapes similar to the related material were created using various objects found in nature and hanged on the geometry tree. For the patterns, the groups took another walk in nature, and the collected leaves were arranged based on a certain

pattern. Patterns that included at least three steps were produced with leaves and stones by the groups. The second-day activities were conducted at Gökçebağ Elementary School garden. After each group built a fishing line model with tree branches, they provided examples for horizontal, vertical, and oblique lines, which are included in the achievements, using these fishing lines. In which previously dig holes the seedlings will be planted was determined by the groups and their instructors. The necessary steps to plant the seedlings were explained by the instructors and saplings were planted by four students from each group. The group spokespersons explained to the group after the seedlings were planted that the rope they used to measure the distance between two seedlings was a straight line and the seedling itself was a beam model. The third-day activities were conducted in Hasankeyf and the groups of students visited the historical Hasankeyf bridge and bazaar, Hasankeyf Mosque, the caves, which were ancient settlements, hexagonal nomad tents produced with goat hair and Hasankeyf promenade terrace, and geometrical shapes found in nature and historical places were observed by the students. The fourth-day activities were conducted in the Başur recreation area. The first student group took pictures of triangle-like objects during the trip; the second group collected square and rectangular-shaped materials; and the third group prepared the point, line, and straight-line models using stones and tree branches. The groups produced angle models with their instructors using the geometrical board and tree branches. The Fifth-day activities were conducted in Tillo, and the historic tomb of His Holiness Ibrahim Hakkı, the Great Mosque, and the Tillo Museum were visited. During these visits, the light phenomenon that was designed by His Holiness Ibrahim Hakkı for His Holiness Ismail Fakirullah was explained to the students. Furthermore, the students also observed geometric models in historical venues and the museum. The tower that is the home of the light phenomenon was visited and activities were conducted with student groups in that location. Members of each group were asked to fold a broadsheet, the sheet was unfolded a little to drop a few drops of ink, and the paper was folded again and left for a while and then unfolded. The resulting shapes were compared, and the groups discussed whether they were symmetrical. Using straws and reeds, awareness on the concepts of square, rectangular, and triangular areas has been established. The sixth-day activities were conducted in His Holiness Veysel Karani complex. The students observed the geometric shapes in the complex. The students were gathered by the instructor in an adequate area in the garden of the complex and the activity was conducted using worksheets.

Development and application of the control group syllabus. The control group students were instructed based on the syllabi developed by the teachers in the schools where the sample was selected and instructed. The syllabi developed by the teachers were reviewed by the project experts and an attempt was made to control the external variables by providing adequate feedback.

Application of the pre-tests. The study data collection instruments, GAT, MMS, and VMLPS, were applied by the authors at the beginning of the experimental process as a pre-test 1 day apart.

Experimental process. Experimental procedures were conducted by the project instructors based on the above-mentioned syllabi in the experiment and control groups. The photographs of the experiments are presented in Figure 1.

Application of the post-tests. GAT, MMS, and VMLPS that were applied as pre-test were applied by the authors after the experimental process as a post-test 1 day apart.

Findings

In this section, the findings related to the impact of activities conducted with the game-based, modeling, collaborative, and conventional instructional methods on geometry achievements, mathematical motivations, and visual mathematics literacy perceptions of the students are presented, respectively. Initially, the effect of the game-based, modeling, collaborative, and conventional instruction activities on geometry achievement was investigated and whether there was a significant difference between mean pre-test and post-test scores was analyzed with related samples *t*-test. The findings are presented in Table 2.

As seen in Table 2, there was no significant difference between the mean pre-test achievement score and mean post-test score of the students in the Experiment A group, $t(11) = 1.60$, $p > .05$. The effect size was not calculated since the difference was not significant. However, there was a significant difference between the mean pre-test and mean post-test achievement scores of the students in the Experiment B group favoring the mean post-test score, $t(10) = 2.36$, $p < .05$. Thus, the effect size was calculated to determine the significance of this difference. In scientific research, the effect size calculated with paired samples *t*-test provides information about the size of the analyzed variance and is calculated with the ratio of the *t*-value calculated in the test to the square root of the number of individuals in the sample. The effect size is considered small if it is between 0.20 and 0.50, moderate between 0.50 and 0.80, and high if it is equal to or greater than 0.80 (Green & Salkind, 2008, p. 165). Thus, the calculated effect size ($d = 0.71$) indicated that the difference was moderate. There was a significant difference between the mean pre-test and mean post-test achievement scores of the students in the Experiment C group favoring the mean post-test score, $t(11) = 4.98$, $p < .05$. The calculated effect size ($d = 1.44$) indicated that the difference was high. In the study, the difference between the mean pre-test and post-test geometric achievement scores of the students in the control



Figure 1. Photographs of the experimental process.

group, where conventional instruction method was implemented, was analyzed and a significant difference was determined in favor of the mean post-test score, $t(25) = 4.66$, $p < .05$. The calculated effect size ($d = 0.91$) demonstrated that the corresponding difference was high. It was stated that one of the most adequate statistical methods to determine the impact of the experimental process between the groups in the pre-test/post-test empirical designs with the control group was the single-factor ANCOVA where the pre-test is controlled as a covariate (Büyüköztürk et al., 2016, p. 124). In the ANCOVA conducted in the present study, pre-test geometric achievement scores that were effective on the

Table 2. Geometry Achievement Test: Pre-test and Post-test Score and *t*-Test Results.

Groups	Test	*N*	*M*	Standard deviation	*df*	*t*	*p*
Experiment A (game-based learning)	Pre-test	12	16.58	1.92	11	1.60	.13
	Post-test	12	17.41	1.56			
Experiment B (modeling based learning)	Pre-test	11	15.81	1.77	10	2.36	.04
	Post-test	11	17.45	1.21			
Experiment C (collaborative learning)	Pre-test	12	15.75	1.21	11	4.98	.00
	Post-test	12	17.50	1.08			
Control (conventional learning)	Pre-test	26	13.11	2.53	25	4.66	.00
	Post-test	26	15.07	2.61			

Table 3. Adjusted Group Post-test Scores.

Applications	*N*	*M*	Standard deviation	*Adj. M*
Experiment A (game-based learning)	12	17.41	1.56	17.12
Experiment B (modeling based learning)	11	17.45	1.21	17.55
Experiment C (collaborative learning)	12	17.50	1.08	16.71
Control (conventional learning)	26	15.07	2.61	16.39

Table 4. Group Geometry Achievement Test: Post-test Score and ANCOVA Results.

Source of the variance	Sum of squares	*df*	Mean of squares	*F*	*p*
Pre-test	17.64	1	17.64	6.12	.01
Group	25.59	3	8.53	2.95	.04
Error	152.81	53	2.88		
Total	16,837.00	61			

post-tests were included in the analysis as the covariate. Thus, the adjusted post-test scores when the group pre-test scores were controlled are presented in Table 3.

As seen in Table 3, adjusted mean post-test scores were calculated for the game-based learning group (*Adj. M* = 17.12), modeling group (17.55), collaborative learning group (16.71), and the control group (16.39). The significance of the difference between the adjusted group scores was analyzed with ANCOVA. The findings are presented in Table 4.

Table 4 demonstrates that there was a significant difference between the mean post-test scores adjusted by controlling the pre-test geometry achievement scores of the groups where the three instruction methods were implemented, $F(3, 53) = 2.95, p < .05$. The results of the Bonferroni test applied to determine the difference between the groups demonstrated that the mean geometric achievement score of the students in the modeling group was higher when compared with the mean geometric achievement scores of the students in the collaborative, game-based, and conventional instruction groups. This group was followed by the experiment groups of the game-based learning group and the cooperative learning group. Second, the effects of activities conducted with the game-based, modeling, collaborative, and conventional instruction approaches on the mathematical motivation of the students were determined in the study, and whether there was a significant difference between the pre-test and post-test mean motivation scores of the students was analyzed with related samples *t*-test. The findings are presented in Table 5.

Table 5 demonstrates that there was no significant difference between the mean pre-test and mean post-test motivation scores of the students in the Experiment A group, $t(11) = 0.84, p > .05$. The effect size was not calculated since the difference was not significant. There was a statistically significant difference between the mean pre-test and post-test motivation scores of the students in the Experiment B group, $t(10) = 3.19, p < .05$, favoring the mean post-test score. The calculated effect size ($d = 0.99$) indicated that the difference was high. There was a significant difference between the mean pre-test and post-test motivation scores of the students in the Experiment C group, $t(11) = 7.14, p < .05$, favoring the mean post-test score. The calculated effect size ($d = 2.15$) indicated that the difference was high. In the study, the difference between the mean pre-test and post-test motivation scores of the students in the control group, where the conventional instruction method was implemented, was

Table 5. Mathematical Motivation Scale: Pre-test and Post-test Scores and *t*-Test Results.

Groups	Test	*N*	*M*	Standard deviation	*df*	*t*	*p*
Experiment A (game-based learning)	Pre-test	12	4.20	0.60	11	0.84	.41
	Post-test	12	4.70	0.59			
Experiment B (modeling based learning)	Pre-test	11	4.14	0.41	10	3.19	.01
	Post-test	11	4.52	0.28			
Experiment C (collaborative learning)	Pre-test	12	4.38	0.28	11	7.14	.00
	Post-test	12	4.46	0.40			
Control (conventional learning)	Pre-test	26	3.13	0.87	25	−0.72	.48
	Post-test	26	3.24	0.82			

Table 6. Group Adjusted Post-test Scores.

Applications	*N*	*M*	Standard deviation	*Adj. M*
Experiment A (game-based learning)	12	4.70	0.59	4.07
Experiment B (modeling based learning)	11	4.52	0.28	4.52
Experiment C (collaborative learning)	12	4.46	0.40	4.46
Control (conventional learning)	26	3.24	0.82	3.24

analyzed and it was found that there was no significant difference between the mean motivation scores, $t(25) = -0.72$, $p > .05$. The effect size was not calculated since this difference was not significant. In the ANCOVA conducted in the study, the pre-test motivation scores, which were effective on the post-tests were included as a covariate. Thus, the adjusted post-test scores when the group pre-test scores were controlled are presented in Table 6.

Based on Table 6, adjusted mean post-test scores were calculated for the game-based learning group (*Adj. M* = 4.07), modeling group (4.52), collaborative learning group (4.46), and the control group (3.24). The significance of the difference between the adjusted group scores was analyzed with ANCOVA. The findings are presented in Table 7.

Table 7 demonstrated that there was a significant difference between the mean post-test group scores adjusted by controlling the motivation pre-test scores of the groups where the three instruction methods were implemented, $F(3, 53) = 4.35$, $p < .05$. The Bonferroni test conducted to determine the difference between the groups demonstrated that the mean motivation score of the students in the modeling group was higher when compared with the mean motivation score of the students in the collaborative, game-based, and conventional instruction method groups. This group was followed by experimental collaborative learning and game-based learning groups, respectively. Finally, the effects of the activities conducted with the game-based, modeling, collaborative, and conventional instruction approaches on the visual mathematics literacy perception of the students were determined and analyzed with related samples *t*-test to determine whether there was a significant difference between the mean pre-test and post-test scores. The findings are presented in Table 8.

Table 8 demonstrates that there was no significant difference between mean pre-test and post-test visual mathematics literacy perception scores of the students in Experiment A group, $t(11) = -0.05$, $p > .05$. The effect size was not calculated since the difference was not significant. However, there was a statistically significant difference between the mean pre-test and post-test visual mathematics literacy perception scores of the students in Experiment B group favoring the mean post-test score, $t(10) = 3.41$, $p < .05$. Thus, the effect size was calculated to determine the significance of the difference. The calculated effect size ($d = 1.07$) demonstrated that the difference was high. There was a significant difference between the mean pre-test and post-test visual mathematics literacy perception scores of the students in the Experiment C group favoring the mean post-test score, $t(11) = 9.09$, $p < .05$. The calculated effect size ($d = 2.62$) indicated that the difference was high. In the study, the difference between mean pre-test and post-test visual mathematics literacy perception scores of the students in the control group, where the conventional instruction method was implemented, was analyzed and it was found that there was no significant difference between the mean scores, $t(25) = -0.72$, $p > .05$. The effect size was not calculated since this difference was not significant. In the ANCOVA conducted in the study, the pre-test visual mathematics literacy perception scores, which were effective on the post-tests, were included as a covariate. Thus, the adjusted post-test scores when the group pre-test scores were controlled are presented in Table 9.

Based on Table 9, adjusted mean post-test scores were calculated for the game-based learning group (*Adj. M* = 2.53), modeling group (2.79), collaborative learning group

Table 7. Group Mathematical Motivation Scale: Post-test Score and ANCOVA Results.

Source of the variance	Sum of squares	*df*	Mean of squares	*F*	*p*
Pre-test	3.37	1	3.37	3.70	.01
Group	1.09	3	0.36	4.35	.00
Error	4.44	53	0.08		
Total	961.14	61			

Table 8. Visual Mathematical Literacy Perception Scale: Pre-test Post-test Scores and *t*-Test Results.

Groups	Test	*N*	*M*	Standard deviation	*df*	*t*	*p*
Experiment A (game-based learning)	Pre-test	12	2.80	0.25	11	−0.05	.95
	Post-test	12	2.81	0.43			
Experiment B (modeling based learning)	Pre-test	11	2.45	0.26	10	3.41	.00
	Post-test	11	2.79	0.21			
Experiment C (collaborative learning)	Pre-test	12	2.52	0.32	11	9.09	.00
	Post-test	12	3.55	0.69			
Control (conventional learning)	Pre-test	26	2.51	0.25	25	0.63	.54
	Post-test	26	2.58	0.22			

Table 9. Group Adjusted Post-test Scores.

Applications	*N*	*M*	Standard deviation	*Adj. M*
Experiment A (game-based learning)	12	2.81	0.43	2.53
Experiment B (modeling based learning)	11	2.79	0.21	2.79
Experiment C (collaborative learning)	12	3.55	0.69	2.80
Control (conventional learning)	26	2.58	0.22	2.52

Table 10. Group Visual Mathematical Literacy Perception Scale: Post-test Score and ANCOVA Results.

Source of the variance	Sum of squares	*df*	Mean of squares	*F*	*p*
Pre-test	0.18	1	0.06	0.314	.00
Group	0.29	3	0.09	1.059	.00
Error	4.93	53	0.09		
Total	427.928	61			

(2.80), and the control group (2.52). The significance of the difference between the adjusted group scores was analyzed with ANCOVA. The findings are presented in Table 10.

Table 10 demonstrates that there was a significant difference between the mean post-test group scores adjusted by controlling the visual mathematics literacy perception pre-test scores of the groups where the three instruction methods were implemented, $F(3, 53) = 0.31$, $p < .05$. The Bonferroni test conducted to determine the difference between the groups demonstrated that the mean mathematics literacy perception score of the students in the collaborative learning group was higher when compared with the mean motivation score of the students in the modeling, game-based, and conventional instruction method groups. This group was followed by the experimental modeling and game-based learning groups, respectively.

Conclusion, Discussion, and Recommendation

In this study, the difference between the pre-test and post-test geometry achievement scores of all the experimental groups and the control group was analyzed and it was observed that there were significant differences between the pre-test and post-test achievement scores of modeling, collaborative, and control groups except the game-based learning group. In other words, while student achievements did not exhibit any significant difference at the end of the instruction process

conducted with the game-based learning method, the impact of the modeling, collaborative, and conventional instruction models on achievement was significant. This could be due to the fact that the activities carried out in the instruction process had a positive impact on achievement. There are studies in the literature which determined that the mathematics or geometry achievements increased based on the instruction methods. In an experimental study conducted by Çoban et al. (2016), it was found that modeling-based instruction did not lead to a significant improvement in metacognitive awareness of eighth-grade students in the secondary school; however, it exhibited a significant improvement favoring the experimental group in conceptual comprehension. There was a significant difference between the mathematics course academic achievements (in the unit "there is no mathematics without geometry") of the students in the experiment group where collaborative learning was implemented and the control group where conventional instruction techniques were used favoring the experimental group in a study by Şahin et al. (2017). Thus, they concluded that the inclusion of collaborative learning in the instruction process increased student achievements. Işık and Çelik (2017) found that the collaborative learning method significantly improved the academic achievements of students when compared with the conventional instruction method among seventh-grade students in four operations with rational numbers topic. In a study on the instruction of decimal fractions to fourth-grade students conducted by Özdoğan (2008), it was determined that collaborative learning improved the attitudes and academic achievements of the students. Jacobs et al. (1996) found that collaborative learning methods were more beneficial when compared with traditional learning methods in increasing the academic achievements of third-, fourth-, and fifth-grade students in the mathematics course. In a study conducted by Altunay (2004) with fifth-grade students, it was found that game-assisted geometry instruction in the experimental group improved the mathematics achievements of the students more when compared with the conventional instruction method implemented in the control group.

Following the analysis of the pre-test and post-test geometry achievement scores in the study, the geometry achievement scores of the experimental and control groups were analyzed within the groups to determine which instruction method was more effective on achievement. The analyses demonstrated that the mean geometry achievements of the students in the modeling group were higher when compared with the mean achievement scores of the students in the collaborative, game-based, and conventional instruction groups. This group was followed by the experimental game-based learning group and the collaborative learning group. This could be due to the raised awareness of the students about the natural models at the end of the instruction. Furthermore, students could have prioritized group achievements in a collaborative learning environment. It could also be due to the focus of the students on the games in game-based learning. A literature review revealed studies with consistent results with the above-mentioned finding. Ünal-Çoban and Ergin (2013) found that the modeling-based education did not lead to a significant difference in students' understanding of scientific knowledge quantitatively and the improvement of the students who were instructed with modeling-based learning was better when the development of the students was observed qualitatively within the groups. In a study by Bilgin (2004), it was determined that the achievements of the students in the group where the course was instructed with collaborative learning method student teams achievement section technique were significantly higher in the mathematics course (polygons topics) when compared with the control group. Chianson et al. (2010) found that students who were instructed with the collaborative learning method learned geometrical concepts better when compared with the students who were instructed with conventional learning methods. In the literature, certain studies argued that collaborative learning had no effect on achievement. Kenneth and Young (1999) found that collaborative learning did not have a significant impact on the academic achievements of pre-service teachers. Similarly, Akbayır (2017) determined that there was no significant difference between the academic achievements of the ninth-grade students in the topic of clusters when they are instructed with the collaborative learning method and the conventional method. Certain studies in the literature reported that game-based learning improved student achievement. In a meta-analysis conducted by Turgut and Temur (2017) on the effect of the game-assisted mathematics instruction in Turkey on mathematics achievement, 31 studies were included. The study findings demonstrated that games in mathematics instruction had a moderate and positive effect on mathematics achievement. In a study, Durgut (2016) determined that the academic achievement of the students in the group where educational math games were used was higher when compared with the student group where the conventional instruction method was used. Vankus (2008) reported that the attitudes of 12-year-old students, who were instructed with didactic games, toward mathematics instruction exhibited a more positive development when compared with the groups of students who were not instructed with didactic games. It was also stated that certain educational games provided a good opportunity for students to improve their communication and argumentation skills, and social and reasoning abilities. Başün and Doğan (2018) reported that students had positive views on the use of game-based instruction method in acquisition of the achievements in middle school sixth-grade factors sub-learning area.

Second, the difference between the pre-test and post-test mathematics motivation scores of the experimental group and control group was analyzed, and it was determined that there was a difference between the pre-test and post-test scores of the modeling and collaborative learning groups. In other words, while mathematics motivation of the students did not exhibit a significant difference with the

implementation of the game-based and conventional instruction methods, their motivation significantly increased with the application of modeling and collaborative instruction methods. This could be due to the fact that the instructional activities conducted in nature positively affected student motivation. The literature review also demonstrated that certain studies reported that instruction processes conducted with these instruction methods increased mathematical motivation. In a study by Urhan and Dost (2016), teachers considered that modeling activities contributed to mathematics instruction, and students could associate daily-life topics more easily with mathematical modeling, which could in turn increase student motivation. Tobias (1992) investigated the reasons for the negative attitudes of the students toward the instruction process and stated that this was due to their lack of interest and motivation in the course, pacifism, and emphasis on grade competition instead of collaboration. However, there are also studies in the literature which claimed that collaborative learning reduced motivation. Klein and Schnackenberg (2000) investigated the effects of informal collaborative learning on achievement, participation motivation, attitude, and communication. The study determined that the participants who used individual strategies learned in the course better than the users of informal collaborative strategies and were highly motivated to work alone. Shachar and Fischer (2004) reported that group research, a collaborative learning technique, was associated with a decrease in student motivation. Certain studies reported that game-based learning increased motivation. Bakar et al. (2008) found that students liked educational game environments and that using such a supplementary environment increased their motivation in the course. Kebritchi et al. (2010) and Lopez-Morteo and Lopez (2007) reported that the use of educational games in mathematics instruction increased motivation in their studies. Van-Eck (2006) stated that games were motivating.

After the analysis of the pre-test and post-test motivation scores in the study, in-group motivation scores for the experimental and control groups were analyzed to determine which instruction method was more effective on motivation when compared with the others. The analyses demonstrated that the mean motivation score of the students in the modeling group was higher when compared with the mean motivation scores of the students in collaborative, game-based, and conventional learning groups. This group was followed by the collaborative learning and the game-based learning groups, respectively. This could be due to the motivation of common achievement in cooperative learning or game-based activities. Also, models may have provided students with convenience and increased motivation. The literature review revealed that there were other studies with consistent findings. In a study conducted by Kal (2013), it was determined that the use of mathematical modeling activities in the instruction process increased the motivation and interest of the students. Ören-Vural et al. (2013) stated that the relationship established between daily life and mathematics through modeling activities improved the motivation of students in mathematics. Hancock (2004) studied the effects of peer-based learning using collaborative learning strategies on the achievements and motivation of the students and concluded that highly focused students were more motivated in learning when compared with those with lower motivation. In a study by Veenman et al. (2005), it was stated that the use of motivational resources in the mathematics course instructed with the collaborative learning method in the study group affected the students' attitudes positively when compared with the control group. Bayırtepe and Tüzün (2007) stated that games increased the level of motivation among the learners, their interest in the topic, self-confidence that they can learn, their comfort, and motivation among the students. Vankus (2008) observed that students in the groups where instructional games were played were motivated for active participation in mathematics courses where instructional games were integrated. Baccus (2004) found that teachers' attitudes, beliefs, and instructional methods they used were significantly correlated with the motivation of students. Partovi and Razavi (2019) and Sung et al. (2012) reported that game-based learning had positive effects on academic achievement and motivation in primary school students.

Finally, the difference between the pre-test and post-test visual mathematics literacy perception scores of the experiment and control groups were analyzed and it was determined that there was a difference between the pre-test and post-test scores of modeling and collaborative learning groups. In other words, at the end of the instruction process conducted with game-based learning and conventional instruction method, visual mathematics literacy perceptions of the students did not exhibit any significant difference; however, the instruction processes conducted with modeling and collaborative instruction methods resulted in significant increases. This could be due to the fact that nature activities increased the level of perception in the instructional process and resulting development in literacy. In the literature review, it was observed that certain studies revealed that the visual mathematics literacy perception or mathematics literacy increased as a result of the instruction processes conducted with these instruction methods. Biembengut (2006) indicated that it was not difficult to plan activities for primary school children that would enable them to understand mathematical relations and use mathematical language or literacy, and mathematical modeling can contribute to the development of important skills in individuals and these concepts. Tekdal and Sönmez (2018) stated that the collaborative learning method, which is one of the modern learning methods, could be used effectively in literacy classes. Çakırer (2017) stated that to support language development or literacy skills, language-related material should be placed in an area where the child normally prefers to play, and they could develop language skills by playing games with these materials.

After the analysis of the pre-test and post-test visual mathematics literacy perception scores in the study, in-group visual mathematics literacy perception scores for the experimental and control groups were analyzed to determine which instruction method was more effective on visual mathematics literacy perception when compared with the others. The analysis results demonstrated that the students in the collaborative learning group exhibited a higher mean visual mathematical literacy perception score when compared with that of the students in the modeling, game-based, and conventional instruction method groups. This group was followed by the modeling and game-based learning groups, respectively. This could be due to the fact that verbal communication improved literacy or models improved perception in the cooperative learning process. The literature review revealed that there were other studies with consistent findings. In a study by Erol (2015) conducted with the ninth-grade students, it was determined that there was an increase in mathematical literacy levels of the study group students where modeling activities were conducted when compared with the control group where conventional instruction method was implemented. In their study, Swan et al. (2006) stated that modeling developed students' ability to use mathematical language and their capacity to ask questions and respond. In a study by Tekdal and Sönmez (2018), it was found that literacy instruction with collaborative learning was more effective when compared with the conventional learning method. In a study by Uyanık (2013), it was noted that the skills of effective language use could be acquired with game activities in preschool mathematics education. Based on the study findings, the following recommendations were made for researchers in the field of mathematics instruction and related fields:

1. The achievements, motivation, and visual mathematics literacy perception levels of the students could be improved by emphasizing the methods discussed in the present study or other student-oriented instruction methods in the instruction process;
2. Further analyses could be conducted by comparing other student-oriented instruction methods that are used in instruction processes;
3. Longitudinal or cross-sectional comparisons could be conducted on student-oriented instruction methods based on different sample groups;
4. Variables that are different from the ones used in the present study could be analyzed when comparing student- or teacher-oriented instruction methods to contribute to the field of mathematics instruction.

Authors' Note

The research discussed in this article was originally presented at the International Social Sciences and Education Conference, November 14–17, 2018, in Diyarbakır, Turkey, an abstract of which was published in Proceeding Book.

Acknowledgments

We thank everyone who participated in this study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The study was supported by The Scientific and Technological Research Council of Turkey (TUBITAK) as project. The Project number was 118B500.

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