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Research Article

The Effects of GeoGebra-Assisted Transformation Geometry Instruction on Student Achievement, Attitudes, and Beliefs

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Abstract

This study aims to investigate the effects of using GeoGebra, a popular dynamic geometry software, on students' mathematics achievement, attitudes toward geometry, and beliefs about mathematics and its teaching in transformation geometry teaching. The study was a quasi-experimental design including experimental and control groups. The sample of the study was 34 7th-grade students from a public middle school in a city in Turkey. The study was conducted in the 2015-2016 academic year, lasting ten lesson hours (three weeks). The data were collected through achievement test and surveys regarding attitudes toward geometry, beliefs about the nature of mathematics, and beliefs about the teaching of mathematics. The quantitative data analyses were carried out by using the Mann-Whitney U test. Results revealed that, although the use of GeoGebra in teaching transformation geometry demonstrated student improvement in achievement, attitudes toward geometry, and beliefs about teaching mathematics, these results were not statistically significant.

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Introduction

As in all areas of life, the use of technology in the field of education is inevitable. The rapid development of computer technology offers students new learning opportunities and ways. Instructional software has also been affected by developments in this field, and the quality and quantity of software have increased significantly (Ministry of National Education [MoNE], 2005). Dynamic geometry software (DGS), a kind of instructional software, was first mentioned in the 2005 mathematics curriculum in Turkey (MoNE, 2005) and has gained the attention of many teachers and educators. It allows students to create and manipulate geometric constructs having certain properties that can be tested and observed to make conjectures. Specifically, it "enhances the visual representation and spatial visualization, increases students' cognitive capacities during learning, encourages greater mathematical discourse, and pushes students to become more mathematical thinkers" (Nelson, 2018, p. 6).

Similar to DGS, transformation geometry (translation, reflection, rotation, translational reflection) was included in the 2005 mathematics curriculum for the first time as a sub-learning domain, and the literature related to transformation geometry has expanded significantly since then. According to the National Council of Teachers of Mathematics (NCTM) (2000), two-dimensional transformations are an important topic for students, and it is recommended that all middle grades students study transformations. Prior research shows that students and teachers have difficulties in understanding and teaching transformation geometry since it is a little more abstract than other mathematics topics (Harper, 2002). With technology, students can illustrate multiple situations using symbolic (algebraic), graphic (geometric), and numeric (arithmetic) representations simultaneously (Erbaş, 2005). Moreover, students can express transformations in many ways such as drawings, coordinates, vectors, function notation, and matrices, by using DGS. Research shows that dynamic representations and DGS improve students' understanding of geometric transformations including translation, reflection, and rotation (e.g., Balcı, 2022; Dixon, 1997; Faggiano & Mennuni, 2020; Flanagan, 2001; Glass, 2001; Harper, 2002; Karakuş, 2008; Kaya, 2013; Yahşi-Sarı, 2012).

DGS, such as GeoGebra, Cabri Geometry, Geometer's Sketchpad, and Cinderella, are known as the general name of software developed for teaching and learning geometry. The most important feature of DGS is dragging objects and manipulating them dynamically (Scher, 2000). Among DGS, GeoGebra (a geometry, algebra, and calculus software) has been recently developed and is often preferred. In the First Eurasia Meeting of GeoGebra placed in İstanbul, the mathematics teachers indicated that being free, available in Turkish, having a user-friendly interface, being easy to use, and providing the links between geometry and algebra make GeoGebra preferable for teachers (Kabaca et al., 2010) and researchers as well. Moreover, it is suggested in the curriculum that dynamic geometry software can be used in activities for achieving the learning objectives of the transformation geometry sub-learning domain for middle grades (MoNE, 2005).

Transformation geometry is an enjoyable topic for students to study. It develops students' creativity and spatial skills (Duatepe & Ersoy, 2003). It allows students to understand the things they see every day in a different context (Knuchel, 2004). It also provides students with a context within which they can view mathematics as an interconnected discipline (Hollebrands, 2003). Considering the nature and the characteristics of transformation geometry, this study assumes that students' investigation of transformation geometry can change their typical beliefs about mathematics (i.e., mathematics is computation, rule-based, and memorization).

Beliefs are formed by students' direct and indirect experiences (Lester, 2002), and teaching is very much related to changing and forming belief systems (Muis, 2004). The relationship between students' mathematics-related beliefs and their classroom practices are also indicated in studies focusing on changes in beliefs (Kıbrıslıoğlu-Uysal & Haser, 2018). For example, in a study conducted by Mason and Scrivani (2004) examining the effects of a specific intervention on 5th-grade students' mathematics-related beliefs, it is implied that students' mathematics-related beliefs can be changed through careful intervention. Additionally, belief systems are change resistant and they can only be changed when students are involved in powerful experiences in mathematical thinking and conceptual understanding (Philippou & Christou, 2002). Therefore, in this study, the effects of using DGS in teaching transformation geometry on 7th-grade students' beliefs about the nature of mathematics and the teaching of mathematics were investigated.

Attitude is another variable that is accepted as more affective in nature and less stable than beliefs (McLeod, 1992). It is suggested that the development of students' positive attitudes toward mathematics is related to their perceptions of mathematics as being interesting and useful whereas, the development of their negative attitudes toward mathematics is linked to their not doing well or views of mathematics as being disinteresting (Bergeson, Fitton & Bylsma, 2000). Indeed, transformation geometry relates to arts and aesthetics that receive students' attention, which may help the development of favorable attitudes toward mathematics and geometry. Since it is claimed that students have low attitudes toward geometry (Duatepe Paksu & Ubuz, 2007), the development of positive attitudes is of great importance for better mathematics achievement. Moreover, middle grades are the most critical period in the formation of attitudes toward mathematics (Bergeson et al., 2000). Therefore, this study aimed to investigate if using GeoGebra in teaching transformation geometry affected 7th-grade students' attitudes toward geometry.

Many researchers have studied the use of DGS in teaching and learning transformation geometry (e.g., Akgül, 2014; Altın, 2012; Dixon, 1997; Flanagan, 2001; Glass, 2001; Guven, 2012; Harper, 2002; Hollebrands, 2003; Kaleli Yılmaz, 2015; Karakuş, 2008; Karakuş & Peker, 2015; Kaya, 2017; Kurak, 2009; Özçakır Sümen, 2013; Yahşi Sarı, 2012). Most of them have worked with middle school students since the topic of transformation geometry is studied comprehensively in the middle grades. However, when studying the effects of using DGS on students' mathematics achievement, a great majority of them have seen contradictory results. Accordingly, there is a need to study DGS in teaching transformation geometry to obtain more consistent results.

Another reason for studying the effects of DGS on students' learning of geometry is students' poor performance in geometry tests. The Trends in International Mathematics and Science Study (TIMSS, 2019) reports that Turkish students have low achievement in geometry tests (Mullis et al., 2020). There still is a need to conduct teaching/learning research that helps students learn geometry concepts meaningfully (Clements & Battista, 1992). In this study, the effects of using GeoGebra in teaching transformation geometry on students' achievement were also investigated.

Previous research revealed that attitudes play a significant role in learning mathematics (Aiken, 1972), and using DGS may foster students' positive attitudes toward geometry. However, only a few studies have examined the development of students' attitudes while using DGS in teaching geometry (Birgin & Topuz, 2021; Kutluca, 2013), and specifically in transformation geometry (Akgül, 2014; Özçakır Sümen, 2013). Therefore, more research is needed in this field of study. Moreover, students' attitudes toward mathematics are related to their beliefs about mathematics (Pyzdrowski et al., 2013). In the related literature, although there are some studies assessing the beliefs of students about mathematics (Kayaaslan, 2006; Kıbrıslıoğlu Uysal & Haser, 2018; Toluk Uçar et al., 2010; Yıldız, 2016) and more recently about geometry (Ünlü & Ertekin, 2018), there are only a limited number of studies related to changes in students' beliefs about mathematics (Bayrak & Hacıömeroğlu, 2018; Kabaca & Tarhan, 2013; Muis, 2004). Research suggests that changing classroom instruction can change students' beliefs about mathematics (Muis, 2004).

Given the obvious role of transformation geometry in mathematics education, the development of students' understanding of transformation geometry is a primary problem for teachers and researchers. Numerous studies have focused on the effects of using DGS in teaching and learning transformation geometry. Most of them investigated the effects of using DGS on students' achievement and obtained some contradictory results owing to the methodology (e.g., research setting, population, sample, instruments, procedure, etc.) they adopted. Likewise, this study differs from other studies in terms of its methodology, and therefore it is believed the results obtained from this study will contribute to the related literature and mathematics teaching in practice in that manner. Moreover, affective factors like attitudes and beliefs play an important role in learning mathematics, and using computers may lead to more positive attitudes and beliefs in students. This study is significant since it can improve not only the practice of using GeoGebra in teaching transformation geometry but also develop a positive attitude toward geometry and belief about the nature of mathematics and teaching because it is based on the implementation of computer-assisted instruction enriched with the use of GeoGebra.

Having established these facts, it seems necessary to design experimental research on the effects of using GeoGebra in teaching transformation geometry and to investigate its effects on students' achievement, geometry attitudes, beliefs about the nature of mathematics, and the teaching of mathematics compared to not using it. Therefore, the research addresses the following questions:

1. What are the effects of using GeoGebra in teaching transformation geometry compared to not using it on 7th-grade students' achievement in transformation geometry?
2. What are the effects of using GeoGebra in teaching transformation geometry compared to not using it on 7th-grade students' attitudes toward geometry?
3. What are the effects of using GeoGebra in teaching transformation geometry compared to not using it on 7th-grade students' beliefs about the nature of mathematics?
4. What are the effects of using GeoGebra in teaching transformation geometry compared to not using it on 7th-grade students' beliefs about the teaching of mathematics?

Method

Design of the Study

The quasi-experimental design was implemented in the study since the participants were not assigned randomly to the experimental and control groups (Fraenkel & Wallen, 2005). The design of the study is summarized in Table 1.

Table 1. The research design of the study

Group	Pretest	Treatment	Posttest
EG	TGAT, GAS, BNMS, BTMS	GGI	TGAT, GAS, BNMS, BTMS
CG	TGAT, GAS, BNMS, BTMS	NGGI	TGAT, GAS, BNMS, BTMS

EG: Experimental Group
CG: Control Group
GGI: GeoGebra-Assisted Instruction
NGGI: Non-GeoGebra-Assisted Instruction
TGAT: Transformation Geometry Achievement Test
GAS: Geometry Attitude Scale
BNMS: Beliefs about the Nature of Mathematics Scale
BTMS: Beliefs about the Teaching of Mathematics Scale

Population and Sample

The target population consists of all 7th-grade middle school students in Bartın. The accessible population is all 7th-grade students (211 students in six classes) at the school in which the study was conducted. Since it was difficult to select a random sample of individuals, convenience sampling was used in this study. Therefore, the sample was 7th-grade students in two classes taught by the researcher in a public middle school in Bartın. The classes were selected based on their equivalency of achievement levels in mathematics according to their previous year's mathematics grades. They were assigned as the experimental and control group, with 17 students in each group. The distribution of the subjects in the experimental and control groups in terms of gender is presented in Table 2.

Table 2. The distribution of the subjects in the groups in terms of the gender

Gender	Group		
	EG (%)	CG (%)	Total (%)
Female	8 (47.1)	9 (52.9)	17 (50)
Male	9 (52.9)	8 (47.1)	17 (50)
Total	17 (100)	17 (100)	34 (100)

Instruments

To collect data, four instruments were used in the study: Transformation Geometry Achievement Test (TGAT), Geometry Attitude Scale (GAS), Beliefs about the Nature of Mathematics Scale (BNMS), and Beliefs about the Teaching of Mathematics Scale (BTMS).

Transformation Geometry Achievement Test (TGAT)

In order to determine students' achievement in transformation geometry, Transformation Geometry Achievement Test (TGAT) was developed. First, the learning objectives of the transformation geometry sub-learning domain in the mathematics curriculum (MoNE, 2013) were determined and a table of specification was prepared accordingly. Moreover, the cognitive domain of Bloom's Taxonomy was used in the preparation of the items. According to the objectives given in the curriculum, they were prepared for the application, comprehension, and knowledge levels of the taxonomy. Accordingly, at least two items were prepared for each objective and 17 multiple-choice items were included in the draft form of the test. While preparing the items, various textbooks and internet resources were used and they were reviewed by experts from different areas (two experts from mathematics education, one expert from measurement and evaluation, and two elementary mathematics teachers) to provide evidence for face and content validity of the test. Based on the opinions of experts, some revisions were made and a pilot study was conducted to check the clarity of questions, the reliability of the test and to select items according to discrimination and difficulty indices for the final version of the test. In the pilot study, the test was applied to 19 8th-grade students and the answers were analyzed using Test Analysis Program (TAP) to check the item and test statistics.

The item and test statistics of the draft version of TGAT were given in Table 3. Accordingly, the mean score was 12.53, and the standard deviation was 4.54. The discriminant indices (r_{jx}) of all items were between -.01 and .77, while the average discrimination index of the test was .35. The difficulty indices of all items were between .21 and .95, while the average difficulty index of the test was .58. KR-20 reliability of the test was .71, which means the test shows a moderate degree of reliability coefficient (Atılgan, Kan & Doğan, 2011).

Table 3. Item and test statistics of the draft version of the TGAT

Item No	Discrimination Index (r_{jx})	Difficulty Index (p_j)
Item 1	.65	.84
Item 2	-.01	.32
Item 3	.41	.63
Item 4	.13	.26
Item 5	.58	.74
Item 6	.73	.58
Item 7	.19	.63
Item 8	.23	.89
Item 9	.58	.63
Item 10	.12	.53
Item 11	.39	.21
Item 12	.77	.63
Item 13	.32	.58
Item 14	.48	.42
Item 15	.11	.63
Item 16	.28	.58
Item 17	.01	.47
Item 18	.19	.84

Item 19	.42	.68
Mean Score		12.53
Standard Deviation		4.54
Mean Discrimination Index (r_{jx})		.35
Mean Difficulty Index (p_j)		.58
KR-20 Reliability		.71

When selecting the items for the final version of the test, the criteria for a discrimination index of .20 and below were used in the study. As a result, five items (1, 4, 10, 15, and 17) were removed from the test and the item and test statistics were calculated again for the remaining 12 items for the final version of the test. The discriminant indices of items 7 and 18, which were below .20 initially, increased to .22 and they were not removed from the test and kept in the final version. The final KR-20 reliability of the test was found .79. The item and test statistics for the final version of the TGAT proved that it was valid and reliable.

Geometry Attitude Scale

The Geometry Attitude Scale (GAS) developed by Bulut et al. (2002) determined students' attitudes toward geometry. The test was three-dimensional having 24 items. Eleven items represent the enjoyment dimension, four items represent the usefulness dimension and two items represent the anxiety dimension. Students were asked to rate statements by marking a five-point Likert scale with the alternatives of strongly disagree, disagree, undecided, agree, and strongly agree. Negative statements were scored as 5, 4, 3, 2, and 1, and positive statements were scored as 1, 2, 3, 4, and 5 in the order of alternatives. The possible scores of the GAS range from 24 to 120. The reliability coefficient of the original scale was .92. In the current study, the reliability coefficient was .90, which indicates the test was highly reliable.

Beliefs about the Nature of Mathematics Scale

In order to determine students' beliefs about the nature of mathematics, the Beliefs about the Nature of Mathematics Scale (BNMS) developed by Mert Kalender (2010) was used. It consists of 12 Likert-type items with five possible alternatives strongly disagree, disagree, undecided, agree, and strongly agree. Negative statements were scored as 5, 4, 3, 2, and 1, and positive statements were scored as 1, 2, 3, 4, and 5 according to the order of alternatives. The possible scores on the scale range from 12 to 60. Mert Kalender (2010) reported the Cronbach alpha reliability coefficient of the scale as .78. In the present study, it was found as .70, which shows the BNMS was reliable.

Beliefs about the Teaching of Mathematics Scale

The Beliefs about the Teaching of Mathematics Scale (BTMS) developed by Mert Kalender (2010) was used in order to determine students' beliefs about the teaching of mathematics. It consists of 13 Likert-type items with five possible alternatives strongly disagree, disagree, undecided, agree, and strongly agree. Negative statements were scored as 5, 4, 3, 2, and 1, and positive statements were scored as 1, 2, 3, 4, and 5 according to the order of alternatives. The possible scores on the scale range from 13 to 65. Mert Kalender (2010) reported the Cronbach alpha reliability coefficient of the scale as .85. In this study, it was found as .87, which indicates the high reliability of the test.

Procedure

The students in the experimental group used GeoGebra while learning the concepts of transformation geometry (congruence, translation, reflection, and composite transformation of translation and reflection) whereas the students in the control group learned the same concepts without using GeoGebra. Both groups were instructed by the researcher (also their mathematics teacher) for three weeks (ten lesson hours in total). The experiment group was taught in a computer laboratory, whereas the control group was taught in their regular classroom. The lessons for the experimental group were conducted by using the lesson plans, activity sheets, and worksheets that were developed by the researcher before the study. They were reviewed by an expert in mathematics education and two mathematics teachers for their appropriateness for implementation and the objectives of the curriculum. Some modifications were made according to their critiques and suggestions. The lessons for the control group were based on their usual textbooks. All lessons were planned according to consistent learning objectives.

Before conducting the study, the students in the experimental group were trained in the usage of GeoGebra, its basic tools, and making some basic constructions using it for two lesson hours. After the training, TGAT, GAS, BNMS, and BTMS were administered to both groups of students as pretests before the treatment. They were administered again to both groups as posttests after the treatment.

The treatment of the experimental group was based on the activities in GeoGebra. They were uploaded to students' computers in the laboratory before the lesson began. After a brief explanation from the researcher about the activity, the students started to work individually on a specific activity. They constructed, dragged, and resized the figures dynamically and observed the changes as a result of their movements and manipulations.

During the lessons, students were active participants. They imagined, communicated, explored, discussed, criticized, discussed, justified, and expressed their ideas. The researcher acted as a facilitator helping students to explore, develop, express, discuss, and critique ideas. At the end of each lesson, the researcher wanted students to share their ideas, discuss them together, and draw conclusions about the topic of study. Moreover, the researcher disturbed worksheets at the end of the lesson to assess their understanding. Sample activities that students performed using GeoGebra are given in Figure 1 below.

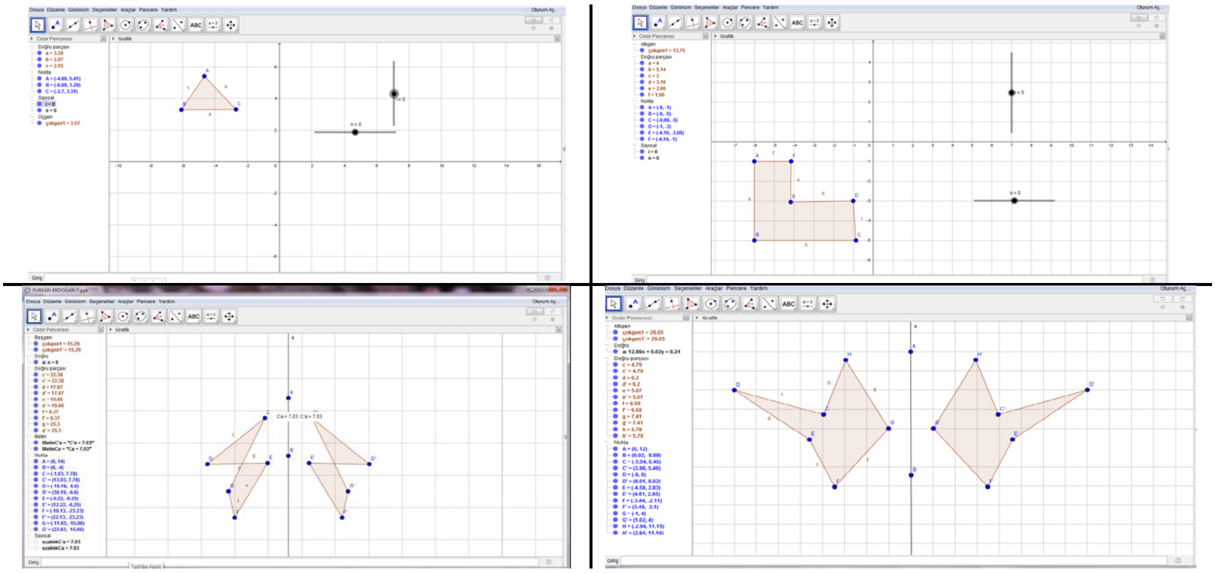

Figure 1. Sample student activities using GeoGebra

The treatment of the control group was based on a textbook in a traditional teaching environment. The students in the control group were taught the same mathematical content using their textbooks as the experimental group. The teacher explained the concepts and gave some definitions without using any technological tools. Then, he solved some examples on the blackboard and wanted students to write them in their notebooks. During the lessons, students were passive receivers. They took notes and listened to their teachers. They asked a few questions and had no discussions. They mainly answered the questions that the researcher asked them. The researcher acted as an information giver and presenter. At the end of each lesson, the researcher gave homework assessments from their textbooks.

Data Analyses

The descriptive statistics; means, medians, minimum and maximum scores, standard deviations, and skewness and kurtosis values, were used to explore the characteristics of the sample. The data collected through the TGAT, GAS, BNMS, and BTMS were analyzed using Statistical Package for Social Sciences (SPSS) 18.0. The non-parametric alternative of the t-test for independent samples, the Mann-Whitney U test, was used in order to answer the research problems of the study. According to Pallant (2010), non-parametric techniques are useful when there are very small samples. The hypotheses were tested at the .05 level of significance which is mostly used value in educational studies.

Results

Descriptive Statistics

As mentioned before, to test for differences between the EG and the CG on the POST-TGAT, PRE-GAS, POST-GAS, PRE-BNMS, POST-BNMS, PRE-BTMS, and POST-BTMS, the Mann-Whitney U test was used in this study. According to Pallant (2010), instead of comparing the means of the two groups, the Mann-Whitney U test compares medians. Therefore, the medians were reported for each group when presenting the results. The descriptive statistics related to the POST-TGAT, PRE-GAS, POST-GAS, PRE-BNMS, POST-BNMS, PRE-BTMS, and POST-BTMS of the experimental and control groups are given in Table 4.

Table 4. Descriptive statistics related to the POST-TGAT, PRE-GAS, POST-GAS, PRE-BNMS, POST-BNMS, PRE-BTMS, and POST-BTMS

Group		Test						
		POST-TGAT	PRE-GAS	POST-GAS	PRE-BNMS	POST-BNMS	PRE-BTMS	POST-BTMS
EG	n	17	17	17	17	17	17	17
	Mean	9.66	83.97	81.37	42.04	44.12	55.33	58.39
	Median	10.00	83.50	84.76	41.50	44.16	56.00	58.50
	SD	1.61	18.08	21.20	7.15	6.57	7.84	6.08
	Skewness	-.905	.595	-.125	-.244	.273	-.084	-.853
	Kurtosis	1.262	-.196	-.674	-.686	-1.005	-1.525	.153
	Max.	12	120	115	52	56	65	65
	Min.	6	59	48	30	35	44	47
CG	n	17	17	17	17	17	17	17
	Mean	8.50	86.26	84.43	45.60	48.32	55.78	55.29
	Median	9.00	79.50	78.50	45.00	51.00	56.50	58.50
	SD	1.91	17.10	15.87	4.61	5.52	6.55	9.14
	Skewness	-.154	.830	1.112	.558	-.144	-.290	-.734
	Kurtosis	-.405	-.654	-.216	.422	-1.865	-.771	-.880
	Max.	12	120	118	55	56	65	65
	Min.	5	68	70	38	41	44	39

As it is seen in Table 4, the median of the POST-TGAT of the EG was higher than that of the CG. The medians of the PRE-GAS and the POST-GAS of the EG were higher than those of the CG. The median score of the EG increased from 83.50 to 84.76, whereas the CG showed a decrease of 1.00. As it comes to the medians related to the PRE-BNMS and the

POST-BNMS, it was observed that the median score of the EG increased from 41.50 to 44.15 and the CG increased from 45.00 to 51.00. According to values, the median scores of the EG showed an increase of 2.65 from the pretest to the posttest and the CG had an increase of 6.00. Lastly, the median scores on the BTMS of both groups increased from the pretest to the posttest. They showed a similar amount of increase in both groups. Moreover, there were no missing data in all pretests and posttests.

Analysis of Pretest Scores of the Experimental Group and the Control Group

Prior to the comparison of the experimental and the control group to investigate the effectiveness of using GeoGebra in teaching transformation geometry, the Mann-Whitney U test was conducted to determine whether the groups differ significantly in terms of their attitude toward geometry and belief about the nature and the teaching of mathematics to their pretest scores of the GAS, BNMS, and BTMS. The results of this analysis are presented in Table 5.

Table 5. Mann-Whitney U test on experimental and control group students' pretest scores of GAS, BNMS, and BTMS

Test	Group	n	Mean Rank	Sum of Ranks	U	z	p	r
PRE-GAS	EG	17	12.88	154.50	76.5	-.38	.70	.08
	CG	17	14.04	196.50				
PRE-BNMS	EG	17	11.46	137.50	59.5	-1.26	.20	.25
	CG	17	15.25	213.50				
PRE-BTMS	EG	17	13.25	159.00	81.0	-.15	.87	.03
	CG	17	13.71	192.00				

*p<.05

As it is seen from Table 5, there was no statistically significant difference between the experiment group and the control group (U = 76.5, z = -.38, p = .70, r = .08) in terms of attitude toward geometry according to the groups' pretest scores on GAS. There was no statistically significant difference between the experiment group and the control group (U = 59.5, z = -1.26, p = .20, r = .25) in terms of belief about the nature of mathematics according to the groups' pretest scores on BNMS. Similarly, there was no statistically significant difference between the experiment group and the control group (U = 81.0, z = -.15, p = .87, r = .03) in terms of belief about the teaching of mathematics according to the groups' pretest scores on BTMS. Therefore, it can be concluded that the groups did not differ significantly in terms of their attitude toward geometry and belief about the nature and the teaching of mathematics before the treatment began.

The Effect of Using GeoGebra in Teaching Transformational Geometry on Students' Achievement in Transformational Geometry

The Mann-Whitney U test was conducted to explore whether there was a statistically significant difference between the experimental and control groups' posttest scores in terms of TGAT after the treatment. Analysis results revealed that there was no statistically significant difference between the experiment group (*Md* = 10.00, *n* = 17) and the control group (*Md* = 9.00, *n* = 17; *U* = 53.0, *z* = -1.62, *p* = .10) in terms of transformation geometry achievement level according to the groups' posttest scores on TGAT.

The Effect of Using GeoGebra in Teaching Transformational Geometry on Students' Attitude toward Geometry

The Mann-Whitney U test was conducted to explore whether there was a statistically significant difference between the experimental and control groups' posttest scores in terms of GAS after the treatment. Analysis results revealed that there was no statistically significant difference between the experiment group (*Md* = 84.76, *n* = 17) and the control group (*Md* = 78.50, *n* = 17; *U* = 78.5, *z* = -.28, *p* = .77) in terms of attitude toward geometry according to the groups' posttest scores on GAS.

The Effect of Using GeoGebra in Teaching Transformational Geometry on Students' Belief about the Nature of Mathematics

The Mann-Whitney U test was conducted to explore whether there was a statistically significant difference between the experimental and control groups' posttest scores in terms of BNMS after the treatment. Analysis results revealed that there was no statistically significant difference between the experiment group (*Md* = 44.16, *n* = 17) and the control group (*Md* = 51.00, *n* = 17; *U* = 50.0, *z* = -1.75, *p* = .08) in terms of belief about the nature of mathematics according to the groups' posttest scores on BNMS.

The Effect of Using GeoGebra in Teaching Transformational Geometry on Students' Belief about the Teaching of Mathematics

The Mann-Whitney U test was conducted to explore whether there was a statistically significant difference between the experimental and control groups' posttest scores in terms of BTMS after the treatment. Analysis results revealed that there was no statistically significant difference between the experiment group (*Md* = 58.50, *n* = 17) and the control group (*Md* = 58.50, *n* = 17; *U* = 70.5, *z* = -.69, *p* = .48) in terms of belief about the teaching of mathematics according to the groups' posttest scores on BTMS.

Discussion and Conclusions

The aim of this study was to investigate the effects of using GeoGebra in teaching transformation geometry on 7th-grade students' achievement in transformation geometry, attitudes toward geometry, and beliefs about the nature of mathematics and its teaching. The findings of the study confirm that using GeoGebra in teaching transformation geometry had no statistically significant effects on mathematics achievement, geometry attitude, and mathematics-related belief compared to not using it in teaching transformation geometry. It is possible to encounter studies in the literature supporting the results of the current study that non-significant difference exists between the experimental and control group in terms of transformation geometry achievement (Kurak, 2009), geometry attitude (Akgül, 2014; Özçakır Sümen, 2013), and mathematics beliefs and its teaching (Kabaca & Tarhan, 2013). One of the reasons for obtaining the non-significant differences can be the statistical test used in the study. According to Pallant (2010), non-parametric tests are less powerful than parametric tests. Therefore, it is less likely to detect a difference between the groups. The sample size is another factor that can influence the power of a test, and when conducting a study with small group size (e.g., n = 20), you should be aware of the power possibility that a non-significant result could be caused by insufficient power (Pallant, 2010). In the current study, since the sizes of the groups were very small, the non-significant results obtained may be due to the insufficient power of the test. In the literature, there are many studies that indicate the positive effect of the use of DGS on students' achievement in transformation geometry with larger sample sizes (Akgül, 2014; Altın, 2012; Dixon, 1997; Guven, 2012; Karakuş, 2008; Özçakır Sümen, 2013; Yahşi Sarı, 2012). According to the results of descriptive statistics regarding the transformation geometry achievement test, the median scores of both groups were very high and close to the maximum score of the test. This indicates that both methods of instruction were effective in students' learning of transformation geometry concepts.

According to the results of the study, even though the increase in the experimental group students' geometry attitude scale posttest scores was not statistically significant, during the lessons, it was observed that students in the experimental group maintained a high level of interest in and enjoyment of transformations. They were more willing to participate in the classroom discussions and offer answers to the questions than students in the control group. According to Curtis (2006), students' attitudes can be affected positively as they experience a learning environment different from traditional teaching. Indeed, one of the reasons for obtaining a non-significant change in students' attitudes toward geometry may be related to the time span of the treatment process. The treatment process lasted three weeks in the present study and this period may not be enough to change students' attitudes toward geometry. This finding also supports the claim that student attitudes toward mathematics are quite stable, especially in grades 7-12 (Bergeson et al., 2000). Another reason for this result might be related to the students' familiarity with GeoGebra. The students had not been introduced to any kind of DGS before this study and had not used GeoGebra prior to the study. Working individually with GeoGebra can be another reason for this result. It is assumed that if students worked in pairs at the computer, they would be able to question the actions of the other with the computer and question or make sense of the reasoning offered.

Similar to attitude toward geometry, the results of the present study revealed that using GeoGebra in teaching transformation geometry had no statistically significant effect on students' beliefs about the nature of mathematics and its teaching. This result is in line with McLeod's (1992) claim that "beliefs and attitudes are relatively stable and resistant to change" (p. 246). It also supports Kabaca and Tarhan's (2013) study that dynamic geometry software enriched learning environment had no effect on high school students' beliefs about mathematics. Notably, both groups in this study made improvements in posttest scores on beliefs about the nature of mathematics and beliefs about the teaching of mathematics scales. This result is consistent with the assumption made at the beginning of the study that the study of transformation geometry can change students' beliefs about mathematics in a favorable way.

Transformation geometry is an important branch of geometry. It links the properties of transformations to the properties of geometric objects (Bouckaert, 1995). Moreover, DGS can allow experimentation with families of geometric objects, with an explicit focus on geometric transformations (NCTM, 2000). This study investigated the effects of using GeoGebra in teaching transformation geometry on 7th-grade students' achievement in mathematics, attitudes toward geometry, and beliefs about the nature of mathematics and its teaching. Although the students using GeoGebra improved their relative posttest scores considering the scores of the students not using it, it was revealed that the improvements were not significant. Based on the results of the present study, the following implications and recommendations can be made for further research.

Evidence supported using DGS to promote student understanding of geometry concepts, geometric thinking, visualization, spatial reasoning, geometric modeling, forming and exploring conjectures, and so on. The effective use of software includes using a constructivist approach (Li & Ma, 2010). Teachers should design well-thought lessons that guide students along a path of discovery. However, as in this study, most of the teachers have a limited background in knowledge and training in using DGS. They have difficulties adapting to a new teaching style. In addition, due to time constraints, students are not allowed to construct and manipulate geometric figures sufficiently. They are limited in their training and comfort with the software. It is recommended that both teachers and students should be fluent in the software in order to reach the potential for it.

The results of this study should not be seen as contradictory to the recommendations of MoNE and NCTM regarding technology implementations. DGS provides a unique way of investigating geometric notions that help some students. Besides, it produces a more positive affect on geometry and an increase in student mathematical discourse. Therefore, it should be the ongoing challenge of the reflective teacher to consider how best to integrate technology or software into his/her teaching.

Further research is required with a larger sample and for a longer time period. Since convenience sampling was used in this study, the results are limited to samples with similar characteristics. Further studies can be done using random sampling methodologies. Moreover, the use of DGS through different teaching strategies might be included in future studies and their effects can be investigated by adapting qualitative, quantitative, or mixed research designs. Lastly, teachers and students with different characteristics should be included in future studies in order to explore the effects of the use of software on students' understanding and achievement in mathematics across several subject areas and domains.

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Author Contribution Statement

Kazim KÜÇÜK: *Conceptualization, literature review, methodology, implementation, data collection, data analysis, reporting, writing, auditing, and editing processes.*

Özge GÜN: *Conceptualization, literature review, methodology, data analysis, reporting, writing, auditing, and editing processes.*

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