Effects of Dynamic Geometry Activities on Seventh Graders' Learning on Area of Quadrilaterals

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The purpose of the study was to investigate the effects of mathematics instruction supported by dynamic geometry activities on seventh grade students' achievements in the area of quadrilaterals, based on their van Hiele geometric thinking levels. The study followed a nonrandomized control group pretest and posttest research design. Participants of the study were 76 seventh grade students. Students in the experimental group worked in a learning environment supported by dynamic geometry software while other students worked in their conventional settings. The results of the study indicated that there is a significant interaction between the effects of method of teaching and van Hiele geometric thinking levels on students' achievement levels in area of quadrilaterals. In addition, mathematics instruction supported by dynamic geometry activities has significant effects on seventh grade students' achievement in the area of quadrilaterals. Moreover, the results revealed that students in the dynamic geometry supported instruction group received significantly higher scores in the area of quadrilaterals than students in the traditional instruction group when students are at second level of van Hiele geometric thinking.

Keywords: dynamic geometry activities, mathematics education, area of quadrilaterals, van Hiele geometric thinking

Introduction

In middle schools, students deal with geometric shapes and figures with their characteristics and relationships between each other (Umay, 2007). The general purposes of geometry education include using geometry within the process of problem solving and understanding and explaining the physical world around them (Suydam, 1985). Similarly, National Council of Teachers of Mathematics (NCTM) (2000) stated that learning geometry provides describing, analyzing and understanding the world for individuals. It develops individuals' logical thinking abilities, spatial intuition about the real world, knowledge for studying higher-level mathematical concepts, and understanding of mathematical arguments (Suydam, 1985). Since another aspect of geometry is measurement, in school mathematics, geometry and measurement complement each other.

Learning measurement has an important place in using mathematics in daily life as well as developing many concepts and skills of mathematics since the concepts and skills related to measurement include basic skills and knowledge which students may encounter frequently in daily life (Clements, 2001; Ojose, 2011; Tan Şişman & Aksu, 2012). The importance of learning measurement, stated by Tan Şişman and Aksu (2009), is that taking into account the important roles of measurement in mathematics and daily life, students should learn and understand means of measuring as well as how to measure. Computer technology can provide such rich environments with dynamic activities about realizing relationships between geometric shapes with multiple views and measurements within them.

Technology and Mathematics

In recent decades, the use of technology has increased and changed our life. Nowadays, we use computers, mobile phones, etc., in every part of our life (Wilken & Goggin, 2012).

Since education forms a basis for our life, educators have started to deal with how this technology can be integrated into education. In mathematics education, digital learning tools can help to concretize an abstract concept of mathematics by transferring it to screen visually (Tutak & Birgin, 2008). Thereby, students are provided with a new learning environment that provides opportunities to construct their knowledge by making discoveries and dynamic interactions (Tutkun, Güzel, Köroğlu & İlhan, 2012).

For the concepts related to geometry and measurement, Dynamic Geometry Software (DGS) are effective and flexible tools for mathematicians, like the telescope or microscope for scientists, to make new discoveries and test theorems (Oldknow, 2007). DGS can provide an invaluable learning environment for school geometry. Hence, students have opportunities to test, observe, record, manipulate and predict geometric objects, concepts, beliefs and theorems with DGS (Forsythe, 2007; Hill & Hannafin, 2001). According to Dye (2001), DGS provides an excellent medium for school geometry. The most important characteristics of DGS to traditional environment are that objects, drawn or constructed, can be moved and resized interactively. In other words, students can manipulate the geometric shapes and can observe changes with real-time measures with DGS. GeoGebra, developed by Markus Hohenwarter, is an example of DGS, and was used as a learning tool in the current study.

DGS can be helpful while teaching both two-dimensional and three-dimensional geometry (Hohenwarter, Hohenwarter & Lavicza, 2010). Several researchers dealt with the effects of computer-based learning with DGS. They found that the use of technology as classroom tools is beneficial for students' learning and developing their understanding in geometry because students can explore, conjecture, construct and define geometrical relationship while interacting with DGS (Jones, 2000). For instance, Baki, Kosa and Guven (2011) conducted research, which aimed to examine effects of using DGS and physical manipulative on learning of pre-service teachers. They found that the students in the DGS supported group performed better than students in the physical manipulative supported group did. Gecü (2011) investigated effects of using DGS on achievement and geometric thinking levels of fourth and eighth graders. She reported that DGS facilitated students' learning for both fourth and eighth graders and improved academic achievement of fourth graders. Moreover, Toker-Gül (2008) investigated effects of DGS supported teaching on sixth graders academic achievement and geometric thinking compared to two different instructional groups, which were paper-pencil based guided discovery group and a conventional teaching group. In her study, she reported that students in DGS based learning group benefited more in terms of academic achievement. Furthermore, for seventh grade level, Ubuz, Üstün and Erbaş (2009) performed a research aiming to compare the effects of instruction based on DGS and conventional lecture based teaching in terms of learning of line, angle and polygon concepts. This study has shown that DGS could improve achievement of students and enhance their ability of analyzing, exploring conjecturing and reasoning if DGS is used appropriately. Similarly, Yılmaz, Şahin, Çakıroğlu and Güven (2009) investigated effects of DGS on seventh graders' learning on topics related to area and perimeter. They concluded that DGS enhanced the academic success level of students. In general, previous studies have indicated that DGS or computer-based instruction improved students' achievement in mathematics, interests on topics and participation in mathematics (Aydoğan, 2007; Baki, Kosa & Güven, 2011; Doğan & İçel, 2011; Gecü, 2011; Güven & Karataş, 2009; Hohenwarter, Hohenwarter & Lavicza, 2010; Şataf, 2011; Toker-Gül, 2008). However, few studies (Kurak, 2009; Selçik & Bilgici, 2011; Ubuz, Üstün & Erbaş, 2009; Yılmaz et al., 2009) focused on the effects of DGS or computer based instruction on seventh grade students' achievement in mathematics. In literature, studies generally focused on investigating the effects of DGS on students' achievement and development of geometric thinking while compared with other instructional methods. There is still a need to understand how students' geometric thinking has effect on their learning and achievement in mathematics with the help of technology.

Rationale for the Study

Effective use of technology in learning is a priority of many school systems, including Turkey. National mathematics curricula in Turkey suggest the use of technology effectively in instruction (Ministry of National Education [MoNE], 2013). In addition, MoNE has begun setting up technology classes (Çelen, Çelik & Seferoğlu, 2011) and initiating large scale projects for enhancing the use of technology in schools (Tezci, 2011). For such initiatives to be effective in schools, useful and various activities based on computer technology for all content areas of mathematics are needed.

Previous studies indicated that middle school students have difficulties and misconceptions with area and perimeter concepts of geometry and measurement, especially in situations where they were required to explain and justify their answers. (Huang & Witz, 2013; Tan Şişman & Aksu, 2009; 2012; Zacharos, 2006). Tan Şişman and Aksu (2009) stated that seventh grade students have difficulties in using formulas for area effectively. Students often understand the concepts of area as a multiplication of the length of two sides (Kordaki & Potari, 2002; Tan Şişman & Aksu, 2012). In addition, students have misconceptions with area conservation and they have difficulties in understanding most of the relationships between quadrilaterals (Fujita & Jones, 2007; Tan Şişman & Aksu, 2012). Moreover, Trends in International Mathematics and Science Study (TIMSS), and Programme for International Student Assessment (PISA) results indicated that the geometry and measurement achievement of Turkish middle school students are lower than the international average (Ubuz, Üstün & Erbaş, 2009).

Pierre van Hiele and Diana van Hiele-Geldof noticed the difficulties of students in understanding geometry content. In order to explain reasons for these difficulties and find solutions, they started to explore the prerequisite knowledge needed for understanding specific geometry content (Malloy, 2002; Mason, 1998). For this reason, they developed a theory involving students' understanding levels of geometry regarding needed knowledge to understand geometric topics (Mason, 1998; Usiskin, 1982). This geometric thinking theory includes five hierarchical levels, which are visualization, analysis, informal deduction, formal deduction and rigor (Crowley, 1987). Firstly, visualization level, which is also known as Level 0, is the initial stage for understanding geometric topics regarding original van Hiele theory (Crowley, 1987). In this level, although students are able to name and recognize geometric shapes by their appearances, they could not identify properties of the shapes (Mason, 1998; Usiskin, 1982). Secondly, in analysis level, which is also named as Level 1, students could identify properties of shapes and use appropriate vocabulary to define these properties, yet they could not make connections between common properties across different shapes (Malloy, 2002). Thirdly, in Level 2, which is informal deduction level, students are able to identify and recognize common properties among different shapes, so they realize value of hierarchical classification of geometric shapes (Crowley, 1987). These three levels were defined as needed to be mastered in elementary school in order to understand mathematical content in high school (NCTM, 2000). The fourth level is formal deduction, which is also referred as Level 3 in original theory. In this level, students could begin to construct proofs, using postulates or axioms and construct formal definition for geometric contents (Crowley, 1987). This level is considered related with the content of high school mathematics. Lastly, the Level 4, Rigor, is the highest level of geometric thinking hierarchy of van Hiele (Mason, 1998). Students mastery at this level could start to work in different axiomatic and geometric systems, and so they can study with non-Euclidean geometries (Crowley, 1987; Mason, 1998). Considering geometric thinking levels of students while designing learning tasks is important to deal with difficulties in geometry and develop students' geometric understanding. Researchers stated the reasons of these difficulties, misconceptions and low level achievements include memorization of concepts, obtaining relevant information from a single source, and not considering geometric thinking levels of students while preparing learning environments (Fidan & Türnüklü, 2010). In order to deal with students' difficulties and misconceptions, researchers suggest preparing experience-based activities, which provide opportunities for students to construct concepts by themselves, realize hierarchical relationships of quadrilaterals, and perform deductive reasoning (Fidan & Türnüklü, 2010; Fujita & Jones, 2007; Tan Şişman & Aksu, 2012).

In this study, activities based on DGS were developed and used in educational settings. It has been argued that students can learn geometric topics effectively if learning activities are prepared by considering their geometric thinking levels (Choi-Koh, 1999; Fidan & Türnüklü, 2010). In this sense, it was also aimed to investigate students' achievement in regarding with their van Hiele geometric thinking level.

In sum, the aim of the study was to investigate the effects of an instructional module supported by dynamic geometry activities on seventh grade students' achievements in the area of quadrilaterals, based on their van Hiele geometric thinking levels.

Methodology

In the current study, computer-based learning environments were prepared to deal with students' difficulties. The study was examined through nonrandomized control group pretest-posttest design since students were not randomly assigned to groups, and this study used already intact groups of students.

Participants

This study was conducted with seventh grade students in a public elementary school in Kırşehir, Turkey. Because of school regulations, it was not possible to assign students randomly to two groups, so this study was conducted with already intact groups. These groups reflected students' mathematics classes. Therefore, two classes of students formed groups in this study.

The participants were 75 seventh graders in a public middle school in Kırşehir. Prior to this study, the participants had some previous knowledge about area of triangles and perimeter of quadrilaterals, but had not yet been taught about area of quadrilaterals. This public middle school was selected conveniently since this school fit the technological requirements of this study and mathematics teacher was willing to integrate the GeoGebra into his curriculum. In total, two classes out of five seventh grade classes were selected from this school since one of the teachers was volunteer for this study. One of these classes formed the comparison group and other formed the experimental group. In the comparison group, there were 36 students and in the experimental group, there were 39 students.

Instruments

There were three instruments in the study to gather data. These are Readiness Test for Area and Perimeter Concepts (RTAP), Area of Quadrilaterals Achievement Test (AQAT) and van Hiele Geometric Thinking Level Test (VHLT). The RTAP and AQAT were developed by the researchers for this study. Therefore, there was a pilot study for RTAP and AQAT to check their reliability, appropriateness, clarity and discrimination power of items. In addition, eleven experts in the field checked the questions in these tests for appropriateness of questions before the pilot study. Participants of the pilot study were 139 students from four different cities of Turkey. These students were selected by using convenience sampling. After the pilot study, four questions of AQAT were excluded from test since these items were not satisfactory. The Cronbach's Alpha reliability coefficient was found as .81 for RTAP and .85 for AQAT

The RTAP was administered to all groups for the pre-test to assess students' level of mathematics achievement in measurement content area before the treatment. There were 18 multiple choice questions in this test. The RTAP was developed based on the objectives of area and perimeter concepts of sixth grade mathematics. The reliability of the test was found as .76 for the actual study. The scores of this test were analyzed to determine whether there exists a significant difference between experimental group and comparison group before treatment.

The AQAT was administered to all groups for the post-test to assess students' level of mathematics achievement in area of quadrilaterals after the treatment. There were 29 multiple choice questions. The AQAT was developed by the researcher based on the objectives of area of quadrilaterals topic in seventh grade mathematics. The reliability of the test was found as .79 for the actual study.

The last instrument was VHLT. The VHLT was administered as a pre-test to all groups to assess students' geometric thinking levels before the treatment. The VHLT was developed by Usiskin (1982). This test was translated and validated in Turkish by Duatepe (2004). There were 25 multiple choice questions in five sequential levels in the original test. First 15 questions were selected for the study, since, according to NCTM (2000), students should achieve the first three levels in primary and middle schools. The reliability of this test was found as .72 for the actual study.

Procedure and Instructional Materials

This study was conducted over eight one-hour lessons with one experimental and one comparison group. Students' regular mathematics lessons were used for the study. The teacher was given training for the treatment, and both groups were taught by this teacher. The researcher was an observer during the study. He focused on technical difficulties and students' engagement during the intervention in the experimental group. In addition, he also observed the nature of instruction in the comparison group. In the experimental group, students learned area of quadrilaterals with GeoGebra based activities in a computer laboratory because of this software supports Turkish language so on easy to use for students in this study. In the comparison group, students learned the same topic according to their regular classroom instruction. Eight dynamic geometry activities for experimental group were developed by the lead researcher by considering the objectives in the curriculum and the activities in Mathematics Textbook of students (Toker, 2012). The main instructional ideas of these activities were estimating area of quadrilaterals, forming an area formula for parallelogram, rhombus and trapezoid, and identifying relationship between perimeter and area. The developed DGS based activities were reviewed by five experts in the field for their appropriateness to topic and curriculum objectives. In addition, in order to familiarize students to GeoGebra, a preparatory course was given to students in experimental group and teacher. This preparatory course included some examples related with usage of dynamic activities for the study.

The lessons in the comparison group were held in students' regular classroom. The lead researcher only observed lessons in order to understand the nature of the instruction in regular and untouched learning environment. The topics was taught to students in comparison group by following official 7th grade textbook of MoNE published by Semih Ofset (Toker, 2012). Conventional type of instruction, which was direct instruction, was dominant in this group. Therefore, students were generally passive receivers. Although this textbook included many activities based on student centered approach, these activities were disregarded by the teacher and given as homework to students. Few activities about the area of parallelogram, rhombus and trapezoid were shown to students with drawings on the board by the teacher. The teacher gave definitions of concepts, drew figures and wrote questions on the board and let students try to solve these questions. In summary, instructional approach in the comparison group generally relied on direct instruction and demonstrations of some critical concepts to students on board.

Treatment in experimental group was mathematics instruction supported by DGS. The lessons in experimental group were held in a computer laboratory. There were 18 computers in computer laboratory. Therefore, students worked as 15 two-student and 3 three-student groups. In the experimental group, students manipulated given objects based on the directions in the worksheets and then they recorded data from their observations, and answered questions. There were eight dynamic geometry activities in the experimental group.

The first activity was about forming an area formula for parallelogram (Figure 1). In this activity, students were expected to observe and understand the relationships between bases, altitude, and area of a parallelogram, as well as to develop a formula for the area of it by analyzing the data they have gathered. There were three movable points (A, B and C) in the activity (Figure 1). Students were asked to move points freely into five different positions and fill tables on activity sheets with measures of lengths of sides, altitudes, perimeter and area.

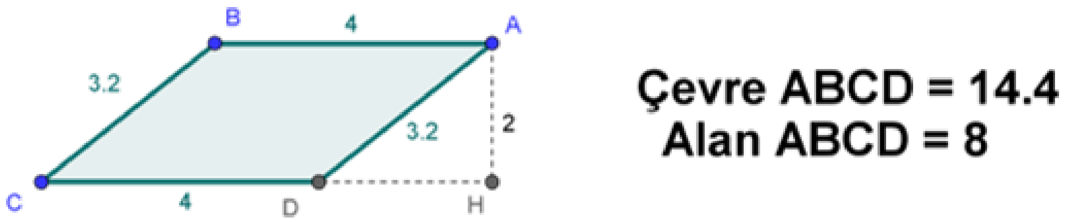

Figure 1. 1st activity; forming an area formula for parallelogram *[Çevre: Perimeter; Alan: Area]*

The second activity was about forming an area formula for a rhombus (Figure 2). In this activity, there was a rhombus inscribed in a rectangle and a button, which separated triangular parts outside the rhombus within the rectangle. After separation, another button appeared, which rotated these triangular parts by 180°. After rotation, another button appeared, which combined these rectangular parts to form a rhombus over the first rhombus. In this activity, students were expected to form an area formula for a rhombus by using the relationships between the area of a rectangle and the area of a rhombus, or the area of a triangle and the area of a rhombus.

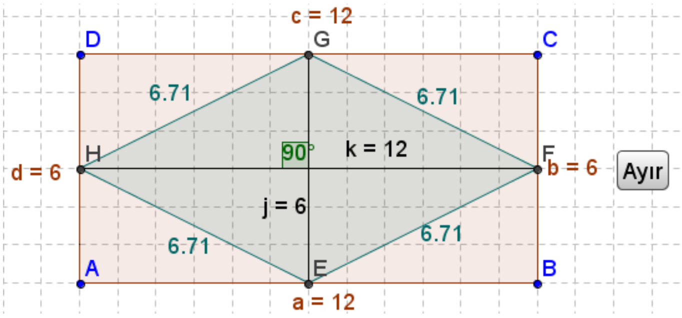

Figure 2. 2nd activity; forming an area formula for rhombus *[Ayır: Separate]*

The third activity addressed area formula for a trapezoid (Figure 3). There were four movable points in this activity. Students were asked to move points freely and fill tables on activity sheets with measures of lengths of sides, altitudes, perimeter and area.

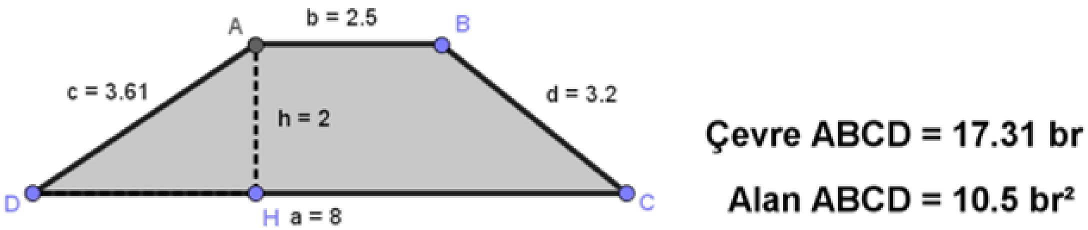

Figure 3. 3rd activity; forming an area formula for trapezoid *[Çevre: Perimeter; Alan: Area]*

The fourth, fifth, and sixth activities were about deriving formulas for area of a parallelogram, rhombus and trapezoid. In the fourth activity (Figure 4), there was a parallelogram and its altitude. The base point of the altitude was movable. In addition, there was a button for cutting the parallelogram into two pieces through the altitude. After cutting the parallelogram there would be two figures. The figure on the left was movable and students moved this figure by following directions on the activity sheet. After moving the left side to form a rectangle, a button appeared, which combined these figures to form a rectangle. After combining, students could start over and move the altitude to a different position and repeat the actions for the new position of altitude. In the fifth activity (Figure 5), there was a rhombus and a button, which copied the rhombus. After copying, a button appeared that would rotate the rhombus by forming a similar view of a parallelogram. Students answered questions on the activity sheet. In the sixth and last activity of this objective (Figure 6), there was a trapezoid and a button, which copied the trapezoid. After copying, a button appeared which rotated the trapezoid by 180°. This rotated trapezoid on the screen was movable. Students were asked to move this figure according to the directions on the activity sheet. Students were expected to answer questions on the activity sheet.

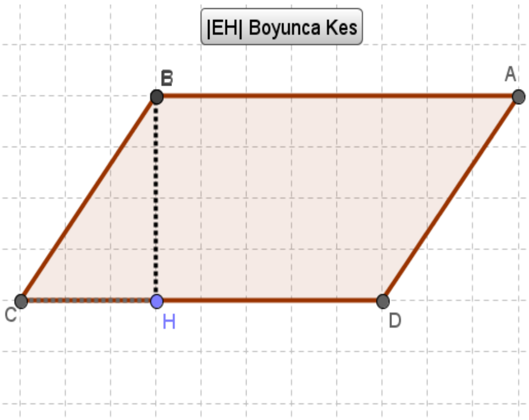

Figure 4. 4th activity using strategies to estimate area of quadrilaterals *[Boyunca Kes: Cut Through]*

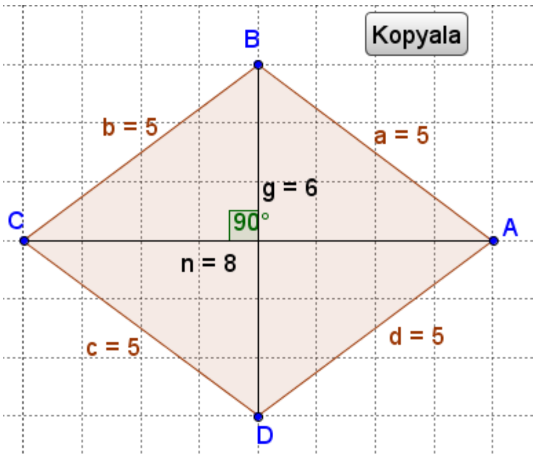

Figure 5. 5th activity using strategies to estimate area of quadrilaterals *[Kopyala: Copy]*

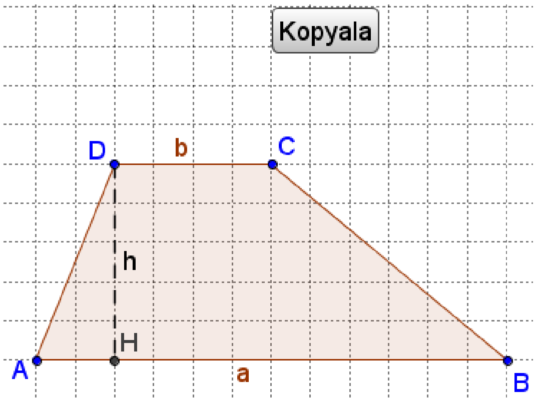

Figure 6. 6th activity using strategies to estimate area of quadrilaterals *[Kopyala: Copy]*

The seventh activity was about the objective of identifying the relationship between perimeter and area, and the last activity was about identifying the relationship between the side's length and area. In these activities, there was a rectangle, and its upper right vertex was be movable. Students were asked to move points freely and take notes about measures of lengths of sides, perimeter and area.

After completion of each dynamic geometry activity, the teacher gave feedbacks on students' errors and started discussion sessions for outcomes of the activity and students' works. After the study, administration of the AQAT took place for both groups of students.

Results

This study was conducted with two groups of students as experimental and comparison groups. As described above, the Readiness Test for Area and Perimeter Concepts (RTAP) was administered to all students as a pretest in order to reveal whether any difference of achievement in area concepts of geometry existed before the study. In addition to this test, the Area of Quadrilaterals Achievement Test (AQAT) was administered to all students as a posttest in order to find out any effect of intervention on achievement of students in area concepts of geometry. Additionally, the van Hiele Geometric Thinking Level Test (VHLT) was also administrated to determine students' geometric thinking levels in terms of van Hiele hierarchy. Descriptive statistics related to the RTAP are presented in Table 1, and related to AQAT in terms of VHLT are presented in table 2.

Table 1
Descriptive statistics for RTAP

Variables	N	Mean	SD	%95 CI	Skewness	Kurtosis
Comparison Grp	36	13.33	3.17	(12.26 – 14.40)	-0.233	-1.113
Experimental Grp	39	14.41	2.86	(13.48 – 15.34)	-0.493	-0.826

Table 2
Descriptive statistics for AQAT in terms of van Hiele hierarchy

Variables	Van Hiele Levels	N	Mean	SD	%95 CI	Skewness	Kurtosis
AQAT	Level 0	8	19.88	2.75	(17.58 – 22.18)	-0.157	-1.779
Com Grp	Level 1	14	20.57	2.50	(19.12 – 22.02)	0.640	0.256
	Level 2	14	25.64	1.95	(24.52 – 26.76)	0.078	-0.475
	All	36	22.39	3.50	(21.21 – 23.57)	0.007	-0.910
AQAT	Level 0	7	19.43	2.88	(16.77 – 22.09)	0.690	-1.355
Exp Grp	Level 1	14	25.36	3.05	(23.60 – 27.12)	-1.095	1.241
	Level 2	18	26.56	1.72	(25.70 – 27.42)	-0.688	1.709
	All	39	24.85	3.57	(23.69 – 26.01)	-1.049	0.214

Before the study, RTAP, which was designed as readiness test, was conducted to determine previous mathematics success level of students as possible confounding variable to the study. The scores of RTAP were analyzed whether there exits any difference between groups in terms of prior achievement levels of students before the study. Therefore, an independent sample t-test analysis was conducted to understand whether comparison and experimental groups differed significantly in terms of their RTAP scores. According to preliminary analysis, students in comparison group (M=13.33, SD=3.17) and experimental group (M=14.41, SD= 2.86) were not statistically different before the treatment ($t(73) = -1.55$, $p = .13$). Therefore, it was concluded that there was no need to adjust scores in groups and to consider RTAP scores as covariate. Hence, a two-way (2 x 3 factorial) analysis of variance was conducted to assess effectiveness of using dynamic geometry software in mathematics instruction, specifically the topics of area of quadrilaterals. Groups of intervention and van Hiele geometric thinking levels of students were used as the independent variables and AQAT scores of students were considered as the dependent variable.

Before conducting two-way ANOVA, assumptions of the ANOVA test were tested. In order to assess normality, skewness and kurtosis values of AQAT were examined and these values are represented in Table 2. According to Cameron (2004), if data are normally distributed, skewness and kurtosis values should fall in the range from -2 to +2. Since skewness and kurtosis values were in acceptable range, the normality assumption was satisfied. Moreover, homogeneity of variances was controlled by Levene's Test of Equality Error Variances ($F(5,69)=1.635$, $p=0.162$). According to this Levene's test, homogeneity of variance assumption had not been violated. Hence, the two-way ANOVA was employed to answer the research questions for AQAT scores in terms of groups and van Hiele levels (Table 3).

Table 3

The results of two-way analysis of variance for scores of AQAT

	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group	51.299	1	51.299	8.742	.004	.112
VHLT	440.801	2	220.400	37.560	.000	.521
Group * VHLT	85.801	2	42.900	7.311	.001	.175
Error	404.891	69	5.868			
Total	43033.000	75				

The results of two-way ANOVA indicated a significant main effect for comparison (M=22.39, SD=3.50) and experimental groups (M=24.85, SD=3.57) on score of AQAT ($F(1, 69) = 8.74$, $p = .004$, partial eta squared = .11). Moreover, the results also showed a significant main effect for levels of VHLT on the scores of AQAT, $F(2, 69) = 220.40$, $p < .05$, partial eta squared = .52. These results revealed significant mean differences for scores of AQAT in terms of both groups and VHLT levels. Additionally, these results revealed that there was a significant interaction effect between categories of VHLT and the groups of students on the scores of AQAT ($F(2, 69) = 7.31$, $p = .001$) with partial eta squared value 0.18. This interaction indicates that the difference between scores of students in groups depends on students' van Hiele Levels (Figure 7). Therefore, in order to find out which VHLT level causes this difference, a follow-up analysis was conducted.

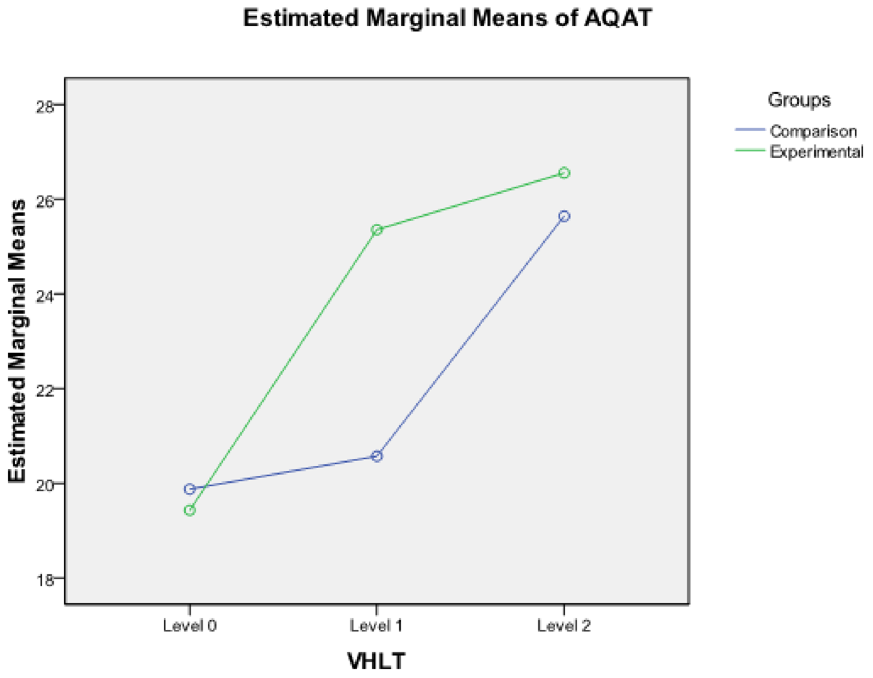

Figure 7. Interaction of groups and scores of VHLT in terms of scores of AQAT.

In Figure 7, this interaction was graphed and this figure clearly shows that mean scores of students in AQAT change dependently to their van Hiele Geometric Thinking Levels (Table 4).

Table 4
Simple main effects analysis

		Sum of Squares	df	Mean Square	F	Sig.
Level 0	Contrast	0.744	1	0.744	0.127	.723
	Error	404.891	69	5.868		
Level 1	Contrast	160.321	1	160.321	27.321	.000
	Error	404.891	69	5.868		
Level 2	Contrast	6.560	1	6.560	1.118	.294
	Error	404.891	69	5.868		

According to the results of this simple main effect analysis, there was no statistically significant mean difference between the comparison group's scores (M=19.88, SD=2.75) and the experimental group's scores (M=19.43, SD=2.88) in AQAT if students are at van Hiele Geometric Thinking Level 0 ($p = .72$). Similarly, there was no statistically significant mean difference between comparison group's scores (M=25.64, SD=1.95) and experimental group's scores (M=26.56, SD=1.72) in AQAT if students are at van Hiele Geometric Thinking Level 2 ($p = .29$). However, as seen in Table 4, there was a significant mean difference between comparison (M=20.57, SD=2.50) and experimental groups' scores (M=25.36, SD=3.05) in AQAT if students are at Level 1 ($p < .05$). In summary, these results showed that students at van Hiele Level 1 in the experimental group benefited from this intervention more than students at van Hiele Level 0 and Level 2.

Discussion and Conclusion

In this study, students' learning of area of quadrilaterals topic and effects of DGS on their achievement regarding their geometric thinking levels were covered. This study included two distinct groups of students as comparison and experimental groups in which instructional methods were different as direct instruction with some demonstrations for comparison group and student-centered instruction aided by DGS for experimental group. Moreover, students were also grouped in terms of their geometric thinking to understand the main effect of geometric thinking level on learning this topic, as well as interaction effect of geometric thinking levels of students and instruction received.

One of the findings of the study indicated significant main effect of treatment with dynamic geometry activities on students' achievement scores on the AQAT. This finding implied that the usage of DGS in mathematics instruction had a positive effect on students' scores in favor of experimental group. Since the dynamic geometry activities were designed to be maximized using dynamic features of the GeoGebra, this construct could help students to make manipulations on geometric figures on the GeoGebra easily. According to Jones (2000), students can explore, conjecture and realize properties of geometric shapes while making dynamic interactions with DGS. In this study, they were provided a learning environment to support learning the topic by making manipulations, seeing different views of quadrilaterals and realizing the relationships between quadrilaterals. Moreover, they have opportunities to explore the relationships and connections among quadrilaterals by themselves. In addition to this, students have a chance to see different views of an object in DGS easily in comparison to paper and pencil construction. This result was consistent with the results of study of Yılmaz and others (2009). They conducted a study with 7th graders to investigate the effects of DGS on students' achievement in perimeter and area concepts, and they found that DGS can increase students' achievement in perimeter and area concepts.

The other finding revealed that there was a significant interaction between the effects of treatment and the van Hiele Geometric Thinking levels on scores on the achievement test. Clearly, this result indicates that if there is a significant difference between experimental group and comparison group, this different depends on students' van Hiele Geometric Thinking levels. In other words, students in dynamic geometry supported instruction were more successful in the area of quadrilaterals topic than other students, who were at van Hiele Geometric Thinking Level 1, which is analysis level. The possible reason for the improvements in achievements of students at van Hiele Geometric Thinking Level 1 can be that the dynamic geometry activities may help them progress from shape properties to geometrical properties by using hierarchical relationships of quadrilaterals. This result was in line with study of Fujita and Jones (2007), who found that activities that included hierarchical relationships of quadrilaterals can help students move from shape properties to geometrical properties. This was because hierarchal relationships among shapes could help students to realize and understand relationships between shapes and inner shapes (Fujita & Jones, 2007). Thus, the dynamic geometry activities provide students some opportunities for interrelating and comprehending properties of shapes within dynamic works. On the other hand, students' achievement scores at other van Hiele levels were not significantly different. Students at Level 2 already achieved logical deduction level and they could see the interrelationships among shapes, and so according to Usiskin (1982), they could already comprehend the hierarchical relationships among shapes. Therefore, these students could accomplish learning goals even with traditional tasks without hierarchical relationships (Usiskin, 1982). For students in Level 0, these students were at visualization level, so they can name shapes by their appearances, these students were not ready to understand interrelationships of quadrilaterals according to van Hiele Theory. This result was consisted with the results of studies of Fujita and Jones (2007), and Tutak and Birgin (2008).

DGS is a useful tool to transform abstract concepts to concrete representations. In addition, different views of a shape or relationships among shapes can be explored by manipulating shapes in DGS. DGS also provides real time measures for perimeter, area or angles for manipulated shapes. Therefore, students can easily explore and analyze how the shapes change or what measures change when manipulating, and they can understand the relationships among shapes, which is the basic requirement for van Hiele Geometric Thinking Level 2, informal deduction. As final words for teachers, they can use GeoGebra based activities to develop students' achievement and understanding geometry while teaching area of quadrilaterals. Hence, their students have opportunities to improve both achievements in related topics and geometric thinking especially when they are at van Hiele Geometric Thinking Level 1, analysis level with dynamic activities based on GeoGebra or other dynamic geometry software in instructional phase while learning area of quadrilaterals topic

This study focused on area of quadrilaterals topic of seventh grade mathematics. Therefore, this study only included the usage of dynamic geometry software in the topic of area of quadrilaterals and achievements of the seventh grade students. In order to analyze the effects of GeoGebra in other topics and other grade levels, further research should be conducted. In addition, this study examined the effect of GeoGebra to students' achievement according to their van Hiele Geometric Thinking levels. In this study, GeoGebra activities had effects only students at van Hiele Geometric Thinking Level 1. In order to examine the effects of GeoGebra to other van Hiele Geometric Thinking levels, different activities should be developed and further research should be conducted. This study lasted for eight one-hour lessons. Therefore, the long-term effects of using GeoGebra on students' achievements in mathematics and their achievements regarding van Hiele hierarchy should be investigated in further research. Moreover, since this study did not include random sampling methods, its results were limited to similar conditions and this study was conducted on a relatively small number of participants. Therefore, new studies should be conducted with larger and randomly selected participants in order to test its results for these conditions.

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Note:

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