



The role of dynamic geometry software in the process of learning: GeoGebra example about triangles

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Abstract

This paper aims to observe effects of dynamic mathematics software (GeoGebra) on eight grade students' achievements for the subjects of triangles. Two eighth grade classes from a primary school were selected as experiment and control groups. A two weeks course was planned in accordance with the official course curriculum for the experiment group. The planned and GeoGebra constructed activities which demand effective use of GeoGebra for this grade shared with the students during the learning and teaching process. Simultaneously, the control group continued their formal teaching and learning procedure. A pre test, a post test and a recall test were used to assess the possible effect of the dynamic mathematics software for the groups both before and after the classroom activities. Possible comparisons between the tests and the groups were performed. The results show that dynamic software (GeoGebra) has positive effects on students' learning and achievements. It has also been observed that it improves students' motivation with positive impact.

Keywords: Dynamic Geometry, GeoGebra, Students' Success, Triangles

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Introduction

Training activities become increasingly more complex day by day parallel with the developments in science and the change in the nature of the knowledge. Meanwhile, technological developments influence ways of transferring information to learning environments in many ways. Most commonly used technologies in the learning environments are computer software packages in today's classrooms. It is a general agreement that the traditional methods force students to learn mathematics by memorization ending up with a falling success and imposing a feeling of being unsuccessful in mathematics. However, the nature of mathematics requires high-level of mental processes such as critical thinking, reasoning, imagination and considering many different features with related facts. To achieve this, it is not enough to use only pencil-drawn shapes on paper or board. In particular, along with the constructivist approach, mathematics courses need to be addressed with different emphases which make them enjoyable, understandable and constructible in terms of students. At the primary age, children mainly use computer for entertainment especially spending more time for gaming. It is accepted that computer and software use in primary education is promising and may improve mathematics education remarkably, if it is directed to teaching and learning process. In this respect, computer based mathematics courses are offered as an alternative to traditional teaching. Geometric constructions acquire dynamic properties with the computer (dragging, transforming, rotating, symmetry, opening and closing of a prism, or a pyramid etc.) so that students can make observations as well as improve their imaginations.

Using computer in geometry teaching is implemented with the new elementary mathematics curriculum in Turkey and has become indispensable (MEB, 2007). The most important role of computer in primary mathematics education is stated by the ministry as "making the learning of abstract concepts easier". Some previous researches in the area reported that computer use is more effective than the traditional approach to learning, especially, in transformation geometry, polygons, prisms and pyramids. Therefore, this research aimed to observe possible effects of GeoGebra based activities on 8th grade students' achievements for triangles including Pythagoras relation.

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Literature Review

Computer algebra systems (e.g. Derive, Maple) and dynamic geometry software (e.g. Cabri Geometry, Geometer's Sketchpad) started to attract more attention along with new developments in technology all around the world. Consequently, new software packages are developed and tried to be integrated into teaching and learning environments. Many recent literatures show that new developments and considerations are highly appreciated all over the world. Mathematics education authors both in teaching and learning mathematics connect the issue with pedagogical considerations (Galbraith and Haines, 1998; Murphy and Greenwood, 1998; Garofalo et. al. 2000; Kadijevich and Haapasalo, 2001; McAlister et. al., 2005). These considerations usually focus on cognitive dimensions of mathematics education and effective computer (and educational software) use in action (Monaghan, 1993, 2004) and highlight their effects on students' learning, achievements and affective dimensions. For example, an acceptable level of computer use has positive effect on students' views, performance and confidence about the context.

The Technology Principle of the NCTM (Principles and Standards for School Mathematics, 2000) identified the "Technology Principle" as one of the six principles of high quality mathematics education and has guidelines and supports about the use of technology. In the *Principles and Standards of School Mathematics*, it is stated that "*Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning (p. 24)*" and "*Teachers should use technology to enhance their students learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well-graphing, visualizing, and computing (p. 25)*". Furthermore, NCTM suggests that appropriate use of technology can facilitate such applications by providing ready access to real data and information, by making the inclusion of mathematics topics useful for applications more practical (e.g., regression and recursion), and by making it easier for teachers and students to bring together multiple representations of mathematics topics.

Parallel with the recent developments in all over the world, primary and secondary mathematics curriculums have been reconstructed in Turkey. It is especially pointed out that Computer Based Mathematics Teaching (CBM) provides meaningful learning experiences of mathematics for students (MEB, 2009). Therefore, it has to be integrated into mathematics courses (Çakıroğlu et al, 2008).

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Geometry is defined as "it examines figures and their movements" in the elementary mathematics curriculum. It is stressed in the curriculum that while the geometrical thinking is developing also knowledge acquired in geometry activities have to provide visual and analytical reasoning and inference with a hierarchical order within the required attention respectively. The results of student's reasoning with intuition are called conjecture. Producing information via inference called conclusion, although very few students may produce information via inference. It is also highlighted that while the students achieve targets about related areas of geometry, special attention and importance should be given for processing of specific skills, affective features, psychomotor skills and self-regulation. It is especially stated in the Ministry's own textbooks that the dynamic geometry software have to be used and experiences should be shared with the students (MEB, 2007).

Sulak (2002) studied effects of computer based instruction on student' achievement and attitudes in mathematics courses. In the study, the computer based teaching was found to be better when compared to the traditional methods in terms of both achievement and attitudes. Similarly, Aktümen and Kaçar (2008) have investigated possible effects of computer algebra system (Mapple) on students' attitudes toward mathematics. They reported that the students who use Mapple in learning environments have more positive attitudes towards mathematics. Güven and Karatas (2003) aimed to determine students' views about computer-based learning environment created by dynamic geometry software Cabri. At the end of the study, the students' views have changed positively for mathematics in general and geometry in particular. The students also find dynamic geometry environment very useful. Furthermore, it is reported that the students gain more confidence by exploratory mathematical activities.

Karakus (2008) intended to determine possible effects of computer-based teaching on student achievement for transformation geometry subjects. In the experimental study, there was significant difference in favour of experiment group. All students of the experiment group have achieved high attainment levels with computer-based instruction in teaching of transformation geometry. Moreover, this difference becomes more significant and gets higher for successful students in the subjects of reflection and rotation. However, there is not any significant difference between experiment and control groups for low successful students; it has been observed that computer-based instruction increased the experimental group success. Similarly, Faydacı (2008) investigated how the new subject of transformation

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geometry in elementary mathematics curriculum effects students' conceptions and how the students construct the knowledge about it. A specially designed teaching program was developed (with the help of Wingeom-tr software) for technology-supported teaching of the subject. Students' handling of transformation geometry subjects, their conceptualization of the concepts and ways of making knowledge meaningful for themselves have been analyzed through the study. During these analyses, they have focused on the source of students' perceptions. Main focus was whether the perceptions are based on seeing the drawings on computer screen, or on the underlying mathematics of the movements. Results of the study showed that the prepared program taking into account of the principles of constructivist approach (for example, assimilation etc.) contributed to the students' learning by doing thought-provoked mathematical abstraction. In addition, it has been identified that the use of technology in learning process has an active role in transition from drawing to the figure of an object.

Üstün and Ubuz (2005) performed an experimental study to compare traditional educational environments with the dynamic learning environments (Geometer's Sketchpad used). According to the results of the study, there was a significant difference in favour of the experiment group on the recall (permanence) test. The most important reason for this significant difference is identified as students' explorations of geometrical shapes to see possible connections by manipulating the computer based environment. Bedir and colleagues (2005) approved that using Geometer's Sketcpad software on teaching of "Angles and Triangles" topic is more effective than the traditional education in the students' achievements.

As dynamic mathematics software, use of GeoGebra is getting more common all over the world. In addition to construct geometry dynamically, it also provides, as a key element of learning geometry, visualization, estimation, conjecture, construction, discovery, proof and etc. GeoGebra is found to be very efficient in mathematics education and can be used effectively both in teacher training (Doğan and Karakırık, 2009) and students' learning (Doğan and İçel, 2010).

GeoGebra is an interactive geometry system. You can do constructions with points, vectors, segments, lines, and conic sections as well as functions while changing them dynamically afterwards. GeoGebra's user interface consists of a graphics window and an algebra window. The two views are characteristic of GeoGebra: an expression in the

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algebra window corresponds to an object in the geometry window and vice versa. On the one hand you can operate the provided geometry tools with the mouse in order to create geometric constructions on the drawing pad of the graphics window. On the other hand, you can directly enter algebraic input, commands, and functions into the input field by using the keyboard. While the graphical representation of all objects is displayed in the graphics window, their algebraic numeric representation is shown in the algebra window. The user interface of GeoGebra is flexible and can be adapted to the needs of the students. GeoGebra can be used with the algebra window, input field, coordinate axes with grid and the drawing pad and many geometry tools.

However, specific benefits of integrating software into mathematics teaching and learning are appreciated all over the world; it is obvious that this consideration has to be discussed along with certain teaching examples. Furthermore, classroom situations may also give opportunities to see possible effects on teaching and learning of mathematics. Thus, it can be said that computer can really lead to an improvement of teaching and learning mathematics by establishing possible benefits of software.

Methods

Sample: This experimental study is conducted in the fall semester of 2009-2010 academic year. Two eighth grade classes from a primary school have been selected as experiment (9 female 11 male) and control (7 female, 13 male) groups.

Aim: The study aims to observe possible effects of computer-based learning environment (GeoGebra software) on students' achievements. The study also gives great opportunity to see possible outcomes of real classroom applications.

The survey

Achievement tests:

Before the classroom activities, a pre-test was applied to the both groups to determine the students' attainment levels. The questions cover seventh grade objectives for the subject (see Appendix 1). The pre-test has total of 13 questions. All questions were analytically evaluated according to their included objectives. The pre-test results show that there is not any statistically significant difference between the groups (Table 2). Therefore, one of the groups selected as experiment and the other as control group.

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A post-test was applied simultaneously to the both groups after two weeks of teaching. The post-test contains questions about all the stated objectives for the eighth grade with total of 11 questions (see Appendix 2). Again, all of the questions were analytically evaluated according to their included objectives. The post-test has been used to see possible effects of GeoGebra on students' success. Furthermore, same post test was applied to the both groups one month after the application as recall test.

Teaching and Learning Activities:

A two weeks course (total of 12 hours) which contains twelve main GeoGebra activities and many other practices about the stated objectives were planned in accordance with the official mathematics curriculum. Then the activities were constructed with GeoGebra for the experiment group. The GeoGebra prepared activities aim to make the subject more dynamic, concrete and visual. GeoGebra software was introduced in introductory hour of the course. In all of the other sessions, the GeoGebra prepared activities were shared with the students both with visual and dynamic features. Furthermore, examples, exercises and drawings on the textbooks were constructed with the GeoGebra during the sessions.

In the official curriculum (MEB, 2007) teaching of triangle for eighth grade takes total of fifteen hours with eight different objectives. These objectives are mainly concentrated on the construction of triangles with specific properties such as; drawing a triangle with a given measures of sufficient elements, constructing mediator, perpendicular bisector, angle bisector and altitude of a triangle etc. Some of the others aim to establish special features of triangles such as; determining the relationship between sum or difference of two sides' lengths of a triangle and length of the third side, determining the relationship between sides' lengths of a triangle and corresponding angles' degrees between the sides, explaining the equality and similarity terms associated with triangles etc. These objectives are stated as follows in the mathematics curriculum.

1. Determines the relationship between sum or difference of two sides' lengths of a triangle and the length of the third side (1 activity).
2. Determines the relationship between sides' lengths of a triangle and corresponding angles' measures between the sides (3 activities).
3. Draws a triangle with given measures of sufficient elements (3 activities)

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4. Able to construct mediator (1 activity), perpendicular bisector (1 activity), angle bisector (2 activities) and altitude of a triangle.

5. Able to construct Pythagoras relation (1 activity).

6. Explains the equality terms associated with triangles.

7. Explains the similarity terms associated with triangles.

8. Determines trigonometric ratios of acute angles for right triangles.

Thus, a total of twelve GeoGebra based activities were mainly used in the teaching and learning process. Simultaneously, the control group continued their formal teaching and learning procedure as guided by the Ministry of Education.

GeoGebra Activities:

A GeoGebra constructed classroom activity is presented here as an example.

Activity: Construction of an Angle Bisector of a Triangle

Step 1: Preparations

- Summarize the properties of an angle bisector of a triangle before you start the construction. Hint: If you don't know the construction steps necessary for an angle bisector of a triangle you might want to have a look at the teacher guide book of mathematics. Use the buttons of the navigation bar in order to replay the construction process.

- Open new GeoGebra file.

- Hide (if you want) algebra window, input field and coordinate axes (*View* menu).

Step 2: Construction process

1. Create three new points A, B and C which can create a triangle.

2. Construct an arbitrary triangle ABC

3. Construct a Circle d with center B and radius 2

4. Create a Point D which is an intersection point of d and c

5. Construct a Circle e with center D and radius 2

6. Create a Point E which is an intersection point of d and a

7. Construct a Circle f with center E and radius 2

8. Create a Line g which is the angle bisector of C, B and A.

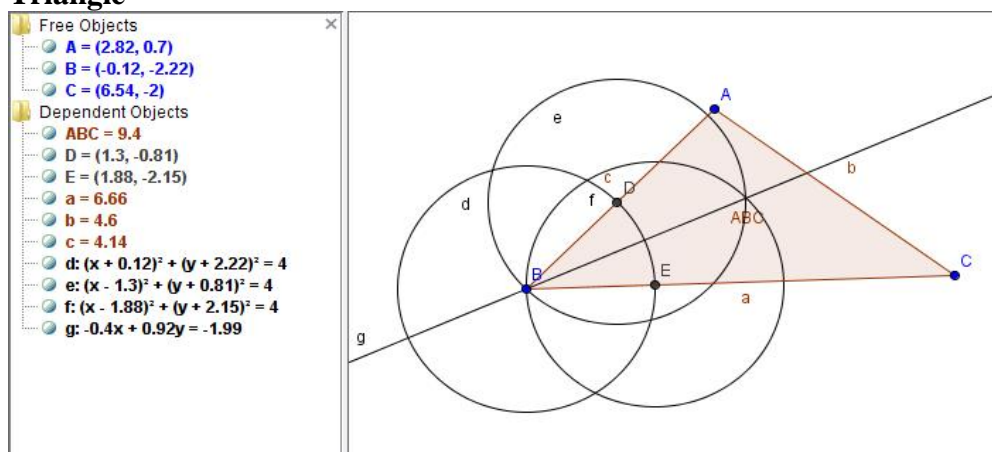
9. Perform the drag test to check if your construction is correct.

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Table 1: GeoGebra's "Construction Protocol" window for construction steps of an Angle Bisector of a Triangle

No.	Name	Definition	Command	Algebra
1	Point A			$A = (2.82, 0.7)$
2	Point B			$B = (-0.12, -2.22)$
3	Point C			$C = (6.54, -2)$
4	Triangle ABC	Polygon A, B, C	$\text{Polygon}[A, B, C]$	$ABC = 9.4$
4	Segment c	Segment [A, B] of Triangle ABC	$\text{Segment}[A, B, ABC]$	$c = 4.14$
4	Segment a	Segment [B, C] of Triangle ABC	$\text{Segment}[B, C, ABC]$	$a = 6.66$
4	Segment b	Segment [C, A] of Triangle ABC	$\text{Segment}[C, A, ABC]$	$b = 4.6$
5	Circle d	Circle with center B and radius 2	$\text{Circle}[B, 2]$	$d: (x + 0.12)^2 + (y + 2.22)^2 = 4$
6	Point D	Intersection point of d, c	$\text{Intersect}[d, c, 1]$	$D = (1.3, -0.81)$
7	Circle e	Circle with center D and radius 2	$\text{Circle}[D, 2]$	$e: (x - 1.3)^2 + (y + 0.81)^2 = 4$
8	Point E	Intersection point of d, a	$\text{Intersect}[d, a, 1]$	$E = (1.88, -2.15)$
9	Circle f	Circle with center E and radius 2	$\text{Circle}[E, 2]$	$f: (x - 1.88)^2 + (y + 2.15)^2 = 4$
10	Line g	Angle bisector of C, B, A	$\text{AngleBisector}[C, B, A]$	$g: -0.4x + 0.92y = -1.99$

Figure 1: GeoGebra' screen view of the construction of an Angle Bisector of a Triangle



Data Analysis

This paper reports quantitative analyses of the results of the tests. Data were analyzed using quantitative statistical techniques. Descriptive analyses included means and standard deviations. A parametric comparison test (t-test) was conducted to see possible differences between the groups for every question and for total tests results.

Results

This section presents main findings of the study.

Pre-test results

Table 2 presents the pre test results. The pre-test was applied to the both groups to determine the students' attainment levels. The questions cover seventh grade objectives for the subject (the test can be found in the appendix which is translated from original Turkish). The pre-test has total of 13 questions. All questions were analytically evaluated according to their included objectives.

Table 2: Pre test results

Questions	Max. Scores	Group	Mean (\bar{x})	Std. Deviation	t-value (Sig.)
1	10	Experiment	5,50	5,104	2,847***
		Control	1,50	3,663	
2	10	Experiment	6,85	4,069	-1,410
		Control	8,45	3,034	
3	10	Experiment	9,50	1,670	,911
		Control	8,85	2,720	
4	5	Experiment	4,25	1,832	,777
		Control	3,75	2,221	
5	10	Experiment	9,75	1,118	-,447
		Control	9,88	,559	
6	10	Experiment	5,80	3,778	1,774
		Control	4,00	2,513	
7	5	Experiment	3,50	2,351	-,346
		Control	3,75	2,221	
8	5	Experiment	4,25	1,832	-1,831
		Control	5,00	,000	
9	10	Experiment	9,50	2,236	,337
		Control	9,25	2,447	
10	5	Experiment	5,00	,000	2,179*
		Control	4,00	2,052	
11	10	Experiment	8,13	2,549	-2,482**
		Control	9,63	,911	
12	5	Experiment	3,25	2,447	,946
		Control	2,50	2,565	
13	5	Experiment	2,75	2,552	-1,322
		Control	3,75	2,221	
Total	100	Experiment	78,00	15,376	,808
		Control	74,40	12,688	

Note: t-test (independent sample) is significant (2-tailed) at the level of: * 0.05, ** 0.01, *** 0.001.

The total pre-test results show that there is not any statistically significant difference between the groups (Table 2). Overall scores are considered as adequate for both the experiment ($\bar{x}=78,00$) and the control ($\bar{x}=74,40$) groups. There are statistically significant differences only for three questions. Experiment group students were more successful for the question 1 and 10. While, the control group students' scores were significantly low for the questions 1 and 10, considerably high for the question 11. However, the attainment levels of

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both groups for question 1 are not adequate. Similarly, the students had difficulties in question 6 which is again about hypotenuses and perpendicular sides of a triangles. These results indicate that the students had difficulties in finding area of a triangle. This may be due the fact that the students did not understand the important associated concepts such as height and hypotenuse of a triangle. Students' attainment levels for all of the other 11 questions were nearly the same and reasonably adequate. The pre-test results show that the students are able to recognize and define triangles according to their sides and angles. They calculate interior angles of a triangle. Furthermore, they are able to find and show both angles and perpendicular bisectors of a triangle successfully. The results also show that the students' attainment levels are satisfactory to achieve new topics.

Post-test and Recall test Results

Table 3 presents the post and the recall tests results together with possible comparisons. The post test was applied to the both groups to determine the students' achievement levels. The questions cover eight grade objectives for the subject. The post test has total of 11 questions. All questions were analytically evaluated according to their included objectives. The total post test results show that there are statistically significant differences between the groups for total scores of the test and for some questions separately.

First two questions are about the third objective. In the questions some properties of a triangle are given. The first question is given with mathematical notations and properties without any figure. It asked to find triangles which can be constructed with the given properties. Second question is very similar to the first question and all data were presented in a context with a figure but not with mathematical notations. It asked to find the needed elements for the construction. The students in the both groups successfully answered the questions. However, there are not any statistically significant differences between the groups for both of the tests; the control group students are slightly more successful than the experiment group for the first question. Moreover, the students in the both groups are more successful for the first question than the second one. This may indicate that students are able to understand mathematical notations. Furthermore, rather than asking to students to find relations and necessary data to solve questions, their chances to respond correctly are increasing when more data are readily presented. For example, figures in the question 2 do not help students very much to solve this problem.

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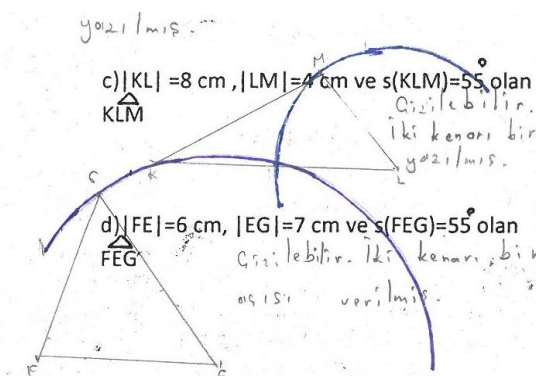
Table 3: Post and recall tests results

Questions	Max. Scores	Group	Post test			Recall Test		
			Mean	Std. Deviation	t-value (Sig.)	Mean	Std. Deviation	t-value (Sig.)
1	10	Experiment	8,38	2,724	-,758	9,13	1,677	-,225
		Control	9,00	2,487		9,25	1,832	
2	10	Experiment	7,00	2,991	,825	8,50	2,351	,650
		Control	6,25	2,751		8,00	2,513	
3	10	Experiment	2,65	3,760	2,032*	7,00	4,413	6,631***
		Control	,75	1,832		,25	1,118	
4	5	Experiment	4,25	1,832	2,483**	5,00	,000	2,179*
		Control	2,50	2,565		4,00	2,052	
5	5	Experiment	4,38	1,597	1,582	4,25	1,642	1,013
		Control	3,38	2,333		3,63	2,218	
6	10	Experiment	5,25	4,723	2,298*	6,00	4,472	2,299*
		Control	2,25	3,432		3,25	2,936	
7	10	Experiment	5,25	4,993	3,619**	7,00	4,413	5,514***
		Control	,75	2,447		*	1,00	
8	10	Experiment	8,50	3,663	,777	9,00	3,078	1,241
		Control	7,50	4,443		7,50	4,443	
9	10	Experiment	2,50	4,136	1,902*	5,25	4,993	1,665
		Control	,50	2,236		3,00	3,403	
10	10	Experiment	6,75	4,363	2,608**	6,05	4,639	-,526
		Control	3,15	4,368		6,80	4,372	
11	10	Experiment	7,88	2,333	2,331	7,38	4,013	,245
		Control	6,00	2,739		7,13	2,188	
Total	100	Experiment	63,15	23,946	3,359**	74,75	22,223	3,692***
		Control	42,45	13,652		*	54,45	

Note: *t*-test (independent sample) is significant (2-tailed) at the level of: * 0.05, ** 0.01, *** 0.001.

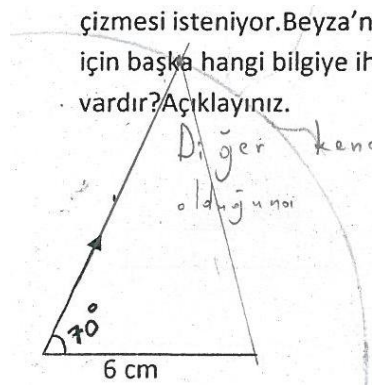
On the other hand, students are more successful in the question 1 which is based on hand data with mathematical notations. In relation to the software, it is clear from the students' answer (Figure 2) that the software has great impact on students' understandings and constructions. It is easily observable that the student gives answer to the question as in the software. Even more, he distinguishes the given data based on the construction steps of a triangle with GeoGebra. None of the students in the control group give such kind of answer

Figure 2: A student answer for the Question 1.



Very similar to question 1 effect of the software activities can be seen very clearly at the Figure 3 for question 2. The student found the correct solution as used and constructed with GeoGebra.

Figure 3: A student answer for the Question 2.



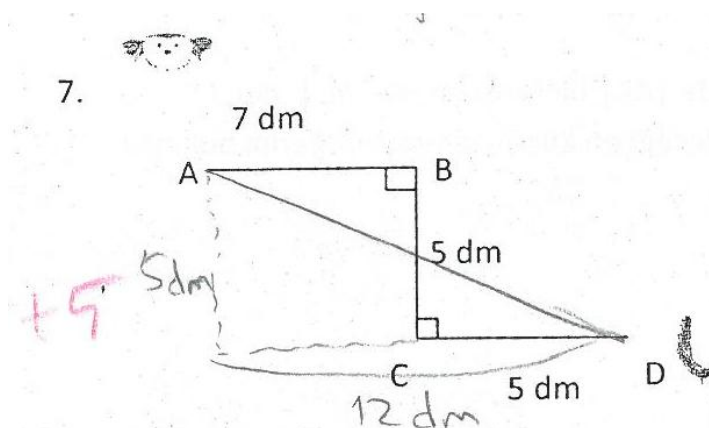
Third and fourth questions are about the first and the second objectives. In the questions some elements of a triangle (side lengths and angles) are given. The third question is given with a figure including a side length and an angle. It is asked to find length of another side of the triangles in the both questions. However, there are statistically significant differences between the groups for the post test; the students' achievement levels both in the experiment and the control groups are not adequate for the third question. The experiment group students are more successful than the control group. Furthermore, when the experiment group students significantly increased their success at the recall test, control group low achievement level even decreased more.

The fourth question is also given with a figure including two sides' lengths. There are statistically significant differences between the groups. Experiment group are significantly successful than the control group for the both pre and post tests. Moreover, the students in the both groups successfully remembered the learned facts and maintained even increased the success level at the recall test as well.

Fifth question is about the fourth objective. The question is given with a figure in isometric points. It is asked to show angle bisectors and mediators of the given triangles. The students both in the experiment and the control groups were quite successful for this question. However, the experiment group students are more successful than the control group for the question, there are not any statistically significant differences between the groups for both of the tests. Students in the both groups successfully constructed the learned facts and knowledge; therefore they are able to produce the correct answer.

Sixth and seventh questions are about the fifth objective. Some properties and elements of triangles are given in the questions. The sixth question is given with a figure including three sides' lengths in units. The seventh question is given with a figure including side lengths and angles. Pythagoras relation is asked at the both questions. The students in the experiment group are more successful for both of the questions; so there are statistically significant differences between the groups for the post and the recall tests. Furthermore, the experiment group' success significantly increased at the recall test for both questions as well. A student' solution for the question is given below (Figure 4). The student constructed a necessary element (which represent the shortest way) and found the correct solution.

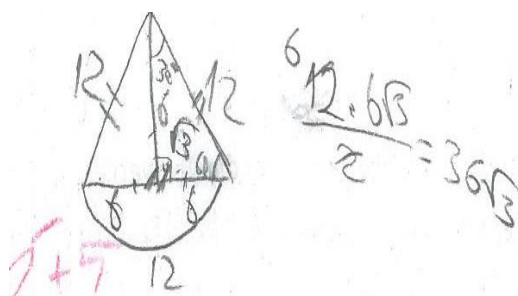
Figure 4: A student's answer for the question 7.



Eighth question is about the second objective. The question is given with a figure including mathematical notations. It is asked to order angles of the triangle according to its sides' lengths. The students both in the experiment and the control groups were successful for this question. However, the experiment group students are more successful than the control group; there are not any statistically significant differences between the groups for both the tests.

Question 9 is about the sixth objective. The question is given without any figure. It is asked to find area of an isosceles triangle with a given altitude. However, there is statistically significant difference between the groups for the post test; the students in both of the groups were not adequately successful for this question. Even so, the experiment group students are more successful than the control group. A student' solution for the question is given below (Figure 5). The student constructed a figure with the given properties and found the correct solution.

Figure 5: A student's answer for the Question 9.



Question 10 is about the seventh objective. The question is given with a figure including some sides' lengths and angles. The question is about finding area of a trapezoid which includes area of a right triangle. There are statistically significant differences between the groups for the post test. The students in the experiment group are more successful than the control group. The students in the control group were not adequately successful for this question. On the other hand, however there is not any statistically significant difference, the control group students' success increased at the recall test.

Question 11 is about the fourth objective. The question is given with figures in isometric points without any mathematical notations. It is asked to show the lines which represent altitudes, angle bisectors and mediators of a triangle at the same time. The students both in the experiment and the control groups were quite successful. However, there is not any statistically significant differences between the groups for both of the tests; the experiment group students are more successful than the control group students.

In total, there are statistically significant differences between the groups for the both post and recall tests. The experiment group are more successful ($\bar{x} = 63,15$) than the control ($\bar{x} = 42,45$) group for the post test. Likewise, the experiment group are more successful ($\bar{x} = 74,75$) than the control ($\bar{x} = 54,45$) for the recall test as well. These overall results clearly indicate that dynamic mathematics software significantly increased students' success. Furthermore, the total recall test results show that the students retain their success more significantly even after a period of time.

A comparison test (t-test) was also conducted to see any possible differences for gender. There are not any statistically significant differences neither for the questions nor the tests.

Conclusion

Besides practical training with many discoveries and constructions, the study conveys important messages for mathematics education as well. First of all, the students get familiar with dynamic mathematics software first time. This practical contribution to mathematics education proves a reality that computer-based classroom activities can be effectively used in the teaching and learning environments. Secondly, geometric facts, figures, shapes and their properties with the actual conditions of constructions were observed by using the software's features. Thus, the students have the chance to verify the conditions by exploring and observing the geometric properties of the shapes with all sufficient conditions. This also gives opportunities to check and prove all features dynamically with the program itself. Therefore, the student has the chance to prove the terms and to observe construction conditions of geometric features for each case. This situation goes beyond simply drawing the geometric shapes and figures. Because, providing all conditions for the construction requires considering all of the related facts and features together with the associated geometric realities. If this high-level of thinking is accomplished, then the construction emerges. This is an indication of acquiring higher order learning skills. In this case, the contribution of the dynamic mathematics software is undeniable. This differs from the traditional training that students draw shapes without considering any factual conditions.

All of the above considerations are proven by this study's results. The students in the experiment group did significantly well than the other group of students at the tests. Additionally, experiment group retained and even developed their attainment levels even after a period of time (recall test). This is very important for permanent mathematics learning. It can be said that dynamic mathematics software has positive effect on retaining knowledge and helps to construct and develop further knowledge. Furthermore, detailed evaluation of the experiment group students' responses clearly reveals that the students use GeoGebra construction properties. Especially, it is very effective in visualization and extra construction needed subjects. Furthermore, computer helps the students to remember facts and make calculations successfully.

Furthermore, the researchers' observation and the students' responses during the activities revealed that the students' motivation in the class is increased with computer-based activities. Even more, the students would like to have more practices about other

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mathematics subjects with such software as well. Thus, the computer and software should be available for both teachers and students. Moreover, adequate level of in-service teacher training for computer-based teaching must be provided and it has to be maintained through the professional life.

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