The Role of Dynamic Geometry Software in the Process of Learning: GeoGebra Example about Triangles*

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Abstract

This study is about using GeoGebra and its effect on eight grade students' achievements for the subjects of triangles. The study is conducted in the fall semester of 2009-2010 academic year. Two eighth grade classes from a primary school were selected as experiment and control groups. Before the classroom activities, a pre test which covered questions about seventh grade objectives was applied to the both groups to determine the students' attainment level. A two weeks course was planned in accordance with the official course curriculum for the experiment group. The course contained GeoGebra activities and practices about the stated objectives. 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. After the two weeks, a post test was applied to the both groups simultaneously. The post test contained questions about the stated objectives for the eighth grade. Furthermore, one month after the application a recall test was applied to both groups as well. Possible comparisons between the tests and the groups were performed. The results show that dynamic software (GeoGebra) has positive effects on students' learning and achievement. It has also been observed that it improves students' motivation with positive impact.

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

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 computers and their software 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. 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 the imagination.

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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 8^{th} grade students’ achievements for triangles including Pythagoras relation.

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 are developed and tried to integrate 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 (NCTM, 2000).

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. Therefore, it has to be integrated into mathematics courses (Çakıroğlu et al, 2008).

Geometry is called 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.

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 favor of experiment group. All students of the experiment group have achieved high attainment level 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 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 based on seeing the drawings from computer screen, or with 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 favor 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 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.

Methodology

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. Before the classroom activities, a pre-test was applied to the both groups to determine the students' attainment level. The questions cover seventh grade objectives for the subject. 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. It aimed to observe possible effects of computer-based learning environment (GeoGebra software) on students' success. 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' degrees between the sides (3 activities).
3. Draws a triangle with given measures of sufficient elements (3 activities)
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 main activities were prepared with GeoGebra and then used in the classroom for this study. Simultaneously, the control group continued their formal teaching and learning procedure as guided by the Ministry. A GeoGebra constructed classroom activity is presented here as an example.

Classroom Activities

A Sample for the GeoGebra Constructed Activities: Construction of an Angle Bisector of a Triangle

1. Preparations

• Summarize the properties of an angle bisector of a triangle before you start the construction. <u>Hint</u>: 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).

• Change (if you want) the labeling setting to *New points only* (menu *Options – Labeling*).

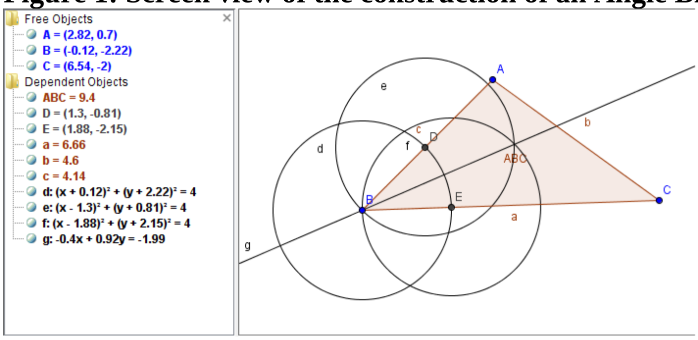
2. Construction process

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.

Table 1: 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	Polygon[A, B, C]	ABC = 9.4
4	Segment c	Segment [A, B] of Triangle ABC	Segment[A, B, ABC]	c = 4.14
4	Segment a	Segment [B, C] of Triangle ABC	Segment[B, C, ABC]	a = 6.66
4	Segment b	Segment [C, A] of Triangle ABC	Segment[C, A, ABC]	b = 4.6
5	Circle d	Circle with center B and radius 2	Circle[B, 2]	d: $(x + 0.12)^2 + (y + 2.22)^2 = 4$
6	Point D	Intersection point of d, c	Intersect[d, c, 1]	D = (1.3, -0.81)
7	Circle e	Circle with center D and radius 2	Circle[D, 2]	e: $(x - 1.3)^2 + (y + 0.81)^2 = 4$
8	Point E	Intersection point of d, a	Intersect[d, a, 1]	E = (1.88, -2.15)
9	Circle f	Circle with center E and radius 2	Circle[E, 2]	f: $(x - 1.88)^2 + (y + 2.15)^2 = 4$
10	Line g	Angle bisector of C, B, A	AngleBisector[C, B, A]	g: -0.4x + 0.92y = -1.99

Figure 1: Screen view of the construction of an Angle Bisector of a Triangle



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. 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. The study also gives great opportunity to see possible outcomes of real classroom applications.

This paper reports quantitative analyses 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. Table 2 presents the pre test results. Table 3 presents the post and the recall tests results together with possible comparisons.

The pre-test was applied to the both groups to determine the students' attainment level. The questions cover seventh grade objectives for the subject. The pre-test has total of 13 questions. All questions were analytically evaluated according to their included objectives. 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 for only a couple of questions. Experiment group students were more successful for the question 1 and 11. While, the control group students' scores were significantly low at the question 1, considerably high at the question 11. Students' attainment levels for all of the other 11 questions were nearly the same and reasonably adequate for the pre test.

Table 2: Pre test results

		Pre test			
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	

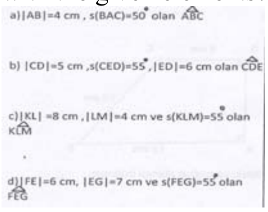
Note: *t*-test (independent sample) is significant (2-tailed) at the level of: * 0.05, ** 0.01, *** 0.001.

The post test was applied to the both groups to determine the students' achievement level. 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 (Table 3).

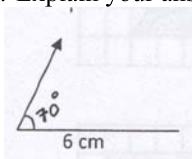
First two questions are about the third objective. In the questions some elements of a triangle are given (Figure 2). The first question is given with mathematical notations and properties without any figure. It asked to find triangles which can be constructed with the given elements. Second question 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 construction. The students both in the experiment and the control 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 figures do not help students to solve this kind of problems.

Figure 2: Question 1 and 2

Question 1: Which of the triangles can be drawn with the given elements?

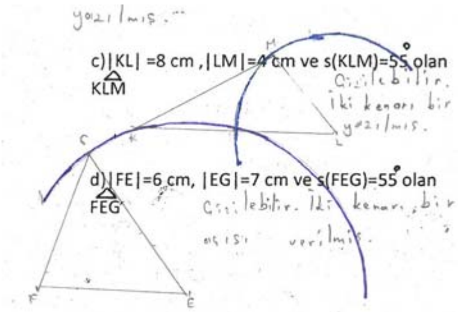


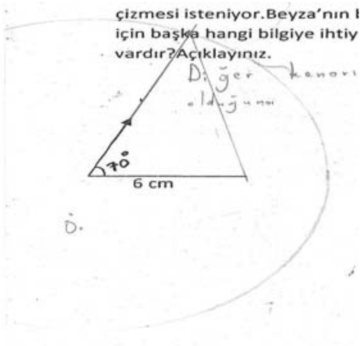
Question 2: Beyza would like to draw a triangle with a given side and an angle.
What kind of other information does Beyza need to draw this triangle? Explain your answer?



Effect of the GeoGebra activities can be seen very clearly at the below figure for question 1 and 2. The student used and created a GeoGebra based construction to find the correct solution.

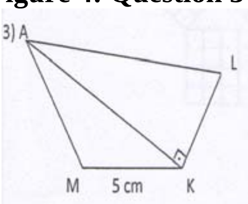
Figure 3: A student answer for Question 1 and 2.



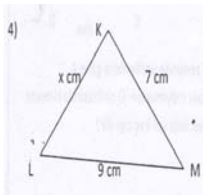


Third and fourth questions are about the first and the second objectives. In the questions some elements of a triangle (side lengths and angles) are given (Figure 4). The third question is given with a figure including a side length and an angle. The fourth question is given again with a figure including two sides' lengths. It is asked to find length of another side of the triangles in the both questions. However, the students' achievement level both in the experiment and the control groups are not adequate for the third question; there are statistically significant differences between the groups for the post test. The experiment group students are more successful than the control group. Furthermore, the experiment group' success significantly increased at the recall test as well. Similarly, there are statistically significant differences between the groups for the fourth question. Experiment group are significantly successful than the other group for both of the tests. Moreover, the both groups' students' success increased at the recall test as well.

Figure 4: Question 3 and 4



Question 3: |AK| is an integer. Find the least possible value of |AL |.



Question 4: Find the all of the possible values of x in the above triangle?

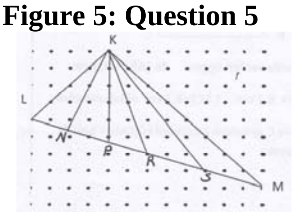
Table 3: Post and recall tests results

Questions	Max. Scores	Group	Post test Mean	Post test Std. Deviation	Post test t-value (Sig.)	Recall Test Mean	Recall Test Std. Deviation	Recall Test 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	2,052	
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	10,526	

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

Fifth question is about the fourth objective. The question is given with a figure in isometric points (Figure5). 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.

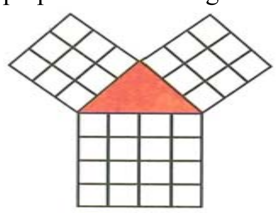
Figure 5: Question 5



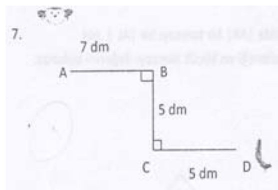
Question 5: Show the angle bisectors and mediators of the KLM triangle?

Figure 6: Question 6 and 7

Question 6: Is the constructed triangle in the figure a perpendicular triangle? Explain your answer?



Question 7: Find the possible shortest way from A to D?



Sixth and seventh questions are about the fifth objective. Some properties and elements of triangles are given in the questions (Figure 6). 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. The student constructed a necessary element (which represent the shortest way) and found the correct solution.

Figure 7: A student's answer to the question 7.

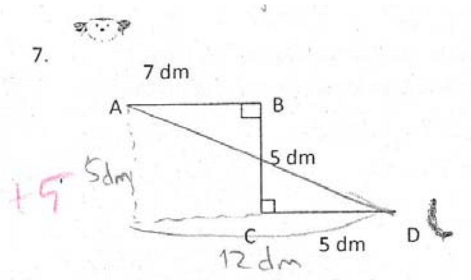
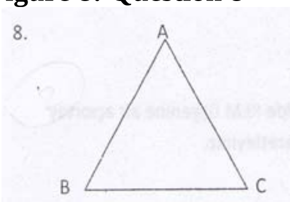


Figure 8: Question 8



Question 8: In the given triangle;
|AB| = 4,1 cm
|AC| = 6,2 cm and
|BC| = 8,3 cm.

Put the angles of A ,B and C from smallest to greatest in order?

Eighth question is about the second objective. The question is given with a figure including mathematical notations (Figure 8). 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: Find the area of the triangle whose altitude is $6\sqrt{3}$ cm?

Question 9 is about the sixth objective. The question is given without any figure. It is asked to find area of the 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. The student constructed a figure with the given properties and found the correct solution.

Figure 9: A student's answer to the question 9.

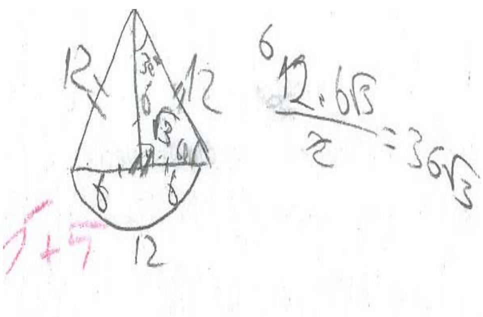
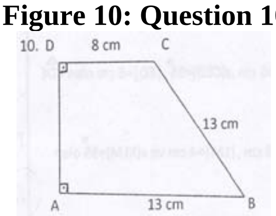


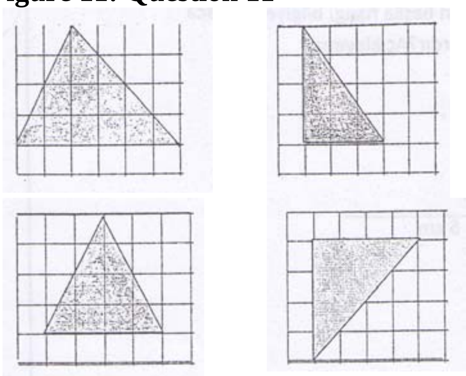
Figure 10: Question 10



Question 10: Find the area of the trapezoid in the figure?

Question 10 is about the seventh objective. The question is given with a figure including sides' lengths and angles (Figure 10). The question is about finding area of a trapezoid. 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.

Figure 11: Question 11



Question 11: Show the lines which represent altitudes, angle bisectors and mediators of a triangle at the same time?

Question 11 is about the fourth objective. The question is given with figures in isometric points without any mathematical notations (Figure 11). 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, the experiment group students are more successful than the control group; there are not any statistically significant differences between the groups for both of the tests.

In total, there are statistically significant differences between the groups for the both 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 massages 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 learning environments. Secondly, geometric shapes and their properties with the actual conditions of constructions were observed by using the software' features. Thus, the students had the chance to construct, explore and observe 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 drawing the geometric shapes simply. Because, providing all conditions for the construction requires considering all of the related features together with the associated geometric realities. If this high-level of thinking occurs, then the construction occurs. This is a sign for high-level learning. Here, 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 the post and the recall tests. The students in the experiment group have done significantly well than the other students at the post test. Additionally, experiment group retain and develop further their attainment level 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 for the questions.

Furthermore, the researcher' observation and the students' responses during the activities revealed that the students' motivation in the class is increased with computer-based teaching. Even more, the students would like to have more opportunities with such software. They also wish to have more practical application about other subjects of mathematics with computer. 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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