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The effect of GeoGebra on academic achievement in geometric place

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Abstract

This study deals with the effect of GeoGebra, one of the dynamic mathematics software, on high school students in learning the subject of geometrical place and the relationship of this effect with the socio-demographic characteristics of the students. The study was carried out with 12th grade students at a private high school located in Çankaya, Ankara. The assignments of the students included in the research to the experimental and control groups were made randomly, and the subject of geometric place was taught to the control group using traditional methods and to the experimental group using GeoGebra software. There were a total of 31 students, 12 girls and 19 boys, in the experimental group, and a total of 32 students, 14 girls and 18 boys, in the control group. "Personal Information Form" and "Achievement Test" prepared by the researcher were used in the research. In the Achievement Test applied as a pre-test, no statistically significant difference was found between the success means of the experimental group and the control group. In the Achievement Test applied as a post-test, a statistically significant difference was found between the experimental group and control group means in favor of the experimental group. On the other hand, a significant difference was observed between the pre-test and post-test in both the experimental group and the control group. In the analysis of the sub-problem of the research, there was a significant difference in the success mean of the experimental group according to the gender variable, but no significant difference was observed in the mean of success in the control group.

Keywords: Computers, Math education, Geometric Place, Dynamic mathematics software

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1. Introduction

Computers have long been used in education in various ways. Computers have been beneficial in various ways, both in the administrative procedures necessary for the execution of educational activities and in the conduct of educational services for educational purposes in courses. In the research so far conducted it has turned out that students participate more actively in the learning process with computers and use this technology as a discovery tool (Baltacı et al., 2016). With the use of computers, even students who are lower in academic achievement than other students can individually cope with the difficulties they encounter during the educational activities. For this, students should be encouraged to learn in groups by using the computer during the learning process, and social interaction environment should be created. This is because the use of computers in group work help students learn more meaningfully (Baltacı et al., 2015).

As a result of the increasing prominence of the computer in the learning and teaching processes, the concept of "Computer Assisted Instruction" (CAD) has emerged as a new method. In CAD, the entrance of computers into math classrooms provided the meaningful learning of the subjects in the lessons by the students. Computers also brought about the establishment of the necessary algorithms, analytical convenience in the research where analysis is required and speed in the process of the execution of transactions (Baydaş, 2010). The presence of the softwares in the educational environment in different ways can reveal new ways to explore mathematical

concepts. These softwares are Computer Algebra Systems and Dynamic Geometry Software (DGS). There is a software called GeoGebra, which combines both computer algebra systems and DGS features (Zengin & Tatar, 2014).

The abstract nature of mathematics not only prevents the formation of mathematical connections, but also prevents students from reaching generalizations. Technology offers important opportunities to solve this kind of problems (Baydaş, 2010). It might be possible to overcome the difficulties experienced in teaching mathematics and analytical geometry by creating rich learning environments. Dynamic mathematics software plays an important role in these environments where ensuring student success is aimed. In the education-teaching process, mathematics software is more useful than other tools and instruments on behalf of increasing student interaction in learning environments. One of the most used software types among this type of mathematics softwares is GeoGebra (Baltacı et al., 2015). The main feature of this software is that after the structure of mathematical objects is established, it enables the objects in this structure to move comfortably, and it causes other objects existing in the structure depending on this object move accordingly.

Therefore, today, the effect of GeoGebra on the academic success of high school mathematics students regarding geometric place has been a matter of curiosity. In this context, the aim of the research is to determine the effect of the mathematics software GeoGebra on the academic achievement of high school students in the subject of geometric place in the mathematics lesson, and to determine whether there is a meaningful difference in terms of socio-demographic characteristics of the students.

2. Material and Methods

This section provides information about the research model, research group, data collection tools, data collection and analysis.

2.1. Model of the research

Experimental research design, which is one of the quantitative research methods, was used in this study (Aliaga & Gunderson 2002; Fraenkel et al., 2012). Random design with pretest-posttest control group, which is one of the real experimental design types, was used in the research (Fraenkel et al., 2012; Karasar, 2005).

2.2. Research group

The research group of the study consists of 63 randomly selected students from among 130 students studying in the 12th grade of a private high school in Ankara province Çankaya district in the spring semester of the 2015-2016 academic year. The convenience sampling method, which is one of the random sampling selections, was used in the sample selection (Patton, 2002). The assignments of the students included in the study to the experimental and control groups were made randomly, so it was aimed to obtain two groups that did not differ in their academic achievements during the pre-test phase. There was a total of 31 students, 12 girls and 19 boys, in the experimental group, and 32 students in total, 14 girls and 18 boys, in the control group. Of the 63 students participating in the study, 26 were girls and 37 were boys. The frequency and percentage values of the groups and genders of the students in the research group are shown in Table 1.

Table 1. Frequency and percentage distribution of students by groups and gender

Research Group		Student's Gender		Total
		Female	Male	
Experimental	f	12	19	31
	%	19.04	30.16	49.21
Control	f	14	18	32
	%	22.22	28.57	50.79
Total	f	26	37	63
	%	41.47	58.73	100

2.3. Data collection tools used in the research

2.3.1. Personal information form

It is a ten-question form prepared by the researcher to determine the socio-demographic characteristics of the students such as date of birth, gender, number of siblings, father's education level, mother's education level, father's occupation, mother's occupation, presence of computer at home, computer usage frequency, daily computer usage hours. The form was prepared after reviewing the relevant literature, examining the questions in similar studies, and taking the opinions of three experts in the field.

2.3.2. Achievement test

Within the scope of the research, an Achievement Test containing the subject of "Geometric Place" was used as a data collection tool. The purpose of the application of this test is to determine the readiness level of the students before the research to be applied, and to determine the effect of the mathematics software GeoGebra on the academic success of high school mathematics students on geometric place at the end of the research.

The following steps were followed in the development of the Achievement Test:

- First, the achievements of the geometric place subject that would be covered in the application process were determined from the MEB (Ministry of National Education) high school Mathematics Program 9-10-11-12 book. Before the achievement test was developed, the relevant literature was searched, and the opinions of teachers specialized in mathematics were taken. A Turkish language expert was interviewed in terms of language, expression, and clarity of the questions. After these enquiries, the test preparation phase was started. In this process, teacher's guidebook, textbook, test books, the questions appeared in the exams by The Measuring, Selection and Placement Center [ÖSYM], and leaf tests

were examined and a test consisting of 52 items was created by the researcher.

- Expert opinions were taken in the prepared Achievement Test, and the necessary arrangements were made in line with these opinions and an Achievement Test with 52 questions was obtained. To test the reliability of the test item number of the prepared draft, 87 first-year students studying at Gazi University, Department of Elementary Mathematics in Ankara were asked to answer the draft and sufficient time was given.
- In the evaluation of the 52-question Achievement Test used in the pilot study, success points were given by giving "1" for correct answers and "0" for mistakes. Test reliability analysis was performed on the data obtained at the end of this application.
- Based on the results of the reliability analysis, questions with negative reliability and less than 0.40 were excluded from the test, and an equal number of questions were included from each acquisition to ensure content validity, while all this being done expert opinion was taken, and the test was finalized with 25 questions.
- According to Özdemir (2009), the reliability of the test is the consistency of the test items within themselves. Reliability takes values between “0” and “+1”. It is desirable that the result of the reliability of the test take values close to “+1”. The reliability of the prepared test was analyzed (Büyüköztürk, 2007).

For the Achievement Test, which was finalized as 25 questions, the Cronbach Alpha coefficient was found to be 0.79. A reliability coefficient of 0.70 or higher is sufficient for the reliability of test scores (Büyüköztürk, 2007; Özdamar, 1999). As a result of the pilot application, the Cronbach Alpha coefficient of the 52-question Achievement Test was found to be 0.85. The item discrimination index is the degree of discrimination used to distinguish low-achieving students from high-achieving ones (Turgut & Baykul, 1992).

If the discrimination index is zero or negative, these items are not included in the test; If the item discrimination index has a value of 0.40 or higher, the item is considered very good and does not need correction; If it is between 0.30-0.40, it is sufficient, it does not need to be corrected; If it is between 0.20 and 0.30, the item can be used in the same way or changed in case of difficulty; If it is less than 0.20, the substance should not be used or corrections should be made again (Turgut & Baykul, 1992).

In addition, the item difficulty index expresses the rate of correct answers to an item in the test and can take values between '0' and '1'. If this numerical expression is close to zero, it shows that the applied item is difficult, and if it approaches one, it shows that the item is easy (Gönen et al., 2011: 40-57). Although the item difficulty of all items in an achievement test is different from each other, it is desirable that it is generally around 0.5 (Çepni et al., 2008). Within the scope of the study, when 27 items with low item discrimination (those below 0.20) (2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14, 15, 16, 19, 20, 22, 23, 24, 25, 27, 29, 31, 33, 36, 45, 47, 49) were removed, the test was reduced to 25 questions. The values in 25 items calculated for item difficulty are also sufficient within the scope of the research. The item difficulty and item discrimination index values calculated for the Achievement Test are given in Table 2.

Table 2. Item difficulty and item discrimination index values calculated for the Achievement Test

Question No	Item Difficulty	Item Discrimination Index	Question No	Item Difficulty	Item Discrimination Index
1*	0.92	0.37	27	0.68	0.14
2	0.93	0.18	28*	0.77	0.38
3	0.97	0.19	29	0.89	0.19
4	0	0.09	30*	0.59	0.32
5	0.77	0.15	31	0.47	0.13
6	0.78	0.16	32*	0.22	0.35
7	0.59	0.14	33	0.36	0.18
8	0.46	0.13	34*	0.44	0.41
9*	0.47	0.29	35*	0.43	0.31
10	0.69	0.11	36	0.59	0.14
11	0.61	0.12	37*	0.23	0.37
12*	0.6	0.37	38*	0.08	0.42
13	0.64	0.09	39*	0.21	0.40
14	0.63	0.15	40*	0.23	0.27
15	0	0.08	41*	0.24	0.28
16	0.69	0.19	42*	0.14	0.29
17*	0.79	0.29	43*	0.18	0.26
18*	0.46	0.37	44*	0.34	0.33
19	0.55	0.17	45	0.06	0.09
20	0.39	0.12	46*	0.25	0.36
21*	0.79	0.40	47	0.07	0.08
22	0.37	0.13	48*	0.2	0.26
23	0.71	0.15	49	0.49	0.19
24	0.24	0.09	50*	0.55	0.34
25	0.77	0.13	51*	0.26	0.41
26*	0.79	0.35	52*	0.35	0.38

*As a result of the analyzes made, the remaining question items in the achievement test

The final form of the Academic Achievement Test consisting of 25 questions was applied to the experimental and control groups. In the evaluation of the answers given by the students in the Achievement Test, the correct answer was evaluated as 1 and the wrong answer as 0.

2.4. Data collection and analysis

The data collection process was carried out by the researcher by going to a private school affiliated to the National Education after obtaining the necessary legal permissions from the Ethics Committee, from the private school in question and from Gazi University Rectorate. In the implementation process of this research, the random design with pretest-posttest control group proposed by (Fraenkel, et al., 2012) was based on. This research was carried out in a private high school located in the Çankaya district of Ankara in the academic year of 2015-2016. Before the research groups were formed, the lecturer

introduced himself to the students in line with the scope of the course and expressed his expectations to achieve the research purpose. In addition, before the applications of the research were carried out, the studies conducted with the students studying in the 12th grade were examined, and it was decided that the GeoGebra software would design the activities to be used in this research implementation process. The activities planned to be developed were organized and updated in detail after sharing with three mathematics teachers who were experts in their fields and taking their opinions and recommendations. The suitability and applicability of the activity, which was decided to be updated, was discussed again by the researchers and expert teachers who came together. Finally, the updated activity plan is arranged to be applied to 12th grade students. The application was made by a single researcher. Before the application, students in the experimental and control groups were randomly assigned in accordance with the research design. The researcher created a smart class intended for the teaching of the course to the experimental group. This smart classroom consisted of a computer, a projector, a blackboard, a dynamic mathematics software GeoGebra, and materials suitable for this program.

The education for the control group, on the other hand, was carried out with the current education-teaching approach included in the Mathematics Curriculum prepared by the Board of Education and Discipline in 2013, and with a student-centered learning-teaching approach by the instructor of the course. Academic Achievement Test with 25 questions developed before the application was applied to both groups as a pre-test. After the pre-test, both the experimental and control groups were given a nine-hour training for three weeks.

SPSS 24 program was used in the analysis of the data obtained in the research. Descriptive statistics and inferential statistics were used in the analysis of the data. In the study, independent sample t-test and dependent sample t-test from parametric tests, Mann-Whitney U test and Wilcoxon Signed Rank test from non-parametric tests were used. As a result of the analyzes made, it can be said that the distribution is normal since the skewness and kurtosis values for both the pretest and the posttest are between ±2 (George & Mallery, 2003). Summary statistics for the pre-test and post-test are given in Table 3.

Table 3. Summary statistics for pre- and post-test

	Pre-test		Post-test	
	Statistics	SE	Statistics	SE
Mean	10.60	0.40	20.56	0.57
Median	11.00		22.00	
Variance	10.11		20.67	
Std. Dev.	3.18		4.55	
Minimum	3.00		9.00	
Maximum	17.00		25.00	
Range	14.00		16.00	
Distortion	0.17	0.30	-0.97	0.30
Kurtosis	-0.08	0.60	-0.17	0.60

3. Results

While 31 of the research group consisting of 63 people were in the experimental group, 32 were in the control group. According to Table 4, there are 26 female and 37 male students in the study. In addition, when the information on the number of siblings was examined, the students reported that they had two and three siblings. When the educational status of the mothers and fathers of the students is examined, it is seen that they have mostly undergraduate education level. Father's occupations are generally worker and pensioner, mother's occupation is generally civil servant. While there are 60 students who have a computer at home, there are 3 students who do not have a computer. While 36 students stated that their daily computer use was between 0-1 hours, 17 students reported that they used computers between 1-2 hours daily.

3.1. Obtaining findings with parametric tests

The results of the independent samples t-test applied to determine whether there is a statistically significant difference between the experimental and control group for pre- and post-test success scores are given in Table 5. It is seen that there is a statistically significant difference between the post-test means of the experimental and control groups ($p<0.05$). According to Table 5, no statistically significant difference was found ($p>0.05$) between the pre-test means of the experimental group (11.06) and the control group (10.16), while the post-test mean of the experimental group (23.58) was higher than the mean of the control group (17.63). GeoGebra education has led to an increase in academic success. Cohen d' formula was used to examine the level of this significant difference (Pallant, 2005), and the effect size was found to be 0.43. This result shows that there is a high level of effect size.

The dependent sample t-test was used to compare the pre- and post-test findings of 12th grade students regarding the Academic Achievement Test in terms of groups. The data for this finding are given in Table 6. According to Table 6, there is a significant difference between the mean of the pre-test (11.06) and the post-test (23.58) for the experimental group ($p<0.05$); similarly, there is also a significant difference between the mean of the pre-test (10.16) and the post-test (17.63) for the control group ($p<0.05$). According to the calculated Cohen'd formula, the effect size between the pre-test and the post-test for the experimental group was 0.95, while the effect size calculated for the control group was 0.71. This result shows that the education given in both groups increased the mean success of the students by large amount. However, the difference shows that the knowledge level of the students in the experimental group increased at a higher level than the students in the control group.

Table 4. Personal information of students

	Group	f	%
Gender	Girl	26	41.27
	Boy	37	58.73
Year of birth	1997	3	4.76
	1998	59	93.65
	1999	1	1.59
Number of siblings	1	1	1.59
	2	36	57.14
	3	24	38.09
	4	1	1.59
	6	1	1.59
Father's educational status	Secondary School	1	1.59
	High school	4	6.35
	Associate degree	2	3.17
	Bachelor	36	57.14
	MSc	12	19.05
	PhD	8	12.70
Mother's educational status	Secondary school	2	3.18
	High school	12	19.05
	Assoc. Degree	2	3.18
	Bachelor	39	61.90
	MSc	6	9.52
	PhD	2	3.17
Father's profession	Civil servant	6	9.52
	Worker	15	23.81
	Craftsman	8	12.70
	Academician	9	14.29
	Pensioner	14	22.22
	Unemployed	7	11.11
	Other	4	6.35
Mother's profession	Civil servant	20	31.75
	Academician	2	3.17
	Pensioner	11	17.46
	Unemployed	10	15.87
	Other	20	31.75
Having a computer	Yes	60	95.24
	No	3	4.76
Use of computer	At School	18	28.57
	School and Home	11	17.46
	Home	27	42.86
	None	7	11.11
Daily computer usage	0-1	36	57.14
	1-2	17	26.98
	2-3	8	12.70
	4 and more	2	3.17

Table 5. Independent samples *t*-test results of experimental and control groups

Test	Group	n	Mean	Std. Dev.	*t*	*p*
Pre-	Experimental	31	11.06	2.92	1.14	0.26
	Control	32	10.16	3.40		
Post-	Experimental	31	23.58	1.48	6.96	0.00*
	Control	32	17.63	4.61		

*Significant at 0.05 level.

Table 6. Comparison of pre- and post-test findings for academic achievement test

Group	Test	n	Mean	Std. Dev.	*t*	*p*
Experimental	Pre-	31	11.06	2.87	24.3	0.00*
	Post-	31	23.58			
Control	Pre-	32	10.16	4.96	8.52	0.00*
	Post-	32	17.63			

*Significant at 0.05 level.

Whether there is a statistically significant difference between the pre- and post-test academic achievement means of the experimental and control groups according to the gender variable is analyzed with an independent sample t-test, and the results obtained are given in Table 7. According to Table 7, the pre-test mean of boys in the experimental and control groups was higher than the pre-test mean of girls. However, there is no statistically significant difference between the means of academic achievement in both the experimental group ($p>0.05$) and the control group ($p>0.05$) according to gender. According to Table 7, while there is a statistically significant difference in favor of boy students (24.05) rather than girl students (22.83) among the academic achievement means of the experimental group according to the gender variable ($p<0.05$), there is no statistically significant difference between the academic achievement means of the control group according to the gender variable ($p>0.05$).

Table 7. Independent samples *t*-test results of academic achievement scores by gender

Test	Group	Gender	n	Mean	Std. Dev.	*t*	*p*
Pre-	Experimental	Girl	12	9.92	3.06	-1.80	0.08
		Boy	19	11.79	2.66		
	Control	Girl	14	9.50	2.88	-0.96	0.34
		Boy	18	10.67	3.76		
Post-	Experimental	Girl	12	22.83	1.03	-2.41	0.02*
		Boy	19	24.05	1.54		
	Control	Girl	14	18.36	4.99	0.79	0.44
		Boy	18	17.06	4.35		

*Significant at 0.05 level.

3.2. Obtaining findings with non-parametric tests

The Mann-Whitney U test results, which were applied to determine whether there was a statistically significant difference in the experimental and control groups pre- and post-test achievement scores of the students, are given in Table 8. According to Table 8, when the students' answers to the academic achievement test are analyzed, there is no statistically significant difference between the experimental group and the control group in the pre-test results ($p>0.05$), while a statistically significant difference was found in the post-test results ($p<0.05$).

Wilcoxon Signed Rank test was used to compare the pre- and post-test scores of 12th grade students on the academic achievement test in terms of groups. According to Table 9, there is a significant difference between the pre-test and

post-test both in terms of the experimental and the control groups ($p<0.05$). This result shows that the education given in both groups increases the success mean of the students.

Table 8. Mann-Whitney U test results for academic achievement scores

Test	*p*
Pre-test	0.33
Post-test	0.00*

*Significant at 0.05 level.

Table 9. Comparison of academic achievement test with Wilcoxon Signed Rank test

Group	*p*
Experimental	0.00*
Control	0.00*

*Significant at 0.05 level.

The Mann-Whitney U test was used to determine whether there was a statistically significant difference in terms of gender variable between the pre- and post-test academic achievement scores of the experimental and control groups, and the findings are given in Table 10. According to Table 10, no significant difference was found between the academic achievement scores of both the experimental group ($p>0.05$) and the control group ($p>0.05$) in terms of gender variable. While, there was a significant difference between the academic achievement scores of the experimental group in terms of gender variable ($p<0.05$), there was no statistically significant difference between the academic achievement scores of the control group in terms of the gender variable ($p>0.05$). As a result, due to the small number of students in the research group, non-parametric tests were also used together with parametric tests. Results obtained from parametric and non-parametric tests are the same.

Table 10. Mann-Whitney U test results of academic achievement scores by gender

Test	Group	*p*
Pre-test	Experimental	0.08
	Control	0.49
Post-test	Experimental	0.01*
	Control	0.56

*Significant at 0.05 level.

4. Discussion and Conclusion

The aim of the research was to determine the influence of the GeoGebra software on the success of high school students on the geometric space in mathematics lessons. In this research, the lessons were taught in accordance with the Ministry of Education curriculum in the control group, and the lessons were taught with a computer, projector, and blackboard in the experimental group. Within the scope of the research, it was investigated whether the use of GeoGebra significantly led to differences in the academic achievement means of the students and while searching for an answer to this problem, the Achievement Test was applied as a pretest-posttest in the experimental and control groups.

In the study, there was no difference in the pre-test between the academic achievement scores of the students in the experimental group and the academic achievement scores of the students in the control group. However, after the applications, it was revealed that the academic achievement of the students in the experimental group in the post-test was higher than the students in the control group. This result can be interpreted as an indicator of the effect of the mathematics software GeoGebra on academic achievement. In addition, it was observed that there was a significant increase in the post-test scores of the teaching applied to the students in the experimental group compared to their pre-test scores. Another reason why Dynamic Geometry Software [DGS] can increase student success is that it provides students with exciting, interesting, and visual learning. For example, according to Büyüköztürk (2007), due to the nature of the quasi-experimental research design, if the experimental and control groups are equal at the beginning of the application, one of the reasons for the difference between the post-tests is the experimental procedure applied. In parallel with the results of this research, similar results have emerged in studies conducted in previous years (Aydoğan, 2007; Filiz, 2009; Memişoğlu 2005; Yenilmez and Karakuş, 2007; Tutak and Birgin, 2008; Tutak, 2008; Vatansever, 2007). Filiz (2009) investigated the effect of DGS such as GeoGebra and Cabri Geometry II on student achievement, and at the end of the research she concluded that the students who study with the prepared web-supported material have a more effective learning compared to the students who receive traditional education.

Another important feature of this research is that it was conducted with a student-centered education-teaching approach. Both in this research and in other research in the literature, it was concluded that student-centered activities increased the mean scores of the students. In the study conducted by Ünlü (2007), the effect of web-based education which was developed according to the theory of education by problem solving and discovery on student success was examined. As a result, it was observed that the education applied in this student-centered research had a positive effect on student achievement. In the study conducted by Vatansever (2007), the effect of learning the seventh-grade geometry subjects in primary education with DGS on success was examined and similarly positive results were obtained.

When the results for the sub-problems of the research were examined, there was no difference between female students and male students in terms of gender either before or after the research. However, when evaluated in terms of

students in the experimental group, it was concluded that the academic achievement scores of male students were significantly higher than the scores of female students. Like this study, studies conducted by Aktümen and Kaçar (2008), Vatansever (2007) and Erden (1995) revealed that the gender variable did not have any effect on academic achievement. However, some studies have revealed that gender influences academic achievement. In the study conducted by Tosun (2006), there was no difference in terms of success between female students and male students in the pre-test for the Word program before the six-week training. However, female students were seen to be more successful than male students in the post-test at the end of the training. In the study conducted by Serin (2010), a difference was found between male and female students in terms of gender. The reason for this difference between the studies might be due to the age ranges of the students and the geographical location they live in. In the study conducted by Tosun (2006), the sample of the research consisted of 94 second-year students in the Department of Primary Education, Faculty of Education, Trakya University. In the study conducted by Serin (2010), the sample of the research consists of seventh grade students in secondary school who are educated in a township. Within the scope of this research, high school students living in Ankara constitute the sample of the research. Therefore, both the age levels of the students and the geographical location where they were educated may have caused the difference between the research results.

Considering the limitations of this study and the results obtained, the following recommendations can be made:

- This research was applied to 12th grade students in Ankara regarding the subject of dynamic place problems. Therefore, the results of this research could not be generalized to different education levels and different subjects. However, by using similar research methods, it can be investigated to what extent student achievement is affected by applying the research to other subjects in the mathematics course.
- This research took three weeks in total. The training process given in other studies may be spread over a longer period.
- A wider research can be done by increasing the number of activities and topics included in the application.
- In future studies, the effect of learning on permanence can be examined by applying a permanence test.
- As a result of the research, the effects of the education process on the students can be examined by taking the opinions of the students.
- In addition to the learning environment in which DGS is used, the research can be expanded by including the web-supported learning environment within the scope of the research.

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Conflict of interest

The authors declare that there is no conflict of interest.

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