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A STUDY ON THE VIEWS OF GRADUATE STUDENTS ON THE USE OF GEOGEBRA IN MATHEMATICS TEACHING

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Abstract:
In this study, it was aimed to determine the views of graduate students on mathematics learning with dynamic mathematics software GeoGebra. Case study method was used in qualitative research patterns. The study group consists of 7 graduate students who were doing their degrees at the Education Faculty of a state university in Turkey. Data were collected with observations, models on the GeoGebra screen made by the students, dynamic worksheets and a semi-structured questionnaire consisting of open and closed ended questions developed by the researcher. The findings show that "visualisation", "ease of use", "motivation", "rich content", "competence", "conceptual learning" and "algebraic thinking" are the themes in the competence of the learning environment created by GeoGebra. In particular, "visualization", "ease of use" and "rich content" themes play a key role in the clarity of "motivation" theme. In addition, the construction protocol and the text tool are effective in gaining the skills of algebraic thinking, while the construction protocol, visualization and concretization features are effective in their conceptual learning. "Simulation" and "content" themes are prominent in the student's views regarding the effective use of GeoGebra in mathematics courses.

Keywords: mathematics teaching, GeoGebra dynamic mathematics software, algebraic thinking, conceptual learning

1. Introduction

The creation of innovative and rich learning environments for effective and permanent learning in mathematics teaching is an inevitable phenomenon in the world and in Turkey. For the past twenty years, the literature of mathematics education has recorded many studies showing that the use of information and communication technologies with appropriate pedagogy has improved and enriched the process of teaching mathematics (Yorganci, 2014). Among these technologies are computer algebra systems

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(CAS) and dynamic geometry software (DGS) as two important technological platforms used in learning-teaching processes. DGS allows to explore mathematical concepts created by defining dependent and independent objects by observing the changes in the object resulting from the dynamic movements of the independent object (Atay, 2015) while CAS have the ability to draw graphs of numerical, symbolic, and several variable functions (Aktümen & Kaçar, 2008). In particular, GeoGebra software, which combines DGS and CAS features, draws attention as an important learning environment used at all levels from elementary. GeoGebra is a software used in geometry, algebra and calculus learning (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008), and is used as a versatile tool in visualizing and concretizing mathematical concepts (Hohenwarter & Jones, 2007). According to Hähkiöniemi (2017), GeoGebra is an important program that contributes to students' understanding of conceptual and operational problems and is effective in the teaching of mathematics based on inquiry. It combines the characteristics of different mathematical software, ease of use and open source structure among the important reasons for GeoGebra's spread among teachers and researchers around the world (Diković, 2009).

Research in Turkey on this subject, the use of GeoGebra in mathematics course reveals that it can contribute positively to students: visualization (Kutluca & Zengin, 2011; Yıldız, Baltacı & Aktümen, 2012), making mathematical thinking easier (Baltacı, Yıldız & Köse, 2015), motivating the student (Er & Kaya, 2017; Horzum & Unlü, 2017), ease of use (Baydaş, 2010; Er & Kaya, 2017; Zengin & Tatar, 2014) and construction knowledge (Baltacı & Baki, 2017; Kutluca & Zengin, 2011). For example, Zengin (2015) found that GeoGebra software in a collaborative learning environment helps students improve their social and communication skills while increasing their self-esteem, interest and motivation. In another study where similar results were obtained, GeoGebra software has shown that it provides students with an environment of discussion and cooperation (Zengin, 2017a) that directly contributes to the provision of mathematical communication. Delice and Karaaslan (2015) have determined that the GeoGebra software, which is used in math classes with appropriate and effective methods, can contribute positively to the students' conceptual learning processes. On the other hand, Öçal (2017) states that GeoGebra contributes significantly to the students' conceptual learning and does not have a significant impact on their operational knowledge.

When the literature on the use of GeoGebra in mathematics course is examined, the GeoGebra activities in the application process are often presented as worksheets prepared by teachers or dynamic GeoGebra materials created by students. A limited number of studies (Bulut & Bulut, 2011) using "dynamic worksheets" as an interactive learning tool have been achieved in Turkey. Dynamic worksheets, interactive html pages created in GeoGebra, are applications that are independent of the program itself, which can be used with any browser that supports Java (Hohenwaster & Fuchs, 2004). The lack of the need to have GeoGebra installed on the computer in order to use dynamic worksheets is one of the key advantages of the program. According to Ljajko and Ibro (2013), in order to achieve better results in the learning environment created with GeoGebra, dynamic worksheets that help students with minimum level of help and that enable them to "explore" mathematics should be prepared to demonstrate the most important features of the subject taught by the teacher. In this study, dynamic worksheets were used in experimental process in accordance with the purpose of the research. A new and interactive learning environment with GeoGebra (Bulut & Bulut, 2011; Hohenwarter, 2004) as a tool for developing and exploring mathematical experiences (Hohenwarter & Preiner, 2007) through the dynamic worksheets were prepared by the students themselves.

This study separates from other studies in this field in terms of GeoGebra activities used in experimental studies as well as in terms of the study group. When the relevant literature is examined, it is observed that the research group was selected from primary school to undergraduate level (Aydos, 2015; Baltacı & Baki, 2017; Er & Kaya, 2017). However, in terms of students studying at the academic level, the GeoGebra program should not be overlooked and examined. Therefore, the study aims to evaluate the graduate students' views on mathematics learning with GeoGebra, dynamic mathematics software. Depending on the purpose of the study, the following sub-problems are included:

1. What are student opinions about the adequacy of the learning environment created with GeoGebra?
2. What are the student's views on the effective use of GeoGebra, dynamic mathematics software, in mathematics course?

2. Method

2.1. Research Design

Case study method was used in the research. "Factors related to a case study (environment, individuals, events, processes, etc.) were investigated with a holistic approach and focused on how they affect the situation and how they are affected by the situation" (Yıldırım & Şimşek, 2013: 83). As stated in the introduction of the research, it is inevitable to create innovative and rich learning environments for effective and permanent learning in mathematics teaching. In this context, the basic details about the efficiency of a dynamic learning environment in mathematics teaching constitute the situation discussed in the research.

2.2. Sampling

The study group consists of 7 graduate students who were doing their degrees at the Education Faculty of a state university in Turkey. The participants selected for the sample are 2 girls and 5 boys. All of the participants with age range of 24-26 are students enrolled in the Department of Mathematics Education Program and are continuing to the course.

2.3. Instrument

The data in the study were collected with observations, models on the GeoGebra screen made by the students, dynamic worksheets and a semi-structured questionnaire consisting of open and closed ended questions developed by the researcher. At the end of each course, the researcher wrote down the situations that the students experienced during the course and noted the positive and negative steps that each student encountered on the computer screen. In addition, students were asked to record the applications they have made on the GeoGebra screen and the steps they have taken with the construction protocol have been reviewed in detail. In particular, screenshots have been seen as an important source of data for students to reflect the information configuration process step by step. Another data collection tool used to determine students' views on mathematics learning with GeoGebra is a semi-structured questionnaire. While preparing the form, a field type scan was performed and expressions to be used in the form were determined. The questions in the form were prepared to collect information about the sub-problems of the research.

After the draft questionnaire was prepared, two measurement evaluation experts with doctor title and two teaching staff working in mathematics education were presented to the opinions of the professors in order to ensure the validity of the scope. In line with the opinions of the experts, after making the necessary adjustments in question statements, the evaluation form has been given the final form.

The developed questionnaire consists of two parts. In the first part, personal information the second part includes questions about students ' views on learning mathematics with GeoGebra.

Students participating in the study "1S, 2S, 3S,.." it is coded in the form of. Sample expressions reflecting students' opinions are presented in quotes.

2.4. Processes

3 hours a week, 14 weeks a total of the first two weeks with a dynamic mathematics and geometry program, GeoGebra software, presentation of the program on the use of mathematics teaching applications were shown to the participants. In the computer laboratory, applications related to the subjects were carried out step by step and various basic applications were made from simple to complex by giving the participants the opportunity to recognize the program.

In accordance with the purpose of the research, GeoGebra applications related to calculus concepts which can be visualized in two or three dimensions, such as Riemann sums, definite integral, area between curves, volume of solid revolutions and arc lengths of plane curves were transferred to the HTML page and dynamic worksheets were produced. Thanks to the students' dynamic worksheets on the internet, GeoGebra has introduced a new and interactive learning environment (Bulut & Bulut, 2011; Hohenwarter, 2004). Some screenshots of the students' sample applications are given in Figure 1.

In the use of the GeoGebra program, students are given detailed information about the "Text tool" which is thought to have an important place especially in algebraic learning. In applications such as the calculation of the area between two curves or the volume of the object formed by rotating around the x and y-axis of a curve, working text box elements connected to the generated slider allow the synchronous monitoring of both algebraic and geometric changes of the desired concepts. Therefore, in applications, students used algebra window, graph window and 3D graph window at the same time as required. Thus, they can examine algebraic and geometric properties of concepts in detail. In this process, students used the construction protocol to repeat the samples, so that they had the opportunity to build concrete experiences by configuring the relevant concepts.

On the other hand, in order for the participants to be able to use the program more efficiently, the materials published on the GeoGebratube website are examined and they are intended to create a richer application library. Towards the end of the last week, the participants themselves have tried to explore the different features of GeoGebra by doing a sample practice on the outside, and they have created different ideas by sharing these practices with their friends in the laboratory environment.

At the end of the experimental process, an evaluation form developed to determine the views of mathematics learning with GeoGebra was applied.

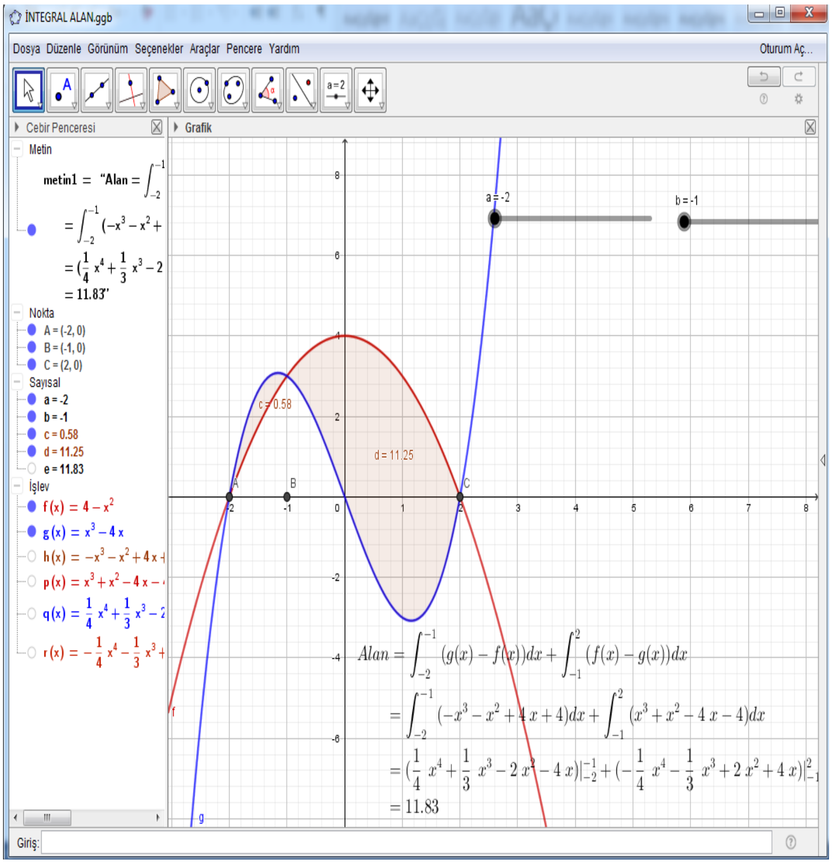
2.5. Data Analysis

The data obtained in the study were analyzed by means of content analysis method. In content analysis, similar data are gathered around specific concepts and themes and interpreted in a way that the reader can understand (Yıldırım & Şimşek, 2013: 259). In this context, the data obtained from the questionnaire were examined and the codes were formed. After the encoding process, the common features used by combining the codes have been determined.

To ensure the reliability of the research, the compatibility of the themes and codes of these themes was once coded by a second person other than the researcher, and the consistency calculation between the two coding was calculated using Miles and Huberman's (1994) formula.

Percent of consensus = consensus / (consensus + disagreement) x 100

According to Miles and Huberman (1994), the percentage of alignment is at least 70% indicates reliability. As a result of this study, there was an 82% consensus on the appropriateness of coding, and reliability was ensured in terms of data analysis.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Dosya Düzenle Görünüm Seçenekler Araçlar Pencere Yardım
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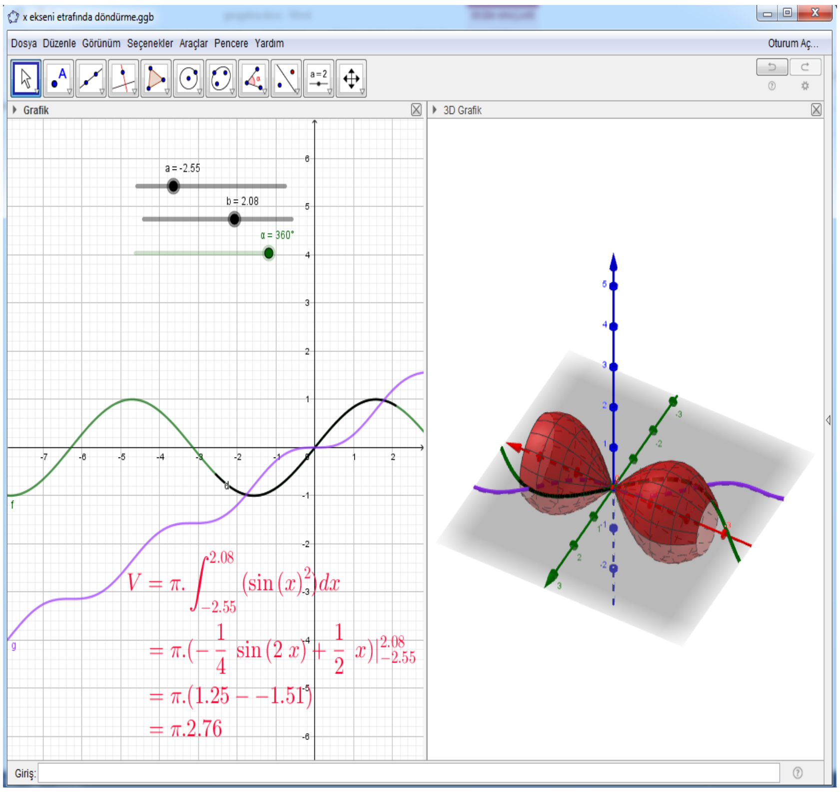
Cebir Penceresi
Grafik
Metin
Nokta
A = (-2, 0)
B = (-1, 0)
C = (2, 0)
Sayısal
a = -2
b = -1
c = 0.58
d = 11.25
e = 11.83
İşlev
f(x) = 4 – x²
g(x) = x³ – 4x
a = -2
b = -1
c = 0.58
d = 11.25
Alan = ∫₋₂⁻¹ (g(x) – f(x))dx + ∫₋₁² (f(x) – g(x))dx
= 11.83
Giriş: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a = -2.55
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α = 360°
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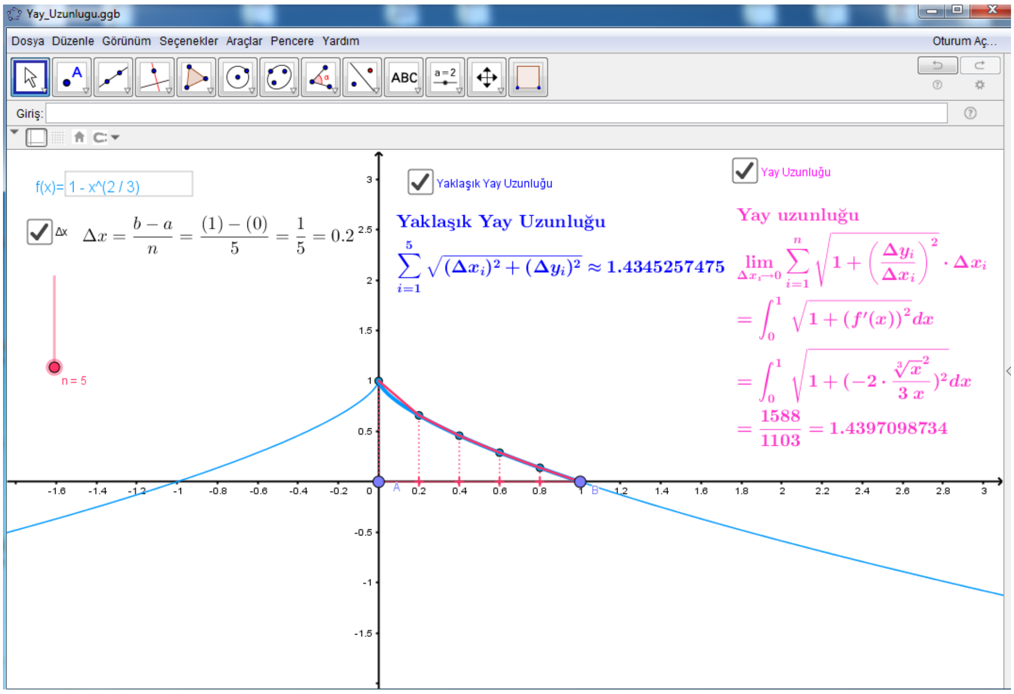

Figure 1: GeoGebra dynamic worksheets

3. Results and Discussion

The main themes of the study and the sub-themes of these themes are presented in Table 1, so that a large number of data can be summarized and the data can be easily understood (Miles & Huberman, 1994).

The results and frequencies of each research problem are classified as Table 2 and Table 3 respectively.

Table 1: The main themes and the sub-themes

Sub-problems	Themes	Sub-themes
Opinions on the adequacy of the learning environment created by GeoGebra	Visualization	Dynamic structure, Concretization, Appropriateness to individual learning,
	Ease of use	Construction protocol, Turkish language support, GeoGebratube
	Motivation	Self-confidence, Increase learning desire, Use of advanced technology
	Rich content	Visual elements, GeoGebratube, Dynamic worksheets
	Competence	Computer literacy, Technical competence, Alienation to mathematical software
	Conceptual Learning	Construction protocol, Visualization, Concretization
	Algebraic Thinking	Algebra window, Text tool, Construction protocol
Views on the effective use of GeoGebra	Simulation	Rich content, Visualization
	Ease of use	Short symbols, Text tool
	Motivation	Construction protocol, Simulation, Animation
	Contents	Visual elements, Concrete elements, GeoGebratube

When the participants' responses to the first sub-problem of the study are examined, the themes included in Table 2 are the weight. The dimensions of “visualisation”, “ease of use”, “motivation”, “rich content”, “competence”, “conceptual learning” and “algebraic thinking” in the competence of the learning environment created by GeoGebra are the themes that are frequently emphasized by the students. Responses show that visualization, ease of use and rich content themes play a key role in the engagement of motivation. In particular, the GeoGebratube website has emerged in both rich content and ease of use.

Table 2: Opinions on the adequacy of the learning environment created by GeoGebra

Themes	Sub-themes	Frequency
Visualization	Dynamic structure	7
	Concretization	6
	Appropriateness to individual learning	4
Ease of use	Construction protocol	5
	Turkish language support	6
	GeoGebratube	3
Motivation	Self-confidence	4
	Increase learning desire	5
	Use of advanced technology	5
Rich content	Visual elements	7
	GeoGebratube	3
	Dynamic worksheets	5
Competence	Computer literacy	3
	Technical competence	2
	Alienation to mathematical software	4
Conceptual Learning	Construction protocol	5
	Visualization	7
	Concretization	6
Algebraic Thinking	Algebra window	5
	Text tool	5
	Construction protocol	4

Participants' responses indicated that GeoGebra was an effective learning tool: *“Technology has an important place in education, as the development of modern technology and the curiosity of the next generation of students is more concerned with technology. With this program, students with visual perception can be more interested in the course”* (4S). *“The program can easily be used in mathematics teaching in schools. The student can meet a new world in mathematics - the concrete world - with this program. More comprehensive than similar programs. Since it is easy to use and Turkish, it is possible to use students at all levels”* (1S, 2S). *“Thanks to the construction protocol, we can configure pre-prepared applications without the need for a teacher by reviewing them step by step. This is a great opportunity for the student”* (1S, 5S, 6S). "*I use GeoGebratube as a tool to answer all my questions. Interesting* *examples exist in*" (3S, 7S). "I think t*he stage of preparing dynamic worksheets is the stage in which concepts are learned*" (2S, 4S, 7S).

It has been observed that the theme of "conceptual learning" which is associated with the sub-themes of construction protocol, visualization and concretization has been addressed by close to all of the students: "*the construction protocol and graphic windows are important in the more meaningful and concrete learning of concepts*" (1S, 2S, 5S). They have emphasized the idea that they base this theme with expressions such as "*these visual tools*" (4S, 7S), that they are learning to see the prerequisite relationships of concepts and the pre-requisite concepts.

In response to the "algebraic thinking" theme, the algebra window, the construction protocol and the text tool are effective: "*when creating dynamic text, we need to make an important effort to express the problem situation with mathematical symbols. But I think this is the most important step in problem solving*" (4S). "*The text box and the construction protocol are important in the use of symbols and algebraic relations. I think the construction protocol contributes to the capacity to re-create relationships*" (1S, 6S).

The disadvantages of the computer-based learning environment created by GeoGebra are concentrated in the context of competence. "*Possible problems that students with low computer literacy will experience in the process of writing mathematical symbols and creating a text box*" (3S, 4S, 5S) emerged as the most important drawback of GeoGebra.

When the answers to the second sub-problem of the study were examined, the themes included in Table 3 appeared.

Table 3: Views on the effective use of GeoGebra

Themes	Sub-themes	Frequency
Simulation	Rich content	5
	Visualization	7
Ease of use	Short symbols	5
	Text tool	4
Motivation	Construction protocol	4
	Simulation	6
	Animation	6
Contents	Visual elements	4
	Concrete elements	4
	GeoGebratube	1

The participants draw attention to content and simulation themes in the effective use of GeoGebra in math class. Content theme, visual elements reveal tangible elements and GeoGebratube features, while simulation theme focuses on rich content and visualization sub-themes. It is important for the participants to be able to represent the topics selected in the effective execution of the computer-based learning environment created by GeoGebra with visual and concrete elements. The answers point out that in order to create rich learning environments in math class, GeoGebra should be considered as a program that bridges geometry and algebra by combining the features of computer algebra system (CAS) and dynamic geometry software (DGS). "*working alone with the algebra window prevents effective learning of subjects. Students who follow the changes in the 2D and 3D graphics window of mathematical elements that can be moved dynamically with sliders can find the possibility to configure concepts that form solution steps step by step in the text box*" (1S, 2S, 5S, 6S). "*Meaningful and permanent learning can occur when mathematical concepts are represented in 2D and 3D windows in a visual and concrete way*" (1S, 3S, 5S, 6S, 7S).

On the other hand, one of the important points that the participants draw attention to is that the simulation and animation examples created in the GeoGebra will contribute to the motivation of the student. "*The student, who has the opportunity to practice with simulations, can also switch from abstract world of mathematics to everyday life*" (1S, 2S, 4S, 5S, 7S) with animation applications.

A major problem with GeoGebra is the definition of mathematical objects and algebraic representations in the input bar and text box. During the application process, it was observed that participants had difficulty writing algebraic entries in the input bar and in the text box correctly or completely for applications such as surface area, rotation around axes, volume calculations. For this reason, effective use of GeoGebra Text tool and algebraic representation aid has emerged with ease of use theme.

4. Conclusion and discussion

In this study, where the views of graduate students on learning mathematics with GeoGebra were investigated, the participants' responses were that GeoGebra was an effective learning tool. Visualization, ease of use, motivation, rich content, competence, conceptual learning and algebraic thinking are the themes that are frequently emphasized by students in the competence of learning environment created by GeoGebra. The findings are similar to the findings obtained from the studies in this area (Arbain &. Shukor, 2015; Bakar, Ayub, Luan, & Tarmızı, 2010; Baltacı & Baki, 2017; Baltacı, Yıldız & Kösa, 2015; Baydaş, 2010; Er & Kaya, 2017; Horzum & Unlü, 2017; Kutluca & Zengin, 2011; Yıldız, Baltacı & Firmü, 2012; Zengin & Tatar, 2014).

In response to the first sub-problem of the research, motivation was found to be one of the main competencies of the learning environment created by GeoGebra. Responses show that visualization, ease of use and rich content themes play a key role in the engagement of motivation. When students started using the GeoGebra software, they preferred to work more individually and created an individual learning environment. Since GeoGebra software is suitable for individual learning, it is an issue that arises in responses to which the student develops his / her confidence and develops a more positive attitude towards the course. Er and Kaya (2017) stated that the materials prepared in the GeoGebra environment could increase the motivation of the students in a positive way, and that they could influence their attitudes towards mathematics in a positive way and that they could love mathematics. As Er and Kaya pointed out, GeoGebra software can be said to be a program that supports individual learning, increases student self-confidence, contributes positively to student motivation, and changes the perspective of the course in a positive way.

Under the theme of conceptual learning, the construction protocol of GeoGebra software, visualization and concretization features have been the most emphasized points in the research. Since the relationships between the interactive construction protocol and the concepts were clearly revealed, students attempted to associate "*new information with the old knowledge*", "the group with the meaning of the concept itself" (Soylu & Aydın, 2006). In particular, the two-and three-dimensional graphic representations of the concepts in the dynamic structure and the dynamic transitions of these representations have enabled them to construct their knowledge and explore the concepts. Studies show that using GeoGebra contributes positively to students' conceptual learning processes (Delice & Karaaslan, 2015; Er & Kaya, 2017; Öçal, 2017; Tatar & Zengin, 2016; Zengin, 2017b). Based on the findings, it can be said that GeoGebra software helps students learn conceptually through its construction protocol, visualization and concretization features.

Responses to the "algebraic thinking" theme have shown that the algebra window, the construction protocol and the text tool are effective. Although algebraic thinking is related to algebra, it has a more comprehensive meaning in the sense of algebraic term (Çelik, 2007). Herbert and Brown (1997) defined algebraic thinking as "*is using mathematical symbols and tools to analyze different situations by representing that information with mathematically in words, diagrams, tables, graphs and equations, interpreting and applying mathematical findings such as solving for unknowns, testing conjectures and identifying functional relationships.*" Research to generalize, formulate and symbolize basic algebraic thinking skills (Çelik, 2007; Gülpek, 2006; Kaput, 1998; Kieran, 1992) classify as. It has been observed that students try to express knowledge with mathematical tools and define functional relationships with applications such as iterating step by step, adding new construction steps or moving a step to other positions when necessary by using the construction protocol in their activities. They also worked with the text tool on the application and interpretation of mathematical findings. Given observations and responses to a semi-structured questionnaire, applications with the construction protocol and the text tool may be considered as an effective tool for gaining core skills such as generalization, formulation and symbolization of students ' algebraic thinking ability.

On the other hand, the most important disadvantage of the learning environment created by GeoGebra was that students who are low in computer literacy or who are unfamiliar with mathematical software have difficulties in writing mathematical symbols and creating text boxes. According to Agyei and Benning (2015), the factors that prevent math teachers from using GeoGebra in their classes are the lack of computer literacy skills for students, as well as technical problems such as time constraints, power failure or irregular internet access. The researchers stated that teachers who want to carry out the GeoGebra-based mathematics course should spend more time developing their designing skills in this new environment.

In response to the second sub-problem of the research, suggestions for simulation, ease of use, motivation and content in the use of GeoGebra effectively in mathematics class are drawing attention. According to Zimmerman and Cunningham (1991) who advocate that visual approaches should be used in teaching as mathematics is related to visual items, students should learn how mathematical concepts can be represented numerically, symbolically and graphically and transitions between these representations. In this way, they learn the concepts deeply and comprehensively and find the opportunity to produce creative and innovative ideas to solve problems. According to Baltacı and Baki (2017), the teacher candidates have the opportunity to configure their knowledge through multiple representations of the GeoGebra software that present both the algebra and the graphics screen together. In this study, it was observed that the participants tried to reinforce the more meaningful and effective learning of mathematics in the computer based learning environment created by GeoGebra with the themes of "*representation of the content with visual and concrete elements*".

As a result, the results of the study indicate that GeoGebra software can be used as an effective tool in teaching mathematics. According to the results, it was determined that the inclusion of GeoGebra software in mathematics course positively reflected students' algebraic thinking skills, conceptual learning and motivation levels. In the learning environment created by GeoGebra software, it is important for students to observe the visual features and algebraic features of the software at the same time so that they can learn mathematical concepts deeply and comprehensively. For this purpose, it is essential that students use algebra window and two-and three-dimensional graphic windows with sliders and text tool for similar research. In addition, improvements have been made in terms of expressing information with mathematical tools and defining functional relationships with the construction protocol. In this case, it has been determined that GeoGebra software can be effective in gaining algebraic thinking skills. Similar to this work, qualitative and quantitative studies on conceptual learning and algebraic thinking on the use of GeoGebra more effectively in mathematics course can open horizons to new and effective ideas in the learning process.

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