A Usability Study of Dynamic Geometry Software's Interfaces

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Abstract. The use of information technology such as dynamic geometry software in mathematics teaching has become more popular and essential. There are several benefits of using this software. In spite of the benefits, they have some difficulties in terms of usability, so users have some problems while using them in learning mathematics. The purpose of this study is to investigate the usefulness of these software interfaces. For this purpose, firstly, we selected two dynamic geometry software. One of them is GeoGebra and the other one is Geometer' Sketchpad. After selecting, 6 tasks designated using this software. In usability test, the participants tried to do task. While doing the tasks, in order to analyze the process, the participants were observed and their eye movements were recorded with eye tracker system. Then their opinions about software asked. Finally all data were analyzed, and discussed.

Keywords: GeoGebra, Geometer's Sketchpad, Usability, Eye Tracking.

1 Introduction

The computer is a powerful and helpful tool in teaching and learning mathematics [10]. With multimedia capabilities, students are able to visualize mathematical concepts which are difficult using traditional methods [5]. There are a lot of powerful software which can be used in classroom teaching such as Logo, Geometer's Sketchpad, Cabri, Derive, Mathemetica and GeoGebra. In the recent years, a number of studies in which dynamic mathematics software GeoGebra and Geometer's Sketchpad are used are seen in the literature. One of this software, GeoGebra can be defined as a software program that was e designed to combine geometry, algebra, and calculus in a single, dynamic geometry [10]. The other software; Geometer's Sketchpad uses exploratory in mathematics. This software allows teachers and students to use the construction and the animation of an interactive mathematics model [7]. There are several benefits of using this software. Previous studies show that the teaching materials, which prepared with GeoGebra, are more successful than traditional method [11]. Other study indicates that teaching the subject of symmetry with GeoGebra is enabling students to teach the subject better [1]. The other study about Geometer's Sketchpad shows that the use of interactive multimedia increases student attention and understanding of mathematics [7].

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2 Research Questions

There are a few studies on usefulness of this software. Dynamic geometry software has some difficulties in terms of usability, so users have some problems while using them in learning mathematics. The purpose of this study is to investigate the usefulness of these software interfaces. For this purpose, we selected two popular dynamic geometry software. One of them is Geogebra which of most features are free and it is open source and written in Java and thus available for multiple platforms [4]. The Geometer's Sketchpad is a popular commercial interactive geometry software program for exploring Euclidean geometry, algebra, calculus, and other areas of mathematics [9].In this study; we will try to find answers of questions: (i) What are the major problems when using these software interfaces? (ii) How much time the user spent for doing a basic task? (iii) Is there any difference doing basic or complex task? (iv) Is there any difference doing same task while using different software?

3 Methodology

The model of this survey is an end-user based research model. At this research, the steps were followed according to this model.

Apparatus. Our study was carried out at the HCI Research and Application Laboratory at the Middle East Technical University. In this laboratory, the devices enable to monitor screen shots on the computers. To record eye movements a Tobii 1750 Eye Tracker System was used. The Tobii 1750 Eye Tracker software provides a video of screen records, watching and analyzing these videos, participants behaviors' observed. Moreover, the records of Eye movements' data analyzed.

The Participants. Our population in this study was six end-users who are research assistant in Middle East Technical University. All of them were female and were at 23, 23, 27, 28, 29, 32 ages (M=27). Two of them were at PhD and the others were at master degree (M=1, 33). The degree of computer usage of this participation was advance (M=6, 83). Half of the participations have experience of using GeoGebra (M=2). However, the others have not any experience. On the other hand, two of them have no experience of using Geometer's Sketchpad, the others have (M=1, 83).

The Tasks. In usability test, 6 specific tasks were done by using GeoGebra and Geometer's Sketchpad. Two of them were easy, two of them had medium degree of difficulty and two of them were difficult. First two of them were basic task. After doing these basic tasks, the difficulties of other tasks increased. (Table 1).

The Application. In application step, we collected data while users do the tasks, the participants were observed and their eye movements were recorded with eye tracker system and they were asked to their opinion about software, giving a questionnaire which consists of 40 questions about each software. It asks users' opinion about the appearance of the interface and the terms which used in the program, and the learning of the system usage. Also this questionnaire was in the users' native language (Turkish). In addition to this questionnaire, we applied John Brooke's System Usability Scale (SUS).

"SUS can be used on very small sample sizes (as few as two users) and still generate reliable results." [8]. We asked 10 item questionnaire which were in Turkish with 5 response options. For each item users gave one response. These two questionnaires were translated from English to Turkish by Kürşat Çağıltay [3].

The Criteria. The other step was that we determined criteria for analyzing the results. Although there were a lot of criteria which used to evaluate systems' usability, we took into consideration Nielsen ten user interface design criteria [6].

Table 1. Tasks

Task 1:	Draw any triangle, show its angle and edge length and add any edge length of this triangle.
Task 2:	Draw any irregular polygon, show its angle and calculate its circumference and area.
Task 3:	Draw a straight line passing through the A (5, 0) and B (0, 2) points and indicate the equation of the line.
Task 4:	Draw a graph of the equation $y = 3x^2+5$.
Task 5:	$f(x) = 2x^3-x^2+6x+4$ Take the derivative of the function. Draw a graph of a derivative.
Task 6:	Draw any circle; calculate its circumference, the radius and area. Create a table of values found by changing the radius of the circle. Draw a graph from the data in this table.

4 Results and Discussion

Qualitative Results. We observed participants and noticed some problems about this dynamic geometry software. The main problem with GeoGebra was not finding and opening "Input Help". The other problem was finding any function under menu options. The icon of "Input Help" menu was not visible and easy to click. Half of the participants opened and used this menu incidentally or they had experience for click and opened it. The other problem was data transferring between windows. Two of the participants tried to transfer input data to from "Algebra" to "CAS" but she did not. And another participant tried to transfer data from "Graphics" to "Spreadsheets", after lots of mouse click she did. The other problem was about error messages which only show errors but not give the correct type or any hints. The other problem was no instruction for using tools. Another problem was that about right click menu options. Some of participants tried to use right click for calculating area and circumference but GeoGebra did not allowed this. Last problem with GeoGebra which we observed was that "CAS" tools were not enough for using easily. One of the participants indicated that learning usage of this software takes long time and its menu was complex and remember the steps were not easy. The main problem with Geometer's Sketchpad was about instructions place on interface. The participants could not recognized instructions while doing the tasks. Instructions are bottom of the page and not recognizable. The other problem was about selecting the objects. The participants had difficulties while calculating and showing the angle. Another problem was menu's classifications of properties and functions. For example; one of the participants looked "Construct" menu for creating table. But she could not find it under "Construct" menu, she find it under "Number" menu. One participant indicated that there were not enough error messages.

Quantitative Results. Firstly, we compared fulfillment of the tasks in this dynamic geometry software. All tasks were completed by all participants using Geometer's Sketchpad. However, Task 6 was not completed by the half of participants using Geogebra. Secondly, we got time to first fixation, total visit duration, mouse click count, and time to first mouse click records of the participants by Tobii software. We calculated the time to first fixation for each task for each software and analyzed the average time to first fixation. We attended to total visit duration time for each task completion. And we calculated mouse click count for each task comparing the software. This gives information about the amount of steps. Lastly, we calculated time to first mouse click for each task. To compare the results we used Paired-Samples t-test for a task which was completed by using this software. We implemented 24 paired samples t-test for the results of Tobii records. We analyzed that there was no big differences for this data. Time to first fixation and time to first mouse click was similar for this software. The results were $p>0.05$ so this results were not meaningful. On the other hand, total visit duration and mouse click count for each task showed differences. Total visit duration for Task 1 in GeoGebra (M= 115, 6283, SD=72, 58297), for Geometers' Sketchpad (M=187, 1700, SD=75, 72062). Paired Samples t-test $p<0.01$. Total visit duration for Task 3 in GeoGebra (M= 25, 7617, SD=6, 92604), for Geometers' Sketchpad (M=54, 7717 SD=54, 7717). Paired Samples Test p<, 029. Total visit duration for Task 6 in GeoGebra (M= 679, 9283, SD=468, 29070), for Geometers' Sketchpad (M=159, 1317SD=32, 80426). Paired Samples t-test p<, 040. This results shows that Total visit duration in the task for Geometer's Sketchpad was longer than GeoGebra except from task 6. The reason of the task 6 was longer than the other was the participants had some problems while using the spreadsheets. And Task 6 was not completed by some participants because of this reason. Mouse Click Count for Task 1 in GeoGebra (M=41, 0000, SD=29, 09983), for Geometer's Sketchpad (M=106, 5000, SD=42, 49588) and $p<0.00$. Mouse Click Count for Task 3 for GeoGebra (M=7, 5000, SD=1, 87083), for Geometer's Sketchpad (M=20, 5000, SD=11, 29159) and $p<0.020$. This result shows that Mouse Click Count while doing a task using Geometer's Sketchpad was bigger than using GeoGebra. This means that users do much steps while using Geometer's Sketchpad. The other quantitative analyzed was done according to the questionnaire. The Paired-Sample t-test was used. The results of this test were that GeoGebra Average (M=6, 1917, SD=1, 80705), Sketchpad Average (M=7, 2208, SD=, 93640). Paired-Sample t-test p>, 05. So the differences are not meaningful as statistics. The last analyzed was done according the SUS. SUS is a reliable, low-cost usability scale that can be used for global assessments of systems usability [2]. The results of Sketchpad's SUS score (71, 66) was higher than GeoGebra's SUS score (58, 33). We investigated this difference and implemented Paired-Samples T-test for this SUS. We found that SUS Score for GeoGebra (M=58,333, SD=19, 5363) and SUS Score for Geometer's Sketchpad (71,667, SD=12, 2134) $p>0.05$. We concluded that this difference has no meaning as statics. Moreover, we decided to compare the questionnaire and SUS results. We analyzed the correlation between these results. First correlation was between SUS Score for GeoGebra and GeoGebra Average (data from questionnaire).The results were; $r = 0,930$ shows that there was a strong relation between our questionnaire and SUS Score for GeoGebra. $r = 0, 723$ shows that there was middle level of relation between SUS Score for Geometer's Sketchpad and Geometer's Sketchpad Average (data from questionnaire). The relation between Geogebra's data was stronger than Geometer's Sketchpad's data. The reason was the difference that limitations of participants size.

5 Conclusion

In this study, we aimed to evaluate dynamic geometry software interfaces. According to the results there are no big differences between GeoGebra and Geometer's Sketchpad in terms of usability. We cannot say that this software have major usability problem. Some of participants were familiar the usage of these software. This provides the adaptability of learning usage new functions. We answered the question was about how much time a user spent while doing a basic task. We observed that there were differences between basic and complex task. Complex task took long time and required much steps. In this study, we cannot make definitive judgments because of some limitations. The participants' size of the study was at the lowest limit of eye tracking studies. Our participants were specific group so reaching more participants was impossible. Future Studies should increase the number of participants to obtain reliable and definitive results. The other limitation was Tobii Eye Tracker Software blocked some functions of Geometer's Sketchpad. So, Task 3 was done again by the user. Finally, in a further study, the task should designed specifically and try to test all functions of the dynamic geometry software.

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