Utilization of GeoGebra in Mathematics Learning

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Abstract

The current digital era opens opportunities for educators to utilize technology in their learning activities. One computer program that can be utilized in mathematics learning is GeoGebra. GeoGebra is a dynamic program, with its various facilities, can be used as a medium for learning mathematics to demonstrate or visualize mathematical concepts and as a tool to construct mathematical concepts. This article presents a description of the GeoGebra program along with examples of GeoGebra application as a medium for learning mathematics.

***Keywords**:* GeoGebra, Mathematics, Learning

Introduction

Science and technology have been developing rapidly over time. In line with the advancement of science in the media and technology era, computer use has become increasingly widespread, not only in the workplace but also in education. This can help accelerate the development and utilization of information and communication media in education. Teachers are required to improve the quality of education and create effective and innovative learning environments. Currently, various technologies have developed that can be utilized to develop education, including supporting mathematics learning, namely as mathematics learning media. One of the learning media that has developed so rapidly is computers with various relevant programs.

As one of the learning components, media cannot be excluded from the overall learning system. The use of media should be a part that teachers must pay attention to in every learning activity. However, the reality is that this part is still often neglected for various reasons. Frequently arising reasons include: limited time for teaching preparation, difficulty in finding the right media, unavailability of funds, and others. This actually does not need to happen if every teacher has equipped themselves with knowledge and skills in learning media. In fact, there are many types of media that can be selected, developed, and utilized according to time conditions, costs, and desired learning objectives. Each type of media has certain characteristics that need to be understood, so that media can be chosen according to the needs and conditions in the field. Students will tend to be more interested in learning media that is easy to understand and contains animated images that attract attention [1].

The development of mathematical application software has been significantly produced, both free and paid. This gives consumers many choices. It would be unfortunate if these software programs are not utilized in learning mathematics, even though their use requires new knowledge. This should not be considered an obstacle but should be seen as a challenge. This challenge is also part of the competency demands that must be possessed in an era where almost

everything is connected with computer technology. Moreover, mathematics is an abstract science where its understanding still requires concrete things as a bridge to achieve abstraction. One of the computer programs that can be utilized as a mathematics learning medium is GeoGebra. With its various features, GeoGebra can be used as a mathematics learning medium to demonstrate or visualize mathematical concepts and as a tool to construct mathematical concepts.

The use of GeoGebra in mathematics learning needs to be considered by teachers, as many research results have recommended its use. Among them are studies conducted by Atikasari and [2] as well as [3] who used GeoGebra in Geometry materials. All these research results show that students' mathematical abilities improved or were better than students who received conventional learning.

This article presents a description of the GeoGebra program along with examples of GeoGebra's application as a mathematics learning medium.

Literature Review

The current development of information technology is increasingly rapid, and the need for information and data processing is very important. Such rapid technological development has an impact on all aspects of life [4]. In the education sector, for example, computer utilization has developed not only as a tool used for administrative purposes, but is also potentially used as an alternative in selecting learning media.

The existence of multimedia computers capable of displaying stationary and moving images (animations) as well as sound should now be used as an effective alternative for learning media. Such an approach needs to be positively received by teachers so that computers can become a medium that helps optimize learning in schools. It is expected to enhance teachers' skills in using applications to create multimedia-based teaching materials [5]. One of the key factors for the success of the learning process is the presence of learning media [6].

The use of computer-based learning media has advantages in influencing learning outcomes (Danny Abrianto, 2014). According to Simon [7] there are three models for delivering material in computer-based learning methods, which are as follows:

a. Practice and Drill. In this computer-based learning model, students are given questions or problems to solve, and then the computer provides a response (feedback) to the answers given by the students. This method is almost similar to homework assigned to students, where a teacher provides feedback. However, in computer-based learning, the feedback is provided immediately to each student, so they know exactly where their mistake is.
b. Tutorial. This computer-based learning model provides a complex learning design that contains learning materials, exercises accompanied by feedback.
c. Simulation. This computer-based learning model presents learning through a simulation system related to the material being discussed.

Various benefits of computer programs in mathematics learning were proposed by [8]. According to him, computer programs are ideal for learning mathematical concepts that require high precision, repetitive concepts or principles, and for solving graphics precisely, quickly, and accurately. Various computer programs have been developed and can be used in mathematics learning, one of which is GeoGebra.

GeoGebra was developed by Markus Hohenwarter (June 24, 1976) starting in 2001. He is an Austrian mathematician and professor at Johannes Kepler University (JKU) Linz. He is the head of the Institute of Mathematics Education.

GeoGebra is an abbreviation of geometry and algebra, but this program not only supports these two topics, it also supports many mathematical topics beyond them. According to Hohenwarter and Fuchs [9]. GeoGebra is a versatile software for mathematics learning in schools.

GeoGebra is a dynamic, free, and multi-platform mathematical software that combines geometry, algebra, tables, graphs, statistics, and calculus in one easy package that can be used for all levels of education. Dynamic means users can create interactive mathematical applications. Free means it can be used and duplicated at no cost and is open-source software, so anyone can modify or improve the program. Multi-platform means GeoGebra is available for all types of computers such as Windows, Mac OS, Linux, and others.
Several benefits of the GeoGebra program in mathematics learning are as follows:

a. Can produce geometric drawings quickly and accurately, even complex ones.
b. The presence of animation features and manipulative movements that can provide visual experiences in understanding geometric concepts.
c. Can be used as feedback/evaluation material to ensure that the geometric drawings that have been made are indeed correct.
d. Makes it easier to investigate or demonstrate properties that apply to a geometric object.

GeoGebra continues to undergo development. Its inventor and designers continue to work on improving and adding features to address any limitations of the GeoGebra program. Currently, GeoGebra 6 has emerged as an improvement and development from GeoGebra 4 and GeoGebra 5.
When first opening GeoGebra, an interface appears as shown in figure 1 below.

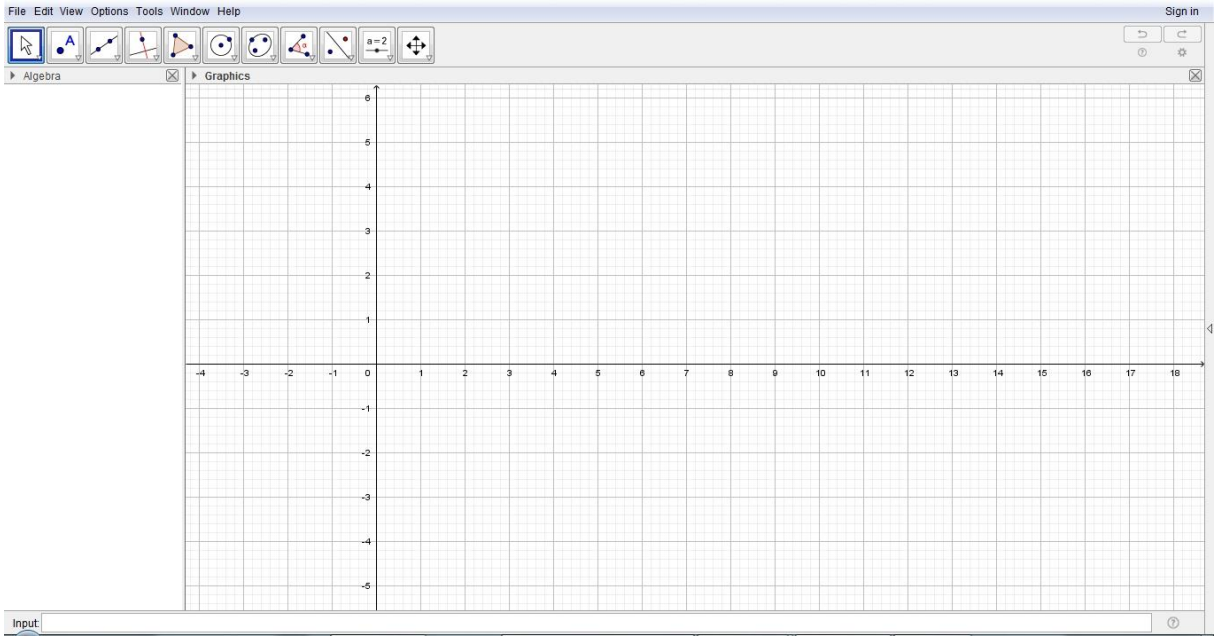

Figure 1. GeoGebra initial interface

As can be seen on the interface, there are two main sections: the algebra view on the left side and the graphics view on the right side. To switch to other view types, you can select options from the View menu. Sometimes on the right side, there is a Perspectives box. This box shows options for screen layouts that can be displayed. If this box is not visible, it can be shown by clicking the arrow mark indicated on the right side of the graphics area. There are six view options provided, which are:

a. Algebra and graphics view (Algebra), as shown on the screen beside. The left section, which is the algebra view, is where the algebraic form of the intended object/equation is displayed. The right section, which is the graphics view, is where the drawing or graph of the intended object/equation is displayed.
b. Geometry view (Geometry), is a graphics view that only displays the geometric form of the intended object/equation.
c. Spreadsheet view (Spreadsheet), is a display of a number processing table consisting of rows and columns. In this view, you can create matrices, tables, and other items that

contain mathematical objects in rows and columns. You can enter into spreadsheet cells not only numbers but all types of mathematical objects supported by GeoGebra, such as point coordinates, functions, and commands. When possible, GeoGebra immediately displays the graphical representation of objects you enter into spreadsheet cells in the Graphics View as well.

d. Computer Algebra System (CAS) view, is a computer algebra system display for symbolic calculations. This CAS view consists of rows where each row has input at the top and output display at the bottom.
e. 3D Graphics view (3D Graphics), is similar to the algebra and graphics view. The left section, which is the algebra view, is where the algebraic form of the intended object/equation is displayed. The right section, which is the graphics view, is where the 3-dimensional drawing or graph of the intended object/equation is displayed.
f. Probability Statistics view (Probability), is a statistical display format. In this view, we can see statistical distribution forms and perform statistical test calculations.

Research Methodology

The method used in this research was the systematic literature review method. A systematic literature review is a research method and process carried out by identifying, critically assessing, collecting, and analyzing data from relevant research to gather empirical evidence to answer specific research questions or hypotheses [10]. In this study, the authors searched for articles on using Geogebra in mathematics learning in the Neliti database, focusing on those published over this year, 2024.

The process of searching for articles analyzed in this study is from identification and eligibility assessment, to the final inclusion of studies for analysis.

a. Analysis
   These articles were identified based on keywords relevant to the research topic. This step aims to gather as many potentially relevant articles as possible, without initially evaluating their suitability in detail. The result of this stage is an initial pool of 2.050 articles.
b. Eligibility Assessment
   From the 2.050 remaining articles, only 34 were deemed eligible for further assessment. At this stage, articles are evaluated based on predefined inclusion and exclusion criteria. These criteria may include factors such as the type of study, the methodology used, the publication year, and the relevance of the topic to the research question.This eligibility assessment involves reading the abstracts, conclusions, or even the full text if necessary, to determine whether the article is truly relevant and suitable for analysis in the systematic literature review. In many cases, articles that are irrelevant or do not meet the criteria are excluded at this point.
c. After passing the eligibility assessment, only 15 articles from the 34 assessed were included in the final analysis. These articles represent the most relevant studies that met all the inclusion criteria set by the researchers. The included studies will beanalyzed in-depth, either qualitatively or quantitatively, depending on the review methodology used.

Results

The use of GeoGebra in mathematics education has seen a notable rise in recent years, as research continues to underscore the positive impact of educational technologies in the classroom. These selected studies provide a detailed and comprehensive insight into the diverse ways GeoGebra is being applied in educational contexts.

a. Impact of Technological and Informational Advancements on GeoGebra Utilization

The integration of GeoGebra aligns with global education reform that focuses on enhancing 21st-century skills such as critical thinking, problem-solving, and creativity. Education policymakers worldwide recognize the need to equip students with these skills to face an increasingly technology-driven world. GeoGebra supports this goal by encouraging students to explore and engage with mathematical ideas in ways that promote critical thinking and Higher Order Thinking Skills (HOTS). It provides a space where students can interactively investigate mathematical relationships, thus deepening their conceptual understanding.

b. Utilization of GeoGebra Across Educational Levels
GeoGebra's flexibility makes it suitable for various educational levels, from junior high school to university. Although most literature focuses on GeoGebra's application in teaching geometry and algebra, the software's capabilities also cover other areas such as calculus, trigonometry, and statistics. This flexibility positions GeoGebra as a valuable tool for teaching various mathematical concepts across different levels of complexity.

c. Benefits of GeoGebra in Mathematics Education
Multiple studies have highlighted the benefits of using GeoGebra in mathematics education. [11] reports that GeoGebra enhances students' learning outcomes, improves problem-solving skills, and boosts both motivation and interest in mathematics.It also helps students communicate their understanding of mathematical concepts more effectively by allowing them to visualize and articulate these ideas clearly.

d. Recommendations for Educators
Given the demonstrated benefits of GeoGebra in mathematics education, it is strongly recommended that educators at all levels—elementary, secondary, and tertiary—incorporate the software into their teaching practices. According to [12]. GeoGebra makes mathematics more engaging and interactive, which helps keep students motivated and interested in the subject.

Conclusion

GeoGebra is an effective and efficient tool to help visualize mathematical objects, especially for function and graph materials. Utilizing the GeoGebra program provides several advantages, namely: drawings can be produced quickly and precisely, GeoGebra can provide clearer visual experiences for students in understanding mathematical concepts, it can be used as feedback/evaluation to ensure that the drawings created are correct, and it makes it easier for teachers/students to investigate or demonstrate properties that apply to a mathematical object.
The GeoGebra program can be utilized as a mathematics learning medium. With its various facilities, GeoGebra can be used as a medium and tool in learning mathematics, especially geometry and algebra materials. GeoGebra is very useful for demonstrating or visualizing mathematical concepts and as a tool to help construct mathematical concepts.

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