

The Use of GeoGebra Software in Learning Quadratic Function Graph to Improve Mathematics Learning Outcomes of First-Year High school Students

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ABSTRACT: *GeoGebra's interactive and dynamic nature is a valuable tool for enhancing mathematics learning outcomes by improving students' understanding, engagement, and mathematical abilities, particularly in quadratic functions. By integrating algebraic and graphical representations and supporting exploration and problem-solving, GeoGebra helps make abstract mathematical concepts more concrete and accessible to learners. This research aims to determine the impact of GeoGebra as a learning medium on student learning outcomes related to quadratic function graph material. A quantitative research method was used, with first-year students from Al-Falah Islamic High School as participants. The instrument consists of validated test questions to measure student learning outcomes. The research design used is a One-Shot Case Study, a type of pre-experimental design. Based on data analysis, the t-test results show that the calculated t-value (11.571) is greater than the tabulated t-value (2.074). Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted, indicating that using GeoGebra as a learning medium for quadratic functions helps students achieve proficiency in their mathematics learning outcomes.*

KEYWORDS: Learning Outcomes, GeoGebra Learning Media, Quadratic Function Graphs.

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1. Introduction

Mathematics has a very important role in various scientific disciplines and advances human thinking, so mathematics needs to be applied at all levels of education. Mathematics needs to be taught from an early age to equip students with the ability to think logically, analytically, systematically, critically, and creatively (Susilo, 2018). By starting early, children have more time to build these skills gradually and solidify their foundation in mathematics, which in turn can significantly improve their mathematics achievement. Besides that, teachers play a crucial role in improving students' mathematics achievement. Teachers are the primary facilitators of learning in the classroom, and their actions and decisions significantly impact students' outcomes.

Moreover, teachers as facilitators play an important role in creating an effective and engaging learning environment that maximizes student learning outcomes. Susanto (2016)

stated that mathematics learning is a teaching and learning process built by teachers to develop students' creative thinking and can improve the ability to construct students' knowledge as an effort to improve mastery of mathematical concepts. According to Hamzah and Muhlirarini (2014), mathematics learning is a complex process that involves building students' understanding of various aspects of mathematics. It involves developing their knowledge of facts, concepts, principles, and skills. Effective mathematics learning involves a combination of these components, and it is essential to integrate them in a way that supports students' understanding and application of mathematical concepts. By leveraging their potential and engaging in these varied learning experiences, students can effectively construct their understanding of mathematics and enhance their problem-solving skills. Based on the opinion above, it can be concluded that learning mathematics is an effort made by teachers to help

students improve their abilities and mastery of mathematical concepts so that they can improve their learning achievement.

However, effective mathematics teaching involves more than just presenting mathematical concepts and procedures; it involves helping students develop a deep understanding of mathematical ideas, their relationships, and their applications. Teachers can create an effective mathematics learning environment by incorporating more varied and innovative learning media. Erdem (2015) mentioned that enriched learning environments, which include a range of tools and resources, can positively impact students' mathematical reasoning and attitudes toward learning mathematics. Moreover, mathematics learning in the 21st century is required to emphasize aspects of creativity and innovation, critical thinking and problem-solving, communication, and collaboration. The creativity and innovation aspect means that students can use various techniques to create useful new ideas, detail, refine, analyze, and evaluate their ideas in order to develop and maximize creative efforts and demonstrate the authenticity of findings, both individually and in groups. The use of technology can make it easier for students to collaborate, be creative, and communicate with others. Students can use digital technology to manage, integrate, and build information/knowledge. They must be able to use technology effectively to investigate, organize, evaluate, and communicate knowledge (Pujiriyanto, 2019). This is in line with the digitalization of schools to accelerate the expansion of access to quality education initiated by the Ministry of Education and Culture.

In the context of mathematics learning, students can utilize various technology-based learning media such as graphing calculators, spreadsheets, computer graphics, algebra software, mathematics software, Global Positioning System (GPS), and strategically appropriate online resources. In addition, students can use technology to communicate mathematical thoughts by constructing them through appropriate graphs of a function or data. On the other hand, teachers are also required

to be able to apply learning models according to the demands of the 21st century. Teachers are also required to master various technology-based learning media. The rapid development of technology also influences models and media in the teaching and learning process. Therefore, teachers are required to master and apply technology-based learning media so that mathematics learning is more fun and does not seem boring.

Furthermore, various technologies can be used as mathematics learning media. One of the learning media that supports the delivery of mathematical concepts is the GeoGebra application. The GeoGebra application is a mathematics learning tool that can be used to draw function graphs, perform algebraic operations, work with matrices and vectors, and conduct statistical data analysis. According to Mahmudi (2010), using the GeoGebra program provides several advantages: 1) the graphs produced are faster and more precise compared to manual drawing using a pencil, ruler, or compass, and 2) there are animation features and manipulation options (Dragging). The GeoGebra program can provide students with a clearer visual experience in understanding mathematical concepts, so using the GeoGebra application can help teachers convey material and serve as a special attraction for students to learn. According to Munir (in Japa, Suarjana, & Widiana, 2017), the GeoGebra application is a way to make mathematics learning more interesting. Using GeoGebra can accommodate the unique needs of each student, make concepts easier to understand and calculate, and increase student interest in learning. Based on the description above, it can be concluded that using the GeoGebra application provides precise and accurate construction of geometric figures and graphs, faster graph drawing, and a clear visual experience, making it easier for students to analyze graphs of quadratic functions.

A quadratic function graph is a curve with an intersection point with an axis, a vertex, and an asymptote. The general equation of a quadratic function is $f(x) = ax^2 + bx + c$. So far, students tend to rely on memorizing formulas but do not understand how these concepts are derived.

This is not effective in the mathematics learning process because it does not develop students' thinking patterns (Novianti, 2020). Additionally, students may struggle if they forget the material. By using the GeoGebra application, students are expected to understand the concept or process of graphing quadratic functions without memorization. GeoGebra allows students to directly and accurately visualize what the graph of a quadratic function looks like. Students can view and explore graphs of quadratic functions using GeoGebra (Syahbana, 2016). Using this application is expected to provide a clear understanding of quadratic function graphs. GeoGebra is a sophisticated, freely available learning tool that supports a variety of mathematical topics. It can be accessed directly and downloaded via www.GeoGebra.com. By using a computer, students can use GeoGebra directly on the official GeoGebra application website.

Al-Falah Islamic High School is an Islamic boarding school where students are prohibited from bringing technological devices such as laptops, computers, and cellphones. However, the school provides complete technological facilities, such as computers, projectors, and laptops, for use as media in the learning process. Initial observations by researchers at Al-Falah Islamic High School showed that many mathematics teachers do not use these facilities during teaching, opting instead to explain using manual graphs on the whiteboard. As a result, students are less active in asking or answering questions. Many students do not pay attention to the lesson, with some resting their heads on the table, though a few are interested in mathematics. In initial discussions with several mathematics teachers, it was explained that students' attitudes toward learning mathematics are indifferent, with many students expressing a dislike for the subject and participating only as an obligation. Furthermore, students stated that mathematics lessons were difficult and uninteresting. In teaching quadratic function graphs, the GeoGebra application has not yet been utilized; instead, a whiteboard and ruler are used to draw the graphs manually, which may lead to student boredom and lack of interest.

This situation motivated the author to implement GeoGebra as a learning medium for quadratic function graph material at Al-Falah Islamic High School.

2. Literature Review

2.1. Learning Media

Learning media refers to the tools, materials, and resources used to facilitate learning and teaching. It encompasses a wide range of physical and digital resources, including books, videos, podcasts, images, interactive software, and online courses. These media can be used in various educational settings, from traditional classrooms to online and remote learning environments, and are designed to support different learning styles and accommodate the diverse needs of learners. Gerlach and Ely (1971) state that media, in a broad sense, includes materials, people, or events that create conditions enabling students to acquire knowledge, skills, or attitudes. More specifically, the concept of media in the teaching and learning process is often interpreted as tools for photography, graphic representation, or electronic processing and rearrangement of visual or verbal information. According to Heinich et al. (1982), media serves as an intermediary that distributes information between sources and recipients. The Association for Education and Communication Technology (1997) defines media as the forms and channels used to convey messages or information. Based on the definitions above, it can be concluded that learning media are resources or tools used to facilitate and enhance the educational process.

Learning media can be any tool or action that conveys material to students with the aim of enhancing their understanding and motivation in the learning process. Initially, educational media consisted mainly of conventional tools like pens, blackboards, and rulers. However, with advances in science and technology, many electronic devices are now used in learning. Various types of technology-based learning media are employed by teachers to present content in ways that are easier for students to understand, including in mathematics education. Numerous technological tools, such as computers and the internet, are

used in teaching mathematics. Arsyad (2017) highlights the benefits of learning media in the student learning process, which include: 1) capturing students' attention, thus fostering motivation to learn; 2) clarifying lesson content, making it easier for students to understand; 3) facilitating mastery and achievement of learning objectives; 4) diversifying teaching methods beyond verbal communication; 5) reducing boredom for students and conserving energy for educators; and 6) enabling students to engage in more learning activities. Based on these points, learning media can provide clearer materials that are easier for students to understand, helping achieve learning objectives and improving student learning outcomes. By incorporating a variety of learning media, educators can address different learning styles, increase student engagement, and improve comprehension and retention of the material.

2.2. GeoGebra Application

GeoGebra is an example of a dynamic and interactive Geometry application. GeoGebra was introduced and developed by Markus Hohenwarter in 2001, and can be downloaded freely from www.GeoGebra.com. According to Hohenwarter (2011) GeoGebra is a computer program for learning mathematics, especially geometry and algebra. The GeoGebra program complements various computer programs for studying algebraic function graphs. The GeoGebra application is free learning software that supports a variety of mathematics materials. According to Diković (2009), that GeoGebra was developed to help students better understand mathematical material and manipulate variables easily by placing objects freely. Using images or sliders, students can use free object manipulation techniques to create variations and see how hanging objects will be affected.

GeoGebra application can be used by students clearly and accurately to see shapes and manipulate graphs of quadratic functions by changing the coefficients and constants of quadratic function equations. Students can independently view and study graphs of quadratic functions with the help of GeoGebra. According

to student interests, the use of GeoGebra can be said to be familiar to all groups in all countries in the world, including students and teachers (Syahbana, 2016). Moreover, according to Mahmudi (2010), the use of the GeoGebra program provides several benefits, there are: 1) geometric paintings are usually produced quickly and accurately compared to using a pencil, ruler or compass; 2) the existence of animation facilities and manipulation movements (Dragging) in the GeoGebra program can provide students with a clearer visual experience in understanding geometric concepts; 3) can be used as feedback/evaluation to ensure that the painting that has been created is correct; and 4) make it easier for teachers/students to investigate or show the properties that apply to a Geometry object. Hohenwarter & Fuchs (2004) also stated that the GeoGebra is very useful as a mathematics learning medium with various activities such as: a) as a demonstration and visualization medium, teachers can use the GeoGebra to demonstrate and visualize certain mathematical concepts; b) as a construction aid, the GeoGebra is used to visualize the construction of certain mathematical concepts, for example constructing the inner circle or outer circle of a triangle, or tangent lines; c) as a tool to aid the discovery process, the GeoGebra is used as a tool for students to discover a mathematical concept, for example the location of points or the characteristics of a parabola graph. Based on the opinion above, using GeoGebra is very useful for changing learning patterns for the better and as a visualization tool to get better learning outcomes. The following is the appearance of the GeoGebra software can be seen in figure 1.

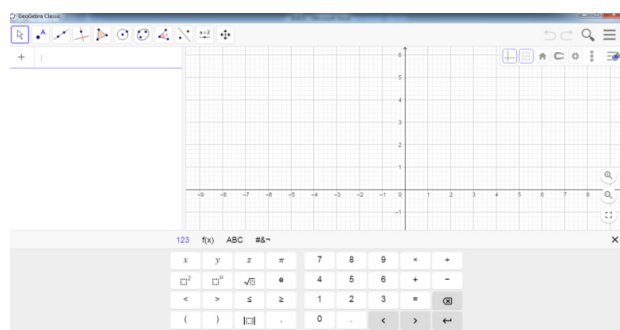


Figure 1. GeoGebra software display

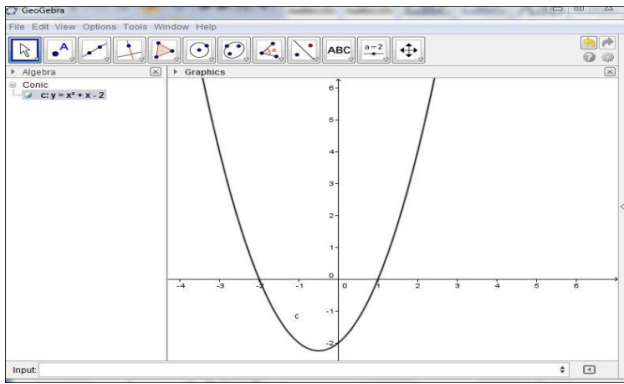


Figure 2. Graph of a quadratic function

GeoGebra application has many uses for mathematics materials such as geometry, algebra and trigonometry. One of them is about quadratic function graphs. The GeoGebra application can be useful, because it can display quadratic function graphs with a clear explanation of each point and line on the graph formed which can be seen in figure 2.

2.2. Graph of a Quadratic Function

Quadratic Functions are part of mathematics material that has elements of algebra and geometry in graphs of quadratic functions. A quadratic function is a function in a set of numbers which is expressed by the function formula

$f(x) = ax^2 + bx + c$ with $a, b, c \in R$ and $a \neq 0$. To graph a quadratic function in Cartesian coordinates, the symbol $f(x)$ can be replaced with y so that $f(x) = ax^2 + bx + c$ can be written $y = ax^2 + bx + c$, where x is called the independent variable and y is the dependent variable. For example, it is known that $f(x) = x^2 - x - 6$ with a quadratic function graph as follows:

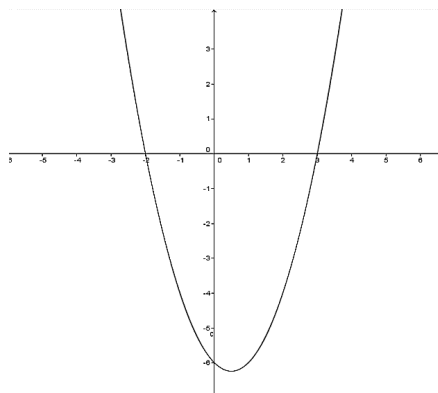


Figure 3. Graph of $f(x) = x^2 - x - 6$

The steps for drawing a quadratic function graph are as follows:

Determining the intersection point with the x axis, the intersection point can be obtained if $y = 0$ or $ax^2 + bx + c = 0$ by factoring, using ABC formula, or perfect squares.

Determining the intersection point with the y -axis, the intersection point can be obtained with $x = 0$ by substituting the value $x = 0$ into the quadratic function equation.

Determine the axis of symmetry and turning point coordinates

- Axis of symmetry equation $x = -$
- Coordinates of the vertex/turning point, $Y_p = (-, -)$ with $D = b^2 - 4ac$

Determine several other auxiliary points (if needed), Take any value of $x \in R$ then substitute it into the quadratic function equation. Here is a drawing graphs of quadratic functions can be seen in figure 4.

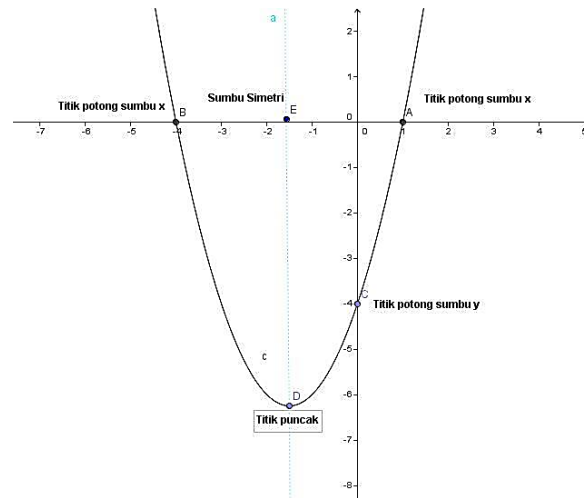


Figure 4. Drawing Graphs of Quadratic functions

2.3. Relationship between learning Media and Learning Outcomes

Learning media is a tool that can help teachers in the teaching and learning process to assist in conveying messages to students so that they can achieve educational goals and improve student learning outcomes (Nurrita, 2018). Arsyad (2017) stated that learning media are essential tools in education that enhance the teaching and learning process by making the content more engaging and easier to understand. The use of

learning media significantly enhances the quality of learning because it not only involves teachers actively providing material to students but also engages students more actively in the learning process. By incorporating learning media into the learning process, teachers can create a more dynamic and effective learning environment that enhances student engagement and improves learning outcomes.

Learning outcomes are the results given to students in the form of assessments after following the learning process by assessing students' knowledge, attitudes and skills with changes in behavior (Sudjana, 2011). There are several things that can improve student learning outcomes with learning media, there are: 1) the teaching and learning process becomes easy and interesting, Teachers can indeed make learning materials more engaging and accessible for students; 2) engaging and relevant learning media can significantly enhance students' concentration and overall learning experience; 4) learning media can increase students' learning motivation; 5) provides a comprehensive learning experience; 6) students are involved in the learning process. So that, the learning process in the classroom runs well, not only the teacher is actively involved in the class but the students are also actively following and involved in the learning process (Sadiman, 2012).

The use of learning media not only makes it easier for educators to convey material to students, but the use of learning media helps to increase students' motivation to learn more interactively and more actively in the classroom. The use of learning media is also very helpful in the effectiveness of the learning process during the teaching and learning process. The use of learning media is a very important factor for improving student learning outcomes and increasing student motivation to learn, because learning media really supports the development of a person's knowledge, especially for students in the learning process. By using learning media, students can also improve their learning achievements. Students can develop their activity in the classroom because the use of learning media can foster students' learning motivation

thereby improving learning outcomes because students are enthusiastic about learning.

3. Methodology

The method used in this research is quantitative. The method used is based on the research question in this research. According to Sugiono (2014), "Quantitative research is research based on the philosophy of positivism which explores large populations or tests hypotheses that have been established using sampling techniques which usually use quantitative data analysis/statistical methods where the research is for random data collection with the aim of test the established hypothesis". Quantitative research was used to determine the completeness of student learning outcomes during the use of GeoGebra learning media on quadratic function graph material in first-year students of Al-Falah Islamic High School.

This research applied a pre-experimental design. The researcher only conducted an experiment on one class which was carried out in class X-IPA 3 at Al-Falah Islamic High School with a One-Shot Case Study design which is described as follows:

Table 1 One-Shot Case Study Design (Sugiyono, 2014)

Treatment	Learning Results Test
X	O

Information:

X = given treatment

O = learning outcomes test score

This design procedure takes the form of: (1) giving treatment (X) to a predetermined sample and within a predetermined time period and (2) giving a test (O) or post-test to determine the learning results and calculating the average value.

4. Results and Discussion

Pre-experimental design research which aims to determine student learning outcomes using the GeoGebra application on quadratic function graphs in first-year students of Al-Falah Islamic

High School. The sample chosen as an experiment is class X-IPA 3 with a total of 23 students which will be taught using the GeoGebra application learning media. The data obtained is based on student test results. The test was carried out to collect data on student learning outcomes using the GeoGebra application. This research was carried out three times for the learning process using the GeoGebra application and one meeting for the test. The average scores obtained by all students are as follows.

Table 2. Student Learning Outcome Test Scores

No	Student initials	Results
1	AZR	90
2	ANY	80
3	AZN	80
4	DFY	90
5	FHS	90
6	ISH	80
7	LIS	98
8	MR	90
9	MRH	90
10	MAF	80
11	MHB	90
12	MPAs	80
13	NUV	75
14	NJF	80
15	NAN	75
16	QNR	90
17	RAR	90
18	RMA	85
19	RMI	80
20	RPA	98
21	TFS	80
22	TRU	75
23	TKA	75

Based on table 2, the lowest and highest test scores were respectively 75 and 98. The

t-test value has an average value of 86.13. The normality test was carried out through the chi-square test. Based on the normality test results obtained, the calculated Chi-Square value 9.658 is less than the tabulated Chi Square value 11.070. Thus, it can be concluded that the data of student score is normally distributed. Then, the hypothesis test is carried out through a paired sample t-test. According to the results, the t value obtained for the test results with t-calculated 11.571 and table = $t_{(0.95)(22)} = 2.074$. It means that the t-calculated is greater than t-table, then it can be concluded that reject Ho and accept Ha. It can be concluded, using GeoGebra in learning mathematics especially quadratic function can improve the learning outcomes of Al-Falah Islamic High School students.

Learning mathematics by using GeoGebra application can be said to achieve completeness when compared to learning without using GeoGebra. This can be seen in determining the minimum completeness criteria score at the school as a reference. Learning using GeoGebra media made students more motivated and interested in improving their abilities in mathematics lessons. This is because learning using GeoGebra media can make it easier for students to understand the material and can see clearly images of quadratic functions. Therefore, there is an increase in student scores when studying using GeoGebra. This is also based on the results of a student questionnaire, where 89% of students gave a positive response to learning using GeoGebra. This is in line with several studies that have investigated the impact of GeoGebra on student learning outcomes, Lumbantobing (2020) mentioned that the learning process designed using GeoGebra interactive media obtained superior learning outcomes compared to traditional methods. The study concluded that GeoGebra was effective in improving student achievement. Other studies also indicated that the learning media had a medium effect on student learning outcomes, which concluded that GeoGebra can improve student learning outcomes (Mandira & Wahyuni, 2022; Widyastiti et al., 2024; Zikri et al., 2021). In summary, the studies consistently demonstrate

that using GeoGebra learning media can significantly enhance student learning outcomes and help achieve completeness in understanding mathematical concepts, particularly in quadratic function graphing.

From the results of interviews with several students, the majority of students really like learning mathematics using GeoGebra. Students thought that learning using GeoGebra can increase enthusiasm and curiosity about learning mathematics. Using GeoGebra learning media is very easy to understand and can display clear images so that it made it easier for students to understand the learning material. Learning using GeoGebra is very enjoyable because of the use of technology in the teaching and learning process, where in this school not many teachers apply technology-based learning media in the learning process. However, students also think that learning using GeoGebra must also be accompanied by conventional learning. According to Dikovic (2009), the aim of GeoGebra is to help students better understand mathematical material and manipulate variables easily by placing objects freely. This is in line with Maulana (2019), that there is an influence of using GeoGebra media on students' mathematics learning outcomes, where the learning outcomes of students who use GeoGebra as a mathematics learning media are higher than the learning outcomes of students who do not use GeoGebra as a mathematics learning media.

5. Conclusions and Recommendation

Based on the results of data analysis and discussion, it can be concluded that using GeoGebra as a learning medium can significantly

enhance student learning outcomes and help achieve a comprehensive understanding of mathematical concepts, particularly in quadratic function graphs. GeoGebra is a highly effective technological tool for visualizing and exploring quadratic functions. It allows students to interactively manipulate parameters and observe changes in the graph, helping them understand concepts such as the vertex, axis of symmetry, and the effects of coefficients on the shape and position of the parabola. This hands-on approach makes abstract concepts more concrete and enhances overall comprehension. According to student interviews, the majority of students reported that learning with GeoGebra increased their curiosity about mathematics because it was easy to understand and provided clear visuals, making it easier for them to grasp the material. GeoGebra's ability to present clear, interactive visualizations makes it an excellent tool for sparking interest in mathematics. By allowing students to experiment with and explore mathematical concepts in a visually engaging way, GeoGebra can make learning more accessible and enjoyable. In summary, this study emphasizes the effectiveness of GeoGebra in enhancing mathematics education by improving conceptual understanding, increasing student achievement, and fostering a more interactive learning environment. Accordingly, this study recommends that future research utilize the GeoGebra application in mathematics learning, which combines a computer algebra system with dynamic geometry software. It is also suggested that further studies explore the integration of other dynamic software in mathematics learning to help improve student achievement.

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