

Research Article

Effectiveness of GeoGebra-Assisted Collaborative Learning on Understanding Mathematical Functions and Graphs

Dwi Oktaviana ¹, Yumi Sarassanti ², and Elay Yusifli Elshad ^{3*}

¹ Universitas PGRI Pontianak1 dwi.oktaviana7@gmail.com

² IAIN Pontianak2 yumisarassanti@yahoo.co.id

³ Manisa Celal Bayar university elayusifli@gmail.com

* Corresponding Author: e-mail : dwi.oktaviana7@gmail.com

Abstract: This study investigates the impact of GeoGebra-assisted collaborative learning on students' understanding of function graphs. Function graphs are fundamental in mathematics education, yet many students struggle to grasp the relationships between variables, primarily due to traditional teaching methods that focus on procedural skills rather than conceptual understanding. To address this challenge, the study incorporates GeoGebra, a dynamic mathematics software, alongside collaborative learning strategies. The research utilizes a quasi-experimental design involving high school students who had previously struggled with function graphs. The results demonstrate that the experimental group, which engaged in GeoGebra-assisted collaborative learning, showed a significant improvement of 27% in their post-test scores, compared to just a 6% improvement in the control group using traditional methods. The study highlights the effectiveness of GeoGebra in fostering a deeper conceptual understanding of mathematical functions by enabling students to visualize and manipulate graphs interactively. Additionally, collaborative learning encouraged peer interaction, reinforcing the learning process and promoting better problem-solving skills. The findings suggest that combining interactive tools like GeoGebra with collaborative learning techniques can enhance students' mathematical comprehension, leading to improved engagement and performance in mathematics education.

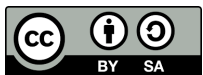
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1. Introduction

Understanding relationships between variables in function graphs is a key concept in mathematics. However, many students struggle to comprehend these relationships, primarily due to misconceptions and a lack of a deeper conceptual understanding of functions and their representations. One common issue is that students often over-rely on procedural methods, such as the vertical line test, without fully grasping the underlying concepts of variations and covariations in functions (Ayeh, 2025). Additionally, students frequently face difficulties interpreting graphs involving continuous independent variables, which can hinder their ability to comprehend key structures and interpret referents (Boote & Boote, 2017).

Another significant challenge in learning function graphs is the lack of active engagement. Traditional teaching methods, which often focus on procedural competencies instead of conceptual understanding, exacerbate this issue (Ng et al., 2020). This lack of active engagement limits students' ability to visualize and understand the dynamic nature of graphs. Active learning strategies, such as incorporating technology-enhanced activities and problem-based collaborative learning, have proven effective in improving student engagement and performance in mathematics (Lukac & Sekerak, 2017). For example, integrating digital tools

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like Desmos and GeoGebra into mathematics instruction helps students connect abstract concepts to real-world applications, thereby enhancing their understanding of functional dependencies (Mingla, 2025).

Recent studies have underscored the value of digital tools in fostering active learning and facilitating a deeper understanding of mathematical concepts. Tools like Desmos and GeoGebra are particularly effective in graphing and interpreting functions, as they provide dynamic visualizations that are crucial for understanding the relationships between variables in function graphs (Mingla, 2025). These tools allow students to explore functions interactively, leading to better engagement and improved learning outcomes.

Active learning strategies, including problem-based collaborative learning and the use of interactive online platforms, have been shown to significantly enhance students' conceptual understanding and performance in mathematics. Research has demonstrated that incorporating game-based learning platforms, such as Kahoot! into calculus courses improves student outcomes and engagement (Ting et al., 2019). These strategies encourage students to engage actively with the content, enhancing their retention and ability to apply mathematical concepts.

Despite the benefits of active learning, students continue to face challenges when transitioning from discrete to continuous variables in function graphs. This challenge can be particularly daunting for students when interpreting complex graphs. Interventions such as scaffolding support and targeted instructional strategies have been shown to improve students' abilities to interpret and analyze these graphs effectively (Rangkuti & Karam, 2022). By providing appropriate support and teaching strategies, students can better understand and navigate the complexities of function graphs.

Understanding function graphs is a critical component of mathematical education, yet it remains a significant challenge for many students. Function graphs are abstract representations that require a conceptual understanding of relationships between variables, which can be difficult to grasp through traditional teaching methods. While these methods often focus on procedural learning, they may not fully capture the dynamic and visual nature of function graphs (Zagoto et al., 2025). Consequently, there is a growing need for alternative approaches that can enhance students' engagement and comprehension of these concepts.

One promising tool is GeoGebra, a dynamic mathematics software that offers interactive and visual tools for exploring mathematical concepts, including function graphs. GeoGebra allows students to manipulate variables and visualize the corresponding changes in the graph, making it easier to understand the behavior of functions (Yerizon et al., 2023). By providing a dynamic, visual, and interactive environment, GeoGebra facilitates a deeper, more intuitive understanding of mathematical functions (Ogbonnaya & Mushipe, 2020).

Collaborative learning, where students work together to solve problems and discuss mathematical concepts, has been shown to further enhance the effectiveness of GeoGebra. Through peer interaction and discussion, students can clarify misunderstandings, reinforce their learning, and develop better problem-solving skills (Ndagijimana et al., 2024). Collaborative learning also promotes a supportive learning environment where students can actively participate in the learning process, thereby increasing their motivation and engagement (Yu, 2024).

The primary objective of this study is to evaluate the impact of GeoGebra-assisted collaborative learning on students' understanding of function graphs. Specifically, the study seeks to determine whether this approach can lead to a deeper understanding of the mathematical concepts associated with function graphs and whether it can improve students' ability to draw and analyze these graphs.

Enhanced understanding and performance, studies have demonstrated that students using GeoGebra in collaborative settings perform significantly better in understanding and drawing function graphs compared to those using traditional methods (Zulnaidi et al., 2020). The interactive nature of GeoGebra allows students to visualize and manipulate function graphs, leading to a deeper conceptual understanding. Improved engagement and motivation, GeoGebra's interactive features increase student engagement and motivation. The software's

ability to provide immediate visual feedback helps maintain students' interest and encourages active participation in the learning process (Pattanapiboon & Nishizawa, 2024).

Collaborative learning benefits, collaborative learning with GeoGebra fosters a supportive learning environment where students can discuss and solve problems together. This peer interaction helps clarify misunderstandings and reinforces learning through teaching others (Ndagijimana et al., 2024). Skill Development, GeoGebra-assisted learning not only improves students' understanding of function graphs but also enhances their overall mathematical communication and reasoning skills. This is particularly evident in tasks requiring the interpretation and analysis of graphical data (Azis & Rohaeti, 2025). Positive feedback from students and teachers, both students and teachers have reported positive experiences with GeoGebra, noting its user-friendly interface and ease of integration into the curriculum. GeoGebra is seen as a valuable tool for making abstract mathematical concepts more accessible (Zetriuslita et al., 2019).

2. Literature Review

Collaborative Learning Theory and Its Impact on Mathematical Understanding

Collaborative learning (CL) is an educational approach in which students work together to solve problems, complete tasks, or create products, with each group member relying on others to achieve a common goal. Key principles of CL include Positive Interdependence, where group members depend on each other to reach a shared goal, fostering teamwork and mutual support (Miniankou & Puptsau, 2023). Individual and Group Accountability requires each member to be responsible for their own contributions and the overall success of the group (Shaik, 2025). Additionally, Interpersonal and Small Group Skills are crucial, such as effective communication and teamwork in collaborative settings (Cartmell & Maher, 2025). Face-to-Face Promotive Interaction encourages direct interaction among group members, which can enhance engagement and cooperation (Miniankou & Puptsau, 2023). Lastly, Group Processing involves reflecting on group activities to improve group functioning and ensure continuous improvement in collaboration (Ting et al., 2019).

Collaborative learning is more than just a set of teaching methods; it is a comprehensive framework that develops essential life skills such as critical thinking, teamwork, and problem-solving within a socially and technologically interconnected learning environment. It emphasizes creativity and critical thinking, offering a rich pedagogical framework that includes diverse methods such as Cooperative Learning, Problem-Based Learning (PBL), Project-Based Learning, Peer Teaching, Jigsaw Techniques, and Socratic Seminars (Shaik, 2025). Each of these methods encourages active student participation and collective engagement, which are crucial for a deeper understanding of the subject matter.

In the context of mathematics education, the use of collaborative learning has been shown to significantly enhance students' understanding and critical thinking. Collaborative learning allows students to tackle complex mathematical problems together, thereby improving their critical thinking and problem-solving abilities. This active engagement has been shown to deepen students' conceptual understanding (Ting et al., 2019). Furthermore, active learning strategies such as collaborative games and problem-based learning have been found to lead to higher performance in mathematics. Students engaged in collaborative environments exhibit better retention of concepts and perform better in exams (Ting et al., 2019).

Collaborative pedagogies also support the development of mathematical reasoning skills, allowing students to explore mathematical concepts from multiple perspectives. However, challenges exist in implementing these methods in traditional classroom settings, particularly in large classes (Miniankou & Puptsau, 2023). Research highlights that student who engage in collaborative learning environments tend to acquire conceptual knowledge more effectively. They are better able to connect abstract concepts and understand the underlying principles of mathematical functions (Cartmell & Maher, 2025).

GeoGebra in Mathematics Education

Functions and Benefits of GeoGebra in Visualizing Mathematics

GeoGebra is a dynamic and interactive mathematics software widely used in education to support the visualization and exploration of mathematical concepts. It plays a significant role in improving students' understanding of abstract mathematical ideas by providing a platform for dynamic manipulation of mathematical objects, which helps students to develop problem-solving and critical-thinking skills. Some of the key benefits of GeoGebra include:

Visualization and demonstration, GeoGebra allows students to visualize mathematical concepts by manipulating geometric shapes, algebraic expressions, and graphical representations. This ability to dynamically illustrate mathematical ideas is particularly beneficial for understanding complex concepts such as functions and transformations (Zagoto et al., 2025; Zhang et al., 2025). Interactive learning, the interactive nature of GeoGebra engages students actively in the learning process, making it easier for them to engage cognitively and emotionally with the content. This interactivity helps students to explore mathematical ideas in depth, promoting greater participation and learning motivation (Hevardani et al., 2024; Kusnadi & Asih, 2023; Ardina & Boholano, 2024).

Conceptual understanding, GeoGebra aids in developing a deeper conceptual understanding of mathematical topics such as functions and their graphs. By allowing students to experiment with different mathematical scenarios and dynamically manipulate mathematical elements, GeoGebra fosters a richer understanding of complex mathematical ideas (Pattanapiboon & Nishizawa, 2024; Ziatdinov & Valles, 2022). Problem-solving skills, GeoGebra supports the development of problem-solving skills by enabling students to visualize outcomes and explore different problem-solving strategies. This ability to experiment with various mathematical problems helps students to strengthen their analytical skills (Zhang et al., 2025; Awaji et al., 2025).

Previous Studies on GeoGebra in Mathematics Learning

A wealth of studies has examined the effectiveness of GeoGebra in improving students' mathematics learning outcomes. These studies highlight its impact on student engagement, learning performance, and teacher perceptions: Effectiveness in learning, research has demonstrated that GeoGebra significantly enhances students' understanding and performance in mathematics. A meta-analysis of studies revealed a positive medium-to-large effect on students' achievement in mathematics due to the use of GeoGebra. Furthermore, it has been found that GeoGebra effectively improves students' understanding of specific mathematical topics, such as quadratic functions (Zagoto et al., 2025; Zhang et al., 2025). Engagement and motivation, studies have shown that GeoGebra increases student engagement and motivation, with its interactive features making learning more enjoyable. The dynamic nature of GeoGebra promotes student involvement, encouraging active participation and a more positive attitude towards learning mathematics (Hevardani et al., 2024; Kusnadi & Asih, 2023). Teacher perceptions, teachers widely view GeoGebra as a valuable tool for teaching mathematics, particularly for making abstract concepts more concrete and accessible. Teachers appreciate GeoGebra's ability to simplify the teaching of complex mathematical ideas, helping students understand and visualize key mathematical concepts more easily (Mwingirwa & Miheso, 2016; Mingirwa, 2016).

Understanding Function Graphs

Importance of Understanding the Relationship Between Variables in Function Graphs

Understanding function graphs is fundamental for mastering many areas of mathematics. Functions and their graphs serve as a foundation for more advanced topics such as calculus, algebra, and applied mathematics. Being able to interpret and create function graphs allows students to better understand the relationships between variables, which is essential for solving real-world problems in various fields, such as physics, economics, and engineering (Redish, 2022; Ayeh, 2025). The ability to interpret and construct function graphs is a critical skill that contributes to the development of mathematical reasoning and logical thinking (Dahal et al., 2022).

3. Research and Method

Research Design

This study utilizes a quasi-experimental design to measure the impact of GeoGebra-assisted collaborative learning on students' understanding of function graphs. The design integrates GeoGebra-assisted collaborative learning with technology-based group discussions, where students engage in group work using GeoGebra to explore function graphs. The research aims to evaluate whether this approach can enhance students' understanding of mathematical concepts, particularly function graphs, through interactive and collaborative methods.

Participants

The participants in this study are high school students who have difficulty understanding function graphs. These students are selected based on their prior performance in mathematics assessments that focus on functions and graphing. The research aims to provide targeted support to these students by introducing them to a more interactive and engaging method of learning using GeoGebra.

Research Instruments

To evaluate the effectiveness of the intervention, the study employs pre-test and post-test assessments. The pre-test will be administered before the intervention to assess students' initial understanding of function graphs. After the collaborative learning sessions with GeoGebra, a post-test will be conducted to measure the improvement in students' comprehension. Additionally, observations and field notes will be taken during the learning sessions to monitor group interactions and the application of GeoGebra in enhancing students' understanding.

Procedure

The procedure begins with the administration of the pre-test, followed by the collaborative learning sessions where students will use GeoGebra in group activities. These sessions are supported by group discussions led by the instructor, helping students to deepen their understanding of function graphs. The process concludes with the post-test, which allows for a comparison of students' performance before and after the intervention, providing insight into the effectiveness of GeoGebra-assisted collaborative learning.

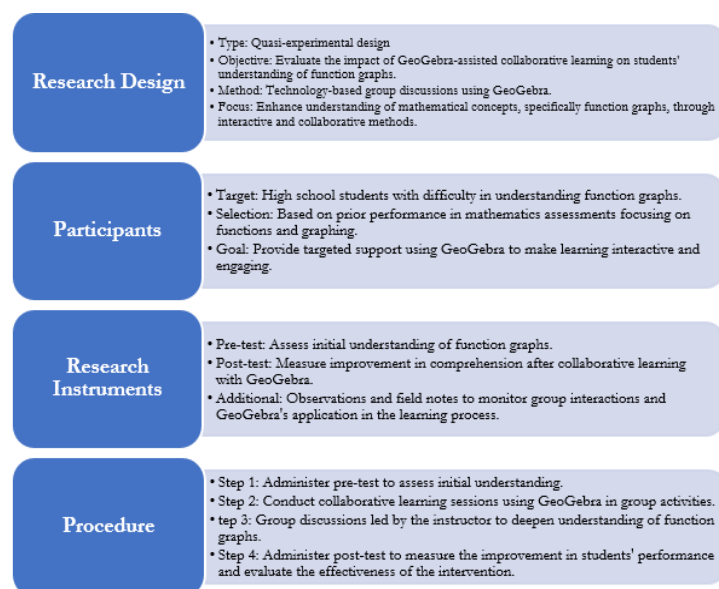


Figure 1. The structure of the Research Methodology flowchart.

4. Results and Discussion

Results

This study aimed to assess the impact of GeoGebra-assisted collaborative learning on students' understanding of function graphs. Data collected from pre-test and post-test results were used to evaluate the improvement in students' understanding after the implementation of GeoGebra in collaborative learning.

Table 1. Comparison of Pre-test and Post-test Results.

Group	Average Pre-test	Average Post-test	Improvement (%)
Experimental Group	55	82	27
Control Group	54	60	6

Table 1 presents the average results of the pre-test and post-test conducted for both the experimental and control groups. The experimental group, which used GeoGebra in collaborative learning, showed an improvement of 27%, while the control group, which did not use GeoGebra, only experienced a 6% improvement. The significant increase in the experimental group suggests that using GeoGebra in collaborative learning can significantly enhance students' understanding of function graphs.

To provide a clearer illustration of the comparison between the pre-test and post-test results for the experimental and control groups, the following graph displays the differences observed in their performance.



Figure 2. Graph Comparison of Pre-test and Post-test Results.

Figure 2 illustrates the comparison of pre-test and post-test results between the experimental and control groups. It is evident that the experimental group, which used GeoGebra, experienced a much more significant improvement compared to the control group. This graph supports the finding that GeoGebra, when used in collaborative learning, greatly enhances students' understanding of function graphs.

Discussion

The results from this study indicate that the use of GeoGebra in collaborative learning has a significant positive impact on students' understanding of function graphs. The experimental group, which used GeoGebra, showed a 27% improvement, whereas the control group demonstrated only a 6% improvement. GeoGebra enables students to interact directly with mathematical concepts, particularly in visualizing function graphs. The collaborative learning approach, which involved group discussions, provided students the opportunity to exchange knowledge and strategies for solving problems, deepening their understanding.

The larger improvement in the experimental group can be attributed to the interactive features of GeoGebra. The software's ability to visualize and manipulate graphs in real-time helps students gain a deeper conceptual understanding of the relationships between variables in a function. In comparison to individual learning, the collaborative approach using GeoGebra promoted more interaction among students, which contributed to a better

understanding. Group discussions allowed students to share their insights, solve problems together, and explore mathematical concepts in a more profound way.

Overall, this study shows that a learning approach that combines GeoGebra with collaborative learning is more effective in enhancing students' understanding than traditional individual learning methods. The interactive nature of GeoGebra and the peer interaction in collaborative learning both played a key role in improving the comprehension of function graphs.

5. Comparison

Experimental Group (GeoGebra-Assisted Collaborative Learning)

The experimental group, which used GeoGebra in a collaborative learning environment, showed a significant improvement of 27% in their understanding of function graphs. This improvement indicates that the interactive and visual features of GeoGebra, when combined with collaborative learning, have a profound impact on students' conceptual understanding of mathematical functions.

Control Group (Traditional Learning)

In contrast, the control group, which followed traditional teaching methods without the aid of GeoGebra, only demonstrated a modest improvement of 6%. This suggests that traditional teaching methods were less effective in engaging students and helping them visualize and understand the dynamic relationships between variables in function graphs.

Key Insights

The interactive nature of GeoGebra allowed students in the experimental group to engage more deeply with the content, facilitating a better understanding of the relationships between variables in function graphs. The collaborative learning component, where students worked together, helped reinforce their understanding through peer interaction and problem-solving. This highlights the importance of peer discussions in enhancing learning outcomes. The graphical comparison between the two groups clearly demonstrates the effectiveness of GeoGebra-assisted collaborative learning in improving student performance in mathematics.

6. Conclusion

The findings of this study underscore the significant impact of GeoGebra-assisted collaborative learning on students' understanding of function graphs. The experimental group, which engaged in collaborative learning with GeoGebra, demonstrated a substantial improvement of 27% in their post-test scores. In contrast, the control group, which did not use GeoGebra, only exhibited a modest improvement of 6%. This marked difference highlights the effectiveness of GeoGebra in enhancing students' conceptual understanding of function graphs.

The success of the experimental group can be attributed to the interactive features of GeoGebra, which allowed students to manipulate and visualize graphs in real-time. This hands-on approach, coupled with collaborative learning, provided students with the opportunity to exchange ideas, solve problems together, and develop a deeper understanding of the material. The collaborative learning environment further enriched the experience by encouraging peer interactions and facilitating a shared learning process.

In conclusion, GeoGebra-assisted collaborative learning proved to be significantly more effective in improving students' comprehension of function graphs compared to traditional individual learning methods. This study suggests that integrating interactive tools like GeoGebra with collaborative learning strategies can lead to enhanced mathematical understanding and better learning outcomes.

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