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Learning Economic Mathematics Through the Implementation of Geogebra Learning Media: An Effectiveness Study

[1]*Yulia Pratiwi Siregar, [2]Enni Sari Siregar

[1] Faculty of Business and Applied Education, Universitas Aufa Royhan, Indonesia

[2] Sharia Economics Study Program, Sekolah Tinggi Agama Islam Negeri Mandailing Natal, Indonesia

*Corresponding Author e-mail: tiwiliasiregar@gmail.com

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Abstract

Formal education plays a crucial role in creating a high-quality workforce, and continuous innovation in the learning process is crucial, particularly through the integration of technology. This study aims to examine the effectiveness of using the GeoGebra application in improving student learning outcomes in mathematical economics, specifically regarding demand, supply, and market equilibrium functions. The method used was a quasi-experimental design with a randomized control group design. This study compared two classes: an experimental class using GeoGebra and a control class using conventional learning. The analysis showed that the use of GeoGebra was effective in improving students' conceptual understanding, particularly in the aspects of procedural fluency and graphical understanding, with a higher average score in the experimental group (88.20) compared to the control group (85.63). Although the statistical significance value ($p > 0.05$) did not indicate a statistically significant difference, these results still indicate that GeoGebra contributes to improved conceptual understanding. Furthermore, the analysis of the role of the moderating variable 'initial mathematical ability' explains that students' initial ability has an influence on learning outcomes, but does not clearly explain the theory underlying the use of this variable. This study provides insight into the importance of using GeoGebra to improve learning outcomes in the context of mathematical economics learning at the tertiary level.

Keywords: Effectiveness; Implementation; Geogebra Aplication; Economic Mathematics

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INTRODUCTION

In an era of rapid technological advancement, the government continues to innovate in both the governance and education sectors. Specifically, changes in education can be seen through the curriculum changes that occur almost every year. Referring (Wibawana, 2024), The curriculum in Indonesia has undergone various changes, starting from the Rencana Pelajaran (Lesson Plan) Curriculum in 1947 to the Merdeka (Independent) Curriculum in 2022.

The Merdeka Curriculum aims to improve the quality of learning through the concept of "independent learning," with a focus on essential material and character development in line with the Pancasila Student Profile. Curriculum optimization can be achieved through the collaboration of various fields of knowledge. Mathematics, as a crucial foundational science, often serves as a prerequisite for other fields. However, research by (Scalise et al., 2025) A study found that interest in learning mathematics did not impact the frequency of instruction or mathematics learning achievement.

Mathematics and Economics have a close relationship. For example, to solve economic problems such as the functions of demand, supply, and market equilibrium, students must first master the material on linear functions and their graphs. Therefore, mathematics is a very important prerequisite subject in the study of economics.

According to (Supranto, 2005), Economic events are interconnected. For example, a rise in a person's income is typically followed by an increase in consumption spending. Conversely, when the price of a good increases while people's income remains the same, the demand for that good tends to fall. Similarly, an increase in national investment will generally raise national income.

Economic problems, particularly those related to demand and supply, directly affect market equilibrium. This phenomenon can be explained by changes in the values of variables within a mathematical function. These changes in variable values, whether increasing or decreasing, can be clearly visualized through the graphs of the demand, supply, or market equilibrium functions. Therefore, if students can solve relevant mathematical problems, they will also be able to solve problems in economics more easily.

To solve math problems, especially those involving graphs, we need a detailed calculation algorithm. Advances in information and communication technology have enabled the automation of graph construction. This development has a significant impact on the world of education.based on (Sapriyah, 2019), Learning media is very helpful for both students and teachers in the teaching and learning process. Students don't get bored as easily and can understand the material more simply. Consequently, learning becomes more effective and efficient, making it easier to achieve learning objectives. One application-based medium (software) that can help solve graphing problems for demand, supply, and market equilibrium functions is the GeoGebra application.

GeoGebra, an abbreviation of Geometry and Algebra, is an application that simplifies the creation of graphs. This application can clearly create points, lines, curves, and line slopes (Bakry & Resha, 2002). GeoGebra can visualize graphs in a tangible and clear way. According to (Kovacs et al., 2020), GeoGebra can be used to explore relationships that produce specific algebraic curves, such as Peaucellier's straight-line construction. Cognitive load theory (Sweller, 2011) explains that visualization can help reduce mental overload when processing information, especially when the concept is complex or abstract. Furthermore, dual coding theory (Mayer, 2005) suggests that using visual and verbal representations simultaneously can improve comprehension and memory. In the context of mathematical economics, GeoGebra serves to visualize changes in demand, supply, and market equilibrium functions, which are often difficult to understand symbolically or in static graphical representations.

Students often find mathematical economics difficult due to its abstract nature and the need to understand complex concepts. These difficulties can be divided into several dimensions: cognitive difficulties related to symbolic and formulaic understanding, graphical difficulties in interpreting visual representations of economic functions, epistemic difficulties in connecting mathematical concepts to economic reality, and procedural difficulties in performing the mathematical calculations necessary for economic analysis. Clarifying these dimensions of difficulty will help clarify the research problem, namely how GeoGebra can help overcome these obstacles in students' understanding of economic concepts.

Various studies have shown that GeoGebra effectively improves mathematics learning outcomes in various topics (functions, calculus, geometry, limits, etc.) through dynamic visualization, multiple representations, and high interactivity (Alabdulaziz et al., 2021; Iwani Muslim et al., 2023; Ziatdinov & Valles, 2022; Zulnaidi et al., 2020). International and Indonesian meta-analyses found a moderate–large effect of GeoGebra use on mathematics achievement (Hedges $g \approx 0.65$ globally and ≈ 0.96 in Indonesia) compared to traditional learning (Juandi et al., 2021; Zhang et al., 2025).

GeoGebra has also been shown to increase students' motivation, engagement, and positive attitudes toward mathematics at various levels (AlAyyubi et al., 2025; Dahal et al., 2022; Etcuban & Leonard, 2025; Fauziah, 2023; Pylypenko, 2025; Sebsibe & Abdella, 2025).

In the context of economics/management education, the use of GeoGebra (including AR) in mathematics for finance and management students improved spatial understanding, academic performance, and linked mathematical concepts to real-life financial applications (Pylypenko, 2025). Specifically in economic mathematics, Warsitasari & Rofiki used GeoGebra-assisted PBL to facilitate logical reasoning in solving economic mathematics problems; the result was a significant increase in students' logical reasoning abilities (Warsitasari & Rofiki, 2023). However, the focus was on logical reasoning, not explicitly “learning outcomes” as content achievement scores.

Several systematic reviews confirm that GeoGebra is widely used in geometry and analysis, predominantly at the upper secondary and tertiary levels, and primarily examines learning performance, HOTS, and attitudes/motivations (Azis & Rohaeti, 2025; Seftiana et al., 2024; Yohannes & Chen, 2023). However, studies on cognitive load, learning anxiety, and engagement are still rare (Schoenherr et al., 2024; Yohannes & Chen, 2023). Based on these findings, it is believed that the use of GeoGebra can help students understand and solve graphical problems related to Demand Function, Supply Function, and Market Equilibrium. With this better understanding, it is expected that students' learning outcomes in the Mathematics Economics course will improve directly.

While numerous studies have addressed the use of GeoGebra in mathematics in general, studies focused more specifically on mathematical economics and the application of technology to address conceptual difficulties in this area are lacking. Most of the existing literature focuses on evidence of GeoGebra's use in general mathematics, not specifically in the context of mathematical economics, particularly regarding concepts such as demand, supply, and market equilibrium.

This study offers several novel contributions that are not only contextual but also provide theoretical and methodological insights applicable to other contexts. Some of the novelties identified in this study are: first, this study examines the use of GeoGebra in teaching economic concepts such as demand, supply, and market equilibrium topics rarely discussed in the existing literature, particularly in economics education in Indonesia; second, this study focuses on designing specific activities that use GeoGebra to visualize shifts in demand and supply curves and changes in market equilibrium, providing a more structured approach to using technology to teach abstract concepts in mathematical economics. Third, this study examines the effects of GeoGebra on students with varying prior abilities, using the moderating variable "prior mathematical ability," which provides further insight into the factors influencing learning outcomes in an economic context. The method used in this study was designed to test these claims, using an experimental design that measured pretest and posttest scores to assess learning outcomes, which offers a more structured methodological approach to assessing the effectiveness of GeoGebra use compared to previous studies that prioritized logical reasoning or higher-order thinking skills without focusing on quantitative conceptual understanding. This novelty is expected to provide theoretical contributions that can be applied more broadly in the teaching of economic mathematics and related topics.

The objective of this study was formulated systematically to test the effectiveness of using the GeoGebra application as a learning medium for economic mathematics in improving student learning outcomes compared to conventional learning. Furthermore, this study also aimed to analyze the extent to which GeoGebra's dynamic visualizations in presenting abstract economic mathematics concepts correlate with improved learning outcomes.

METHOD

Research methods are procedures or steps used to ensure that research is conducted in a focused and systematic manner. Sahir, (2021) states that the research method is a series of activities to find the truth of a study, starting with problem formulation and ending with drawing conclusions. This study used a quasi-experimental approach with a pretest-posttest non-equivalent control group design to measure the effectiveness of using GeoGebra in learning economic mathematics. This design was chosen because it involved two non-randomized groups: an experimental group using the GeoGebra application and a control group using conventional learning. Although it did not involve random assignment, the comparison between the two groups was carried out by ensuring equality of initial abilities through a pre-learning test. The pre-learning test was given to both groups to measure their initial level of understanding of the economic mathematics concepts to be learned. The pre-test results showed no significant difference between the two groups in terms of initial understanding of the economic mathematics material, ensuring equality between the experimental and control groups before the treatment began. The following table shows a comparison of the average pre-test scores between the experimental and control groups:

Table 1. Pre-test scores of the experimental group and the control group

Group	Number of Students	Average Pretest Score	Standard Deviation	P-Value
Experiment	30	75.32	8.21	0.63
Control	30	74.89	7.89	

The table above shows that both groups had almost identical mean scores on the pre-learning test, with a p-value of 0.63 which is greater than 0.05, indicating that the difference between the experimental and control groups in initial ability was not statistically significant.

The experimental design applied was O1 - X - O2 for the experimental group, where O1 is the pretest, X is the treatment (GeoGebra), and O2 is the posttest. Meanwhile, for the control group using conventional learning, the design was O1 - O2. Grouping participants into experimental and control groups used a purposive sampling technique, where two existing classes were selected based on their willingness to participate in the experimental conversation. Although the classes were not randomized, they came from the same population, with the aim of minimizing selection bias.

The experimental and control groups were not completely randomized, as sampling was conducted purposively. Two existing classes, based on their willingness to participate in the experimental conversation, were used as the experimental and control classes. Although there was no randomization of individuals within the classes, the classes were drawn from the same population to minimize bias.

The study participants consisted of 60 Economics students at a university in Indonesia. This population was selected because they were taking the Mathematics Economics course in a particular semester. The sampling technique used was purposive sampling, selecting two comparable classes based on the results of an initial ability test. The two groups, each consisting of 30 students, were divided into an experimental group using GeoGebra and a control group using conventional learning. Demographic data such as age, educational background, and technology experience were also collected to ensure equality between the two groups, which will later be analyzed to evaluate whether these factors influence learning outcomes.

This study used three main variables: the independent variable (GeoGebra application), the dependent variable (learning outcomes), and the moderator variable (initial ability). GeoGebra was used as a learning medium for the experimental group, allowing the visualization of economic mathematical concepts, such as changes in demand, supply, and market equilibrium functions. In this experiment, students were asked to use the slider feature in GeoGebra to simulate changes in price and quantity that affect market equilibrium. The tasks given included shifting the demand or supply curve and observing changes in market equilibrium dynamically. This medium was designed to facilitate students in understanding abstract economic concepts through interactive visual representations. Initial ability is considered an important factor influencing students' learning success. This is because this ability is believed to help students construct new knowledge. This view is also explained by

(Granberg, 2016) that they engaged in several Schoenfeld episodes and successfully reconstructed useful prior knowledge and constructed new, correct knowledge - solving problems. Details of the relationship between the three variables are shown in Table 2 below.

Table 2. Relationship between Students' Initial Ability and the Use of the GeoGebra Application in Influencing Economic Mathematics Learning Outcomes.

Initial Abilities	GeoGebra Application Implementation	Conventional
Height (B_1)	B_1K_1	B_1K_2
Low (B_2)	B_2K_1	B_2K_2

Notes:

B_1K_1 : Learning outcomes of students with high initial abilities taught using the GeoGebra application.

B_1K_2 : Learning outcomes of students with high initial abilities who are taught using conventional methods.

B_2K_1 : Learning outcomes of students with low initial abilities taught using the GeoGebra application.

B2K2 : Learning outcomes of students with low initial abilities taught using conventional methods.

The instrument used in this study was an essay test designed to measure students' understanding of mathematical economics concepts, such as demand and supply functions, elasticity, and market equilibrium. Each test item was developed to assess students' understanding in the context of real-world applications of these concepts. Instrument validity was assessed through expert review in the fields of mathematical economics and education, who examined the suitability of the test items to the learning objectives. Instrument reliability was measured using Cronbach's alpha, which yielded a value of 0.87, indicating good internal consistency. Furthermore, the assessment rubric used to assess students' essays was also tested for inter-rater consistency.

Table 3. Test items used in this study

No	Test Items	Constructs Measured
1	Explain How change price can influence request in something market .	Understanding request
2	Describe shift curve offer moment happen improvement cost production .	Understanding offer
3	Simulate change balance market with use GeoGebra .	Understanding balance market

The experimental group was taught using the GeoGebra application, which allows for dynamic visualization of abstract concepts in mathematical economics. The experimental group participated in six 90-minute learning sessions, each focused on using GeoGebra to draw supply and demand graphs and simulate changes in market equilibrium. In contrast, the control group followed a conventional learning method consisting of lectures and manual exercises, with equivalent duration and number of sessions. Both groups were taught by the same instructor, ensuring consistency in the implementation of the learning procedures.

To measure changes in learning outcomes, a comparison between pretest and posttest scores was conducted for both groups. Data analysis was performed using an independent sample t-test to compare posttest scores between the experimental and control groups. To control for the effect of prior ability, an Analysis of Covariance (ANCOVA) analysis was conducted with the pretest as a covariate. In addition, a two-way ANOVA was used to evaluate the interaction between the type of instruction (GeoGebra vs. conventional) and students' prior ability (high vs. low). Effect sizes, such as Cohen's d, were also calculated to evaluate the magnitude of the differences between the experimental and control groups and the effect of the interaction between instruction and prior ability. All analyses were conducted using SPSS statistical software.

RESULTS AND DISCUSSION

Comparison of Experimental and Control Classes

This study began by dividing the sample into two groups based on their initial ability, namely high and low initial ability. The data distribution from this grouping can be seen in Table 4.

Table 4. Grouping of the Sample Based on Initial Ability and Research Class

Initial Ability	**Class**	
	Experimental	**Control**
High	16	17
Low	14	13
Total	**30**	**30**

This study began by grouping the sample based on their initial ability, into high and low categories. The data distribution from this grouping can be seen in Table 5.

Table 5. Statistical Description of Final Test Data

Class	**Sum**	**Mean**	**Standar Deviasi**	**Varians**
Experimental	*882.00*	88.20	0.63	0.40
Control	685.00	85.63	1.77	3.13

Based on the available data, the average score of the experimental class (88.20) is higher than the control class (85.63). This indicates that the use of GeoGebra has a significant influence on students' ability to solve economic problems.

Furthermore, to ensure the data's viability, a normality test was conducted using Chi-Square and a homogeneity test with Levene’s test. The results of these tests, which focused on the high initial ability group in both the experimental and control classes, are presented in Table 6.

Table 6. Results of Normality and Homogeneity Tests for the High Initial Ability Group

	Experimental Class	**Control Class**	**Homogenitas**
Chi-Square	7.818^{a}	8.333^{b}	0.074
Df	2	1	
Asymp. Sig.	.048	.061	

Based on the data, the values obtained in both the experimental and control classes with high initial ability are greater than 0.05. This means that the data in both of these classes, with high initial ability, has a normal and homogeneous distribution. Additionally, a normality test was also conducted on the experimental and control classes with low initial ability, with the calculation results visible in the Table 7.

Table 7. Testing the Normality and Homogeneity of Data in the Low Initial Ability Groups (Experiment and Control)

	Experimental	**Control**	**Homogeneity**
Chi-Square	6.400^{a}	4.500^{b}	0.053
Df	1	1	
Asymp. Sig.	.041	.062	

Based on the data, the values obtained in both the experimental and control classes with low initial ability are greater than 0.05. This indicates that the data in both of these classes has a normal and homogeneous distribution.

T-Test Results

Table 8 shows the results of the t-test for the comparison between the experimental and control groups. The Sig. (2-tailed) value for the experimental group is 0.045, which is less than 0.05, indicating a significant difference between the two groups. Cohen's d for the experimental group (0.68) indicates a medium effect size, while the control group has Cohen's d (0.32), indicating a small effect size.

Table 8. T-Test Results (Comparison of Experimental and Control Groups)

Group	N	Posttest Average	Sig. (2-tailed)	Cohen's d
Eksperiment	30	88,20	0,045	0,68
Control	30	85,63	0,053	0,32

First Hypothesis Test

Next, the first hypothesis test was conducted to determine the effectiveness of using GeoGebra in the experimental and control classes with high initial ability. The results of this analysis are presented in the following Table 9.

Table 9. Data Analysis for Hypothesis 1

	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Experimental Class	260.446	20	.045	85.47619	84.7916	86.1608
Control Class	554.287	20	.053	88.33333	88.0009	88.6658

Based on the test criteria, the significance value for both the experimental and control classes with high initial ability is greater than 0.05. This indicates that the Alternative Hypothesis (Ha) is accepted, meaning that the use of the GeoGebra application is effective in improving the learning outcomes of students with high initial ability. This improvement occurred in the topics of demand functions, supply functions, and market equilibrium. Figure 1 shows the improvement in learning outcomes more clearly. This graph compares the results from the experimental and control classes.

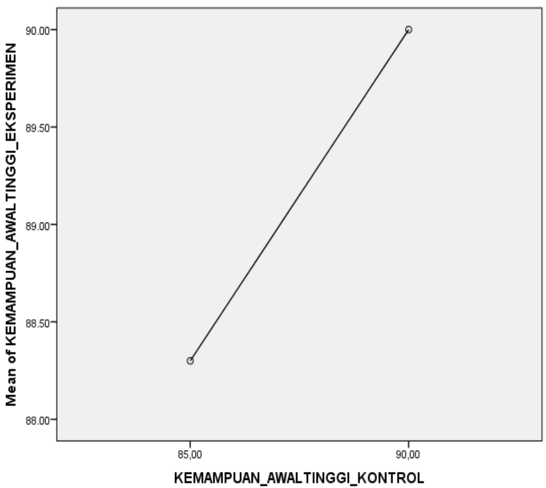

Figure 1. Effectiveness of GeoGebra Use

The mean posttest results (or improvement) by group, with 95% Confidence Intervals (CIs) for each group. This graph provides a more complete picture of the variability in the data and shows that although the experimental group had a higher mean, there was variability in improvement between individuals.

Second Hypothesis Test

Next, we analyzed the second hypothesis to see how effective GeoGebra was for students with low initial ability in the experimental and control classes. The results of this data analysis shows in Table 10.

Table 10. Data Analysis for Hypothesis 2

Class	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Experimental	441.000	9	.040	88.20000	87.7476	88.6524
Control	137.000	7	.057	85.62500	84.1471	87.1029

Based on the test criteria, the significance value for both the experimental and control classes with low initial ability is greater than 0.05. This means that the Alternative Hypothesis (Ha) is accepted. In other words, using the GeoGebra application is effective in improving the learning outcomes of students with low initial ability on the topics of demand functions, supply functions, and market equilibrium.

Interaction or Moderation Effects

An ANCOVA test was conducted to examine the interaction between the type of instruction (GeoGebra vs. conventional) and students' prior ability (high vs. low). The analysis results showed a significant interaction between instruction and students' prior ability ($p = 0.034$), indicating that the effect of GeoGebra on learning outcomes varies depending on students' prior ability. Students with higher prior ability showed greater improvement in learning with GeoGebra compared to students with lower prior ability.

Table 11. ANCOVA Results for the Interaction of Instruction and Initial Ability

Variabel	F-value	p-value
Instruction x initial ability	4.65	0.034

Table 11 shows the results of an ANCOVA analysis testing the interaction between instruction type (GeoGebra vs. conventional) and students' prior ability (high vs. low). The results indicate that the interaction between instruction and prior ability is significant with $p = 0.034$, indicating that the effect of GeoGebra on learning outcomes varies depending on students' prior ability.

Discussion

There's a significant difference in learning outcomes between high-ability students who used the GeoGebra application and those who learned conventionally. The significance value (Sig.) was less than 0.05, which proves this difference. Therefore, using the GeoGebra application is more effective at improving the learning outcomes of high-ability students in the topics of Demand Functions, Supply Functions, and Market Equilibrium Functions.

This conclusion is in line with the research findings (Rizana & Safitri, 2018) In a study on Economic Mathematics, a significant improvement was found in students' mathematical problem-solving abilities. This finding is also consistent with various quasi-experimental studies: the use of GeoGebra improves students' achievement in the topics of functions and limits, quadratics, 3D geometry (Uwurukundo et al., 2022, 2024), polar coordinates and complex numbers, and various other topics in secondary school (Arbain & Shukor, 2015;

Batiibwe, 2024). This improvement was demonstrated by the increase in the average score from 62.33% (sufficient) in Cycle I to 85.07% (very good) in Cycle II. Students' mathematical problem-solving skills also improved from 78.06 in Cycle I to 91.78 in Cycle II.

Furthermore, another study by (Turgut et al., 2022) explains that the change from two-dimensional to three-dimensional in the mathematization process of linear combinations can be concretely presented using GeoGebra software.

For students with a low initial ability in both the experimental and control classes, a further analysis was conducted. The results showed a significance value (Sig.) of less than 0.05, leading to the conclusion that using GeoGebra is an effective way to improve learning outcomes for students with low initial ability. This was specifically noted for topics such as demand, supply, and market equilibrium functions. This finding aligns with (Dikovic, 2009) who suggested that new trends in educational technology, like GeoGebra, are crucial for the future of e-learning in college-level mathematics, making it more interactive and creative.

A separate analysis was conducted to see how effective GeoGebra was for students with both high and low initial abilities in an experimental class. The analysis found that students with high initial ability were generally more active and grasped the material more easily with the GeoGebra application. In contrast, students with low initial ability often needed repeated explanations to understand how to use the software to solve economic problems. This finding aligns with a study by (Hidayati et al., 2022), which stated that students with poor mathematical connection skills often struggle to solve problems or meet performance indicators. Additionally, the data showed that students in the experimental class had higher learning outcomes compared to those in the control group.

Beyond using GeoGebra, students must also grasp various linear and non-linear function models. This is supported by (Sharifzadeh, 2021) research, which found that a combination of the MIP formulation approach, an efficient MIP algorithm, and NLP creates a robust solution framework. This framework is capable of finding global or near-global solutions and outperforms advanced methods in non-convex ED.

Initial ability isn't the only factor impacting learning outcomes; self-efficacy, or self-confidence, also plays a significant role. Students with a high initial ability tend to have greater self-confidence, which helps them effectively use GeoGebra to solve problems. Conversely, students with a low initial ability are often hesitant when using the application and frequently doubt the steps they take. This finding is consistent with a 2022 study by (Purwasih et al., 2022) which found that mathematics instruction using GeoGebra software can boost students' self-efficacy compared to instruction without it.

Self-efficacy can be influenced by more than just initial ability; economic factors also play a role. According to a study by (Joshi et al., 2025) students from upper-middle-income countries are more engaged in digital learning activities outside of class compared to students in lower-middle-income and high-income countries. This highlights the need for policymakers and educators to address the gap in digital resource usage to improve educational equity.

This is consistent with another study by (Suhaifi et al., 2022), which found that learning with the GeoGebra application had a more significant impact on student outcomes than conventional teaching methods. This suggests that using GeoGebra is a more effective way to improve student learning.

Based on this information, we can conclude that using GeoGebra is effective at improving learning outcomes for topics like demand functions, supply functions, and market equilibrium. This effectiveness is particularly evident when considering students' initial abilities. Students with a higher initial ability in the experimental group found it easier to understand and solve problems using the application. Beyond initial ability, self-efficacy (or self-confidence) is another key factor that influences the improvement of learning outcomes, especially when using GeoGebra.

This study has several limitations that should be noted. First, the sample size was limited to a single educational institution, which limits the generalizability of these findings to a broader population. The study also did not include a delayed posttest, which could have provided further insight into the long-term sustainability of GeoGebra's impact on student learning outcomes. Without a delayed posttest, it is difficult to assess whether the observed improvements in posttest results are temporary or sustained.

Furthermore, this study relied solely on quantitative data from the posttest, which may not fully capture the complexity of GeoGebra's impact on student understanding. Qualitative data, such as student interviews or observations of how students interact with GeoGebra during instruction, could provide a deeper understanding of the learning process and the challenges students face in using this tool. Therefore, future research should consider incorporating qualitative data to enrich the analysis.

CONCLUSION

Based on clear statistical results, it was found that the experimental group using GeoGebra showed a significant improvement in posttest results, with a $p = 0.045$, which is lower than the established significance level (0.05). This indicates that GeoGebra has a positive effect on improving students' understanding of concepts such as demand, supply, and market equilibrium. These results are consistent with previous findings, which suggest that interactive visualization tools like GeoGebra can help students understand complex relationships in economics.

However, these findings also revealed that the effect of GeoGebra varies depending on students' prior ability. Students with higher prior ability tended to respond better to GeoGebra use, leading to more substantial increases in understanding. Conversely, students with lower prior ability showed smaller improvements, suggesting they may need additional support to maximize the benefits of this technology. Therefore, instructors should consider students' prior abilities when designing technology-based interventions to ensure that all students receive optimal benefits.

Overall, this study demonstrates that GeoGebra can be highly effective in teaching economic mathematics, especially when tailored to the abilities and needs of each student. Instructors should use GeoGebra as a learning tool that enriches students' understanding, but also provides additional support for those who struggle, by introducing more exploratory and interactive learning methods.

RECOMMENDATION

Based on the findings of this study, it is recommended that instructors incorporate GeoGebra into their teaching practices for economic mathematics, especially in topics that involve complex concepts like supply, demand, and market equilibrium. GeoGebra’s ability to visualize and interact with these concepts in real time can significantly enhance students' understanding. However, it is crucial that instructors recognize the varying levels of students' prior knowledge and adjust their teaching strategies accordingly. For students with higher prior knowledge, GeoGebra can serve as a powerful tool to deepen their understanding, while for students with lower prior knowledge, additional support and guidance are necessary to help them fully benefit from this technology.

Furthermore, future studies should consider investigating the long-term impact of GeoGebra on student learning, incorporating delayed posttests to assess the sustainability of the observed improvements. It is also recommended that future research explores qualitative data, such as student feedback and observational studies, to better understand how students engage with and benefit from such technological tools in the learning process. This holistic approach will provide a deeper understanding of the pedagogical benefits and limitations of using GeoGebra in economic mathematics education.

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AUTHOR CONTRIBUTIONS STATEMENT
This study applies the Contributor Roles Taxonomy (CRediT) to describe the contributions of each author as follows:

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Yulia Pratiwi Siregar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	
Enni Sari Siregar	✓	✓				✓	✓	✓	✓	✓	✓	✓		

C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

DATA AVAILABILITY
Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

Alabdulaziz, M. S., Aldossary, S. M., Alyahya, S. A., & Althubiti, H. M. (2021). The effectiveness of the GeoGebra Programme in the development of academic achievement and survival of the learning impact of the mathematics among secondary stage students. *Education and Information Technologies*, *26*(3), 2685–2713. https://doi.org/10.1007/s10639-020-10371-5

AlAyyubi, I., Noerzanah, F., Lidiawati, L., Anggraeni, A., & Nurhikmah, N. (2025). Does the GeoGebra Application Affect Students' Motivation in Learning Mathematics? *Wulang: Jurnal Pendidikan Guru Madrasah Ibtidaiyah*, *3*(1), 1–13. https://doi.org/10.55656/wjp.v3i1.341

Arbain, N., & Shukor, N. A. (2015). The Effects of GeoGebra on Students Achievement. *Procedia - Social and Behavioral Sciences*, *172*, 208–214. https://doi.org/10.1016/j.sbspro.2015.01.356

Azis, Y. M., & Rohaeti, E. E. (2025). A systematic literature review on implementation of GeoGebra: Benefits and challenges in mathematics education. *Infinity Journal*, *14*(3), 655–672. https://doi.org/10.22460/infinity.v14i3.p655-672

Aziz, A., Ahyan, S., & Fauzi, L. (2016). Implementasi Model Problem Based Learning (PBL) dalam Meningkatkan Kemampuan Berpikir Kritis Mahasiswa Lesson Study. *Jurnal Elemen*.

Bakry, & Resha, M. (2002). Pemanfaatan Aplikasi GeoGebra dalam Menentukan Fungsi Permintaan, Fungsi Penawaran, dan Keseimbangan Pasar. *Journal of Natural Science and Technology Adpertisi (JNSTA)*.

Batiibwe, M. S. K. (2024). Integration of GeoGebra in Learning Mathematics: Benefits and Challenges. *East African Journal of Education Studies*, *7*(4), 684–697. https://doi.org/10.37284/eajes.7.4.2454

Dahal, N., Pant, B. P., Shrestha, I. M., & Manandhar, N. K. (2022). Use of GeoGebra in Teaching and Learning Geometric Transformation in School Mathematics. *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(08), 65–78. https://doi.org/10.3991/ijim.v16i08.29575

Dikovic, L. (2009). Aplication GeoGebra into Teaching Some Topics of Mathematics at the College Level. *Article in Computer and Information Systems*, *6*(2), 191–203.

Etcuban, J. O., & Leonard, L. (2025). GeoGebra: Its Effects on Education Students' Attitudes, Motivation, and Performance in College Algebra. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1). https://doi.org/10.30998/formatif.v15i1.23138

Fauziah, G. N. (2023). The Effect of Using the Geogebra Application on the Learning Outcomes of Applied Mathematics Courses at Makassar Shipping Science Polytechnic Cadets. *International Journal of Social Service and Research*, *3*(6), 1375–1384. https://doi.org/10.46799/ijssr.v3i6.416

Granberg, c. (2016). Discovering and Addressing Errors During Mathematics Problem-Solving-A Productive Struggle. *The Journal of Mathematical Behavior*, *42*, 33–48.

Granberg, c., & Olsson, J. (2015). ICT-Supported Problem Solving and Collaborative Creative Reasoning: Exploring Linear Functions Using Dynamic Mathematics Software. *The Journal of Mathematical Behavior ELSEVIER*, *37*, 48–62.

Hidayati, A., FIrdaussiah, L., Utami, I., & Ayu, N. (2022). Analisis Kesulitan Mahasiswa dalam Menyelesaikan Soal Matematika Ekonomi pada Materi Fungsi Permintaan dan Penawaran ditinjau dari Kemampuan Koneksi Matematis. *Jurnal Jendela Pendidikan*, *2*(3), 451–458.

Iwani Muslim, N. E., Zakaria, M. I., & Yin Fang, C. (2023). A Systematic Review of GeoGebra in Mathematics Education. *International Journal of Academic Research in Progressive Education and Development*, *12*(3), Pages 1190-1201. https://doi.org/10.6007/IJARPED/v12-i3/19133

Joshi, D. R., Khanal, J., Chapai, K. P., & Adhikari, K. P. (2025). The Impact of Digital Resource Utilization on Student Learning Outcomes and Self-Efficacy Across Different Economic Contexts: A Comparative Analysis of PISA 2022. *International Journal of Educational Research*, *8*.

Jovanov, D., Vujic, B., & Vujic, G. (2018). Optimization of the Monitoring of Landfill Gas and Leachate in Closed Methanogenic Landfills. *Journal of Environmental Management*, *216*, 32–40.

Juandi, D., Kusumah, Y. S., Tamur, M., Perbowo, K. S., & Wijaya, T. T. (2021). A meta-analysis of Geogebra software decade of assisted mathematics learning: What to learn and where to go? *Heliyon*, *7*(5), e06953. https://doi.org/10.1016/j.heliyon.2021.e06953

Kovacs, Z., Recio, T., & Velez, P. M. (2020). Reasoning About Linkages with Dynamic Geometry. *Journal of Symbolic Computation ELSEVIER*, *97*, 16–30.

Purwasih, R., Saringingsih, R., & Sari, I. (2022). Self-Efficacy terhadap Kemampuan High Order Thinking Mathematics Siswa Melalui Pembelajaran Berbantuan Software GeoGebra. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(1), 166–173.

Pylypenko, O. (2025). GeoGebra with augmented reality as a tool for teaching mathematics in the training of specialists in the field of management and administration. *Economics and Technical Engineering*, *3*(1), 54–65. https://doi.org/10.62911/ete.2025.03.01.05

Rizana, D., & Safitri, E. (2018). Implementasi Aplikasi Geogebra Graphing Calculator sebagai Media Pembelajaran pada Mata Kuliah Matematika Ekonomi. *Jurnal Math Educator Nusantara (JMEN): Wahana Publikasi Karya Tulis Ilmiah Di Bidang Matematika*, *4*(2), 177–185.

Sahir, S. H. (2021). *Metodologi Penelitian*. Penerbit KBM Indonesia.

Sapriyah. (2019). Media Pembelajaran Dalam Proses Belajar Mengajar. *Prosiding Seminar Nasional Pendidikan FKIP*, *2*(1), 470–477.

Scalise, N. R., Gladstone, J. R., & Cotto, D. M. (2025). Maximizing Math Achievement: Strategies from the Science of Learning. *Journal of Experimental Child Psychology ELSEVIER*, *257*(106281), 1–16.

Schoenherr, J., Strohmaier, A. R., & Schukajlow, S. (2024). Learning with visualizations helps: A meta-analysis of visualization interventions in mathematics education. *Educational Research Review*, *45*, 100639. https://doi.org/10.1016/j.edurev.2024.100639

Sebsibe, A. S., & Abdella, N. M. (2025). The effect of GeoGebra integrated instruction on students' learning of the quadratic function concept. *F1000Research*, *14*, 671. https://doi.org/10.12688/f1000research.163113.1

Seftiana, G., Lestari, N., Isnawan, M. G., & Rusmayadi, Muh. (2024). Utilization of GeoGebra software in mathematics learning: A Literature Systematic Review. *Polyhedron International Journal in Mathematics Education*, *2*(1), 156–163. https://doi.org/10.59965/pijme.v2i1.95

Sharifzadeh, H. (2021). Sharp Formulation of Nonconvex Piecewise Linear Functions to SOlve the Economic Dispatch Problem with Valve-Point Effect. *International Journal of Electrical Power & Energy Systems*, *127*.

Suhaifi, A., Rufi'i, R., & Karyono, H. (2022). Pengaruh Penggunaan Aplikasi GeoGebra terhadap Hasil Belajar Matematika. *Jurnal Inovasi Teknologi Pendidikan*, *8*(2), 220–230.

Supranto, J. (2005). *Matematika Untuk Ekonomi dan Bisnis* (Pertama). Penerbit Ghalia Indonesia.

Turgut, M., Smith, J. L., & Larson, C. A. (2022). Symbolizing Lines and Planes as Linear Combinations in a Dynamic Geometry Environment. *The Journal of Mathematical Behavior*, *66*, 1–20.

Uwurukundo, M. S., Maniraho, J. F., Tusiime, M., Ndayambaje, I., & Mutarutinya, V. (2024). GeoGebra software in teaching and learning geometry of 3-dimension to improve students' performance and attitude of secondary school teachers and students. *Education and Information Technologies*, *29*(8), 10201–10223. https://doi.org/10.1007/s10639-023-12200-x

Uwurukundo, M. S., Maniraho, J. F., & Tusiime Rwibasira, M. (2022). Effect of GeoGebra Software on Secondary School Students' Achievement in 3-D Geometry. *Education and Information Technologies*, *27*(4), 5749–5765. https://doi.org/10.1007/s10639-021-10852-1

Warsitasari, W. D., & Rofiki, I. (2023). Utilizing Geogebra for Solving Economic Mathematics Problems: Promoting Logical Reasoning in Problem-Based Learning. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(3), 3445. https://doi.org/10.24127/ajpm.v12i3.7300

Wibawana, A. W. (2024). Kurikulum di Indonesia. *News.Detik.Com*.

Yohannes, A., & Chen, H.-L. (2023). GeoGebra in mathematics education: A systematic review of journal articles published from 2010 to 2020. *Interactive Learning Environments*, *31*(9), 5682–5697. https://doi.org/10.1080/10494820.2021.2016861

Zhang, Y., Wang, P., Jia, W., Zhang, A., & Chen, G. (2025). Dynamic visualization by GeoGebra for mathematics learning: A meta-analysis of 20 years of research. *Journal of Research on Technology in Education*, *57*(2), 437–458. https://doi.org/10.1080/15391523.2023.2250886

Ziatdinov, R., & Valles, J. R. (2022). Synthesis of Modeling, Visualization, and Programming in GeoGebra as an Effective Approach for Teaching and Learning STEM Topics. *Mathematics*, *10*(3), 398. https://doi.org/10.3390/math10030398

Zulnaidi, H., Oktavika, E., & Hidayat, R. (2020). Effect of use of GeoGebra on achievement of high school mathematics students. *Education and Information Technologies*, *25*(1), 51–72. https://doi.org/10.1007/s10639-019-09899-y