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GeoGebra as a Visualization Tool: Implications for Mathematics Anxiety in Analytical Geometry Lectures

Maria Martini Aba[1*], Yus Mochamad Cholily[2], Baiduri[3], Siti Inganah[4], Zainur Wula[5], Abdulkadir Rahardjanto[6]
[1] Mathematics Education, Muhammadiyah University of Kupang
Jl. K. H. Ahmad Dahlan, Kayu Putih, Kota Kupang, Nusa Tenggara Timur, Indonesia
[2,3,4] Mathematics Education, Muhammadiyah University of Malang
Jl. Raya Tlogomas No. 246, Malang, Jawa Timur, Indonesia
[5] Sociology, Muhammadiyah University of Kupang
Jl. K. H. Ahmad Dahlan, Kayu Putih, Kota Kupang, Nusa Tenggara Timur, Indonesia
[6] Biology Education, Muhammadiyah University of Malang
Jl. Raya Tlogomas No. 246, Malang, Jawa Timur, Indonesia

e-mail: [*] martiniaba11@gmail.com
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*corresponding author**

Abstract

This study investigates the impact of using GeoGebra as a geometric visualization tool on reducing mathematics anxiety among students in a Mathematics Education program. GeoGebra, an interactive software, enables dynamic visualization of geometric concepts, potentially fostering deeper conceptual understanding and alleviating anxiety in learning mathematics. A one-group pretest-posttest design was employed, consisting of three phases: preparation, implementation, and data analysis. Data were collected through a mathematics anxiety questionnaire administered before and after the intervention using Google Forms. The participants were 45 Mathematics Education students enrolled in an Analytical Geometry course. Data analysis involved tests of normality, homogeneity, and a paired sample t-test. The results indicate that: (1) GeoGebra effectively reduces students' anxiety in learning geometry; (2) its interactive visualizations enhance conceptual understanding and mitigate anxiety levels; (3) there is a statistically significant difference in anxiety levels before and after the use of GeoGebra; and (4) students reported a more enjoyable and less stressful learning environment, which increased their engagement with the course content. These findings suggest that integrating GeoGebra into geometry instruction can be a valuable pedagogical strategy for reducing mathematics anxiety and promoting meaningful learning experiences.

Keywords: Analytical Geometry; Interactive Learning; Geometric Visualization; GeoGebra; Mathematics Anxiety;

1. Introduction

Mathematics, particularly geometry, often triggers math anxiety among students because it demands strong spatial visualization skills (Thom et al., 2024; Lavicza et al., 2023). Yet, geometry plays a crucial role in developing spatial reasoning, which is key to success in STEM fields. Skills such as visualization and mental rotation are essential, for example, in engineering and architecture. Integrating technology into geometry learning has been proven to strengthen these abilities while reducing math anxiety (Cotabish et al., 2024). Strong spatial understanding not only helps students recognize and manipulate two- and three-dimensional objects but also fosters reflection, autonomy, and collaboration skills that support holistic learning (Amdar et al., 2024; Lübeck, 2023).

Geometry is often considered a difficult topic in mathematics by many students. This difficulty is frequently attributed to the abstract nature of geometric concepts, which require strong visual understanding. Students commonly struggle with fundamental topics, such as the properties of shapes and circle theorems, resulting in poor performance on geometry assessments. Moreover, a lack of visualization skills further complicates their ability to grasp geometric principles, as many learners are unable to effectively manipulate or visualize geometric objects (Mudhefi et al., 2024).

Difficulty in understanding geometry is also influenced by another important factor: anxiety. Mathematics anxiety is a common phenomenon among students across various levels of education. It significantly affects students' ability to learn geometry, as studies have shown that students experience varying levels of anxiety depending on their geometric reasoning skills, which in turn can hinder their problem-solving performance (Wahyuni et al., 2024; Samosir & Dasari, 2022). At the visualization level, students show moderate anxiety, which can escalate to panic, while at the analysis level, students show moderate anxiety (Handayani & Permatasari, 2022). Anxiety arises during certain stages of problem solving, such as confusion in applying the Pythagorean theorem and uncertainty in providing the correct answer (Sunardi et al., 2019). This anxiety can negatively impact students' motivation to learn, their concentration, and their academic outcomes-particularly in geometry, which requires a deep understanding of visual-spatial objects and the ability to connect abstract concepts with visual representations (Isa & Johari, 2023; Maghfiroh et al., 2023).

The effective use of visual representations, such as digital tools, can enhance comprehension and reduce anxiety, leading to improved performance in geometry tasks (Zakelj & Klančar, 2022). As technology advances, innovations in education have focused on the use of interactive software that can help students understand abstract concepts more easily (Salami & Spangenberg, 2024). One of the most popular and effective software in learning mathematics, especially geometry, is GeoGebra. Technologies such as GeoGebra create dynamic and interactive visualizations of geometric concepts, and have been recognized as tools that can help students better understand abstract concepts (Schmid et al., 2023; Ardina & Boholano, 2024). The integration of Geogebra software into educational practices has shown significant benefits across multiple dimensions of learning and enables dynamic visualization of geometric concepts, making abstract ideas more tangible to students (Santiago, 2024). This software combines geometry, algebra, and calculus, facilitating a comprehensive understanding of mathematical relationships (Banu, 2024).

GeoGebra has the potential to reduce mathematics anxiety as it aligns with modern learning theories. Constructivist theory emphasizes the active role of students in constructing their own knowledge (Thi Thu & Thi Thu, 2023; Mijanović, 2023). Accordingly, GeoGebra enables students to actively develop their understanding of geometry through object manipulation and concept exploration, thereby enhancing learning control and reducing fear (Silveira, 2018). Furthermore, Bandura's self-efficacy theory indicates that successful experiences and positive feedback can increase self-efficacy (Pinheiro, 2009; Davison, 2015). Studies have shown a negative relationship between self-efficacy and mathematics anxiety (Hendral & Hidayati, 2023). GeoGebra provides instant visual feedback that can enhance students' self-efficacy, leading to a decrease in negative emotional responses, including anxiety in learning mathematics (Azizah et al., 2023).

Studies show that using GeoGebra in geometry topics has a positive impact on student engagement and test performance, fostering a more interactive learning environment, and making learning more accessible and engaging (Farhan & Yahfizham, 2023). Teachers are encouraged to incorporate technology to facilitate better understanding and interaction with geometric principles, as well as effective teaching strategies including problem-based learning and the use of manipulative aids, which have been identified as beneficial in geometry instruction (Amdar et al., 2024). GeoGebra aligns with the needs of 21st-century education by utilizing technology to stimulate interest and enhance understanding of mathematical concepts (Salsanabila et al., 2024). By using GeoGebra, students can see visual representations of geometric shapes and their calculation processes, which are expected to reduce students' anxiety in facing mathematical problems, especially geometry. However, although GeoGebra's potential in reducing anxiety has been recognized theoretically, there is still limited empirical research that specifically explores the direct impact of GeoGebra use on students' anxiety in learning mathematics.

The use of GeoGebra applications in mathematics learning provides benefits not only for students but also offers practical advantages for teachers and prospective teachers, such as helping to visualize abstract concepts interactively, accelerating lesson preparation, and providing instant feedback that facilitates the correction of students' understanding (Hohenwarter & Lavicza, 2009). In addition, GeoGebra encourages exploration-based learning so that students are more active in constructing knowledge, while teachers take on the role of facilitators (Setiawi et al., 2021). With the support of this technology, teachers can enhance their confidence in teaching, adjust the level of learning difficulty according to students' needs, and at the same time create a fun learning environment to reduce mathematics anxiety (Raisatunnisa et al., 2025).

There is a research gap in the study of GeoGebra usage, namely the lack of studies that specifically examine the direct impact of GeoGebra on students' anxiety in learning geometry, although many studies have discussed its role in improving mathematical understanding. Most studies still focus on improving learning outcomes and conceptual understanding, without further examining whether the technology can also reduce the inhibiting emotional factor, namely anxiety towards mathematics. The urgency of this research is grounded in the existing literature on anxiety. Although specific statistical data on the prevalence of mathematics anxiety in Indonesia is still limited, studies indicate that mathematics anxiety affects 67.6–86.2% of Indonesian students' academic performance (Sari & Mujazi, 2024; Maf'ulah & Fadhilah, 2024). Global data show varying prevalence across countries, with the majority of students reporting anxiety in learning mathematics. A large-scale study in Qatar involving 10,093 students in grades 7–12 revealed that 20% of students experienced high mathematics anxiety (Megreya et al., 2024). In the United States, 47% of pre-service teachers reported moderate to high mathematics anxiety, and 53% of prospective school counselors experienced moderate to high mathematics anxiety (Gill, 2018). Thus, mathematics anxiety is a global issue that impacts students' academic achievement in various countries (Shakmaeva, 2022). In Indonesia, research has shown that mathematics anxiety has a significant negative effect on students' mathematics learning achievement (Maghfiroh et al., 2024).

This research is important because mathematics anxiety, especially in the context of geometry, can hinder students' ability to understand important concepts. By using GeoGebra, it is hoped that students can reduce the anxiety they feel when learning mathematics, especially geometry, thereby increasing the overall effectiveness of learning. The research problems in this study are as follows: (1) Can the use of GeoGebra reduce students' anxiety in learning geometry? (2) How does the visualization provided by GeoGebra affect students' understanding of geometric concepts and their mathematics anxiety? (3) Is there a significant difference in students' anxiety levels before and after using GeoGebra in mathematics learning? (4) How are students' experiences in using GeoGebra related to their feelings of anxiety toward mathematics?

This study took respondents from prospective mathematics teacher students, who are currently in their 3rd semester and taking the analytical geometry of plane course program. This study is highly relevant for prospective mathematics teachers, as it highlights the potential of visualization tools to enhance student engagement and understanding in analytical geometry. By integrating GeoGebra into their teaching practices, future educators can overcome common challenges in conveying abstract mathematical concepts, thereby reducing student anxiety and improving learning outcomes.

GeoGebra has been shown to significantly increase student interest in learning analytical geometry, as evidenced by studies showing that students report positive attitudes towards its use (Listiani et al., 2024). The software facilitates a deeper understanding of geometric principles, which is essential for future educators who must convey these concepts to their (Narh-Kert & Sabtiwu, 2022). Thus, the objectives of this study are not merely to fill the literature gap regarding the effects of GeoGebra use on students' anxiety in mathematics learning, but also to: (1) Identify the extent to which the use of GeoGebra can reduce students' anxiety in learning geometry. (2) Analyze the influence of the visualizations provided by GeoGebra on students' understanding of geometric concepts and their levels of anxiety. (3) Compare the differences in students' anxiety levels before and after using GeoGebra in mathematics learning. (4) Describe students' experiences in using GeoGebra and their relation to feelings of anxiety toward mathematics.

2. Method

This study is a type of quasi-experimental quantitative research, with a one group pretest-posttest design. The design does not use a control or comparison group and measures the differences before and after treatment in the same group. The one-group pretest-posttest design is considered effective for determining the impact of treatment directly on the same subject, although it has limitations in terms of control over other variables that affect the results (Stratton, 2019; Kongkaew et al., 2020).

Experimental research generally uses a control group to compare treatments; however, a research design without a control group is still considered appropriate in this context, with the consideration of focusing on participants' internal changes (Pretest–Posttest Design). The main objective of this study is to examine whether the use of GeoGebra as a visualization tool has implications for changes in students' mathematics anxiety levels. Thus, what is more important is analyzing the changes within participants before and after the treatment (within-group changes), rather than comparing between groups. The one-group pretest–posttest model is sufficiently strong to address this research question.

The data collection technique was by survey using Google Forms fully online. The survey was conducted from October to November 2024. The respondents of this study were all third-semester students of the Mathematics Education study program who were taking the Analytical Geometry course with the topic of the coordinate system (determining coordinate points and drawing straight lines between points on a plane), with a total of 45 students. The respondents were students with a low level of ability in determining coordinate points on the Cartesian plane. This was identified when the researcher asked the students to manually determine coordinate points on a diagram drawn on the whiteboard. The GeoGebra platform was downloaded and installed on a laptop, then displayed through PowerPoint, followed by an explanation of how to use it to understand the concepts being studied.

The variables of mathematics anxiety before and after using Geogebra were measured using a Likert scale questionnaire with 10 items each. Descriptions of indicators and questionnaire statement items before and after using GeoGebra are presented in Table 1 and Table 2.

Table 1. Students' Mathematics Anxiety Questionnaire Before Using GeoGebra

Instructions: Please mark the answer that best describes how you feel about mathematics before using GeoGebra. The scale used is a Likert scale with the following ranges: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

No	Statement
1	I feel nervous when I start math class.
2	I feel like I can't understand math problems.
3	I often feel anxious when I have to take math tests.
4	I avoid math class because I feel stressed.
5	I feel uncomfortable every time I have to do math problems.
6	I feel panicked when I can't solve math problems quickly.
7	I often feel stressed during math class.
8	Every time I think about math, I feel stressed.
9	I am not confident in my ability to solve math problems.
10	I feel scared when I have to solve complicated math problems.

Table 2. Students' Mathematics Anxiety Questionnaire After Using GeoGebra

No	Statement
1	Using GeoGebra makes me more confident in solving math problems.
2	I feel more comfortable facing math lessons after using GeoGebra.
3	GeoGebra helps me to understand math concepts better.
4	I feel calmer when solving math problems using GeoGebra.
5	I feel GeoGebra helps me reduce my fear of difficult math problems.
6	I feel more relaxed during math lessons after using GeoGebra.
7	GeoGebra makes math easier to understand and more fun.
8	I am more confident in facing math exams after using GeoGebra.
9	Using GeoGebra helps me focus more on math lessons.
10	After using GeoGebra, I feel math becomes easier and more interesting.

The questionnaires in Tables 1 and 2 were adapted from the mathematics anxiety scale used by Ramirez et al., (2018) and Dowker et al., (2016) with slight modifications according to the research objectives. The validity test of the instrument used the item-total correlation test, declared valid if the Item Sig. correlation value <0.05, while the reliability measure was determined based on the Cronbach's Alpha coefficient value and declared reliable if the Alpha value ≥ 0.6. The validity and reliability coefficients of each statement in the questionnaire are presented in Table 3.

Table 3. Validity and reliability coefficients of the anxiety questionnaire before and after using GeoGebra

Before			After		
Item	**Sig.***	**Alpha****	**Item**	**Sig.***	**Alpha****
1	0,000	0,814	1	0,000	0,902
2	0,000		2	0,000	
3	0,000		3	0,000	
4	0,000		4	0,000	
5	0,000		5	0,000	
6	0,006		6	0,000	
7	0,000		7	0,000	
8	0,000		8	0,000	
9	0,006		9	0,000	
10	0,000		10	0,000	

*) Corrected Item – Total Correlation
**) Cronbach's alpha coefficient

Table 3 shows that all items both before and after the intervention have Sig. values below 0.05, indicating that all questionnaire items are declared valid (Chakrabartty, 2020). Furthermore, the reliability test aims to determine the consistency of the instrument in measurement. The Cronbach's Alpha value is used as an indicator of reliability. According to Raykov et al., (2022), an Alpha value ≥ 0.70 is considered to indicate good reliability. In Table 3, the Cronbach's Alpha value is 0.814 before the intervention and 0.902 after the intervention, indicating that the instrument has a high level of reliability.

The procedure for completing the research questionnaire was as follows : before the distribution began, the researcher provided a brief explanation of the purpose of the questionnaire and the instructions for filling it out, emphasizing that all responses would remain anonymous and confidential. Students were asked to answer honestly based on their personal experiences, not on assumptions they believed to be correct, and not by following their peers' answers. The questionnaire was administered via Google Form, which could be easily accessed using either a laptop or a smartphone. Respondents were instructed to complete the questionnaire in the classroom after the lecture ended so that they were in the same situation and condition.

The research procedure consists of three main stages: preparation stage, implementation stage and data processing stage. The process in each stage is presented in Figure 1.

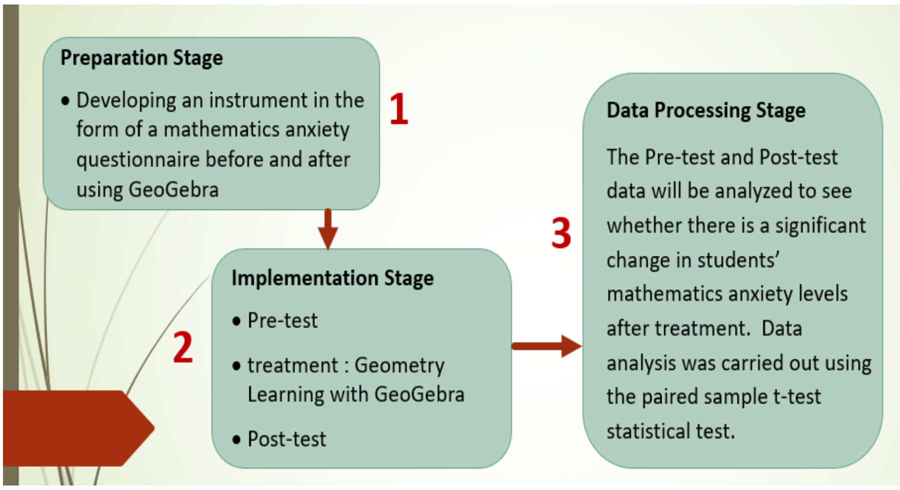

Figure 1. Research Procedures.

3. Results and Discussion

3.1 Results

The purpose of this study was to determine whether the use of GeoGebra as a visualization tool in geometry learning has an impact on students' mathematical anxiety. The description of the survey results in the form of tabulation of mathematical anxiety data before using GeoGebra is presented in Table 4.

The data tabulation in Table 4 interprets the respondents' perception data on mathematics anxiety before using GeoGebra as a learning aid. There are 10 statements describing various aspects of mathematics anxiety, with five response categories: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. Before using GeoGebra, students' mathematics anxiety levels were generally low to moderate. This is reflected in the dominance of "Disagree" and "Neutral" responses in most statements. There were 14.01% of respondents who agreed with the anxiety indicators and 2.45% who strongly agreed with the anxiety indicators, so there were still 16.46% of mathematics education students who were anxious when facing mathematics. There were indications of higher anxiety in certain situations, such as time pressure and mathematics exams. Furthermore, the tabulation of mathematics anxiety data after using GeoGebra is presented in Table 5.

Table 4. Data Tabulation Mathematics Anxiety Before Using GeoGebra

No	Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1	I feel nervous when I start math class.	11.1	37.8	44.4	4.4	2.3
2	I feel like I can't understand math problems.	8.9	37.8	44.4	6.7	2.2
3	I often feel anxious when I have to take math tests.	4.4	33.3	33.3	26.7	2.3
4	I avoid math class because I feel stressed.	24.4	57.8	15.6	2.2	0
5	I feel uncomfortable every time I have to do math problems.	8.9	48.9	40	0	2.2
6	I feel panicked when I can't solve math problems quickly.	0	17.8	24.4	46.7	11.1
7	I often feel stressed during math class.	11.1	57.8	28.9	2.2	0
8	Every time I think about math, I feel stressed.	13.3	57.8	22.2	6.7	0
9	I am not confident in my ability to solve math problems.	4.4	28.9	48.9	17.8	0
10	I feel scared when I have to solve complicated math problems.	6.7	31.1	31.1	26.7	4.4
	Average	9,36	40,9	33,32	14,01	2,45

Table 5. Data Tabulation Mathematics Anxiety After Using GeoGebra

No	Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1	Using GeoGebra makes me more confident in solving math problems.	0	2.2	17.8	68.9	11.1
2	I feel more comfortable facing math lessons after using GeoGebra.	0	0	24.4	62.3	13.3
3	GeoGebra helps me to understand math concepts better.	0	0	8.9	68.9	22.2
4	I feel calmer when solving math problems using GeoGebra.	0	2.2	26.7	57.8	13.3
5	I feel GeoGebra helps me reduce my fear of difficult math problems.	0	6.7	22.2	51.1	20
6	I feel more relaxed during math lessons after using GeoGebra.	0	2.2	26.7	62.2	8.9
7	GeoGebra makes math easier to understand and more fun.	0	2.3	24.4	51.1	22.2
8	I am more confident in facing math exams after using GeoGebra.	0	2.2	26.7	57.8	13.3
9	Using GeoGebra helps me focus more on math lessons.	0	4.4	17.8	66.7	11.1
10	After using GeoGebra, I feel math becomes easier and more interesting.	0	0	22.3	64.4	13.3
	Average	0	2.22	21,77	61,12	14,87

The data in Table 5, shows that the majority of students gave a positive response to the use of GeoGebra in learning mathematics. An average of 61.12% of students agreed and 14.87% strongly agreed that GeoGebra helped them feel more confident, comfortable, and understand mathematical concepts better. The most agreed statement was that GeoGebra helped them understand mathematical concepts (91.1% combined agree and strongly agree). In addition, students also felt calmer, more focused, and more prepared for exams after using GeoGebra. The level of disagreement was very low (average 2.22%), and no students strongly disagreed. This shows that GeoGebra is generally well accepted and contributes positively to reducing anxiety in learning mathematics.

To clarify the results of the Pretest and Posttest, Table 6 Change of mathematics anxiety before and after using GeoGebra and Figure 2 presents a comparison of the average levels of mathematics anxiety before and after using GeoGebra.

Table 6. Change (%) of Mathematics Anxiety Before and After using GeoGebra

Treatment	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Before Geogebra	9,36	40,9	33,32	14,01	2,45
After Geogebra	0	2,22	21,77	61,12	14,87
Change (%)	-9,36	-38,68	-11,55	47,11	12,42

The most significant decrease occurred in the **Disagree** category across almost all items. Item 4 decreased from 57.8% to 2.2% (-55.6%), while Item 1 also showed a substantial drop from 37.8% to 2.2% (-35.6%). This indicates that students' doubts about their ability to deal with mathematics were drastically reduced after using GeoGebra. The **Strongly Disagree** category also experienced a sharp decline. For Item 4, the percentage dropped from 24.4% to 0% (-24.4%). This means that almost no students strongly disagreed with the positive statements about their experience after GeoGebra-assisted learning.

For the **Neutral** category, the trend tended to decrease in most items. Item 3 dropped from 33.3% to 8.9% (-24.4%), and Item 1 decreased from 44.4% to 17.8% (-26.6%). This decline shows that students who were previously hesitant or had no clear opinion began to shift toward a more positive (agree) stance.

The most significant increase was observed in the **Agree** category. Item 1 rose from 4.4% to 68.9% (+64.5%), Item 4 increased from 2.2% to 57.8% (+55.6%), and Item 5 rose from 0% to 51.1% (+51.1%). This means that after learning with GeoGebra, the majority of students agreed that their mathematics anxiety had decreased. The **Strongly Agree** category also showed an increase, although not as substantial as the Agree category. Item 3 increased from 2.3% to 22.2% (+19.9%), and Item 5 rose from 2.2% to 20% (+17.8%). This indicates that there was a group of students who developed a very strong confidence in their positive feelings after using GeoGebra.

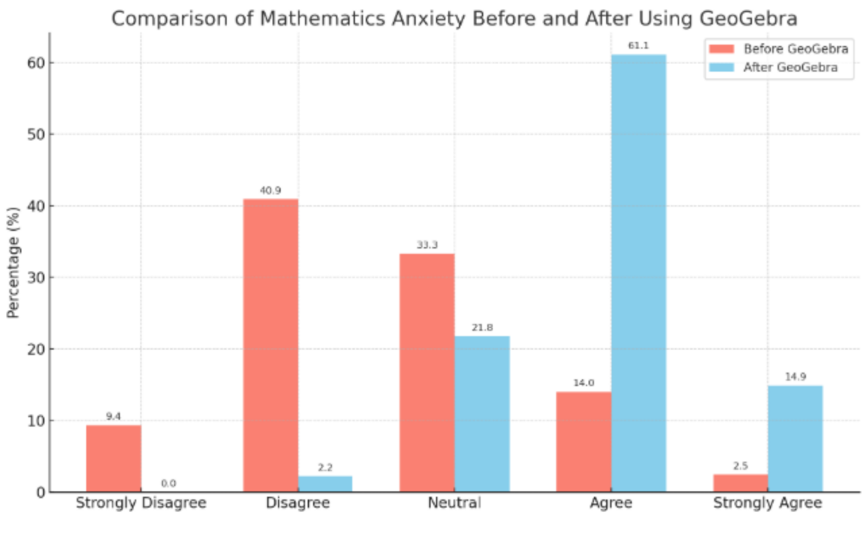

Figure 2. Comparison of Mathematics Anxiety Before and After Using Geogebra

Before using GeoGebra, the majority of students were in the Disagree (40.9%) and Neutral (33.3%) categories, indicating that they tended to disagree or remain neutral regarding statements of anxiety. After using GeoGebra, there was a significant increase in the Agree (61.1%) and Strongly

Agree (14.9%) categories, meaning that students felt more comfortable, confident, and supported with GeoGebra. Meanwhile, the Strongly Disagree and Disagree categories decreased drastically, indicating a reduction in doubt and negative anxiety.

To answer the research question 1 to 4, a Paired Sample t-Test analysis was then carried out. Before conducting the analysis, normality and homogeneity tests were carried out. (The results see Tables 6 and 7).

Table 6. Shows the Asymp. Sig (2-tailed) parameters, p value = 0.263. If $p > 0.05$, then the data is considered normally distributed. $p = 0.263 > 0.05$, so the research data is normally distributed. Next, a homogeneity test was carried out, the results of the homogeneity test are presented in Table 7.

Table 6. Result Normality Test

One-Sample Kolmogorov-Smirnov Test		
N		Results 90
Normal Parameters[a,b]	Mean	71,59
	Std. Deviation	12,786
Most Extreme Differences	Absolute	,106
	Positive	,078
	Negative	-,106
Kolmogorov-Smirnov Z		1,007
Asymp. Sig. (2-tailed)		,263

Table 7. Result Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
3,620	1	88	,060

The purpose of the homogeneity test is to determine whether the variance between groups is homogeneous (the same). Because Sig. = 0.060 > 0.05, the variance between groups is declared homogeneous. This means that the assumption of homogeneity is met, so that the ANOVA analysis can be continued in Table 8.

Table 8. ANOVA Test Results (One-Way ANOVA)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3373,344	1	3373,344	27,095	,000
Within Groups	10956,044	88	124,501		
Total	14329,389	89			

One-Way ANOVA test in Table 8, is used to determine whether there is a significant difference between two or more groups of means in the dependent variable. The F value = 27.095 shows the ratio of variation between groups to variation within groups. Significance value (Sig.) = 0.000, Sig. = 0.000 <0.05, indicating a statistically significant difference between groups before and after using GeoGebra on math anxiety. Because the data is normally distributed and homogeneous, and shows differences through ANOVA analysis. Furthermore, parametric statistical analysis is carried out, namely the Paired Sample t-Test to test the research hypothesis. The results of the Paired Sample t-Test analysis can be seen in Table 9.

Table 9. Result Paired Sample T-Test

1. Paired Samples Statistics

Uji	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	65,44	45	12,623	1,882
Post-test	77,73	45	9,701	1,446

2. Paired Samples Correlations

		N	Korelasi	Sig.
Pair 1	Pre-Test & Post-test	45	-0,014	0,928

3. Paired Samples Correlations

		Mean Difference	Std. Deviation	Std. Error	t-value	df	Sig. (2-tailed)
Pair 1	Pre-test & Post-test	-12,289	16,026	2,389	-5,144	44	**0,000**

95% Confidence Interval of the Difference	
Lower	Upper
-17, 104	-7,474

Table 9 number 1 shows the sample size tested was 45 respondents. The average post-test score was higher (77.73) compared to the pre-test (65.44). Table 9 number 2, shows the correlation value between pre-test and post-test scores is very low and not significant ($p = 0.928 > 0.05$).

Table 9 number 3, shows the Mean Difference = -12.289, which means the post-test score increased by an average of 12.289 points compared to the pre-test. The t-value = -5.144, with a p-value = 0.000, shows that this difference is highly statistically significant (since $p < 0.05$). The 95% confidence interval for the difference in scores is between -17.104 and -7.474, does not include zero, confirming that this difference is significant.

To determine the strength of the effect, an effect size calculation was conducted using Cohen's d, based on the t-value.

$$d = \frac{t - value}{\sqrt{N}} = \frac{-5{,}144}{\sqrt{45}} = \frac{-5{,}144}{6{,}708} = -0{,}77$$

(The negative sign is not considered, as it does not indicate the strength of the effect).

Based on the calculation, the value obtained was d = 0.77. According to Cohen's interpretation (d = 0.2 = small, d = 0.5 = medium, and d = 0.8 = large), the effect size of d = 0.77 falls within the medium-to-large category. This indicates that the use of GeoGebra not only has a statistically significant impact but also demonstrates a substantial effect strength in improving students' learning outcomes (Cohen, 1988).

3.2 Discussion

The findings of this study demonstrate that the integration of GeoGebra exerts a significant positive influence on students' self-efficacy in the context of geometry learning. Students who initially expressed doubts about their own abilities reported increased confidence in exploring mathematical concepts after utilizing GeoGebra. According to Gale et al., (2021), successful experiences serve as a primary source of self-efficacy enhancement. Through the use of GeoGebra, students experienced a sense of achievement in comprehending and solving tasks, which in turn positively contributed to their self-efficacy. Moreover, the interactive visualizations provided by GeoGebra not only facilitated a deeper understanding of the subject matter but also fostered a sense of control over the learning process, thereby further strengthening students' self-efficacy. These results are consistent with the findings of Zetriuslita et al., (2020), who emphasized that the integration of GeoGebra can reinforce learners' confidence in addressing mathematical challenges.

Furthermore, students' statements that GeoGebra helped them better understand mathematical concepts (91.1% agreed and strongly agreed) provide evidence of a significant improvement in conceptual understanding after the use of GeoGebra. The spatial visualization and dynamic simulation features made it easier for students to grasp the interconnections between concepts, particularly in the topic of analytic geometry. This improvement was reflected in the substantial differences between pretest and posttest scores, accompanied by a strong effect size, indicating that the impact of GeoGebra is not merely coincidental but truly substantive. In line with the findings of Ziatdinov & Valles (2022), GeoGebra enables the simultaneous integration of graphical, algebraic, and numerical representations, thereby facilitating students in developing deeper and more meaningful conceptual understanding. Thus, GeoGebra supports the transition from procedural learning to more meaningful conceptual learning. A solid conceptual understanding, in turn, helps reduce uncertainty and stress in learning mathematics.

The main novelty of this study lies in the empirical evidence that the use of GeoGebra not only enhances understanding but also quantitatively reduces mathematics anxiety among students. The majority of students reported feeling more comfortable (75.6% agreed and strongly agreed), calm (71.1%), and relaxed (71.1%) when learning mathematics with GeoGebra. The results of the analysis indicate a significant decrease in anxiety scores after the use of GeoGebra, with a medium to large effect size, confirming that this intervention has a tangible impact on students' affective dimensions. This reduction in anxiety can be explained through Cognitive Load Theory (Chadwick, 2024), whereby GeoGebra helps lower cognitive load by providing instant visualizations, thus preventing students from being overwhelmed by complex symbolic calculations. These findings are consistent with Zakelj & Klančar (2022), who demonstrated that interactive and dynamic educational technologies can reduce stress and anxiety in mathematics education. Furthermore, the high interactivity of GeoGebra makes learning more engaging and alleviates students' psychological pressure. In addition, these results align with the findings of Putri et al., (2020) and Min et al., (2024), who argued that visual learning media can help reduce mathematics anxiety by making abstract concepts more accessible and comprehensible, thereby lowering anxiety levels.

Another indicator shows that GeoGebra helps students remain more focused during learning. This finding is consistent with the studies of Ardina & Boholano (2024) and Farhan & Yahfizham (2023), which reported that interactive tools not only reduce anxiety but also enhance engagement and motivation in mathematics classes. Ingram et al., (2020) found that active participation in the learning process improves attention and information processing. In this context, GeoGebra creates a learning environment that fosters independent exploration and concentration, thereby indirectly shifting students' attention from anxiety toward meaningful learning activities. Students' statements that mathematics became easier and more enjoyable after using GeoGebra indicate a transformation in perception. According to Melo & Leal (2024), affective perceptions of mathematics strongly influence the level of anxiety. When students perceive mathematics as engaging and non-threatening, the likelihood of experiencing anxiety is reduced.

The primary objective of this study is to examine the implications of using GeoGebra. These findings are highly significant for prospective mathematics teachers, as they are not only expected to master the subject matter but also to develop pedagogical strategies capable of reducing students' affective barriers. With evidence that GeoGebra enhances self-efficacy, improves conceptual understanding, and simultaneously reduces anxiety, this study emphasizes that the integration of technology in mathematics learning can serve as a holistic approach. In this sense, GeoGebra is not merely a visualization tool but also a pedagogical instrument that optimizes both cognitive and affective dimensions, making it worthy of consideration in the teacher education curriculum.

The significant improvement in pre-test and post-test scores after using GeoGebra also highlights potential implications for teacher training and curriculum development, especially in addressing mathematics anxiety and improving learning outcomes. Integration of educational technology such as GeoGebra can transform traditional teaching methods, fostering a more engaging and effective learning environment. This supports the results of previous research by Em & Roman, (2020) which stated that teachers should receive training to effectively integrate GeoGebra into their lessons, focusing on its features that promote interactive learning. And in line with research by Martinez (2017) which stated that the curriculum should incorporate technology-based tools, aligned with standards that emphasize the use of manipulatives to enhance understanding of complex mathematical concepts. The curriculum should include GeoGebra as a standard tool for teaching various mathematics topics, as it has been shown to improve student performance and confidence (Pentang et al., 2022).

4. Conclusion

This study affirms that the use of GeoGebra in geometry learning provides not only cognitive benefits in terms of enhanced conceptual understanding but also affective benefits through the reduction of mathematics anxiety. This represents the main novelty of the research, positioning GeoGebra not merely as a visualization tool but also as an affective intervention that is empirically proven. These findings make an important contribution to the development of theory, methodology, and practice in mathematics education by emphasizing that technology integration should be viewed holistically—addressing both cognitive and affective aspects—so that mathematics learning becomes more inclusive, humanistic, and enjoyable.

The strategic implication of this study lies in the need for learning design in higher education, particularly in mathematics teacher education programs, to systematically integrate technologies such as GeoGebra into the curriculum. In doing so, prospective teachers will become accustomed to using visualization software as a pedagogical strategy that not only supports conceptual mastery but also fosters self-efficacy, reduces emotional barriers, and enhances students' mathematical well-being. Moreover, universities should instill the awareness that success in mathematics learning is measured not only by cognitive achievement but also by reduced anxiety and increased student confidence.

Nevertheless, this study has several limitations, including the absence of a control group, the short duration of the intervention, and external factors that could not be fully controlled, making the findings not yet generalizable to all contexts. Therefore, further research with stronger experimental designs, longer interventions, and better control of external variables is needed to ensure the sustainability and broader applicability of these findings in diverse learning contexts.

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