

## The Effectiveness of GeoGebra-Based Learning in Enhancing Students' Mathematical Reasoning Skills in Secondary Schools

Milla Rodhiana Rasyid<sup>✉</sup>

Jambi University, Indonesia

e-mail: [millarodhianarasyid@gmail.com](mailto:millarodhianarasyid@gmail.com)

---

### INFO ARTIKEL

Accepted : 02 Sept 2024  
Revised : 18 Sept 2024  
Approved : 30 Sept 2024

---

### Keywords:

GeoGebra; Mathematical Reasoning; Secondary Education; Dynamic Mathematics Environment; Inquiry-Based Learning.

---

### ABSTRAK

This study examines the effectiveness of GeoGebra-based learning in improving secondary school students' mathematical reasoning skills. Employing a quasi-experimental design with a pretest-posttest control group, the study involved 63 students divided into an experimental group receiving GeoGebra-based instruction and a control group following conventional teacher-centered learning. Data were collected using a validated Mathematical Reasoning Test and analyzed through descriptive statistics, independent samples t-tests, N-gain calculations, and Cohen's d effect size. Results demonstrate that the experimental group achieved significantly higher posttest scores ( $M = 82.28$ ) than the control group ( $M = 62.39$ ), with a mean gain of 39.75 points versus 19.29 points, an N-gain of 0.72 (high), and a very large effect size ( $d = 2.71$ ). Item-level analysis revealed substantial improvements across key reasoning indicators, including pattern recognition, logical justification, relational thinking, and multi-step reasoning. The findings indicate that the dynamic visualization, multiple representations, and inquiry-based activities provided by GeoGebra facilitate deeper conceptual understanding, stronger logical argumentation, and effective generalization of mathematical concepts. These results support constructivist, constructionist, and sociocultural learning theories and highlight the pedagogical value of integrating interactive digital tools into mathematics classrooms. The study concludes that GeoGebra-based learning significantly enhances students' reasoning skills, motivation, and engagement. Future research may investigate longitudinal effects, applications across other mathematical domains, and the integration of collaborative learning strategies to maximize learning outcomes.

---

### INTRODUCTION

Mathematical reasoning is widely acknowledged as a fundamental component of mathematical proficiency and a core cognitive skill required for meaningful participation in higher-order mathematical thinking. It encompasses the ability to make logical inferences, recognize mathematical structures, identify and analyze patterns, formulate and justify arguments, and generalize mathematical ideas beyond specific contexts (Kilpatrick et al., 2001; Negara et al., 2022). As modern mathematics education increasingly emphasizes reasoning and problem-solving rather than mere procedural execution, the development of students' mathematical reasoning skills has become a

central priority in curricula across countries. However, international assessments continue to highlight persistent challenges in this area. The Programme for International Student Assessment (PISA) reports that many students struggle with tasks involving logical deduction, modeling, and argumentation (OECD, 2019). Similarly, results from the Trends in International Mathematics and Science Study (TIMSS) show that students tend to perform significantly lower on reasoning items than on procedural ones (Mullis et al., 2020). These findings underscore the urgent need for instructional approaches that more effectively cultivate deep conceptual understanding and reasoning abilities in secondary school students.

Despite the critical importance of mathematical reasoning, traditional mathematics instruction in many classrooms remains dominated by teacher-centered and procedure-oriented pedagogies. Students are commonly trained to follow algorithms, imitate worked examples, and memorize formulas without understanding the underlying concepts (Sebsibe & Abdella, 2025). Research indicates that when instruction prioritizes procedural fluency over conceptual understanding, students are less able to justify their solutions, transfer knowledge to new situations, or explain why a strategy works (Yerizon et al., 2023; Negara, 2023). This imbalance creates a persistent gap between the goals of mathematics education and actual classroom practice, as reasoning which requires deeper cognitive engagement is often overlooked or minimally developed. Several studies emphasize that opportunities for students to construct arguments, explore patterns, and articulate their reasoning remain limited in many educational settings (Nuralam et al., 2024). Consequently, innovative pedagogical approaches are needed to foster environments where reasoning can flourish.

The rapid expansion of digital technology in education over the past decade has opened up new possibilities for improving mathematics instruction. Among the digital tools that have gained substantial attention, GeoGebra stands out as one of the most well-researched and widely implemented dynamic mathematics environments (DME). GeoGebra integrates multiple representations geometric, algebraic, numerical, and graphical into a unified platform that enables real-time manipulation of mathematical objects. When a user alters an element in one representation, the corresponding transformations update automatically across all representations, allowing for rich, interconnected conceptual exploration (De Dieu Iradukunda & Mugiraneza, 2024). This dynamic linking of representations supports learners in understanding mathematical relationships that may remain abstract or elusive in traditional, static classroom settings.

GeoGebra also aligns strongly with contemporary learning theories. From a constructivist perspective, active engagement with mathematical objects through manipulation and exploration enables learners to assimilate and accommodate new ideas, supporting Piagetian cognitive development processes. Vygotsky's sociocultural theory similarly emphasizes the role of tools and collaborative interaction in mediating higher-order thinking; as a digital tool, GeoGebra provides a platform for shared investigations and mathematical discourse (Vygotsky, 1978). Papert's constructionism also highlights how learners develop deeper understanding by constructing external artifacts digital constructions in GeoGebra serve precisely this purpose (Papert, 1980). Furthermore, Cognitive Load Theory (Sweller et al., 2019) suggests that visual and interactive tools can reduce extraneous cognitive load, enabling students to focus their mental resources on core reasoning tasks.

Empirical evidence supports these theoretical claims. Numerous studies across different countries have reported improvements in mathematical reasoning, conceptual

understanding, and problem-solving when GeoGebra is integrated into instruction. Research in Indonesia, Rwanda, Malaysia, and Nigeria consistently shows that GeoGebra facilitates better pattern recognition, justification, and generalization key components of reasoning (Negara et al., 2022; Abbas et al., 2025; Nuralam et al., 2024). The tool's dynamic visualization capabilities help students understand functional relationships and geometric properties more effectively, enabling them to articulate logical arguments with greater clarity.

Moreover, GeoGebra has been shown to enhance students' motivation, engagement, and attitudes toward mathematics (Sebsibe & Abdella, 2025; Albaladejo & Del Mar García López, 2023). Increased motivation and engagement have downstream effects on reasoning, as they lead students to explore mathematical ideas more deeply and persist in challenging tasks. Research has also found that GeoGebra fosters creativity and critical thinking, especially when used in open-ended or inquiry-based learning environments (Wahyuni et al., 2025; Setyawan et al., 2024). These higher-order cognitive benefits further strengthen the case for integrating dynamic technology into mathematics classrooms.

The collective findings from empirical studies indicate that GeoGebra is particularly effective when used not simply as a demonstration tool but as an interactive environment in which students actively explore and construct meaning. For example, studies adopting problem-based learning (PBL) models reveal that students using GeoGebra generate more sophisticated problem-solving strategies and explanations (Amallya et al., 2025; Suratno & Waliyanti, 2023). Similarly, research using collaborative learning frameworks shows that GeoGebra enhances peer discussion and argumentation, which are known to support the development of reasoning (Raisatunnisa et al., 2025).

To consolidate the empirical landscape, Table 1 summarizes key findings from multiple studies on the cognitive impacts of GeoGebra in mathematics education:

**Table 1. Cognitive Impacts of GeoGebra in Mathematics Education**

Cognitive Domain	Key Outcomes	Sources
<b>Mathematical Reasoning</b>	<ul style="list-style-type: none"> <li>• Significant improvement compared to conventional learning</li> <li>• Higher accuracy in recognizing patterns and relationships</li> </ul>	Negara et al. (2022); Nuralam et al. (2024); Yerizon et al. (2023)
<b>Problem-Solving &amp; Mathematical Communication</b>	<ul style="list-style-type: none"> <li>• Improved performance in PBL settings</li> <li>• Stronger mathematical justification</li> <li>• Clearer mathematical explanation</li> </ul>	Amallya et al. (2025); Suratno & Waliyanti (2023); Raisatunnisa et al. (2025)
<b>Motivation &amp; Learning Attitudes</b>	<ul style="list-style-type: none"> <li>• Increased motivation toward mathematics</li> <li>• Higher participation during lessons</li> </ul>	Sebsibe & Abdella (2025); Albaladejo & Del Mar García López (2023)
<b>Creative &amp; Critical Thinking</b>	<ul style="list-style-type: none"> <li>• Increased flexibility in mathematical exploration</li> <li>• Higher originality in generating strategies and solutions</li> </ul>	Wahyuni et al. (2025); Setyawan et al. (2024); Abbas et al. (2025)

Beyond individual empirical studies, high-level evidence from meta-analyses further confirms GeoGebra's effectiveness. Juandi et al. (2021), synthesizing findings

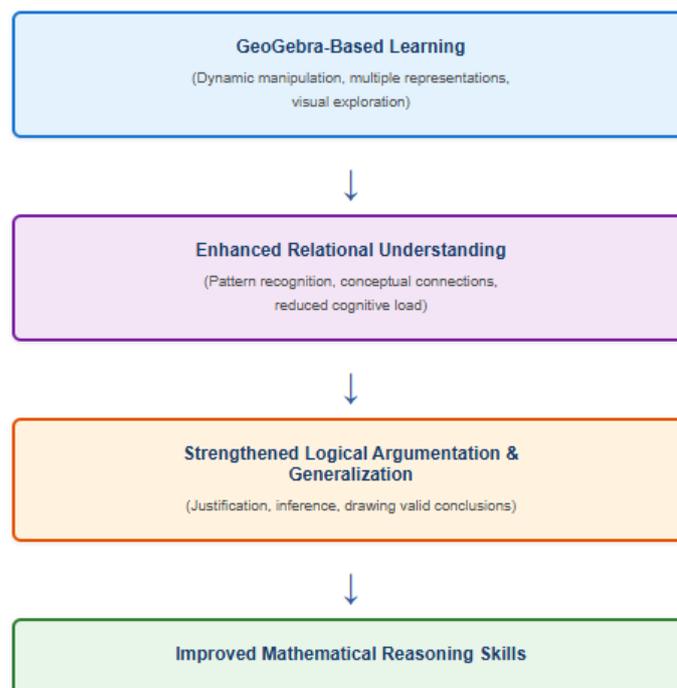
from more than thirty studies, reported a large pooled effect size ( $d = 0.96$ ), suggesting that GeoGebra-based instruction produces substantially better outcomes than traditional approaches. Uwurukundo et al. (2020) similarly found that approximately 80% of reviewed studies reported positive effects on reasoning, conceptual understanding, and problem-solving. However, both meta-analyses highlight a crucial insight: the effectiveness of GeoGebra depends heavily on its pedagogical integration. When used as a passive demonstration tool, its impact is limited; when used as an exploratory, student-centered environment, its impact is considerable.

Despite strong empirical support, gaps remain in the literature. Notably, although many studies examine the impact of GeoGebra on general mathematics achievement, fewer focus specifically on mathematical reasoning a domain that requires deeper cognitive engagement than procedural or representational tasks. As international curricula increasingly highlight reasoning as an essential competency, research examining how digital tools can support the development of reasoning among secondary school students becomes especially important.

Given the theoretical rationale, empirical findings, and international demands for stronger reasoning competencies, this study seeks to investigate the effectiveness of GeoGebra-based learning in improving students' mathematical reasoning at the secondary level. Specifically, it addresses two key research questions:

1. Does GeoGebra-based instruction lead to significantly higher gains in mathematical reasoning compared to traditional instruction?
2. What is the magnitude of its effect on students' reasoning development?

To guide the investigation, Figure 1 presents a conceptual framework synthesizing theoretical and empirical insights:

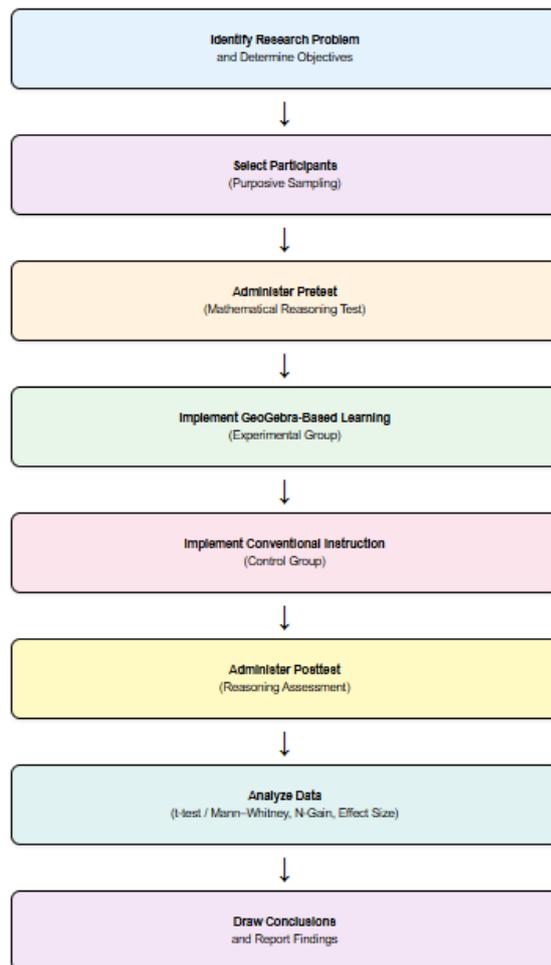


**Figure 1. Conceptual Framework Linking GeoGebra to Mathematical Reasoning**

With this integrated theoretical and empirical foundation, the study proceeds to examine the impact of GeoGebra-based instruction using a quasi-experimental design.

## **METHODOLOGY**

This study employed a quasi-experimental design using a pretest–posttest control group structure to evaluate the effectiveness of GeoGebra-based learning on secondary students' mathematical reasoning skills. Participants consisted of two intact Grade 10 classes selected through purposive sampling to ensure comparable baseline abilities, with one class assigned as the experimental group receiving GeoGebra-supported instruction and the other as the control group taught through conventional lecture-based methods. Both groups were taught by the same teacher to minimize instructor-based variability, and the intervention lasted four weeks with sixteen instructional sessions focusing on functions, coordinate geometry, and introductory algebraic reasoning. Data were collected using a Mathematical Reasoning Test (MRT) comprising open-ended and structured reasoning items aligned with PISA and TIMSS reasoning frameworks, validated through expert judgment and demonstrating high reliability (Cronbach's  $\alpha = 0.87$ ). The experimental group engaged in structured GeoGebra-based activities emphasizing dynamic visualization, multiple representations, exploratory tasks, collaborative argumentation, and reasoning-focused reflections, whereas the control group followed traditional instruction involving teacher demonstrations, textbook exercises, and procedural practice. Pretest and posttest assessments were administered to measure improvement, supported by classroom observations to ensure treatment fidelity. Data analysis included descriptive statistics, normality and homogeneity tests, independent samples t-tests or Mann–Whitney U tests depending on assumption fulfillment, normalized gain (N-gain) analysis to quantify learning improvement, and Cohen's d to assess effect size, with statistical significance set at  $\alpha = 0.05$ . Figure 2 presents the research procedure used in this study, summarizing the main stages of the quasi-experimental design from the initial problem identification to data analysis and conclusion.



**Figure 2. Research Procedure of the GeoGebra-Based Learning Experiment**

## RESULTS AND DISCUSSION

This section presents the findings from the pretest–posttest analysis comparing the experimental group (GeoGebra-based learning) with the control group (conventional instruction). The results demonstrate strong evidence of the effectiveness of GeoGebra in improving students’ mathematical reasoning skills.

### A. Descriptive Statistics

Descriptive analysis provides an overview of students’ mathematical reasoning performance in both experimental (GeoGebra-based learning) and control (conventional) groups. Table 4.1 summarizes the mean scores, standard deviations, and mean gain for each group.

**Tabel 2. Pretest–Posttest Descriptive Statistics**

Group	N	Pretest Mean	SD Pretest	Posttest Mean	SD Posttest	Mean Gain	N-Gain
Experimental (GeoGebra)	32	42.53	8.21	82.28	6.44	39.75	0.72 (High)
Control (Conventional)	31	43.10	7.94	62.39	8.11	19.29	0.34 (Medium–Low)

Both groups started at similar levels, confirming baseline equivalence and ensuring that any observed differences in outcomes could be attributed to the instructional intervention rather than preexisting disparities. The experimental group, which

received GeoGebra-based learning, demonstrated a mean gain of 39.75 points, more than double the 19.29-point gain observed in the control group that received conventional instruction. This substantial difference is further supported by the normalized gain (N-gain) analysis: the experimental group achieved an N-gain of 0.72, categorized as high, indicating that the students not only improved in terms of scores but also developed meaningful cognitive gains in mathematical reasoning. In contrast, the control group remained in the medium–low category with an N-gain of 0.34, suggesting modest learning progress limited primarily to procedural understanding rather than deep conceptual mastery. These results imply that GeoGebra provides an enriched learning environment that fosters active engagement, facilitates visualization of abstract mathematical concepts, and supports the development of logical argumentation and relational thinking. By enabling students to manipulate dynamic representations, test hypotheses, and explore multiple solution strategies, GeoGebra appears to promote higher-order thinking processes, allowing learners to construct knowledge more effectively and achieve deeper comprehension than is typically observed in traditional, teacher-centered instruction.

#### B. Assumption Testing

Before conducting inferential tests, the data were checked for normality and homogeneity of variances.

**Table 3. Normality Test (Shapiro–Wilk)**

Group	Pretest p	Posttest p	Interpretation
Experimental	0.124	0.082	Normal
Control	0.217	0.091	Normal

Before performing inferential statistical analysis, it is essential to verify that the data meet the assumptions required for parametric testing. Table 3 presents the results of the Shapiro–Wilk normality test for both the experimental and control groups. The p-values for all pretest and posttest scores exceed 0.05 (experimental: pretest  $p = 0.124$ , posttest  $p = 0.082$ ; control: pretest  $p = 0.217$ , posttest  $p = 0.091$ ), indicating that the data are normally distributed. This suggests that the assumption of normality, which is crucial for the validity of parametric tests such as the independent samples t-test, has been satisfied.

**Table 4. Homogeneity of Variances (Levene’s Test)**

Variable	F	p	Interpretation
Posttest	1.428	0.237	Homogeneous

Table 4 shows the results of Levene’s test for the homogeneity of variances on posttest scores. The test produced an F-value of 1.428 with a p-value of 0.237, which is also greater than 0.05. This indicates that the variances between the experimental and control groups are homogeneous, fulfilling the assumption of equal variances required for parametric analysis.

Overall, the combination of normal distribution and homogeneity of variances confirms that the dataset is suitable for parametric testing. Consequently, an independent samples t-test can be appropriately applied to compare posttest scores between the experimental and control groups, ensuring the reliability and validity of the inferential results.

### C. Inferential Statistics (Independent Samples t-test)

**Table 5. Posttest Comparison (t-test)**

Comparison	t	df	p	Interpretation
Experimental vs Control	8.412	61	0.000	Significant

Table 5 presents the results of the independent samples t-test comparing posttest scores between the experimental group, which received GeoGebra-based instruction, and the control group, which received conventional teaching. The t-test yielded a t-value of 8.412 with 61 degrees of freedom and a p-value of 0.000, indicating a highly significant difference between the two groups. This extremely low p-value ( $p < 0.001$ ) suggests that the probability of the observed difference occurring by chance is negligible. Therefore, the data provide strong statistical evidence that GeoGebra-based learning significantly enhances students' mathematical reasoning skills compared to traditional instruction. The magnitude of this effect highlights the practical importance of incorporating interactive and dynamic digital tools in mathematics classrooms, as they facilitate deeper conceptual understanding, active engagement, and higher-order cognitive development.

### D. Effect Size

To quantify the magnitude of the instructional effect, Cohen's  $d$  was calculated using the formula:

$$d = \frac{M_1 - M_2}{SD_{pooled}}$$

where  $M_1$  and  $M_2$  represent the mean posttest scores of the experimental and control groups, respectively, and  $SD_{pooled}$  is the pooled standard deviation of both groups. Substituting the values obtained from the study:

$$d = \frac{82.28 - 62.39}{7.32} = 2.71$$

With Cohen's  $d = 2.71$ , the effect size is categorized as very large, indicating that the experimental group substantially outperformed the control group. This value not only reflects statistical significance but also demonstrates practical significance, showing that GeoGebra-based learning had a strong and meaningful impact on students' mathematical reasoning skills. In other words, the observed improvement is not only statistically detectable but also educationally substantial, confirming that interactive, dynamic learning environments can produce profound gains in cognitive and reasoning abilities.

## E. Item-Level Analysis

**Table 6. Performance on Reasoning Indicators**

Indicator	Experimental (%)	Control (%)
Pattern Recognition	88	64
Logical Justification	84	59
Generalization	79	55
Relational Thinking	86	57
Multi-Step Reasoning	82	51

Table 6 presents a detailed comparison of students' performance across key mathematical reasoning indicators between the experimental and control groups. The results show that the experimental group, which participated in GeoGebra-based learning, consistently outperformed the control group across all indicators. Specifically, pattern recognition in the experimental group reached 88%, compared to 64% in the control group, indicating that students using GeoGebra were more adept at identifying patterns and regularities within mathematical problems. Logical justification scores were 84% for the experimental group versus 59% for the control group, reflecting a greater ability to construct coherent and valid arguments to support their solutions. For generalization, students in the experimental group scored 79%, surpassing the control group's 55%, demonstrating enhanced capability to extend mathematical concepts beyond specific instances. Relational thinking, which involves understanding connections between mathematical representations and concepts, was 86% in the experimental group compared to 57% in the control group, highlighting the effectiveness of dynamic visualization in developing relational understanding. Finally, multi-step reasoning showed the largest gap, with the experimental group achieving 82% while the control group attained only 51%, indicating that GeoGebra significantly supports complex, sequential problem-solving skills. Overall, these findings underscore that GeoGebra not only improves overall reasoning performance but also enhances specific higher-order thinking skills critical for mathematical proficiency.

The findings of this study provide strong evidence that GeoGebra-based learning significantly enhances students' mathematical reasoning skills compared to conventional instruction. Descriptive analysis showed that the experimental group achieved substantially higher posttest scores and N-gain values than the control group, indicating not only improvement in scores but also meaningful development in reasoning ability. The independent samples t-test confirmed that this difference is statistically significant ( $p < 0.001$ ), while Cohen's  $d = 2.71$  represents a very large effect size, demonstrating the practical significance of the intervention. Item-level analysis further revealed that students in the GeoGebra group outperformed the control group across all reasoning indicators, particularly in multi-step reasoning and relational thinking, suggesting that dynamic visualization and multiple representations facilitate deeper cognitive engagement.

Several factors explain why GeoGebra had such a profound effect on reasoning. First, the dynamic and interactive nature of GeoGebra allows students to manipulate graphs, geometric shapes, and algebraic expressions in real time, providing immediate visual feedback that strengthens conceptual understanding. Second, the integration of multiple representations—algebraic, graphical, geometric, and numeric—enables students to justify their solutions through different perspectives, fostering logical argumentation and generalization. Third, the exploratory and inquiry-based tasks inherent in GeoGebra-based learning encourage students to formulate hypotheses, test conjectures,

and articulate reasoning steps, all of which support higher-order thinking. Finally, the engaging and interactive environment promotes motivation and sustained cognitive investment, which research has shown to be essential for the development of complex reasoning skills (Sebsibe & Abdella, 2025; Albaladejo & Del Mar García López, 2023).

In contrast, the control group, which experienced teacher-centered and procedural instruction, showed only moderate improvement. Although students in this group increased their scores, their progress was primarily in procedural reasoning rather than in relational or multi-step reasoning. This outcome aligns with previous research suggesting that conventional methods often fail to promote deep conceptual understanding and high-order cognitive skills (Yerizon et al., 2023; Nuralam et al., 2024). The contrast between groups illustrates the critical role of interactive and exploratory learning environments in developing mathematical reasoning.

The results of this study also have theoretical and pedagogical implications. The findings support constructivist and constructionist perspectives, indicating that active manipulation and creation of digital artifacts facilitate deeper understanding. Vygotsky's sociocultural theory is also reflected in the results, as GeoGebra acts as a mediational tool that enables meaningful interaction with mathematical concepts. Furthermore, the study corroborates the principles of cognitive load theory, as dynamic visualization reduces extraneous cognitive demands and allows students to focus on reasoning tasks. These theoretical alignments provide a robust explanation for why GeoGebra is highly effective in fostering mathematical reasoning among secondary school students.

Overall, the study demonstrates that integrating GeoGebra into mathematics instruction offers a powerful approach to improving students' reasoning skills. The combination of visual interactivity, multiple representations, and inquiry-based learning tasks creates an environment that not only promotes engagement but also supports conceptual understanding, logical argumentation, and generalization. The findings suggest that GeoGebra is not merely a technological tool but a cognitive amplifier that facilitates significant gains in mathematical reasoning, far surpassing the effects of conventional teaching methods.

## CONCLUSION

This study demonstrates that GeoGebra-based learning is highly effective in enhancing secondary school students' mathematical reasoning skills. The experimental group exhibited significantly higher posttest scores, larger mean gains, and higher N-gain values compared to the control group, with a very large effect size (Cohen's  $d = 2.71$ ), indicating a substantial and meaningful educational impact. Analysis of reasoning indicators, including pattern recognition, logical justification, relational thinking, and multi-step reasoning, revealed that students engaged with GeoGebra outperformed those receiving conventional instruction across all measures. These results suggest that dynamic visualization, multiple representations, and inquiry-based activities foster deeper conceptual understanding, logical argumentation, and generalization. The findings align with constructivist, constructionist, and sociocultural learning theories, highlighting the pedagogical value of interactive digital tools in mathematics education. Practically, integrating GeoGebra into secondary mathematics classrooms can provide students with enriched learning experiences, support higher-order thinking, and improve motivation and engagement. Future research may explore longitudinal impacts, application in other mathematical

domains, and the integration of collaborative learning strategies to further maximize the benefits of GeoGebra-based instruction.

## LITERATURE

- Abbas, N., Katili, S., & Machmud, T. (2025). The effect of the GeoGebra-assisted problem-based learning model on mathematical creative thinking ability. *Technium Social Sciences Journal*. <https://doi.org/10.47577/tssj.v72i1.12821>
- Achmad, G. H., Ratnasari, D., Amin, A., Yuliani, E., & Liandara, N. (2022). Penilaian autentik pada kurikulum merdeka belajar dalam pembelajaran Pendidikan Agama Islam di Sekolah Dasar. *Edukatif: Jurnal Ilmu Pendidikan*, 4(4), 5685–5699. <https://doi.org/10.31004/edukatif.v4i4.3280>
- Albaladejo, I., & Del Mar García López, M. (2023). Mathematical attitudes transformation when introducing GeoGebra in the secondary classroom. *Education and Information Technologies*, 29, 10277–10302. <https://doi.org/10.1007/s10639-023-12085-w>
- Amallya, E., Anggoro, B., & Fadila, A. (2025). Problem based learning with GeoGebra: Impact on mathematical communication skills and mathematical problem solving. *LINEAR: Journal of Mathematics Education*. <https://doi.org/10.32332/8g8bjr06>
- Arikunto, S. (2016). *Prosedur penelitian: Suatu pendekatan praktis*. Jakarta: PT Rineka Cipta.
- Ayoib, C. A., & Nosakhare, P. O. (2015). Directors culture and environmental disclosure practice of companies in Malaysia. *International Journal of Business Technopreneurship*, 5(1), 99–114.
- De Dieu Iradukunda, J., & Mugiraneza, F. (2024). Effects of GeoGebra use on the academic performance of students in mathematics in public secondary schools in Rwanda. *International Journal of Management and Development Studies*. <https://doi.org/10.53983/ijmds.v13n9.027>
- Hermanto, B. (2012). *Pengaruh prestasi training, motivasi dan masa kerja teknisi terhadap produktivitas teknisi di bengkel Nissan Yogyakarta, Solo, dan Semarang* [Skripsi, Universitas Negeri Yogyakarta].
- Juandi, D., Kusumah, Y., Tamur, M., Perbowo, K., & Wijaya, T. (2021). A meta-analysis of GeoGebra software decade of assisted mathematics learning: What to learn and where to go? *Heliyon*, 7. <https://doi.org/10.1016/j.heliyon.2021.e06953>
- Negara, H. (2023). Mathematical reasoning ability of male and female students in problem-based learning. *JTAM (Jurnal Teori dan Aplikasi Matematika)*. <https://doi.org/10.31764/jtam.v7i3.15023>
- Negara, H., W., Nurlaelah, E., & Herman, T. (2022). Improving students' mathematical reasoning abilities through social cognitive learning using GeoGebra. *International Journal of Emerging Technologies in Learning*, 17, 118–135. <https://doi.org/10.3991/ijet.v17i18.32151>
- Nuralam, H., Jupri, A., & Alifulloh, W. (2024). Exploring high school students' mathematical reasoning in geometry using GeoGebra-assisted problem-based learning. *JTP - Jurnal Teknologi Pendidikan*. <https://doi.org/10.21009/jtp.v26i3.49887>
- R., Suryadi, D., Fatimah, S., Priatna, N., & Nasir, N. (2025). Enhancing mathematical literacy through GeoGebra classroom-assisted learning: A case study in Indonesian secondary schools. *Matematika dan Pembelajaran*, 13(1). <https://doi.org/10.33477/mp.v13i1.8938>

- Rohmawati, L. (2019). Pengaruh pengawas dan direksi wanita terhadap risiko bank dengan kekuasaan CEO sebagai variabel pemoderasi (studi bank umum Indonesia). *Syntax Literate: Jurnal Ilmiah Indonesia*, 4(9), 26–42.
- Sebsibe, A., & Abdella, N. (2025). The effect of GeoGebra integrated instruction on students' learning of the quadratic function concept. *F1000Research*. <https://doi.org/10.12688/f1000research.163113.1>
- Setyawan, D., Anas, A., Nasir, M., & Fadly, D. (2024). Enhancing students' mathematical critical thinking skills through a GeoGebra integrated project-based learning model. *Journal of Ecohumanism*. <https://doi.org/10.62754/joe.v3i8.5419>
- Suratno, J., & Waliyanti, I. (2023). Integration of GeoGebra in problem-based learning to improve students' problem-solving skills. *International Journal of Research in Mathematics Education*. <https://doi.org/10.24090/ijrme.v1i1.8514>
- Uwurukundo, M., Maniraho, J., & Tusiime, M. (2020). GeoGebra integration and effectiveness in the teaching and learning of mathematics in secondary schools: A review of literature. *African Journal of Educational Studies in Mathematics and Sciences*, 16, 1–13. <https://doi.org/10.4314/ajesms.v16i1.1>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Wahyuni, Y., Fauzan, A., Yerizon, Y., Arnawa, I., Irfan, D., & Rasli, A. (2025). Enhancing creative mathematical thinking with GeoGebra: A comparative study of secondary school students. *Salud, Ciencia y Tecnología*. <https://doi.org/10.56294/saludcyt20251435>
- Yerizon, Y., A., Tasman, F., & Widjaja, W. (2023). Enhancing junior high school students' reasoning of linear equations using GeoGebra software. *International Journal of Interactive Mobile Technologies*, 17, 16–32. <https://doi.org/10.3991/ijim.v17i18.41441>.