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GeoGebra Enhances Mathematical Conceptual Understanding in Straight-Line Equations

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ABSTRAK

Rendahnya pemahaman konsep matematis menyebabkan siswa kesulitan memahami materi abstrak seperti persamaan garis lurus. Penelitian ini bertujuan menguji efektivitas GeoGebra sebagai media pembelajaran untuk meningkatkan pemahaman konsep tersebut. Metode yang digunakan adalah eksperimen (one-shot case study) dengan sampel 30 siswa kelas VIII di SMP Kec. Bayongbong (purposive sampling). Data dikumpulkan melalui tes uraian dan observasi aktivitas siswa, kemudian dianalisis secara statistik deskriptif dan inferensial (uji-z). Hasil menunjukkan bahwa GeoGebra tidak efektif dalam meningkatkan pemahaman konsep matematis. Temuan ini menyiratkan perlunya integrasi GeoGebra dengan metode lain, seperti scaffolding guru atau pembelajaran berbasis masalah.

Kata Kunci: *GeoGebra*; Pemahaman Konsep Matematis; Persamaan Garis Lurus

ABSTRACT

The limited comprehension of mathematical concepts by students hinders their ability to grasp abstract material, such as linear equations. The objective of this study is to assess the efficacy of GeoGebra as a learning medium to enhance comprehension of the concept. The method employed was an experiment (one-shot case study) with a sample of 30 students in class VIII at SMP Kec. Bayongbong (purposive sampling). The data were collected through the implementation of descriptive tests and student activity observations. Subsequent to the collection of the aforementioned data, the data were analyzed descriptively and inferentially (z-test). The findings indicated that GeoGebra did not demonstrate efficacy in enhancing mathematical concept comprehension. This finding suggests the necessity for GeoGebra integration with alternative methods, such as teacher scaffolding or problem-based learning.

Keywords: GeoGebra; Mathematical Concept Understanding; Straight Line Equation

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1. INTRODUCTION

Mathematics is widely regarded as the foundational language of the sciences, underscoring the significance of conceptual understanding for students' academic and professional development (Kurniyawan, Vitantri, & Rohmatin, 2019; Alam & Mohanty, 2024). The National Council of Teachers of Mathematics (NCTM, 2000) identifies five core competencies that depend on conceptual mastery: problem solving, communication, connections, reasoning, and representation. These competencies are congruent with the national education objectives of Indonesia (Permendiknas No. 22/2016, as cited in Novitasari, 2016; Hidayat & Chao, 2025), which underscore the flexible application of mathematical concepts. However, conceptual misunderstandings in the early stages can lead to compounding difficulties in advanced mathematics due to the subject's hierarchical nature (Sari, Supriadi, & Putra, 2022; Brinus, Makur, & Nendi, 2019; Afriansyah et al., 2024; Obeng et al., 2024).

A review of international assessments indicates that Indonesia's mathematics education system is facing significant challenges. The 2018 Program for International Student Assessment (PISA) results indicated that Indonesia ranked 73rd out of 79 countries with a score of 379 (Tohir, 2019). The 2022 PISA results indicated that Indonesia ranked 70th out of 80 countries (Sumliyah, Junaedi, & Mulyono, 2025), highlighting notable deficiencies in conceptual understanding. TIMSS 2015 further corroborated these deficiencies, placing Indonesia 44th among 49 nations in applying conceptual knowledge (Hadi & Novaliyosi, 2019; Halawa, Hsu, & Zhang, 2024). These outcomes stem from two systemic issues: (1) teacher-centered pedagogies that prioritize rote memorization over constructive learning (Magdalena & Surya, 2018; Bhardwaj et al., 2025), and (2) the abstract nature of mathematical concepts, which contradicts students' developmental stage—most junior high school learners remain in the concrete-to-abstract transition phase (Hershkowitz in Kurniyawan et al., 2019; Semenets et al., 2022). This phenomenon is particularly problematic in the context of topics such as linear equations, where a significant proportion of students encounter difficulties with Cartesian coordinate visualization (Putra, 2016; Schermerhorn et al., 2022) and 78% of students are unable to discern between different equation forms (Permatasari, 2018; Gardenia et al., 2021).

Interactive learning media such as GeoGebra have been shown to offer a promising solution by bridging abstract concepts and visual understanding (Puspitasari et al., 2023; Kurniawan et al., 2024; Hardianti, Yusuf, & Koswara, 2025). A multitude of studies have demonstrated the efficacy of GeoGebra across a variety of implementations, including but not limited to: (1) Video-based: Nurdin et al. (2019) demonstrated a 23% enhancement in concept comprehension, though they did not incorporate real-time interaction. (2) Web-platform: Raditaningtyas (2021) achieved 31% gains in coordinate geometry, though these gains were contingent on stable internet connectivity. (3) Software-based technology: Aprienti (2020)

reported significant improvements ($p < 0.05$) in Islamic schools; however, conventional junior high settings were excluded from the study.

This study addresses three critical gaps in extant research. Firstly, it addresses the implementation method. Previous studies employed pre-recorded or web-dependent formats; in contrast, the present study utilizes direct classroom projection for real-time interaction. The second component, population specificity: The present study deviates from previous research conducted in high school or Madrasah contexts by focusing on Grade VIII students in mainstream junior high schools. The third component of the study is comprehensive assessment. Beyond the assessment of learning outcomes, specifically the KKM achievement, the evaluation encompasses two additional components: student engagement, defined as a minimum activity threshold of 75%, and teacher management competence, measured using the 63-87% TKG scale. The integration of these metrics provides a comprehensive effectiveness measure, as previously outlined in the works of Saadi and Halidjah (2013) and Ramadhani (2016).

The present study investigates the efficacy of projector-mediated GeoGebra implementation in enhancing conceptual understanding of linear equations. This topic necessitates visualization yet remains underrepresented in extant studies. The findings will contribute to the development of more effective, context-appropriate technology integration strategies in Indonesian mathematics education.

2. METHOD

The present quantitative study employed a single-group quasi-experimental design, specifically a one-time case study, for the purpose of evaluating post-intervention outcomes in a natural classroom setting (Peleg & Levy, 2025). This design was chosen because the primary objective was to assess the effects without the confounding factors that would be present in a controlled setting. The population of this study comprised Grade VIII students from a public junior high school in Bayongbong District (N=120). A purposive sample of 30 students (Class VIII-A) with pre-test scores below the KKM (Minimum Completeness Criteria) was selected for the study. The research was conducted over a period of six weeks (October – November 2024), with GeoGebra implemented on two occasions per week in 45-minute sessions.

The following data were collected: The assessment tool employed in this study consists of two components: a 7-item descriptive test and structured observation sheets. The 7-item descriptive test was validated through expert review and pilot testing on Class IX students, resulting in a Cronbach's α of 0.82. The structured observation sheets assess student activity using a 5-point Likert scale and teacher management using the TKG rubric.

Prior to analysis, instruments were subjected to rigorous testing to ensure their validity (Pearson correlation > 0.3), reliability, difficulty, and discrimination. The subsequent analysis

employed two primary methods: (1) Descriptive statistics (mean, SD); and (2) Inferential statistics: Prerequisite tests: The Lilliefors normality test (α = 0.05), F-test homogeneity, and one-sample t-test were employed to compare post-test scores against the KKM threshold (μ = 65). Ethical approval was obtained, with participant consent secured.

3. RESULT AND DISCUSSION

a. Research Result

The following section presents an overview of the mathematics posttest results of the students selected as research samples.

Table 1. Analysis of Posttest Results

Statistic	Statistic Value
Sample Size	30
Ideal Score	100
Lowest Score	39,29
Highest Score	96,43
Score Range	57,14
Mean	64,88
Median	60,71
Modus	53,57
Standard Deviation	17,55
Variance	307,96
Standard Error	3,20

As illustrated in Table 1, the study sample consists of 30 students, and the mean test score for students' mathematical concept understanding ability after the learning process, facilitated by GeoGebra learning media, is 64.88. This score is derived from the ideal score of 100, with a standard deviation of 17.55, a variance of 307.96, and a standard error of 3.20. The students' scores exhibited a range from a minimum of 39.29 to a maximum of 96.43, with a mean of 57.14. The mean value of the distribution of score data is 60.71, with the highest score obtained by students being 53.57.

The data from the posttest, which evaluates students' mathematical concept understanding abilities after the learning process by applying GeoGebra learning media, are categorized based on the Minimum Completeness Criteria (KKM) as follows.

Table 2. Achievement of Student Mathematical Concept Understanding Ability Test Learning Completeness After the Application of GeoGebra Learning Media

Score	Category	Frequency	Percentage (%)
$0 \leq x < 65$	Incomplete	17	57
$65 \leq x \leq 100$	Complete	13	43

A student is considered to have met the necessary standards if they obtain a score of 65 or higher on the mathematics portion of the assessment, as defined by the KKM for that subject. As illustrated in Table 2, 17 students (representing 57% of the total number of students) did not meet the KKM, while 13 students (43%) met the KKM. This finding indicates that the number of students who did not complete the test exceeded the number of students who completed it. If Table 2 is associated with the indicator of the completeness of student learning outcomes, then the test results of students' mathematical concept understanding abilities after applying GeoGebra learning media have not met the indicator of classical learning outcomes completeness.

Table 1 presents a summary of the post-test scores obtained by the students in relation to their comprehension of mathematical concepts (n=30). The mean score was 64.88 (SD=17.55), which is below the KKM threshold of 65. It is noteworthy that 57% of students obtained a score below 65 (Table 2), thus failing to meet the classical completeness criteria (i.e., ⩾ 85% of students achieving a KKM).

Table 3. Average Analysis of Learning Effectiveness Indicators

	Meeting - (%)			
	1	2	3	$\bar{x}$
Student Activity	67,42	77,20	80,76	75,13
Teacher's Ability to Manage Learning	88,64	90,91	97,73	92,42

The efficacy of student activity in this study is said to be contingent upon the active involvement of at least 75% of students during the learning process. As illustrated in Table 3, during the initial meeting, 67.42% of students exhibited active engagement. In the subsequent meeting, 77.20% of students exhibited active engagement. In the third meeting, 80.76% of students exhibited active engagement. As the series of meetings progresses, there is a discernible upward trend in the percentage of observation results pertaining to student activity during the learning process. A total of 75.13% of the students exhibited active engagement during the learning process, thereby substantiating the efficacy of the educational approach.

Notwithstanding suboptimal test results, process effectiveness was achieved: Student activity demonstrated a marked improvement, rising from 67.42% to 80.76% across meetings, thereby surpassing the 75% threshold (see Table 3). Furthermore, Teacher management exhibited consistent high performance, with an average score of 92.42%.

The prevailing notion posits that the efficacy of an educator's capacity to facilitate learning is contingent upon the attainment of at least 75% in the "effective" category. As indicated in Table 3 from the initial meeting, the instructor's proficiency was classified as

88.64% within the "good" category. In the second meeting, the teacher demonstrated an ability of 90.91% in the "good" category. In the third meeting, the teacher demonstrated an ability of 97.73%, which falls within the "good" category. It has been observed that the instructor's proficiency in leveraging GeoGebra learning media to facilitate learning has shown consistent enhancement in the context of the ongoing meetings. A comprehensive evaluation reveals that 92.42% of the teacher's proficiency in managing learning through the effective integration of GeoGebra learning media is classified as "good," thereby affirming the efficacy of the learning process.

To assess the normality of posttest data, researchers employed the Lilliefors test. The results of the data normality test demonstrate that the data does not follow a normal distribution. To ascertain the efficacy of the GeoGebra learning media application, a z test was employed for analysis. The results of the z test, conducted with the assistance of the Microsoft Excel software, are presented below.

Table 4. Results of Hypothesis Test Analysis with z Test

	Posttest
N	30
Significance level (α)	0,05
Z_{count}	-2,49
z_{table}	1,65
Description	Ho rejected

Based on Table 4, the value of z_{count} = -2,49 < -z_{table} = -1,65 is obtained, so Ho is rejected. This means that the application of GeoGebra learning media is not effective on students' mathematical concept understanding ability on straight-line equation material.

Normality tests (Lilliefors, $p<0.05$) indicated non-normal score distribution. A z-test (α =0.05) was applied due to sample size (N=30). Results (z_{count} =−2.49 z_{count} =−2.49, z_{table} = ± 1.65 z_{table} = ± 1.65) led to H0H0 rejection, suggesting GeoGebra did not significantly improve test scores.

b. Discussion

The present study's findings—that GeoGebra did not enhance test scores—are at odds with those of Raditaningtyas (2021), who reported substantial gains with web-based GeoGebra. However, three critical differences explain this discrepancy: (1) Implementation: Raditaningtyas' 12-week intervention facilitated more profound conceptual internalization, while the three-meeting limit that was employed in this study (in contrast to the 10 meetings recommended by As'ari et al., 2017) was deemed inadequate. (2) Access: In contrast to the approach adopted by Nurdin et al. (2019), who furnished individual devices, our projector-only delivery model

constrained hands-on engagement. While Aprienti (2020) employed multi-method evaluations, our study exclusively utilized post-tests, which may have resulted in the oversight of incremental gains.

It is noteworthy that the metrics of our process (75.13% student activity, 92.42% teacher performance) align with constructivist theories (Hershkowitz in Kurniyawan et al., 2019), thereby confirming GeoGebra's engagement value. This finding aligns with Magdalena and Surya's (2018) and Suryani et al.'s (2024) observations that Indonesian students exhibit a favorable response to technology-mediated learning, even in contexts where academic performance is suboptimal.

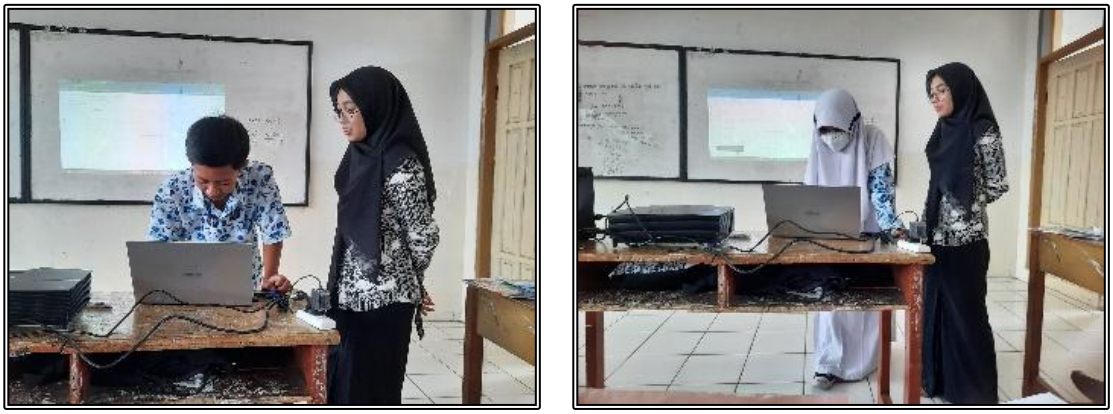

Figure 1. Student Activity Trying to Operate GeoGebra

Figure 1 underscores this paradox: students eagerly operated GeoGebra (consistent with Nur's (2017) usability findings), yet abstract concept transfer remained weak—possibly due to the cognitive load of simultaneous software mastery and mathematics learning (Azimi, Jafari, & Mahdavinasab, 2023; Bedewy et al., 2023). Future studies should implement interventions, such as pre-training on GeoGebra, and extend the duration to bridge this gap.

While the efficacy of GeoGebra learning media in enhancing students' mathematical concept understanding skills is questionable, the medium can be utilized to facilitate student comprehension, in line with Rochim and Herawati (2021) and Afhami (2022) research. This phenomenon is substantiated by the presence of active student engagement throughout the learning process.

4. CONCLUSION

The study's findings indicate that while GeoGebra learning media did not achieve a substantial enhancement in students' comprehension of linear equations, falling short of the KKM benchmark, it did achieve a notable increase in student engagement (75.13% activity) and an improvement in teacher management (92.42% effectiveness). This discrepancy underscores the

efficacy of GeoGebra as a pedagogical instrument, promoting classroom engagement, rather than serving as a standalone solution for conceptual mastery.

The primary contribution of this study lies in its identification of critical implementation barriers, including insufficient intervention duration (with a mere three meetings conducted in contrast to the recommended ten meetings for linear equations), restricted media access (with projector-only use as the sole permitted medium), and significant student readiness gaps following online learning. These findings suggest a need for caution regarding the integration of technology that is short-term and limited in application. They further emphasize the importance of developing support systems that address individuals' needs on a comprehensive, integrated basis. The findings indicate that educators can effectively utilize GeoGebra in conjunction with formative assessments to mitigate engagement-concept discrepancies and extend practice sessions to ensure comprehension. Future researchers should prioritize longitudinal designs with larger samples, ensure hands-on GeoGebra access, and investigate blended approaches for abstract topics. It is recommended that students partake in guided self-paced practice, utilizing GeoGebra's interactive features to augment classroom learning.

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