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To cite this article:

Verallo, E.R. & Cajandig, A.J.S. (2024). Enhancing critical thinking skills in geometry through the guided discovery approach with GeoGebra. *International Journal of Studies in Education and Science (IJSES), 5*(4), 416-431. https://doi.org/10.46328/ijses.110

International Journal of Studies in Education and Science
2024, Vol. 5, No. 4, 416-431 https://doi.org/10.46328/ijses.110

Enhancing Critical Thinking Skills in Geometry through the Guided Discovery Approach with GeoGebra

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Article Info

Article History

Received:
10 February 2024
Accepted:
13 July 2024

Keywords

Guided discovery approach
GeoGebra
Critical thinking
Geometry

Abstract

In this modern era of K-12 curriculum, if students are expected to be knowledgeable and skilled, it is a requirement for the teachers to meet and cope with the necessary skills and competencies for the students to be more competent. This study is developed to investigate the effect of the Guided Discovery Approach (GDA) with GeoGebra on critical thinking skills in ninth-grade geometry students at Baluan National High School during the 2022-2023. Employing a true experimental research design, the study revealed that the student's level of achievement in critical thinking skills in creating, applying, analyzing, and evaluating both in the conventional and experimental groups increases in mean gain scores of 28.27 and 32.8 respectively. The t-test result further shows a t(28) = 2.70 and a p-value = 0.01 indicating that the GDA with GeoGebra in teaching Geometry significantly improved students' critical thinking. It further reveals a significant increase in post-test scores for the experimental group emphasizing the effectiveness of GDA with GeoGebra. While students moderately accepted GeoGebra, there is no significant relationship between their critical thinking skills and acceptability. The findings underscore the importance of instructional methods in improving critical thinking skills, showcasing the potential of GDA with GeoGebra in Geometry.

Introduction

Experts in the field of education have great experience in dealing with the problems addressing the difficulties of the students in learning Mathematics. These challenges of the experts might affect the linearity of the learning of the students in Mathematics. They must adapt and innovate diverse teaching strategies, and alternative tools for them to limit the struggles of the students and deliver the lessons effectively (Dizon, 2019). Due to these abrupt changes in curriculum, experts innovate approaches such as the discovery method that aids spiral curriculum (McLeod, 2019). Problem-based learning with the integration of GeoGebra can statistically increase students' mathematical critical thinking ability (Rahman, 2021). These strategies might not suit everybody. This prompts experts to formulate another experiment, especially in unlocking the key elements of critical thinking skills in learning geometry.

In a study in Nepal, Math teachers were missing out on the chance to use GeoGebra in the digital as technology

advances. As a result, the study on geometry revealed that the students' characteristics on the types of spatial ability and geometric thinking level are required to instill the geometry lecture strategy (Waluya, 2019). In line with this, (Aizikovitsh-Udi & Amit, 2010) recommend that teachers be encouraged to use a variety of instructional strategies. They must create well-planned of suited situations that could necessitate the development of critical thinking skills in abrupt or in the long run.

Despite being creative and innovative of experts here in the Philippines and in other countries, the Department of Education (DepEd) reported that Filipino student's performance in Programmed for International Student Assessment (PISA) ranked last among 79 participating countries, near the bottom in Science and Mathematics (Gonzales, 2019) and had lowest mean critical thinking scores (Schleicher, 2019). This result from PISA is also correlated and observable based on the performance of the students in Baluan National High School many of them had trouble in solving problems involving Geometric concepts.

Various significant research data analyses revealed that the students remained in the sufficient category for the two abilities that influenced geometry learning (Trimurtini, 2021). Students continue to struggle when presented with application questions involving multiple geometric concepts. If students deviate from the norm, material delivery must be adjusted following the level of geometric thinking. Additionally, students struggled more with learning Geometry, such as drawing diagrams for a given geometric problem and applying more than one theorem to solve a given Geometry problem. Also, students' disinterest in the geometry component, as well as their family background, influences their Geometry learning (Juman, 2022).

However, there is a limited existing study that discusses the unlocking of key elements of critical thinking skills with the use of a guided discovery approach with GeoGebra in learning geometric concepts specifically in quadrilaterals. Hence, experimental investigation will be conducted to explore the beauty of critical thinking skills in learning geometry among students in Baluan National High School. Furthermore, the primary goal of this study is to contribute to this understanding by investigating whether GeoGebra software, used as a mathematical instructional tool with the Guided Discovery Approach (GDA), contributes to the unlocking of key elements of students' critical thinking skills in learning geometry and mathematics. This study also seeks if there is a significant difference between conventional learning, and the Guided Discovery Approach (GDA) with Geogebra.

Learning Geometry with a Guided Discovery Approach

Geometry in particular is difficult to teach and learn, which has led to widespread exam failure. Many students indeed fail mathematics exams, and student performance has been trending downward. According to a study by Juman et al. (2022), students had more trouble understanding geometry, particularly when it came to drawing diagrams for a given geometric issue and using more than one theorem to solve it. Also, students' family backgrounds and interests in the geometry component have an impact on how well they learn the subject. Also, the teaching experiment's findings show that student-based learning strategies outperform more traditional Geometry teaching strategies (1). Most math teachers have weak backgrounds in geometry. (2) The students' mathematical foundation is weak. (3) The setting for instruction and learning is unfriendly.

To close this gap, teachers and students should encourage teamwork, based on the gaps and concerns discussed above and the findings of the studies. To increase students' interest in studying mathematics geometry, teachers should arm themselves with a variety of strategies and understand useful applications and tools.Guided discovery learning proves beneficial in teaching and learning, fostering independent knowledge acquisition. Acting as facilitators, teachers provide limited guidance to avoid resembling direct learning (Yang, 2010). Bruner views discovery learning as applying constructivist theory, encouraging students to draw on prior knowledge (Bruner, 1961). In guided discovery, students formulate, process data, make conjectures, and verify with teacher support (Markaban, 2006). This model enhances critical thinking, problem-solving, and independent thinking skills (Ismail Hanif Batubara, 2019). It involves students actively participating, integrating information, and problem-solving collaboratively (Shieh & Yu, 2016).

Research highlights the effectiveness of guided discovery in STEM education, improving attitudes, performance, and intentions to pursue STEM careers (Casad and Jawaharlal, 2012). It positively impacts mathematical communication ability (Suratno et al., 2019) and problem-solving skills (Herdiana, 2017). Guided discovery enhances critical thinking skills and dispositions in mathematics (Sri Hastuti Noer, 2018). Overall, the approach proves effective in promoting active learning, problem-solving, and critical thinking across various disciplines.

GeoGebra, an open-source application, transforms mathematics education by offering a platform for visualizing and manipulating data. It is universally accessible, irrespective of the user's device, and boasts an active development community. Utilizing GeoGebra in mathematics learning enhances the discovery, visualization, and construction of mathematical concepts. The tool positively impacts students' mathematical skills, including proof abilities, reasoning, and problem-solving. Both teachers and learners find GeoGebra user-friendly, facilitating effective implementation. Future research could benefit from quasi-experimental designs to comprehensively evaluate GeoGebra's impact, emphasizing the importance of teacher proficiency in the software. Regular student engagement with GeoGebra is recommended to enhance skills and minimize errors (Tamam, 2021).

Most teachers at all educational levels have responded positively to the use of GeoGebra in learning. As a result, it is mainly recommended as a cutting-edge teaching technique mathematics that is assisted by technology (Zakaria and Lee, 2012). By these findings, another study discovered that many students have favorable perceptions of using GeoGebra software, which improves students' learning outcomes (Shadaan and Leong, 2013).

However, most students are enthusiastic about learning with GeoGebra software because it improves their grasp of the concepts taught. Not only that, but it improves students' mathematical communication abilities with geometry material (Kusumah, Kustiawati, & Herman, 2020). Hence, the use of GeoGebra in learning results in effective interaction between educators and students during in the lesson (Zulnaidi, Oktavik & Hidayat, 2020). GeoGebra in mathematics also facilitates the learning process by providing easy-to-use visualization with rich content (Yorganci, 2018). Furthermore, another study discovered that students who are learning geometry with GeoGebra understand the topic better than students who take geometric features without GeoGebra (Japa, Suarjana & Widiana, 2017). This finding is supported by another study that shows e-learning with GeoGebra

skillfully increases students' geometry ability to comprehend (Sudihartinih & Wahyudin, 2019).

Currently, many researchers are looking into the benefits of using GeoGebra. One of those studies discovered several advantages to using GeoGebra, such as its ability to be used independently by students, its appealing animations and images, and the provision of a simple experiment (Saputra & Fahrizal, 2019). Other research results show that Geogebra helps learners realize geometry better (Alkhateeb & Al-Duwairi, 2019). The most recent study also discovered that GeoGebra influenced students' enjoyment and interest in computer-assisted mathematics learning. Students with lower computer literacy, on the other hand, struggled to use Geogebra (Celen, 2020). Following deliberation, a strongly suggests using Geogebra software in the mathematics teaching and learning process because numerous studies show that it improves students' comprehension of the lesson taught (Jelatu, 2018).

Many researchers have investigated the learning process in geometry by using GeoGebra. The ongoing research to investigate the positive impact of using GeoGebra in learning. GeoGebra can help students improve their competency and perception by incorporating it into their geometry lessons. Another study found that delivering GeoGebra to students increased their level of comprehension to very good. As a result, students' mathematical skills improved significantly after learning geometry with GeoGebra software. Furthermore, while learning geometry with GeoGebra, students demonstrate a positive attitude and can encourage their mathematical problem-solving abilities. Geometry also helps students understand geometry concepts better than having to learn geometry without Geometry. Another study discovered that learning with Geogebra is also an effective process (Jelatu et al., 2018).

Critical Thinking Skills of Students

This study emphasizes the significance of mathematical critical-thinking skills in twenty-first-century learning (Syafril, 2020). Chatfield (2018) characterizes critical thinking as reasoning, interpreting, analyzing, and evaluating concepts, essential for decision-making and problem-solving. Mathematical critical thinking involves sub-skills like reasoning, applying, analyzing, synthesizing, assessing, and problem-solving (Eva, 2018; Chatfield et al., 2018; Pu & Evans, 2019; Butterworth & Thwaites, 2013). It aids students in rational decision-making, drawing alternative conclusions, and tackling complex problems in mathematics.

Engaging critical thinking in mathematics reduces errors and fosters problem-solving, original idea generation, and logical argumentation (Fonseca & Arezes, 2017). The Watson-Glaser Critical Thinking Assessment evaluates cognitive abilities globally (Davies & Stevens, 2019). Educational systems worldwide prioritize critical thinking skills for their role in assessing facts and making informed decisions (Chusni, 2020; Nygren, 2019). Critical thinking, aligned with Bloom's taxonomy, encompasses knowledge, understanding, application, analysis, synthesis, and evaluation (Bloom, 1956).

However, the taxonomy's rigid structure faced criticism, leading to a revised version with added subcategories to address distinctions between groups (Anderson, 2001; Krathwohl, 2013). The revised taxonomy maintains the

idea of a flexible hierarchy, acknowledging that mastery of simpler categories may not always be a prerequisite for complex ones (Agarwal, 2019). This study aims to explore the updated Bloom's taxonomy and its assumptions, addressing gaps in research and practice. The development of logical and critical thinking on mathematical issues via systematic thought.

Statement of the Problem

Based on the literature review, the following research questions have been formulated:

1. What is the student's level of achievement in critical thinking skills in the pre-test and post-test of the conventional approach and the Guided Discovery Approach (GDA) with GeoGebra groups in learning geometry in terms of:
   1.1 applying;
   1.2 analyzing;
   1.3 evaluating; and,
   1.4 creating?
2. What is the student's level of acceptability towards GeoGebra after being exposed to the treatments in terms of:
   2.1 skills in designing models; and,
   2.2 skills in solving problems?
3. Is there a significant difference between students' mean gain scores in critical thinking skills in geometry mathematics as influenced by the conventional approach and guided discovery approach with GeoGebra?
4. Is there a significant relationship between the post-test scores in the achievement in critical thinking skills of the students in the Guided Discovery Approach with GeoGebra and the students' acceptability towards GeoGebra?

Methodology

The research employed a true experimental design with a pre-test and post-test control group, using a t-test for statistical analysis. This design aimed to address threats to internal validity, such as maturation and testing, through random assignment. Ranked set sampling (RSS) was employed, utilizing students' pre-test scores for stratification. This cost-effective method ensured structured sampling, with 15 students in each group. The respondents were 30 ninth-grade students from Sampaguita and Gumamela sections at Baluan National High School, selected based on criteria including enrolment, grade level, age, math subject enrolment, and language proficiency. The study was conducted at Baluan National High School due to its capacity to provide tablets for GeoGebra usage and the researcher's affiliation with the school.

The researcher chose the appropriate topic in Geometry in quarter 3 that was highly recommended for the usage of Geogebra and prepared the lesson plan that was aligned in the Guided Discovery Approach. Moreover, the lesson plans were subjected to consultation to professionals who were experts in this field, this ensured appropriateness and alignment to the assessment. During the implementation of the lesson, the respondents were

advised to have the software of GeoGebra, for them to easily realize and cope with the topic.

Two research instruments were utilized for data gathering in this study. The first instrument was a researcher-made test questionnaire aligned with revised Bloom's taxonomy, focused on higher-level thinking skills: applying, analyzing, evaluating, and creating. Content validation by mathematics experts yielded a mean of 4.46, indicating very high validity. The test underwent pilot testing, resulting in 50 accepted items out of 66, with a Kuder-Richardson 20 reliability of 0.81, signifying high correlation and very good reliability. To determine the level of critical thinking skills among students, the Rating Scale and Transmutation Table that is enclosure from DepEd Memorandum 42 series of 2020 were utilized. This rating scale is adapted from the DepEd's Grading System in the K – 12 curricula.

The second instrument was an adapted-modified survey questionnaire measuring respondents' perception on the acceptability of the Guided Discovery Approach with GeoGebra. Derived from Pamugkas (2021), the survey included two domains: skills in solving problems and skills in designing models, with a total of 29 indicators. Content validation by experts yielded a mean of 4.17, indicating very high validity. The survey demonstrated acceptable reliability with a Cronbach's alpha value of 0.72. These validated and reliable instruments ensured unbiased data collection, allowing for a precise investigation into the impact of the guided discovery approach with GeoGebra on critical thinking skills and acceptability among ninth-grade students at Baluan National High School.

To determine and interpret the respondents' level of acceptability on the Guided Discovery Approach with GeoGebra in learning Geometry, the rating scale of Pimentel (2019) below was used.

Rating	Mean Interval	Description	Interpretation
5	4.21 – 5.00	Strongly Agree	Highly Acceptable
4	3.41 – 4.20	Moderately Agree	Moderately Acceptable
3	2.61 – 3.40	Neutral	Neutral
2	1.81 – 2.60	Slightly Disagree	Slightly Acceptable
1	1.00 – 1.80	Disagree	Not Acceptable

The data acquired from the study were organized, tabulated, analyzed, and interpreted depending on the results following the phases of research at the end of the conduct of the study, particularly the gathering of the data needed from the respondents. Descriptive statistics was used in analyzing the collected data. Moreover, t - test is settled to be the statistical treatment in knowing the difference in students' level of critical thinking skills in geometry mathematics as influenced by the conventional approach and guided discovery approach with GeoGebra.

Results and Discussion

Critical Thinking Skills in Geometry among Students

The study yielded noteworthy results regarding the enhancement of critical thinking skills, specifically in the

application of knowledge to geometry-related scenarios. Table 1 shows that both groups showed similar pre-test scores (54% and 53% for experimental and control, respectively), but the experimental group utilizing the Guided Discovery Approach with GeoGebra achieved significantly higher post-test scores of 79% (outstanding) vs. 71% (outstanding). Additionally, while the control group displayed more consistent scores, the experimental group exhibited greater variability (Sd =1.75 and Sd = 0.92, for experimental and control, respectively), suggesting diverse development levels. These findings, supported by research emphasizing the effectiveness of technology-aided discovery learning (Shieh & Yu, 2016), highlight the value of such strategies in fostering robust critical thinking skills, essential for academic and real-world success.

Table 1. Critical Thinking among Students in terms of Applying.

Groups	**N**	**Mean Percentage Score**	**SD**	**Equivalent Rating**	**Interpretation**
Control Group					
Pre-test		53%	1.15	79	Fairly Satisfactory
Post-test	15	71%	0.92	93	Outstanding
Experimental Group					
Pre-test		54%	1.45	80	Satisfactory
Post-test	15	79%	1.75	99	Outstanding

Table 2 presents the pre-and post-test critical thinking scores of the experimental and control groups in their analytical skills in geometry. Both groups demonstrated comparable scores in the pre-test (49% and 47% for experimental and control, respectively). However, the control group's score, translating to a DepEd rating of 74 (did not meet expectations), indicated a deficiency in analytical skills and unsatisfactory performance in solving geometry problems. In contrast, the experimental group achieved a 76 rating (fairly satisfactory), suggesting a better foundation in analytical skills.

Table 2. Critical Thinking among Students in terms of Analyzing

Groups	**N**	**Mean Percentage Score**	**SD**	**Equivalent Rating**	**Interpretation**
Control Group					
Pre-test		47%	2.14	74	Did Not Meet Expectations
Post-test	15	55%	1.84	80	Satisfactory
Experimental Group					
Pre-test		49%	2	76	Fairly Satisfactory
Post-test	15	67%	1.5	90	Outstanding

Post-test results, significant differences emerged. The control group improved to a satisfactory 55% (rating), while the experimental group reached an outstanding 67%. While both groups improved, the control group's result suggested limited proficiency in analytical skills, while the experimental group showcased outstanding competence in deconstructing and drawing conclusions from geometrical information. These findings highlight

the effectiveness of the guided discovery approach with GeoGebra in enhancing critical thinking skills in geometry analysis, aligning with research on the need for such strategies to foster essential critical thinking abilities (Beyer, 2001; Zhang & Li, 2022).

Table 3 shows the pre-test and post-test critical thinking achievement of both the control and experimental groups in terms of evaluating acquiring geometry skills. According to the findings, the mean percentage score of the control and experimental groups in their pre-test were not close in terms of range, with the groups having computed values of 46% and 42%, respectively. Both the control and experimental groups fell short of meeting expectations, obtaining equivalent ratings of 74 and 73, respectively. This deficiency indicated a lack of evaluating skills, leading to suboptimal performance in drawing geometry problems. Post-treatment, the control group (conventional learning) and experimental group (guided discovery with GeoGebra) exhibited improved critical thinking abilities, with the control group gaining 53% (79 rating) and the experimental group gaining 63% (86 rating). While the control group achieved fairly satisfactory results in evaluating skills, the experimental group showcased very satisfactory competence. The study underscores the efficacy of employing guided discovery with GeoGebra in enhancing students' ability to make judgments about the value of ideas, items, and materials in geometry, ultimately elevating critical thinking skills. Notably, the experimental group significantly outperformed the control group. Interestingly, the standard deviation analysis revealed more consistent scores in analyzing skills within the experimental group compared to the control group

Table 3. Critical Thinking among Students in terms of Evaluating

Groups	**N**	**Mean Percentage Score**	**SD**	**Equivalent Rating**	**Interpretation**
Control Group					
Pre-test	15	46%	2.31	74	Did Not Meet Expectations
Post-test		53%	1.58	79	Fairly Satisfactory
Experimental Group					
Pre-test	15	42%	1.73	73	Did Not Meet Expectations
Post-test		63%	1.57	86	Very Satisfactory

Building on research emphasizing critical thinking skills in elementary school students (e.g., Sarwanto & Chumdari, 2021), this study underscores its importance as a fundamental educational goal. Critical thinking involves utilizing data and evidence for informed decision-making (Sarwanto & Chumdari, 2021). While existing literature highlights a deficiency in higher-order critical thinking skills at the high school and college level (Khosravi & Khosravi, 2020), this study demonstrates promising results for both the experimental and control groups in improving evaluation skills., potentially aligning with previous findings (Sarwanto & Chumdari, 2021; Khosravi & Khosravi, 2020).

Table 4 presents the creating skills among students under the guided discovery approach with GeoGebra group compared to traditional learning group in geometry. Both the experimental and control groups initially demonstrated similar pre-test scores in the "creating" skill (29% and 32%, respectively), translating to a "below

expectations" rating on the DepEd grading system.

Table 4. Critical Thinking among Students in terms of Creating

Groups	N	Mean Percentage Score	SD	Equivalent Rating	Interpretation
Control Group					
Pre-test	15	29%	1.42	70	Did Not Meet Expectations
Post-test		50%	0.92	76	Fairly Satisfactory
Experimental Group					
Pre-test	15	32%	1.58	70	Did Not Meet Expectations
Post-test		56%	1.45	81	Satisfactory

Post-intervention, the experimental group displayed significantly higher gains (56% with a "satisfactory" rating) compared to the control group (50% with a "fairly satisfactory" rating). This suggests the guided discovery approach positively impacts critical thinking development. Additionally, the control group exhibited greater variability in post-test scores (standard deviation of 0.92), implying less consistent learning outcomes compared to the experimental group (standard deviation of 1.45).

These findings hold potential implications for educational practice. Implementing innovative methods like guided discovery with technology can equip students with essential critical thinking skills. This aligns with existing research highlighting the positive impact of such strategies on critical thinking and academic performance (Ebrahimi & Gholami, 2019). While both groups improved, the control group still exhibited concerning deficiencies, echoing concerns raised by prior studies about the need for effective strategies to address this gap (Chumdari et al., 2021). Future research could explore the long-term effects of such interventions and their impact on students in diverse contexts.

Table 5 displays pre-test and post-test critical thinking achievement in geometry for control and experimental groups.

Table 5. Overall Students' Critical Thinking in Learning Geometry

Groups	N	Mean Percentage Score	SD	Equivalent Rating	Interpretation
Control Group		20.87	4.78	73	Did Not Meet Expectations
Pre-test	15				
Post-test		28.27	3.58	83	Satisfactory
Experimental Group					
Pre-test	15	22.07	3.49	74	Did Not Meet Expectations
Post-test		32.8	2.7	90	Outstanding

Initial mean scores were 20.87 (control) and 22.07 (experimental), both translating to 42% and 44%. However,

converted to DepEd grading, both groups received lower ratings (73 and 74), indicating insufficient critical thinking abilities.After treatments (GeoGebra for experimental, conventional for control), the experimental group outperformed with mean scores of 28.27 (experimental) and 32.80 (control). Post-treatment, control gained 57%, and experimental 67%, equivalent to ratings of 83 (satisfactory) and 90 (outstanding). Experimental group showed significant improvement, demonstrating superior critical thinking skills in geometry problem-solving.

The experimental group, exposed to guided discovery with GeoGebra, excelled in making rational decisions compared to the control group. The results advocate for the adoption of this approach and software in teaching geometry to enhance students' critical thinking skills. In terms of variability, pre-test standard deviation for the experimental group was 3.79 and 4.78 for control, indicating greater consistency in experimental group scores. Post-test standard deviation for experimental was 2.70, and control was 3.58, suggesting increased dispersion in control group scores.

Acceptability towards GeoGebra in terms of Designing Models

This study investigated students' perceptions of GeoGebra following its implementation in their learning. The results revealed, in Table 6, a moderate level of acceptance towards GeoGebra, with an overall mean score of 3.76 (SD = 0.87). The highest mean score, 4.33 (SD = 0.62), indicated strong agreement that GeoGebra fostered diligence and encouraged frequent use. However, the lowest mean score, 2.80 (SD = 1.15), reflected neutral acceptance regarding reliance on classmates for model design, suggesting some students still sought assistance.

Table 6. Students' Level of Acceptability towards GeoGebra in terms of Skills in Designing Models

Indicators	Mean	Interpretation
1. I became more diligent in learning and often tried to use GeoGebra.	4.33	Highly Acceptable
2. GeoGebra software is easy to apply menus when designing models.	4.27	Highly Acceptable
3. I find it easy to use GeoGebra in designing models involving parallelograms.	4.27	Highly Acceptable
4. I feel comfortable and confident in designing models involving parallelograms.	4	Moderately Acceptable
5. I find it more interesting to make figures in GeoGebra.	3.93	Moderately Acceptable
6. While using the GeoGebra, I felt my learning more real.	3.87	Moderately Acceptable
7. I can visualize the models using GeoGebra.	3.8	Moderately Acceptable
8. I can manage it myself in designing mathematical models in GeoGebra	3.8	Moderately Acceptable
9. GeoGebra software helps design models involving parallelograms.	3.53	Moderately Acceptable
10. I can clearly understand the mathematical concepts when designing models in GeoGebra.	3.53	Moderately Acceptable

Indicators	Mean	Interpretation
11. I am interested in using GeoGebra while designing models because it is more complicated.	3.47	Moderately Acceptable
12. I can design and create geometry builds with GeoGebra applications.	3.4	Neutral
13. I no longer rely on my classmates to design models in GeoGebra.	2.8	Neutral
14. I find it easy to analyze the properties of parallelogram when designing models in GeoGebra.	3.6	Moderately Acceptable
Mean	**3.76**	**Moderately Acceptable**

These findings align with previous research, where students generally enjoyed and found GeoGebra helpful in learning mathematics. While not all studies conclusively demonstrate improved academic performance with GeoGebra (e.g., some report no significant difference), student opinions often remain positive (e.g., finding it enjoyable and fun). This study further contributes by highlighting the software's potential in fostering diligence and encouraging independent learning alongside its moderate overall acceptance.

Table 7 reveals student perceptions of GeoGebra in problem-solving. The highest mean score (4.60, SD = 0.63) with a "Highly Acceptable" interpretation indicates strong agreement that GeoGebra promotes diligence and active engagement in solving parallelogram problems. Conversely, the lowest mean score (2.40, SD = 1.52) interpreted as "Slightly Acceptable" reflects the least frequent occurrence of students still seeking help from classmates after using GeoGebra. This suggests a trend towards increased independence in problem-solving. Overall, the moderate acceptance level (mean = 4.02, SD = 0.84) indicates potential benefits of GeoGebra in fostering problem-solving skills.A research study was conducted to explore how students responded to using GeoGebra to improve their problem-solving skills. The findings revealed that students showed a moderate level of acceptance towards GeoGebra as a tool for enhancing their problem-solving abilities. It was observed that the used of GeoGebra positively influenced the mathematical abilities of students. In fact, a meta-analysis of various studies on GeoGebra-based learning indicated.

Table 7. Students' Level of Acceptability towards GeoGebra in terms of Skills in Solving Problems

Indicators	Mean	Interpretation
1. After using GeoGebra, I felt more active and diligent in solving problems involving parallelograms.	4.6	Highly Acceptable
2. I can easily interpret questions involving parallelograms with the use of GeoGebra	4.53	Highly Acceptable
3. I can easily solve problems in parallelograms with the use of GeoGebra.	4.53	Highly Acceptable
4. I find it easy understanding the properties of the parallelogram with GeoGebra	4.33	Highly Acceptable
5. I can think creatively and critically when using GeoGebra.	4.33	Highly Acceptable

Indicators	Mean	Interpretation
6. Learning with GeoGebra software made me better understand learning materials.	4.27	Highly Acceptable
7. I am interested using GeoGebra in understanding parallelogram.	4	Moderately Acceptable
8. I can independently solve problems after learning GeoGebra	4	Moderately Acceptable
9. It is easy for me to understand the questions involving properties of parallelogram with the use of GeoGebra.	3.87	Not at all Acceptable
10. I find it easy answering questions involving parallelogram with the use of GeoGebra.	3.87	Moderately Acceptable
11. GeoGebra software can perform accurate calculations of geometry question.	3.87	Moderately Acceptable
12. After learning, I can work on the problem efficiently.	3.73	Moderately Acceptable
13. I am interested in using GeoGebra when it comes solving models in parallelogram	3.67	Moderately Acceptable
14. GeoGebra software is helpful in solving problems involving parallelogram.	3.67	Moderately Acceptable
15. I no longer ask questions to my classmates in solving problems, after learning GeoGebra.	2.4	Slightly Acceptable
Mean	**3.98**	**Moderately Acceptable**

Furthermore, this study has demonstrated that the use of GeoGebra had a positive impact on teachers' knowledge and attitudes towards mathematics. Additionally, there was evidence suggesting that the effectiveness of GeoGebra software was linked to students' achievements in mathematics. In conclusion, the overall use of GeoGebra software has shown a positive impact on students' mathematical abilities and is considered a moderately accepted intervention for improving problem-solving skills.

Comparative Analysis of Students' Critical Thinking Skills

The results presented in Table 8 compare the level of critical thinking skills in geometry mathematics between the conventional approach and the guided discovery approach with GeoGebra. The gain score for the conventional approach was 7.40 with a standard deviation of 2.59, while the mean score for the experimental group using the guided discovery approach with GeoGebra was 10.73 with a standard deviation of 4.01. These results indicate a higher gain in scores for the experimental group compared to the conventional group. Furthermore, the findings showed a significant difference in the scores, with a $t(28) = 2.70$ and a p-value = 0.01

To support these results, the study of (Zachary Schaver, 2019) found that GeoGebra showed an increase in student achievement scores in critical thinking skills. The use of GeoGebra in mathematics learning is effective in improving students' understanding of mathematical concepts and promoting critical thinking skills. Moreover,

the guided discovery approach with GeoGebra as the intervention is particularly effective in improving students' test scores in geometry. Furthermore, this suggests that the guided discovery approach with GeoGebra, as the intervention, resulted in an improvement in the test scores of students in geometry. The null hypothesis was rejected, indicating that there is a statistically significant difference between the two approaches.

Table 8. Difference in the Mean Gain Scores in Two Groups

Sources of Variations	N	Mean	Sd	difference	Df	t	p	interpretation
Conventional	15	7.4	2.59	3.33	28	2.7	0.01	significant*
GDA with GeoGebra	15	10.73	4.01					

*Significant at 0.05 level of significance

Acceptability of GeoGebra towards Students' Critical Thinking Skills

Table 9 shows an analysis of the relationship between students' critical thinking post-test scores and their acceptance of GeoGebra revealed a very weak positive correlation (Pearson r = 0.13). This correlation coefficient indicates a negligible association between the two variables. Further supporting this, the p-value associated with the correlation coefficient is .65, which is significantly greater than the alpha level of 0.05. As the p-value is larger than the alpha level, we fail to reject the null hypothesis, meaning there is no statistically significant relationship between critical thinking scores and GeoGebra acceptance. In simpler terms, students who found GeoGebra less acceptable did not necessarily experience lower gains in their critical thinking skills compared to those who found it more acceptable. This suggests that even if students have varying levels of acceptance towards GeoGebra, the intervention can still be effective in fostering critical thinking development in geometry.

Table 9. Relationship between the Students' Post–Test Scores and Acceptability towards GeoGebra

Sources of Correlation	mean	SD	R	p-value	interpretation
Post - Test Scores	32.8	2.7	0.13	0.65	not significant*
Level of Acceptability	3.86	0.42			

Not Significant at 0.05 level of significance

The study did not consider each indicator individually tested to consider having a relationship. Instead, it focused on the relationship between the level of acceptability of the students towards the application of GeoGebra and their critical thinking skills in Geometry Mathematics after the intervention. However, other studies have found that GeoGebra can have a positive impact on student achievement scores, critical thinking/problem-solving skills, engagement, motivation, and conceptual knowledge in mathematics.

Conclusions

Based on the results students' scores in the post-test as influenced by the conventional and Guided Discovery Approach with GeoGebra resulted in an increase in scores compared to the pre-test. More importantly, the use of

the Guided Discovery Approach with GeoGebra resulted in an increase in the transmuted grades than that of the conventional approach. These results led to the acquisition of thorough competence and critical thinking skills development in the students in the experimental group. Students moderately accepted GeoGebra as an intervention to increase their skills in designing models and solving problems in Geometry. Additionally, there is a significant difference in the gain scores of the students in the conducted post-test using the conventional and Guided Discovery Approach with GeoGebra. Significantly, the results showed an increase in the scores. It was found that there exists no significant relationship between students' level of critical thinking skills after the intervention and their level of acceptability towards GeoGebra.

Furthermore, it was clear in the results using the appropriate statistical tool that the students acquired thorough competence and skills in unlocking key elements of critical thinking skills as they exposed their selves in guided discovery approach with GeoGebra. There is variation of critical thinking skills when the students exposed to the different approaches, and it was evident to the experimental group in the increased of their post test scores. Additionally, the increased of post test score does not imply to acceptability of the usage of GeoGebra.

Recommendations

Based on the study's findings, several recommendations are offered:

1. *Integration of Guided Discovery with GeoGebra:* Implementing the Guided Discovery Approach (GDA) with GeoGebra software is recommended as an intervention strategy to enhance students' skills in both model design and problem-solving within geometry education. This approach has demonstrated effectiveness in addressing learning difficulties and gaps in these areas, making it a valuable consideration for educators and school administrators seeking to improve student learning outcomes.

2. *Student Engagement with the Intervention:* Students are encouraged to actively engage with the GDA with GeoGebra intervention. This study's findings indicate its potential to improve their skills in geometry mathematics, making it a worthwhile learning tool to explore and utilize.

3. *Expanding Future Research:* For future research endeavors, two key recommendations are suggested. Firstly, increasing the sample size is crucial to enhance the generalizability of study results and ensure wider applicability. Secondly, exploring the intervention's effectiveness with diverse populations beyond the current sample is recommended to gain broader insights into its potential benefits across different educational contexts.

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