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GeoGebra Integration in Mathematics Teaching: Bridging Research and Classroom Practice

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Abstract. The integration of technology in mathematics education offers dynamic tools for enhancing students' Mathematics engagement, motivation, and understanding. This study assessed and explored the practical application of GeoGebra, a dynamic mathematics software, to translate research findings into actual classroom practices within a teacher education context. Using a mixed-method sequential explanatory design, the study developed and implemented nine structured GeoGebra-integrated lesson plans guided by Madeline Hunter's Instructional Model. The participants were Bachelor of Secondary Education students majoring in Mathematics from a private university in Cebu province. Quantitative data on students' mathematics motivation, engagement, and understanding were collected using validated instruments, followed by qualitative analysis of students' perceptions and experiences. Results showed numerical improvements across all domains, with post-test findings indicating higher levels of Mathematics motivation, engagement, and understanding. However, statistical tests revealed no significant differences between pre- and post-test scores, although significant positive correlations were found among the three constructs. Thematic analysis highlighted benefits such as improved visualization and deeper understanding, alongside challenges including limited access to devices, unstable internet connections, and initial difficulties in using GeoGebra. Despite these constraints, students appreciated the creative possibilities offered by GeoGebra and its ability to connect mathematical concepts to real-world applications. The study culminated in the development of a compendium of lesson plans designed to support educators in effectively integrating GeoGebra into their instruction. These findings highlight the potential of structured technology integration in developing student-centered and interactive mathematics learning environments, while also underscoring the need for adequate pedagogical support for successful implementation.

Keywords: Translational research; GeoGebra integration; Mathematics engagement and motivation; Mathematics understanding; Transformation of functions.

1.0 Introduction

Mathematics education has undergone significant evolution with the integration of technology, providing innovative approaches to enhance students' conceptual understanding and engagement. Digital tools enhance student engagement by offering interactive learning experiences, which are crucial for grasping abstract mathematical concepts (Letchumanan et al., 2023; Saat et al., 2024). One of the most widely used digital tools in mathematics instruction is GeoGebra, a dynamic software that facilitates interactive learning through visual representations and simulations. GeoGebra enables students to explore mathematical concepts, such as algebra, geometry, and calculus, in an intuitive and engaging way. Research has shown that integrating technology into mathematics education enhances students' problem-solving skills, promotes more profound understanding, and fosters a more active learning experience (Seftiana et al., 2024; Ardina & Boholano, 2024). However, despite its potential, the practical application of GeoGebra in classrooms remains limited, often due to a lack of structured lesson plans, teacher training, and awareness of its pedagogical benefits.

Despite the growing body of research highlighting the advantages of technology-enhanced learning, a gap still exists between research findings and actual classroom implementation. These barriers include inadequate infrastructure, insufficient teacher training, and a lack of comprehensive frameworks connecting theory to practice (Ferrari et al., 2011; Alzankawi, 2024). In the Philippines, the integration of digital tools into the educational curriculum has been met with various challenges, particularly within teacher education programs. Many educators face significant challenges due to poor internet connectivity, especially in underserved areas. The insufficient access to devices and inadequate school resources further complicate the integration of digital tools (Kunjiapu et al., 2025). Locally, many pre-service and in-service teachers struggle to effectively blend technology with traditional teaching approaches due to inadequate training, lack of resources, or limited exposure to evidence-based instructional strategies. Without proper guidance, students may fail to fully utilize the benefits of GeoGebra, resulting in low motivation, poor engagement, and difficulty in developing higher-order thinking skills in mathematics.

To address the identified gap in integrating research-based technological tools into classroom practice, this study proposes a structured approach to incorporating GeoGebra into mathematics instruction. Specifically, it aims to design and implement GeoGebra-integrated lesson plans that align with mathematical concepts and problem-solving strategies. These lesson plans will serve as a guide for educators, ensuring that GeoGebra is utilized to enhance the teaching and learning process. Additionally, the study aims to evaluate the effectiveness of this integration by examining its impact on students' motivation for mathematics, engagement, and understanding of the subject. Using an explanatory sequential design, the study will first gather and analyze quantitative data on students' mathematics motivation, engagement, and understanding of mathematics. This will be followed by a qualitative phase to explore students' experiences, challenges, and perceptions of learning mathematics through GeoGebra. The sequential nature of this design enables a deeper interpretation of quantitative results by revealing the reasons behind students' performance and attitudes (Bascones et al., 2024). Understanding these challenges will help refine teaching strategies and provide recommendations for more effective implementation of GeoGebra.

The Technological Pedagogical Content Knowledge (TPACK) framework, proposed by Mishra and Koehler (2006), serves as the foundation for this study, as it provides a comprehensive model for integrating technology into teaching. The TPACK framework emphasizes the interplay of three essential knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). In the context of this study, GeoGebra represents the technological component (TK), which must be effectively combined with appropriate pedagogical strategies (PK) and a deep understanding of mathematical content knowledge (CK) to maximize student learning outcomes. The framework emphasizes that successful technology integration necessitates not only familiarity with digital tools but also an understanding of how these tools interact with instructional strategies and subject matter to enhance student engagement, motivation, and conceptual understanding.

The integration of digital tools in mathematics education is important for creating interactive and engaging learning experiences that enhance student understanding and performance (Ardyan, 2024). If successfully implemented, this study will help to enhance the quality of mathematics instruction by providing educators with structured strategies for integrating GeoGebra into their teaching. By utilizing GeoGebra-based lesson plans, teachers can create a dynamic and interactive learning environment that nurtures deeper conceptual understanding among students. This initiative is expected to increase student engagement and motivation, leading to improved mathematical understanding in mathematics (focused on transformation of functions). Moreover, the research findings will serve as a valuable reference for educational institutions, guiding them in their strategies for integrating technology into mathematics education.

The study aimed to investigate how the integration of GeoGebra bridges the gap between research and classroom practice. Specifically, it sought to address the following; (1) Design GeoGebra-integrated lesson plans that enhance conceptual understanding and problem-solving skills in mathematics classrooms, (2) Assess the effectiveness of GeoGebra-based instructional strategies in enhancing students' Mathematics motivation, Mathematics engagement, and Mathematics understanding, (3) Assess the change between Mathematics motivation, Mathematics engagement, and Mathematics understanding of the students, (4) Assess the relationship between Mathematics motivation, Mathematics engagement, and Mathematics understanding of the students (5) Determine the challenges and opportunities encountered by the students in integrating GeoGebra into mathematics instruction, (6) Develop a compendium of lesson plans for teachers on utilizing GeoGebra to create an interactive learning environment for selected topics in mathematics.

2.0 Methodology

2.1 Research Design

This study employed a mixed-method approach using a sequential explanatory design, which involves two distinct phases: a quantitative phase followed by a qualitative phase. Initially, the study assessed students' level of mathematics motivation, engagement, and understanding using standardized instruments. This quantitative data provided a broad overview of how GeoGebra integration influences students' learning experiences. Following the quantitative phase, the study analyzed the effect and relationship between mathematics motivation, engagement, and understanding to determine how these factors interact in the context of GeoGebra-enhanced instruction. In the qualitative phase, thematic analysis was conducted to gain deeper insights into the challenges and opportunities students encounter when using GeoGebra in mathematics instruction. Through open-ended survey responses or interviews, students' perspectives were explored, providing a richer understanding of how technology integration affects their learning process.

2.2 Participants and Sampling Technique

The participants in this study were mathematics major students from the College of Teacher Education (CTE) at a university in Cebu Province. Given the study's focus on technology integration in mathematics instruction, a purposive sampling method was employed to ensure that the selected respondents possess relevant experience or exposure to digital tools, such as GeoGebra. This sampling approach was appropriate because it allows the study to target individuals who are currently enrolled in mathematics education courses or have prior experience with technology-assisted learning environments. By selecting participants with a background in mathematics education and some familiarity with technology integration, the study aimed to gather meaningful insights into the effectiveness, challenges, and opportunities associated with the use of GeoGebra in mathematics instruction.

2.3 Research Instruments

A structured survey questionnaires were adapted to collect data on key variables. The Mathematics Motivation Questionnaire (MMQ) by Fiorella et al. (2021) was categorized into five factors: intrinsic value, self-regulation, self-efficacy, utility value, and test anxiety. These variables were measured using a five-point Likert scale with response options of always, usually, occasionally, rarely, and never. The finalized MMQ consists of 19 items with an overall Cronbach's alpha of .85, indicating excellent reliability. The reliability indices for each factor range from .73 to .89, demonstrating good to perfect consistency. The MMQ has also undergone and passed content and internal structure validity tests. The Mathematics Engagement Scale, developed by Wang et al. (2016), is classified into four dimensions: cognitive, behavioral, emotional, and social engagement. These factors were measured using a five-point Likert scale, with responses ranging from 'highly engaged' to 'highly not engaged', including 'engaged', 'neutral', and 'not engaged'. The overall level of engagement, measured through 33 items, has a Cronbach's alpha of .93, indicating excellent reliability. Each of the four factors exhibits good to excellent reliability indices, ranging from .74 to .89. The instrument has also undergone predictive validity tests, which confirmed its significance ($p < .001$). Finally, the researcher developed a questionnaire based on the literature to assess the level of Mathematics Understanding. The questionnaire underwent content checking and validation by experts. The seven-point Likert scale questionnaire, with response options ranging from "strongly agree" to "strongly disagree," consists of 25 items focused on the transformation of functions in Mathematics. It was pilot tested for reliability among thirty-five (35) Bachelor of Secondary Education Major in Mathematics students with a Cronbach's alpha of 0.985, which indicated an excellent reliability.

2.4 Data Gathering Procedure

The research process consisted of four key phases. In the Preparation Phase, the researcher reviewed related literature to establish a theoretical foundation and develop GeoGebra-integrated lesson plans aligned with research-based instructional strategies. Following this, the Data Collection Phase, a pre-test was administered to assess students’ initial levels of mathematical motivation, engagement, and understanding before the integration of GeoGebra. The lesson sessions incorporating GeoGebra were then implemented. Approximately two to three months later, the post-test was conducted. In the Data Analysis Phase, the collected data were analyzed using descriptive statistics and inferential statistics to determine the effectiveness of GeoGebra in enhancing students’ mathematical understanding. Additionally, thematic analysis was applied to the qualitative responses, identifying the challenges and opportunities associated with integrating GeoGebra. Finally, in the Development of the Compendium Phase, a structured module containing GeoGebra-integrated lesson plans was designed based on the research findings. This compendium will serve as a resource for educators, providing practical strategies for integrating GeoGebra into mathematics instruction.

2.5 Data Analysis Procedure

The Quantitative data was analyzed using descriptive and inferential statistics. The descriptive statistics (Mean and Standard Deviation) were used to assess the level of students' mathematics motivation, engagement, and understanding. The inferential statistics (Wilcoxon signed-rank test and Spearman row-rank order correlation) were used to assess the effectiveness and relationships of the study’s construct. Qualitative data analysis involved identifying, examining, and interpreting recurring patterns or themes within textual data to evaluate how they answer the research questions (The Pell Institute, 2022). In this study, qualitative analysis techniques, specifically thematic analysis, were used to discover key themes, as suggested by Clarke and Braune (2016). The process includes six key steps: becoming familiar with the data, generating initial codes, identifying potential topics, refining and reviewing themes, presenting the themes clearly, and interpreting the findings. This structured approach ensures a thorough exploration of the data, providing meaningful insights that align with the study's objectives.

2.6 Ethical Considerations

The study adhered to several ethical considerations. First, there was no conflict of interest, as the objective was purely for educational development and professional growth. Second, privacy and confidentiality were maintained by not disclosing any identifying information of the participants. Third, informed consent was obtained from the participants, who are fully informed of the study’s purpose and procedures. No risks were involved, as data collection takes place in the school and/or on an online platform. Lastly, the recruitment process adheres to established inclusion criteria, and the study findings may benefit both the participants and future students.

3.0 Results and Discussion

3.1 Development of Lesson Plans Using Madeline Hunter’s Instructional Model

The researcher developed a series of lesson plans guided by Madeline Hunter’s Instructional Model to structure the teaching and learning process, incorporating the use of GeoGebra. A total of nine lesson plans were created, two of which focused on teaching functions about the transformation of functions, and seven covered selected topics in Geometry. The first two lesson plans were collaboratively developed with the teacher and fourth-year pre-service teachers in Mathematics, emphasizing the use of GeoGebra in visualizing and manipulating mathematical functions. Lesson 1 explored Graphing Functions Using GeoGebra (Transformation of Functions), while Lesson 2 introduced Coloring Functions and Geometric Shapes Using GeoGebra. These two lessons were adapted from the Function Art Project (Bautista et al., 2024, 2025b). The geometry-focused lessons included: Lesson 3 on Lines, Angles, and Triangles, Lesson 4 on Congruent Triangles, Lesson 5 on Basic Angle Theorems, Lesson 6 on Parallel Lines, Distances, and Angle Sums, Lesson 7 on Parallelograms, Trapezoids, Medians, and Midpoints, Lesson 8 on Circles, and Lesson 9 on Area and Perimeter. Each lesson plan was strategically designed to enhance mathematical understanding and engagement through visualizations and interactive learning experiences provided by GeoGebra.

Although the researcher covered broad topics in Mathematics, in terms of Mathematical understanding, the researcher measured only on the topics related to functions (Transformation of functions, coloring of functions, and geometric shapes using GeoGebra). Figure 1 displays a sample of function art, one of the students' outputs. Function art refers to artworks that incorporate graphs of mathematical functions (Bautista et al., 2024). The artwork displayed is from the third batch of the implementation, translating research findings into classroom practice. The first implementation happened last S.Y. 2022-2023 with theme “GeoGebra and Function Arts: Linking Mathematics, Art, and Technology”, the second implementation was in S.Y. 2023-2024 with the theme

“GeoGebra and Function Arts: Linking Mathematics, Art, and Culture”, and the third implementation in S.Y. 2024-2025 with the theme “GeoGebra and Function Arts: Linking Mathematics, Art, and Creativity”

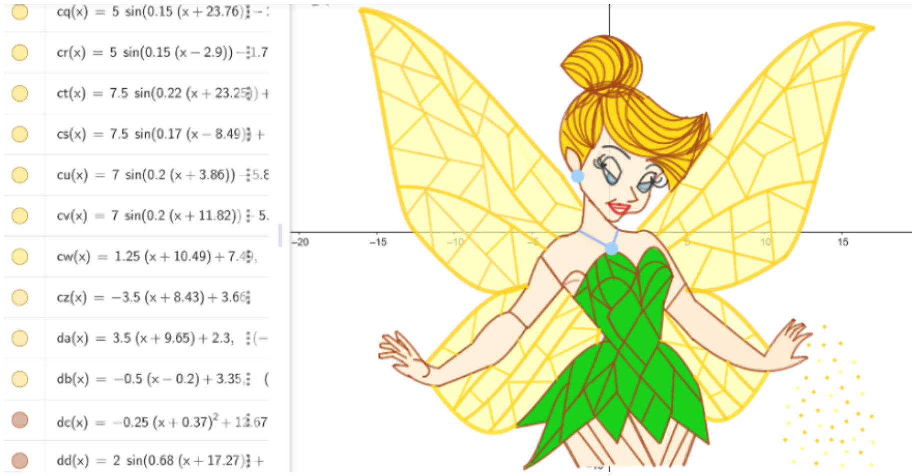

Figure 1. *An Artwork Created Using Polynomial and Trigonometric Functions*

This function art titled “Tinker Bell: A Mosaic of Whimsical Magic” is composed of 203 functions with 125 linear functions, 14 quadratic functions, four cubic functions, and 60 trigonometric functions. Coloring of functions and Geometric shapes was integrated to add details to the image.

3.2 Descriptive Measures of Students’ Levels of Mathematics Motivation, Engagement, and Understanding Before GeoGebra Integration

Table 1. *The Students’ Pretest in Mathematics Motivation*

Mathematics Motivation	Mean	Standard Deviation	Interpretation
Intrinsic value	4.55	0.522	Always
Self-regulation	4.27	0.786	Always
Self-efficacy	4.09	0.539	Usually
Utility value	4.36	0.674	Always
Test anxiety	3.27	1.272	Rarely
Composite mean	**4.18**	**0.603**	**Usually**

Note. n=11. 1.00-1.79 – Never; 1.80-2.59 – Rarely; 2.60-3.39 - Sometimes; 3.40-4.19- Usually; 4.20-5.00 – Always

The pretest results on mathematics motivation reveal that students generally exhibit a “Usually” level of motivation toward the subject, as indicated by the composite mean of 4.18 (SD = 0.603). Among the motivational factors, intrinsic value received the highest mean score (M = 4.55, SD = 0.522), suggesting that students find inherent enjoyment and interest in learning mathematics. Students who perceive learning as beneficial and satisfying are more likely to engage deeply with the material, resulting in improved outcomes (Harefa, 2023). This is closely followed by utility value (M = 4.36, SD = 0.674) and self-regulation (M = 4.27, SD = 0.786), indicating that students recognize the usefulness of math in real-life contexts and demonstrate effort in managing their learning behaviors. This finding aligns with previous research that students often perceive mathematics as practical and essential for everyday decision-making and problem-solving (Barete & Taja-on, 2024). Self-efficacy also shows a relatively high score (M = 4.09, SD = 0.539), reflecting a solid level of confidence in their ability to succeed in mathematics. Students with high self-efficacy perceive challenging tasks as manageable (Sukmawati et al., 2023). However, test anxiety recorded the lowest mean (M = 3.27, SD = 1.272), suggesting that some students still experience moderate to high levels of nervousness or worry during math assessments, with a wider variation among responses. The onset of math anxiety can often be traced back to early educational experiences. Negative experiences with math teachers or challenging math problems can lead to a persistent anxiety that affects students' performance during assessments (Perry, 2004). These findings highlight both strengths and areas for potential intervention to enhance motivation further and reduce anxiety in math learning.

Table 2. *The Students' Pretest in Mathematics Engagement*

Mathematics Engagement	Mean	Standard Deviation	Interpretation
Cognitive engagement	4.18	0.405	Engaged
Behavioral engagement	4.09	0.539	Engaged
Emotional engagement	4.55	0.522	Highly Engaged
Social engagement	4.09	0.701	Engaged
Composite mean	**4.27**	**0.647**	**Highly Engaged**

Note. n=11. 1.00-1.79 – Highly Not Engaged; 1.80-2.59 – Not Engaged; 2.60-3.39 - Neutral; 3.40-4.19- Engaged; 4.20-5.00 – Highly Engaged

The pretest results on mathematics engagement indicate that students are generally highly engaged across various dimensions, as reflected by the composite mean of 4.27 (SD = 0.647). While the overall engagement levels are high, it is essential to recognize that not all students experience engagement uniformly. Factors such as individual needs and classroom dynamics can lead to varying levels of engagement, highlighting the complexity of nurturing a universally engaging learning environment (Goldin, 2019). Emotional engagement received the highest mean score (M = 4.55, SD = 0.522), suggesting that students have a strong positive emotional connection to mathematics, such as enjoyment, interest, or enthusiasm during math activities. Students' emotional states are closely tied to their motivation and self-concept in mathematics. Positive emotions can lead to higher engagement and better performance (Hanin & Nieuwenhoven, 2016). Cognitive engagement is characterized by a high mean (M = 4.18, SD = 0.405), indicating that students are actively investing effort in understanding and mastering mathematical concepts. Cognitive engagement is reflected in students' ability to apply critical thinking and problem-solving skills in mathematics (Calicdan & Gementiza-Cubio, 2025). Both behavioral and social engagement share similar mean scores (M = 4.09), although social engagement shows greater variability (SD = 0.701), suggesting that while most students participate and interact well in group or class settings, some may be less inclined to engage socially during math activities. A study found that students demonstrate high behavioral engagement through active participation in class activities and timely task submissions (Calicdan & Gementiza-Cubio, 2025). Overall, the data reflect a highly engaged profile among students, characterized by strong emotional and cognitive involvement; however, continued support is necessary to foster collaborative and behavioral participation, which may further enhance engagement.

Table 3. *Students' Pretest on Their Mathematics Understanding*

Construct	Mean	Standard Deviation	Interpretation
Mathematics understanding	5.36	1.43	Agree

Note: n=11. 6.16-7.00- Strongly Agree; 5.30-6.15- Agree; 4.44-5.29 – Slightly Agree; 3.58-4.43 – Neutral; 2.72-3.57 – Slightly Disagree; 1.86-2.71 – Disagree; 1.00-1.85 – Strongly Disagree

The pretest results for mathematical understanding, measured on a 7-point Likert scale, show an "Agree level" of self-perceived understanding among students, with a mean score of 5.36 (SD = 1.43). This suggests that, on average, students feel confident in their grasp of mathematical concepts and processes prior to any intervention or instructional support. Teaching practices that incorporate real-world applications of mathematics can significantly boost students' confidence. Students reported that relatable scenarios and supportive teaching nurtured a deeper understanding and increased motivation (Barete & Taja-on, 2024). However, the standard deviation of 1.43 indicates a considerable variation in responses, meaning that while many students rate their understanding positively, a number of them still perceive gaps or inconsistencies in their comprehension. This spread in scores highlights the need for differentiated instruction or targeted support to address individual learning needs and ensure a more consistent level of understanding across the group.

3.3 Descriptive Measures of Students' Levels of Mathematics Motivation, Engagement, and Understanding After GeoGebra Integration

Table 4. *The Student's Post-test in Mathematics Motivation*

Mathematics Motivation	Mean	Standard Deviation	Interpretation
Intrinsic value	4.90	0.316	Always
Self-regulation	4.40	0.516	Always
Self-efficacy	4.40	0.516	Always
Utility value	4.70	0.483	Always
Test anxiety	3.10	1.197	Rarely
Composite mean	**4.50**	**0.527**	**Always**

Note. n=11. 1.00-1.79 – Never; 1.80-2.59 – Rarely; 2.60-3.39 - Sometimes; 3.40-4.19- Usually; 4.20-5.00 – Always

The post-test results on mathematics motivation reveal an overall increase in students' motivation, as evidenced by an “Always level” in composite mean of 4.50 (SD = 0.527) compared to the pretest. This finding aligns with previous research that implementing a realistic mathematical approach leads to increased motivation (Lestari et al., 2019). Among the motivational components, intrinsic value remains the highest (M = 4.90, SD = 0.316), suggesting a further strengthening of students’ interest and enjoyment in learning mathematics. Studies have shown that intrinsic motivation correlates positively with mathematics performance, even during challenging times (Bravo & Nobles, 2023). Increases were also observed in self-regulation and self-efficacy, both scoring a mean of 4.40 (SD = 0.516), indicating that students became more confident and better at managing their learning behaviors after the intervention. Research indicates that intrinsic value is a stronger predictor of self-regulated learning strategies than self-efficacy (Ahmed, 2017). Utility value also improved (M = 4.70, SD = 0.483), reflecting a stronger recognition of the practical applications of mathematics in real-life situations. A realistic mathematics approach has been shown to increase student interest and enthusiasm, leading to active participation and a positive attitude towards learning (Unaenah et al., 2023). Notably, test anxiety decreased slightly to a mean of 3.10 (SD = 1.197), although it still exhibits a wide variation among students. Facilitating anxiety can enhance concentration and motivation, helping students prepare and perform better in evaluative situations. Understanding the nature of test anxiety can help in developing effective strategies to manage it (Numan & Hasan, 2017). Overall, the results suggest that the learning experience had a positive impact on enhancing students' motivation toward mathematics, particularly by deepening their interest and improving their self-perception as capable learners.

Table 5. *The Student’s Post-test in Mathematics Engagement*

Mathematics Engagement	Mean	Standard Deviation	Interpretation
Cognitive engagement	4.36	0.674	Highly Engaged
Behavioral engagement	4.36	0.505	Highly Engaged
Emotional engagement	4.64	0.505	Highly Engaged
Social engagement	4.36	0.505	Highly Engaged
Composite mean	**4.45**	**0.522**	**Highly Engaged**

Note. n=11. 1.00-1.79 – Highly Not Engaged; 1.80-2.59 – Not Engaged; 2.60-3.39 - Neutral; 3.40-4.19- Engaged; 4.20-5.00 – Highly Engaged

The post-test results for mathematics engagement show an improvement in all dimensions, with a composite mean of 4.45 (SD = 0.522), indicating an overall enhancement in students’ active participation and connection with mathematics. This finding aligns with Saralar-Ara's (2022) research, which suggests that Geogebra helps students engage more effectively in mathematics lessons. Emotional engagement remains the highest (M = 4.64, SD = 0.505), indicating that students continue to experience positive feelings, such as enjoyment, curiosity, and enthusiasm, when learning math. This is supported by findings that cognitive engagement enhances emotional and social engagement (Joshi et al., 2022; Calicdan & Gementiza-Cubio, 2025). Meanwhile, cognitive, behavioral, and social engagement all share an identical mean of 4.36, showing balanced gains in students’ intellectual effort, participation in learning activities, and collaboration with peers. Studies show that cognitive engagement positively correlates with academic achievement, indicating that students who think critically are more likely to excel (Lei et al., 2018). Behavioral engagement encompasses participation in learning activities and is linked to creativity and problem-solving skills (ElSayary, 2023). The integration of social processes with cognitive processes has been shown to enhance learning experiences, as students benefit from collaborative environments (Koretsky, 2017). Compared to the pretest scores, the increases across all subdomains suggest that the intervention or learning experience positively influenced students' engagement, leading to deeper involvement and interest in mathematics both individually and socially. These results suggest that the students became more mentally invested, behaviorally engaged, emotionally connected, and socially engaged with the subject following the learning experience.

Table 6. *Students’ Post-test on Their Mathematics Understanding*

Construct	Mean	Standard Deviation	Interpretation
Mathematics understanding	5.90	1.10	Agree

Note: n=11. 6.16-7.00- Strongly Agree; 5.30-6.15- Agree; 4.44-5.29 – Slightly Agree; 3.58-4.43 – Neutral; 2.72-3.57 – Slightly Disagree; 1.86-2.71 – Disagree; 1.00-1.85 – Strongly Disagree

The post-test results for mathematical understanding indicate a notable improvement in students' perceived comprehension, with a mean score of 5.90 (SD = 1.10) on a 7-point Likert scale. This reflects a higher level of confidence in understanding mathematical concepts, specifically on the transformation of functions, compared to the pretest mean of 5.36. GeoGebra facilitates the teaching and understanding of abstract transformation concepts. The reduction in standard deviation from 1.43 to 1.10 suggests more consistency among student responses, indicating that a greater number of students felt similarly confident in their understanding after the intervention. This positive shift suggests that the instructional strategies and learning tools employed, such as the integration of GeoGebra, were effective in enhancing students' mathematical comprehension and reducing disparities in learning outcomes. Research indicates that GeoGebra enhances understanding across various mathematical domains, including geometry, algebra, calculus, and trigonometry. This software enables students to explore concepts independently, fostering analytical and abstract thinking skills that are essential for mathematical proficiency (Uwurukundo et al., 2020; Seftiana et al., 2024).

3.4 Inferential Measures of Changes in Students' Mathematics Motivation, Engagement, and Understanding as a Result of GeoGebra Integration

Table 7. *The Effects of the Level of Mathematics Motivation, Mathematics Engagement, and Mathematical Understanding of the Students*

Construct		Statistic	p	Interpretation
Mathematics Motivation	Wilcoxon W	0.00[a]	0.174	Not significant
Mathematics Engagement	Wilcoxon W	0.00[a]	0.346	Not significant
Mathematics Understanding	Wilcoxon W	5.00[a]	0.281	Not significant

The Wilcoxon signed-rank test results in Table 7 indicate that there were no statistically significant effects observed between the levels of mathematics motivation, mathematics engagement, and mathematical understanding of the students, as all p-values exceeded the conventional alpha level of 0.05 (Mathematics Motivation, $p = 0.174$; Mathematics Engagement, $p = 0.346$; Mathematics Understanding, $p = 0.281$). This finding aligns with previous research that indicates a statistically insignificant change in student mathematics motivation following the incorporation of Geogebra (Ardina & Boholano, 2024). This suggests that, despite observed numerical changes in these constructs, the differences between pretest and posttest scores were not substantial enough to be considered statistically significant. The data further indicated that the respondents were already motivated and engaged in learning mathematics, as they were all Mathematics majors. The lack of significant results may reflect the complexity of student motivation and engagement in mathematics, as highlighted in studies that emphasize the multifaceted nature of these constructs (Pantziara & Philippou, 2015; Xia et al., 2022).

Table 8. *The Relationship between the Level of Mathematics Motivation, Mathematics Engagement, and Mathematical Understanding of the Students*

		MM	ME	MU
Mathematics Motivation (MM)	Spearman's rho	—		
	df	—		
	p-value	—		
Mathematics Engagement (ME)	Spearman's rho	0.833**	—	
	df	9	—	
	p-value	0.001	—	
Mathematics Understanding (MU)	Spearman's rho	0.747**	0.810**	—
	df	9	9	—
	p-value	0.008	0.003	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 8 presents the Spearman's rho correlation results, which reveal statistically significant and positive relationships among mathematics motivation, mathematics engagement, and mathematical understanding. Specifically, mathematics motivation is strongly correlated with mathematics engagement ($\rho = 0.833$, $p = 0.001$), indicating that more motivated students tend to be more engaged in their learning. Associated with a genuine interest in mathematics, intrinsic motivation positively correlates with engagement and achievement (Tran & Nguyen, 2021). Additionally, mathematics understanding is significantly correlated with both mathematics motivation ($\rho = 0.747$, $p = 0.008$) and mathematics engagement ($\rho = 0.810$, $p = 0.003$), suggesting that students who are more motivated and engaged also demonstrate a deeper understanding of mathematical concepts (Chandra et al., 2021; Ardina & Boholano, 2024). These findings highlight the interrelated nature of affective and cognitive domains in learning, emphasizing the importance of fostering both motivation and engagement to enhance students' comprehension in mathematics.

3.5 The Challenges and Opportunities Encountered by the Students in Integrating GeoGebra into Mathematics Instruction

Based on the analysis of the qualitative data, the following themes emerged.

Technical and Accessibility Constraints

One of the most prominent challenges experienced by students in using GeoGebra is the issue of technical and accessibility constraints (Semenikhina et al., 2019; Ardina & Boholano, 2024). Several students noted the limitations caused by inadequate access to devices and unstable internet connections, which significantly impacted their ability to use the tool efficiently. A participant stated, *"I do not have enough devices to use."*, highlighting the disparity in access to necessary digital resources among students. Similarly, issues such as lagging and slow software performance were frequently reported:

"The application becomes slower and more difficult to navigate."

Particularly when multiple functions are input, these technical challenges not only hinder learning but also discourage students from fully exploring GeoGebra's capabilities. Additionally, poor internet connectivity was a recurring issue that affected the seamless integration of GeoGebra into lessons. One student shared:

"There are also problems with internet connection or slow devices."

Emphasizing the importance of setup in supporting technology-enhanced learning. Without sufficient hardware and connectivity, the effectiveness of digital tools like GeoGebra becomes limited. These challenges suggest the need for schools and educators to ensure that students have equitable access to digital tools and provide offline alternatives or institutional support to address these barriers.

Theme 2: Initial Learning Challenges

Another challenge observed in the data revolves around the initial difficulties students encounter when learning to use GeoGebra. For students unfamiliar with digital tools, understanding and navigating GeoGebra can be overwhelming (Matthews & Scott, 2017). One student expressed:

"It can be a bit confusing when the lesson moves too fast while you are still figuring things out."

This reflects the difficulty of learning new software while simultaneously keeping pace with the curriculum. The lack of sufficient guidance or orientation in using the tool compounds this problem, as students may struggle to discover the functionalities independently. The learning curve was particularly emphasized by students who encountered complex features early in their usage. A respondent mentioned:

"I did, however, find it a bit daunting to learn the different tools in it."

Suggesting that familiarity with the tool develops over time but is initially intimidating. Other students mentioned difficulty manipulating specific mathematical elements, such as "curving function at first and how to manipulate it." These responses suggest that while GeoGebra has immense potential, practical training is crucial to minimize confusion and foster confidence among new users.

Improved Visualization and Understanding

GeoGebra has been widely praised for its ability to enhance students' understanding through the dynamic visualization of mathematical concepts. This supports the previous study, which found that Geogebra promotes students' conceptual understanding in mathematics (Bautista et al., 2025b; Uwurukundo et al., 2020; Seftiana et al., 2024; Mursyida et al., 2024). Many students noted that seeing graphs and functions in a visual format made abstract topics more concrete and easier to understand. One student shared: *"GeoGebra makes learning math more fun and visual."*, highlighting the shift from passive learning to an engaging, interactive experience. Another stated:

"The graphs become very easy to visualize, making it very effective."

This reinforces the idea that visualization helps in comprehension and retention of lessons. Through real-time manipulation of functions and diagrams, students were able to better grasp complex topics, especially in algebra and geometry.

"GeoGebra allows dynamic visualization of complex math equations."

One student wrote, emphasizing its practical benefit. These insights suggest that integrating visualization tools, such as GeoGebra, can support a deeper conceptual understanding, particularly for visual and kinesthetic learners. The platform serves as a bridge between abstract mathematical ideas and tangible representations, facilitating more meaningful learning experiences.

Integration of Creativity and Math

Beyond enhancing comprehension, GeoGebra provided a unique opportunity for students to explore the creative side of mathematics (Ardyan, 2024). Despite these obstacles, students were drawn to the self-learning concept and the slider feature during their educational experiences. Several students mentioned that the tool enabled them to engage in artistic expressions using math. A notable comment was: *"I was able to make artistic output with the use of mathematics."*, illustrating how GeoGebra supports interdisciplinary learning by blending math and art. Another student noted: *"The opportunity to integrate math with creativity."*, revealing their appreciation for the flexible and exploratory nature of the tool. For many students, the experience expanded their perception of what mathematics can be. One participant remarked:

"I was given a view in math that there was something that could very well be an integration of art in math... it made me think what other branches could be linked to math."

This quote captures the transformative impact of GeoGebra in reshaping students' perceptions of the subject. By encouraging exploration, the platform not only develops technical skills but also fosters a sense of wonder and possibility within the learning process.

The challenges and opportunities identified in this research closely align with those presented by Bautista et al. (2025a). Our study revealed that many students struggled with navigating GeoGebra, particularly in the early stages of construction, highlighting the need for orientation and support. In their research, Bautista et al. reported various digital challenges, including limited access to technology and the internet, as well as unfamiliarity with GeoGebra. Software lag was also frequently cited as a barrier to practical use.

On the other hand, our findings on students' attraction to self-directed learning echo Bautista's observations. Their study noted that students often relied on online or offline resources and occasionally sought assistance from their friends and peers. This parallel suggests a broader trend: while technological and learning curve challenges persist, students are capable of overcoming them through resourcefulness and peer collaboration, mainly when motivated by the creative and interactive possibilities that tools like GeoGebra offer.

3.6 The Compendium of Lesson Plans for Teachers on Utilizing GeoGebra to Create an Interactive Learning Environment for Selected Topics in Mathematics

As one of the study's intentions is to help students and provide guidance to teachers who may be using the same mathematics tool, the researcher initiated the idea of creating a compendium of lesson plans. Develop a compendium of lesson plans (using Madeline Hunter's model) for teachers on utilizing GeoGebra to create an interactive learning environment for selected mathematics topics.

Lesson plan 1: Graphing Functions Using GeoGebra (Transformation of Functions)
Lesson plan 2: Coloring Functions and Geometric Shapes Using GeoGebra
Lesson plan 3: Lines, angles, and triangles
Lesson plan 4: Congruent triangles
Lesson plan 5: Basic angle theorems
Lesson plan 6: Parallel lines, distances, and angle sums
Lesson plan 7: Parallelograms, trapezoids, medians, and midpoints
Lesson plan 8: Circle
Lesson plan 9: Area and Perimeter

4.0 Conclusion

Therefore, it is concluded that integrating GeoGebra into mathematics instruction has a positive impact on students' motivation, engagement, and understanding. Quantitative data showed improvements in all domains, including increased intrinsic value, utility value, self-regulation, and self-efficacy, as well as higher levels of emotional, cognitive, behavioral, and social engagement, and a gain in perceived mathematical understanding. Qualitative analysis revealed themes that supported these findings. Students found GeoGebra to be an educational tool for visual learning, creative exploration, and deeper comprehension, although they also encountered technical and accessibility challenges. Overall, the intervention enhanced not only students' academic performance but also their attitude and interest toward learning mathematics. Based on the findings, the following recommendations are proposed: sustain and expand the use of GeoGebra across various math topics to continuously support visualization, exploration, and creativity in learning; provide technical support and resources, such as stable internet access and adequate devices, to minimize challenges related to connectivity and device limitations; and promote collaboration with other mathematics teachers in both private and public schools to develop a comprehensive compendium of lesson plans that integrate GeoGebra, ensuring consistent and innovative teaching practices across educational contexts.

5.0 Contributions of Authors

Author 1(Genaro T. Ardina): conceptualization, proposal writing, data gathering, statistician, and data analysis. Author 2 (Guillermo Bautista, Jr): literature, proposal writing, and validation of the questionnaire. Author 3 (Maria Salud M. delos Santos): proposal writing, verification of the results, and adviser.

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7.0 Conflict of Interests

This study has no conflict of interest and is conducted solely for educational purposes.

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