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Integration of Geogebra and Spatial Thinking Tasks: Its Effect on Students' Conceptual Understanding in Trigonometry

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ABSTRACT

This study examined how GeoGebra-integrated and spatial thinking-based instruction can help Grade 10 students better understand trigonometry. It aimed to determine students' performance before and after the intervention, examine whether the experimental group performed better than the control group, investigate the relationship between students' spatial thinking skills and their understanding of trigonometry, and assess the practical impact of the intervention. This study employed an experimental research design. The experimental group experienced GeoGebra-integrated and spatial thinking-based lessons, while the control group received traditional instruction. Pre-tests and post-tests were administered to both groups, and the data were analyzed using Mean Percentage Score (MPS), independent samples *t*-test, and Cohen's *d*. Results revealed that students started with a low pre-test MPS of 21.29, but improved to 54.76 after the intervention. The experimental group (n=21) achieved a mean post-test score of 18.29 (SD=3.7168), higher than the control group (n=22), which scored 16.00 (SD=3.6904). The difference was statistically significant (t = 2.0266, p = 0.0493), indicating that students exposed to the intervention performed better. Additionally, there was a significant relationship between spatial thinking skills and conceptual understanding of trigonometry (p = 0.0493). The computed Cohen's d of 0.6184 indicated a medium effect size, showing that the intervention had a meaningful impact on students' learning. In conclusion, combining GeoGebra with spatial thinking activities significantly enhanced students' understanding of trigonometry. The study highlights the value of using interactive tools and reasoning-based strategies in the classroom to make abstract concepts more accessible and improve learning outcomes.

Keywords: *Conceptual Understanding, Effect size, Experimental instruction, GeoGebra, Spatial thinking, Trigonometry*

INTRODUCTION

Mathematics is widely recognized as a subject that requires not only computational skills but also deep understanding and abstract thinking. Among the different areas of mathematics, trigonometry is often considered one of the most challenging topics for secondary students. Its abstract concepts and heavy use of symbols make it difficult for many learners to understand, especially when lessons are disconnected from visual or real-life contexts (Uttal & Cohen, 2012). As a result, students tend to rely on memorization of formulas rather than developing meaningful understanding (Lohman, 2019).

Trigonometry plays an important role in secondary education because it links geometry and algebra and supports applications in science, technology, engineering, and everyday problem-solving. However, in many

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classrooms, instruction still focuses on procedural methods and formula-based teaching. This approach limits students' opportunities to explore concepts visually and conceptually, making it harder for them to grasp how trigonometric ideas actually work (Jones et al., 2013).

In the Philippine educational context, these learning difficulties remain evident. Despite the Department of Education's efforts to improve numeracy through teacher training programs and assessment-based interventions, many students continue to struggle in mathematics. International assessments such as the Programme for International Student Assessment (PISA) have consistently shown that Filipino learners perform below the global average, with mean scores of 353 in 2018 and mid-350s in 2022. These results reflect persistent gaps in students' understanding and problem-solving abilities.

At the local level, the situation is equally concerning. In SDO Masbate Province, ALNAT and division-level assessments conducted in March 2025 identified 91,895 learners in Need of Major Support, indicating serious challenges in numeracy development. Similarly, at Quezon National High School, the SY 2024–2025 Rapid Mathematics Assessment (RMA) revealed that all 68 Grade 10 students scored below the Proficient Level in mathematics. In particular, the Visualizing and Modeling component showed only a 38.2% mastery level. Since visualization skills are essential in learning trigonometry, these results highlight the urgent need to improve students' spatial reasoning and conceptual understanding.

One way to address these challenges is through the use of technology-enhanced instruction. Dynamic mathematics software such as GeoGebra offers students an interactive learning environment where they can manipulate figures, explore relationships, and observe mathematical changes in real time. Instead of passively receiving information, learners become active participants who can experiment with triangles, angles, and graphs, helping them develop a clearer and deeper understanding of trigonometric concepts.

Equally important is the development of spatial thinking skills. Spatial thinking involves the ability to visualize objects, understand relationships between shapes, and interpret graphical representations. In trigonometry, students constantly work with angles, triangles, coordinate systems, and graphs. When learners are able to mentally visualize these elements, they are more likely to connect visual representations with symbolic expressions and develop meaningful understanding that can be applied to new situations.

The integration of GeoGebra and spatial thinking strategies provides a more engaging and learner-centered approach to trigonometry instruction. This combination allows students to explore mathematical concepts dynamically, encourages critical thinking, and promotes deeper conceptual learning. Compared to traditional methods that emphasize memorization, this approach helps students build understanding that is more flexible and transferable (Rakes, 2017).

Guided by national assessment results, DepEd monitoring data, and local school performance indicators, this study aimed to respond to the existing challenges in trigonometry instruction. Specifically, the study entitled "Integration of GeoGebra and Spatial Thinking: Its Effect on Students' Conceptual Understanding in Trigonometry" sought to examine how the use of dynamic technology and spatial-based teaching strategies can improve students' learning outcomes. The findings of this research are expected to support school-based remediation programs, enhance teacher instructional practices, and contribute to the improvement of numeracy and conceptual understanding among secondary learners.

Statement of the Problem

This study aimed to investigate the effect of integrating GeoGebra and spatial thinking on the conceptual understanding of trigonometry among Grade 10 students at Quezon National High School during the School Year 2025–2026. It focused on the use of technology-based and spatially oriented learning activities to help students better visualize and understand trigonometric concepts. Specifically, the study sought to answer the following research questions:

1. What is the Mean Percentage Score (MPS) of the control group in pretest and posttest?
2. What is the Mean Percentage Score (MPS) of the experimental group before and after the intervention?
3. Is there a significant difference between the posttest means of the two groups in trigonometry?

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4. What is the effect size of the intervention?

Hypotheses

Anchored on the framework RQs, researcher came up with assumptions hereunder:

1. There is no significant difference in the Mean Percentage Scores (MPS) of the two groups of Grade 10 students before and after the intervention.
2. There is a difference in the Mean Percentage Scores (MPS) of the two groups of Grade 10 students after the implementation of the intervention, suggesting a possible improvement in performance following the integration of GeoGebra and spatial thinking tasks.
3. There is no significant difference between the post-test mean scores of the two groups of respondents in trigonometry after the intervention.
4. The integration of GeoGebra and spatial thinking tasks has a significant effect on students' conceptual understanding in trigonometry, as indicated by the computed effect size

Significance of the Study

This study is significant because it seeks to understand how the integration of spatial thinking and GeoGebra can improve students' conceptual understanding of trigonometry at Quezon National High School. The findings are expected to offer valuable insights and practical implications for various stakeholders in education, particularly in teaching and learning mathematics.

Teachers. Mathematics teachers can use the results of this study to design lessons that incorporate spatial thinking. By emphasizing visualization, geometric manipulation, and the link between abstract and visual concepts, teachers can help students develop a deeper understanding of trigonometry and improve their overall performance.

School Administrators and Department Heads. Administrators and department heads can benefit from the study by gaining insights into effective teaching strategies that enhance student achievement in mathematics. The research provides evidence-based recommendations for professional development, instructional planning, and classroom support systems that promote the use of spatial thinking in teaching abstract concepts.

Curriculum Planners and Policymakers. The findings can help curriculum planners and education policymakers design instructional frameworks that integrate spatial thinking. Incorporating these strategies into the mathematics curriculum ensures that teaching methods align with how students learn best, fostering deeper conceptual understanding and preparing students for advanced mathematics and STEM-related fields.

Department of Education (DepEd). This study offers empirical data that can guide national and regional efforts to improve mathematics instruction. Insights from this research can support the development of teacher training programs, informed resource allocation, and policies that prioritize cognitive strategies like spatial reasoning to enhance learning outcomes.

Future Researchers. Finally, this study lays a foundation for future research in mathematics education and cognitive development. Other researchers can build on its findings to explore new instructional strategies, investigate long-term effects of spatial thinking interventions, or examine its application across different grade levels, topics, and learning contexts.

Scope and Limitation of the Study

This study focused on designing and validating teaching strategies that integrate spatial thinking and GeoGebra to help Grade 10 students develop a deeper and more meaningful understanding of key trigonometric concepts. The activities and assessment tools were designed to align with the Rapid Mathematics Assessment (RMA) framework, ensuring they promote both spatial thinking skills and conceptual understanding of trigonometry. The instructional material specifically covered important topics in trigonometry, including right-angled triangles, trigonometric ratios, the unit circle, and the graphing of sine and cosine functions. By integrating these concepts into spatial-thinking-based activities and tasks, the study sought to explore the relationship between students' spatial reasoning abilities and their overall comprehension of trigonometry.

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The intervention material was tailored for students within the K-12 curriculum, particularly those who may need extra support in grasping complex mathematical ideas. The key element of the study was the creation of the RMA-aligned assessment tool to evaluate students' spatial thinking skills, conceptual understanding, and ability to apply these in trigonometric tasks. This tool aimed to measure whether incorporating spatial thinking into classroom instruction enhances student comprehension and to examine how spatial reasoning relates to conceptual mastery. To ensure the quality, accuracy, and effectiveness of the instructional activities, the study included a rigorous validation process carried out by subject matter experts, mathematics educators, and assessment specialists. They evaluated the materials based on content relevance, mathematical accuracy, instructional effectiveness, and alignment with international assessment standards.

The study involved forty-three (43) Grade 10 students (Key Stage 3) from Quezon National High School during the Academic Year 2025–2026. Participants underwent pretest and posttest assessments to measure their spatial thinking abilities and conceptual understanding of trigonometry before and after the intervention. This research aimed to determine how spatial thinking strategies, supported by GeoGebra, can help students better connect abstract trigonometric concepts with visual and spatial representations, leading to improved conceptual understandings. In addition, the study sought to contribute to the development of teaching practices that effectively bridge visual and abstract modes of reasoning, supporting deeper learning and improved performance in trigonometry.

However, the scope of this study was limited to Quezon National High School and therefore did not represent students across different schools or regions. It focused only on selected trigonometry concepts and did not extend to other branches of mathematics or more advanced trigonometric applications. The intervention was conducted within a single academic term, which may limit the observation of long-term learning retention or transfer of knowledge. External factors, such as students' prior mathematical knowledge, motivation, and learning environment, may also influence outcomes and have not fully controlled. Additionally, while validated instruments like pretests, posttests, and classroom observations were used, these tools may not capture all aspects of students' cognitive or affective development.

The delimitation of the study lies in its focus on a specific group of learners, subject area, and instructional context. It was confined to Grade 10 students of Quezon National High School and selected trigonometry topics. The research did not cover other mathematical domains or higher-level trigonometric applications such as inverse functions or identities. Likewise, the intervention occurred only during a limited period in the academic term, and the long-term impact of spatial-thinking integration is beyond the scope of this study. Finally, the study focused primarily on cognitive and instructional aspects, without deeply examining affective factors such as students' attitudes or motivation toward mathematics

METHODS

Research Design

This study employed a true experimental research design to determine the effect of integrating GeoGebra and spatial thinking strategies on students' conceptual understanding of trigonometry. This design was appropriate because it allowed the researcher to establish a cause-and-effect relationship between the instructional intervention and students' learning outcomes through random assignment, controlled conditions, and systematic comparison between groups.

The study followed several key phases. First, GeoGebra-supported, spatial thinking-based tasks and activities were designed and developed to enhance students' understanding of core trigonometric concepts. These learning materials incorporated dynamic visualizations, interactive geometric representations, and spatial reasoning exercises that encouraged students to explore mathematical relationships more meaningfully. The instructional materials were validated by subject-matter experts to ensure content accuracy, clarity, and alignment with the Grade 10 Mathematics curriculum.

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Next, an RMA-aligned assessment instrument was constructed to measure students' conceptual understanding and mathematical literacy in trigonometry. To ensure proper alignment with both curriculum standards and RMA frameworks, a table of specifications was prepared. This blueprint guided the distribution of test items across content areas and cognitive skills, ensuring balanced coverage of the learning competencies addressed in the intervention.

Grade 10 classes from Quezon National High School were selected and randomly assigned to either the experimental group or the control group. The experimental group received instruction that integrated GeoGebra and spatial thinking strategies, including interactive simulations, visualization tasks, and dynamic exploration of trigonometric relationships. Meanwhile, the control group was taught using the traditional lecture-discussion method commonly practiced in mathematics classrooms.

This research design allowed for a direct comparison of learning outcomes between students who experienced technology-enhanced, spatially enriched instruction and those who received conventional teaching. Moreover, it supported the study's objective of examining how the integration of GeoGebra and spatial thinking strategies influenced students' conceptual understanding of trigonometry, while maintaining systematic control and reliability throughout the research process.

Research Locale

This study was conducted in Quezon National High School, one of the institutions under the Schools Division of Masbate Province. The chosen school is located in Quezon, Claveria, Masbate, Philippines, and serves a diverse population of students from various socio-economic backgrounds. The institution has a reputation for academic excellence and provides a supportive environment for implementing innovative teaching strategies.

The participants of this study were primarily Grade 10 students enrolled in mathematics classes during the academic year 2025-2026. These students are at the stage of their education where abstract mathematical concepts, such as trigonometry, become increasingly complex and cognitively demanding. By focusing on this age group, the study aimed to understand how spatial thinking can support students in bridging the gap between abstract formulas and their visual representations. Moreover, the school's curriculum, teaching practices, and available learning resources provide an ideal setting for investigating the integration of spatial thinking strategies in mathematics instruction. The locale not only provides easy access to participants but also offers a realistic context in which the effects of spatial-thinking-based interventions on conceptual understanding can be observed and measured.

In summary, the chosen school and its Grade 10 mathematics classes served as a representative setting for exploring the role of spatial thinking in enhancing students' comprehension of trigonometric concepts, providing both practical relevance and academic rigor to the study.

Sampling Technique

The study employed a purposive sampling technique to select the participants, ensuring that the sample consisted of learners who were most relevant to the objectives of the research. Specifically, the respondents were Grade 10 students from Quezon National High School who were enrolled in mathematics classes during the period of the study. This sampling method was chosen because it allowed the researcher to focus on students who would directly benefit from and engage with the GeoGebra and spatial-thinking-based instructional activities in trigonometry. The sample included both male and female learners from diverse academic backgrounds, providing a representative view of the classroom population.

Prior to participation, the students were fully informed about the purpose of the study, the procedures involved, and ethical considerations such as voluntary participation, confidentiality, and informed consent.

A total of 43 respondents (22 for experimental group and 21 for control group) were deemed sufficient to ensure that the data collected would accurately reflect the effectiveness of spatial-thinking strategies in enhancing students' conceptual understanding and problem-solving skills in trigonometry.

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RESULTS AND DISCUSSION

This chapter presents the findings of the study on the effectiveness of GeoGebra-integrated and spatial thinking-based instruction in improving the conceptual understanding of trigonometry among Grade 10 students. The presentation of results follows the sequence of the Statement of the Problem. The findings are analyzed and interpreted using the statistical data gathered before and after the intervention.

Mean Percentage Scores (MPS) of the Control Group in Pre-Test and Post-Test

To examine the changes in students' performance, the Mean Percentage Scores (MPS) of the control group were analyzed before and after the instructional period. The pre-test results served as a baseline measure of the students' initial level of conceptual understanding in Trigonometry, while the post-test results reflected their level of learning after exposure to the conventional teaching approach.

By comparing these scores, the study was able to determine the extent of change in students' performance within the control group. The computation of the Mean Percentage Score (MPS) provided a clear and quantitative basis for describing students' progress over time. This comparison is essential in understanding how much learning occurred under traditional instruction and serves as a reference point in evaluating the overall effectiveness of different instructional strategies used in the study.

To determine the performance of the respondents before and after the instructional period, the Mean Percentage Score (MPS) in the pre-test and post-test was computed.

Table 2. *Comparison of Mean Percentage Scores (MPS) Between Pre-test and Post-test for the Control Group*

Test Type	Mean Percentage Score (MPS)	Interpretation
Pre-Test	22.87	Low Baseline Performance
Post-Test	51.61	Substantial Improvement
Mean Gain	28.74	Moderate Effect Size

The Mean Percentage Scores (MPS) of the Control Group in both the pre-test and post-test indicate a clear improvement in students. Table 2 shows that the control group obtained an MPS of 22.87 in the pre-test and 51.61 in the post-test. This reflects a gain score of 28.74, indicating a substantial improvement in students' performance after the instructional period.

The increase in MPS suggests that students benefited from the conventional teaching methods employed during the study. Their exposure to structured lessons, guided practice, and teacher explanations likely contributed to the observed improvement. This finding implies that even without the experimental intervention, learning still occurred as students gradually developed their understanding of the concepts presented.

From a statistical perspective, the positive gain score indicates a meaningful difference between pre-test and post-test performance. While no inferential test (e.g., t-test) is presented, the magnitude of the increase suggests that the improvement is educationally significant. However, the post-test MPS of 51.61 still reflects a moderate level of mastery, indicating that students may not have fully achieved deeper conceptual understanding.

These findings are supported by the theory of Benjamin Bloom, which explains that learning progresses through stages and improves with continuous instruction and reinforcement. Similarly, Robert Gagné emphasized that structured teaching and systematic presentation of content can lead to measurable learning gains, even in traditional classroom settings.

Furthermore, related studies suggest that while conventional teaching methods can improve student performance, they often result in only moderate achievement levels, particularly in mathematics. Research in mathematics education highlights that students tend to perform better when instructional strategies go beyond procedural teaching and incorporate visualization and active engagement. This is particularly relevant in trigonometry, where abstract concepts require spatial reasoning skills to be fully understood.

The results imply that traditional teaching methods remain effective in facilitating basic learning gains; however, they may not be sufficient to achieve high levels of mastery. The moderate post-test performance suggests a need for instructional enhancement.

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For educators, this highlights the importance of integrating more dynamic and student-centered approaches, such as visual tools, technology (e.g., GeoGebra), and spatial reasoning activities. For researchers, the findings strengthen the rationale of the present study, which focuses on bridging abstract and visual learning. The observed improvement in the control group serves as a baseline, emphasizing that any additional gains in the experimental group may be attributed to the effectiveness of the intervention.

Overall, the findings support the view that while conventional instruction contributes to learning, combining it with innovative strategies can lead to more meaningful and sustained understanding.

Mean Percentage Score (MPS) of the Experimental Group Before and After the Intervention

Following the implementation of the intervention involving the integration of GeoGebra and spatial thinking tasks, the Mean Percentage Scores (MPS) of experimental groups were computed using their pre-test and post-test results. This analysis aimed to describe the level of students' conceptual understanding in trigonometry and to examine the changes in performance after the intervention was administered.

To determine the level of students' performance before and after exposure to the intervention, the mean percentage score was computed.

Table 3. *Comparison of the Experimental Group's Mean Percentage Score (MPS) Before and After the Intervention*

Test Type	Mean Percentage Score (MPS)	Descriptive Interpretation
Pre-Test	20.89	Very Low
Post-Test	58.99	Moderate Level
Mean Gain	38.10	High Improvement

Table 3 presents the mean percentage scores of the Experimental group before and after the implementation of the intervention. The results show a marked improvement in students' performance. The experimental group obtained a pre-test MPS of 20.89, which increased significantly to a post-test MPS of 58.99, resulting in a gain score of 38.10. This indicates a substantial improvement in students' conceptual understanding of Trigonometry after the implementation of the GeoGebra-integrated and spatial thinking-based instruction.

The low pre-test score suggests that students initially had limited understanding of Trigonometric concepts, which is common when learners are introduced to abstract mathematical topics without visual or spatial support. However, after the intervention, the notable increase in MPS reflects that students were able to better grasp the concepts when these were presented through visual and interactive learning tools.

This improvement can be explained through the cognitive theory of learning, particularly the ideas of Jerome Bruner, who emphasized that learners understand abstract concepts more effectively when they are represented in visual and concrete forms before moving to symbolic understanding. Similarly, Richard Mayer supports the idea that multimedia and visual-based instruction enhance meaningful learning by reducing cognitive load and improving conceptual connections.

The findings also align with studies in mathematics education that highlight the effectiveness of dynamic geometry environments such as GeoGebra in improving students' understanding of Trigonometry. Research shows that visualization tools help students connect angles, sides, and functions more meaningfully, making abstract relationships easier to understand and retain.

The results imply that integrating GeoGebra and spatial thinking tasks significantly enhances students' conceptual understanding compared to traditional instruction alone. The substantial gain score suggests that students benefit from visual and interactive learning environments that allow them to explore mathematical relationships dynamically.

For teachers, this highlights the importance of incorporating technology-based tools in mathematics instruction, especially in topics that are highly abstract. For curriculum developers and school administrators, the findings support the need to provide training and resources that encourage the use of dynamic learning tools like GeoGebra in classroom instruction.

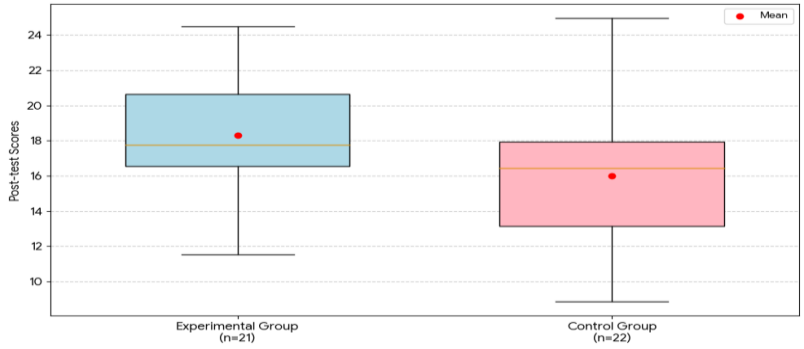
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Overall, the results affirm that when students are exposed to visual and exploratory learning experiences, their understanding of mathematical concepts becomes deeper and more meaningful, leading to improved academic performance in Trigonometry.

Post-test Means of the Two Groups of Respondents

This section examines whether there is a significant difference between the post-test mean scores of the two groups of respondents in relation to their conceptual understanding in trigonometry. It focuses on comparing the performance of the control and experimental groups following the integration of GeoGebra and spatial thinking tasks, with the aim of determining whether any observed differences in their mean scores are statistically significant. To determine whether a significant difference existed between the post-test means of the Experimental and Control groups, an independent samples *t*-test was used.

Figure 4. *Box Plot of Post-Test Scores: Experimental vs. Control Group*



The results presented in Figure 4 show the comparison between the post-test mean scores of the Control and Experimental groups. The Experimental Group obtained a higher mean score of 18.29 compared to the Control Group's mean score of 16.00. In terms of variability, both groups had almost the same standard deviations (3.7168 for the Experimental Group and 3.6904 for the Control Group), indicating that the spread of scores in both groups was relatively similar. This suggests that the difference in mean scores is not due to extreme variations in performance, but rather reflects a consistent difference between the two groups.

To determine whether this difference is statistically significant, a t-test was conducted. The computed t-value of 2.0266 and p-value of 0.0493 show that there is a significant difference between the post-test scores of the two groups at the 0.05 level of significance. Since the p-value is less than 0.05, the null hypothesis is rejected. This means that the performance of the students in the Experimental Group is significantly higher than that of the Control Group after the intervention.

This finding indicates that the use of GeoGebra combined with spatial thinking strategies was more effective than traditional instruction in improving students' understanding of Trigonometry. The higher mean score of the Experimental Group suggests that students benefited from the interactive and visual features of the intervention, which may have helped them better understand abstract concepts and relationships.

The result of this study is supported by previous research. For instance, Zengin et al. (2012) found that students who used GeoGebra demonstrated significantly higher achievement compared to those who were taught using traditional methods. Similarly, Hohenwarter highlighted that dynamic mathematics environments can enhance students' conceptual understanding by allowing them to explore and visualize mathematical ideas more effectively. These studies support the present findings, particularly the observed improvement in the Experimental Group.

Overall, the results imply that the intervention had a positive and measurable effect on student performance. The significant difference between the two groups confirms that the instructional approach used in the Experimental Group created a more effective learning experience. This suggests that integrating interactive

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tools and spatial thinking strategies in teaching can help improve students' understanding, especially in topics that are abstract and require visualization. Therefore, educators may consider adopting similar approaches to enhance learning outcomes and make mathematics instruction more engaging and meaningful.

Effect Size of the Intervention

This section presents a summary of the effect size measures derived from the data analysis in relation to the integration of GeoGebra and spatial thinking tasks. It aims to determine the magnitude of the intervention's effect on students' conceptual understanding in trigonometry, thereby providing a deeper interpretation of the results beyond statistical significance.

To determine the practical significance of the intervention, Cohen's *d* was computed.

Table 4. *Summary of Effect Size Measures*

Measure	Value	Interpretation
Pooled Standard Deviation	3.7033	—
Cohen's d	0.6184 (~0.62)	Medium Effect Size

Table 4 presents the effect size of the intervention using Cohen's d. The pooled standard deviation was computed at 3.7033, and the resulting Cohen's d value is 0.6184, which can be interpreted as approximately 0.62. Based on standard benchmarks, this value indicates a medium effect size. This means that the difference in performance between the Control and Experimental groups is not only statistically significant but also meaningful in practical terms.

A medium effect size suggests that the intervention had a noticeable impact on students' learning. In this study, it indicates that the use of GeoGebra combined with spatial thinking strategies contributed to a moderate improvement in students' understanding of Trigonometry. While the improvement may not be considered large, it is substantial enough to show that the instructional approach made a real difference in how students learned the material.

This finding is supported by previous studies. For example, Hattie (2009) emphasized that an effect size of 0.40 and above can already be considered educationally meaningful, indicating that the result of this study exceeds that benchmark. Similarly, Zengin et al. (2012) reported that the use of GeoGebra in mathematics instruction resulted in moderate to high improvements in student achievement, particularly in topics requiring visualization. These studies support the present findings, showing that technology-supported and interactive approaches can produce meaningful gains in learning outcomes.

In practical terms, the medium effect size means that the advantage of the Experimental Group over the Control Group is evident and can be observed in actual classroom performance. The intervention helped students better understand concepts that are typically difficult to grasp, especially those involving abstract relationships and spatial reasoning. This implies that integrating tools like GeoGebra and incorporating spatial thinking strategies can enhance the effectiveness of instruction. Therefore, the approach used in this study has strong potential for classroom application, particularly in improving students' conceptual understanding and engagement in learning trigonometry.

CONCLUSION

This study was conducted to examine the effectiveness of integrating GeoGebra and spatial thinking strategies in enhancing Grade 10 students' conceptual understanding of trigonometry. Specifically, it addressed the Mean Percentage Scores (MPS) of both the control and experimental groups, compared their posttest performance, and determined the magnitude of the intervention's effect.

The findings revealed that both groups started with relatively low and comparable pretest MPS, indicating similar baseline knowledge in trigonometry. However, after the intervention, both groups showed improvement, with the experimental group achieving a notably higher posttest MPS than the control group. This suggests that while conventional instruction can support learning gains, the integration of GeoGebra and spatial thinking strategies provides a more effective means of improving students' understanding.

Furthermore, the analysis of posttest results demonstrated a statistically significant difference between the performance of the two groups. This indicates that the observed improvement in the experimental group was not due to chance, but rather to the instructional approach employed. Supporting this, the computed effect size revealed a moderate and meaningful impact of the intervention, highlighting its practical significance in the classroom.

Taken together, the results of the study affirm that integrating GeoGebra with spatial thinking tasks enhances students' conceptual understanding of trigonometry more effectively than traditional teaching methods alone. The approach not only improves performance outcomes but also fosters deeper comprehension of mathematical concepts. Therefore, it can be concluded that the intervention is both statistically and practically effective, and it holds strong potential for improving mathematics instruction in secondary education.

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