Problem-Based Learning (PBL) Approach and Academic Performance of Students in Trigonometric Ratios

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ABSTRACT

This study investigated the effect of the Problem-Based Learning (PBL) approach on the academic performance of Grade 9 students in Trigonometric Ratios. The study involved 40 Grade 9 students enrolled during School Year 2025–2026. Specifically, it compared the pre-test and post-test performance of students taught using the Lecture Method and the PBL approach and determined whether a significant difference existed between the two instructional approaches. A true experimental research design using a pre-test–post-test control group design was employed. The control group improved from a pre-test mean of 10.35 (SD = 2.60), interpreted as Low Mastery, to a post-test mean of 27.20 (SD = 4.60), interpreted as Moving Towards Mastery. The experimental group improved from a pre-test mean of 10.00 (SD = 2.73), interpreted as Low Mastery, to a post-test mean of 34.25 (SD = 3.45), interpreted as Moving Towards Mastery. The paired-samples t-test showed a significant improvement in the experimental group, $t(19) = -56.602$, $p < .001$, with a derived Cohen's d of approximately 12.65. The independent-samples t-test also showed a significant difference between the experimental and control groups at post-test, $t(38) = -5.437$, $p < .001$, with a derived Cohen's d of approximately 1.72. The findings indicate that students exposed to PBL demonstrated significantly higher post-test performance than those taught using the Lecture Method, suggesting that PBL can be an effective approach for improving students' learning outcomes in Trigonometric Ratios.

Keywords: Problem-Based Learning (PBL); Trigonometric Ratios; Academic Performance; Grade 9 Students; Mathematics Education; Lecture Method; Pre-test and Post-test; Experimental Research; Mathematics Achievement; Secondary Education

INTRODUCTION

Trigonometry is an important area of mathematics that focuses on the connections between the angles and sides of triangles and the use of trigonometric functions. It serves as a foundation for many advanced mathematical concepts and is widely applied in fields such as science, engineering, architecture, and modern technology. Despite its significance, many students find Trigonometry challenging because it involves abstract ideas, complex symbols, and concepts that require a solid understanding of algebra and geometry. In many classrooms, instruction is still centered on memorizing formulas and completing repetitive exercises, which may limit students' interest and understanding of the subject. As a result, learners often experience difficulties in mastering key concepts and achieving satisfactory academic performance (Wati & Yerizon, 2024).

Despite its importance, student performance in Trigonometry continues to be a concern. Studies in the Philippines and abroad reveal that learners often struggle with negative attitudes toward mathematics, low confidence, and difficulty in connecting trigonometric concepts to real-life applications. Research conducted during the pandemic also highlighted challenges in blended and online learning environments, where students reported difficulties in mastering Trigonometry due to limited interaction, lack of immediate feedback, and reduced motivation (Gervacio, 2022; Nuevo & Valdez, 2024). These findings suggest that systemic issues such as teaching strategies, learning environments, and student attitudes contribute to persistent gaps in Trigonometry achievement.

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Problem-based learning (PBL) may serve as a significant factor influencing student achievement in Trigonometry. By situating mathematical concepts within authentic problems, PBL encourages learners to actively participate, collaborate with peers, and develop strategies for solving complex tasks. This process fosters behavioral engagement through participation, affective engagement through interest and enjoyment, and cognitive engagement through deeper investment in learning. When students are motivated to explore and apply trigonometric principles in practical contexts, they are more likely to retain knowledge and perform better academically. Thus, PBL may serve as a significant factor in improving Trigonometry performance, bridging the gap between abstract theory and meaningful application (Fererde, Mihrka, Ayele, & Arara, 2024; Montejo, Buscay, & Nasayao, 2023).

The purpose of this study was to examine the impact of problem-based learning on student performance in Trigonometric Ratios. Specifically, it sought to determine whether PBL can address existing gaps in achievement and enhance students' understanding of trigonometric concepts. The rationale for this study lies in the urgent need to strengthen mathematics education outcomes in the Philippines, particularly in areas where students consistently struggle with abstract reasoning and application. By exploring PBL as a pedagogical intervention, the study aimed to contribute to the development of effective teaching practices that foster engagement, critical thinking, and improved performance in Trigonometry (Wati & Yerizon, 2024; Montejo et al., 2023).

METHODOLOGY

This study employed a quantitative true experimental research design, specifically the pre-test–post-test control group design, to determine the effect of the Problem-Based Learning (PBL) approach on the academic performance of Grade 9 students in Trigonometric Ratios. The study was conducted among Grade 9 students enrolled at a public high school in the Negros Island Region during the School Year 2025–2026. The design allowed the researcher to compare students' performance before and after the intervention and to determine whether the PBL approach produced better learning outcomes than the traditional Lecture Method.

The participants of the study were 40 Grade 9 students from the Gemini section who were officially enrolled during School Year 2025–2026. The students were ranked according to their Mathematics grades during the first and second quarters. A matched-pairing technique was employed to form comparable groups based on relevant characteristics that could potentially influence the outcome of the experiment. After matching, a simple randomization procedure through a coin toss was used to designate the control and experimental groups. One group was assigned to the control condition, which utilized the Lecture Method, while the other group was assigned to the experimental condition, which utilized the PBL approach.

Data were gathered through a 40-item learning assessment administered as a pre-test and post-test. The assessment items were derived from previously administered periodical tests and their corresponding Table of Specifications provided by the Division Office. These materials had previously undergone evaluation and testing. To minimize test familiarity, the order of the item numbers and choices was rearranged for administration. Formative assessments were likewise administered after each lesson to monitor learners' understanding of the lessons. The assessment materials were based on the Learning Modules/Learner's Packets developed by the Department of Education and the DepEd Central Office.

The learning assessment underwent validation by experienced Mathematics teachers, was checked by the Department Head, submitted to the Education Program Specialist at the Division Office for validation, and subsequently submitted to the Learning Resource for release to schools. The assessment materials were adopted from the K–12 Mathematics Learning Modules and Teachers' Guides. Thus, the instrument used in the study was based on established instructional and assessment resources rather than a newly constructed researcher-made questionnaire.

For data collection, the researcher first secured permission from the Schools Division Superintendent and subsequently obtained approval from the School Principal to conduct the study among Grade 9 students. The researcher personally handled the Mathematics 9 classes for approximately four weeks. The Grade 9 students were divided into two groups. The control group was taught using the Lecture Method from 8:33 to 9:33 AM, while the experimental group received instruction using the PBL approach from 9:48 to 10:48 AM. Both groups were taught for the same intervention period and were assessed using the same pre-test and post-test instrument.

The experimental procedure consisted of three phases: pre-intervention, intervention, and post-intervention. During the pre-intervention phase, a pre-test was administered to both groups following their regular class schedules. During the intervention phase, the same teacher handled both groups to maintain consistency in instruction. The control group received instruction through the traditional Lecture Method, whereas the experimental group was taught using the PBL approach. Both groups covered the same lessons and learning competencies based on the prescribed curriculum and the Department of Education's Budget of Work. The four-week intervention included competencies on the six trigonometric ratios and special angles, angles of elevation and depression, applications of trigonometric ratios to real-life problems involving right triangles, the Laws of Sines and Cosines, and problems involving oblique triangles.

During the post-intervention phase, a post-test was administered to both the control and experimental groups using the same assessment instrument used during the pre-test. The results were analyzed to obtain the mean performance of the two groups. The pre-test and post-test performance of the experimental group were compared to determine the effect of the PBL approach, while the post-test performance of the experimental and control groups was compared to determine whether students exposed to PBL achieved better outcomes than those taught through the traditional Lecture Method.

The collected data were systematically organized, tabulated, and analyzed using appropriate statistical procedures. The mean and standard deviation were used to describe the pre-test and post-test performance of students in both the control and experimental groups. Students' scores were interpreted using the mastery-level categories adopted for the study based on the cited DepEd mastery-level framework. The Paired-Samples t-test was employed to determine whether a significant difference existed between the pre-test and post-test performance of the experimental group. An independent-samples t-test was used to determine whether a significant difference existed between the post-test performance of the experimental and control groups. In addition to statistical significance, Cohen's d effect size was calculated to determine the magnitude of the observed differences. The within-group effect size was derived from the paired-samples t statistic and sample size, while the between-group effect size was derived from the independent-samples t statistic and equal group sizes. These analyses provided a more comprehensive basis for evaluating the effectiveness and practical magnitude of the PBL approach.

RESULTS AND DISCUSSIONS

Level of Pre-test and Post-test Performance in Trigonometric Ratios of Students in the Control Group

Table 1. Level of Pre-test and Post-test Performance in Trigonometric Ratios of Students in the Control Group.

Performance in Trigonometric Ratios	N	Mean	SD	MPS	Interpretation
Pre-test	20	10.35	2.6	25.88%	Low Mastery
Post -test	20	27.20	4.6	68.00%	Moving Towards Mastery

Legend: (38.40–40.00)-Mastered; (34.40–38.00)-Closely Approximation Mastery; (26.40–34.00)-Moving Towards Mastery; (14.00–26.00) Average Mastery; (6.00–13.60) Low Mastery; (2.00–5.60) Very Low Mastery; (0–1.60) Absolutely No Mastery

Table 1 presents the pre-test and post-test performance in Trigonometric Ratios of students in the control group. The findings revealed that the students obtained a pre-test mean score of 10.35 (SD = 2.60), equivalent to an MPS of 25.88%, interpreted as Low Mastery. In the post-test, the mean score increased to 27.20 (SD = 4.60), equivalent to an MPS of 68.00%, interpreted as Moving Towards Mastery based on the mastery-level legend adopted in the study. The increase in mean score from 10.35 to 27.20 represents a gain of 16.85 points, indicating that students demonstrated improvement in their performance following the instructional period.

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The improvement observed in the control group suggests that conventional instruction, together with classroom discussion, guided examples, practice exercises, and teacher-directed activities, contributed to students' learning gains in Trigonometric Ratios. However, the post-test performance remained within the Moving Towards Mastery category, indicating that although students improved their understanding and application of trigonometric concepts, they had not yet reached the higher mastery levels.

This result provides an important basis for comparison with the experimental group. While the control group demonstrated improvement after receiving the Lecture Method, the experimental group achieved a higher post-test mean and MPS. The difference suggests that the Problem-Based Learning approach may provide additional learning benefits by engaging students in contextualized mathematical problems and requiring them to actively apply trigonometric concepts in solving authentic situations.

Similar findings were noted by Nordlander (2022), who explained that conceptual understanding and visualization strategies significantly improve students' comprehension of trigonometric concepts. In the same way, Ngu and Phan (2020) emphasized that structured instructional approaches and comparative learning activities help learners improve their procedural and conceptual understanding in solving trigonometry problems.

Level of Pre-test and Post-test Performance in Trigonometric Ratios of Students Under the Experimental Group

Table 2. Level of Pre-test and Post-test Performance in Trigonometric Ratios of Students Under the Experimental Group.

Performance in Trigonometric Ratios	N	Mean	SD	MPS	Interpretation
Pre-test	20	10.00	2.73	25.00%	Low Mastery
Post -test	20	34.25	3.45	85.63%	Moving Towards Mastery

Legend: (38.40–40.00)-Mastered; (34.40–38.00)-Closely Approximation Mastery; (26.40–34.00)-Moving Towards Mastery; (14.00–26.00) Average Mastery; (6.00–13.60) Low Mastery; (2.00–5.60) Very Low Mastery; (0–1.60) Absolutely No Mastery

Table 2 presents the pre-test and post-test performance in Trigonometric Ratios of students in the experimental group. The findings showed that the students obtained a pre-test mean score of 10.00 (SD = 2.73), interpreted as Low Mastery, while the post-test mean increased to 34.25 (SD = 3.45), interpreted as Moving Towards Mastery based on the mastery-level legend used in the study. The increase of 24.25 points in the mean score indicates a substantial improvement in students' performance following exposure to the Problem-Based Learning (PBL) approach.

The result suggests that PBL provided students with opportunities to engage actively with trigonometric concepts through problem identification, exploration, application of mathematical procedures, and interpretation of solutions. Rather than relying primarily on memorization of formulas, students were encouraged to use trigonometric concepts in solving meaningful problems. Such an approach is consistent with Wati and Yerizon (2024), who emphasized the relevance of problem-based learning to trigonometry because contextual problem solving can strengthen students' problem-solving abilities and support the development of meaningful learning experiences.

The finding is also consistent with Fererde et al. (2024), who found that contextualized mathematical modeling instruction improved students' conceptual understanding, problem-solving skills, and ability to apply trigonometric concepts to real-life situations. Their findings support the view that connecting mathematical concepts with contextual problems can help students move beyond procedural computation toward more meaningful application of knowledge.

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Although the experimental group reached Moving Towards Mastery, the mean score of 34.25 remained just below the next mastery category under the scoring legend adopted in this study. Therefore, the result should not be interpreted as full mastery of Trigonometric Ratios. Instead, it indicates substantial progress toward mastery and suggests that continued practice, feedback, and exposure to increasingly complex contextual problems may further strengthen students' mathematical competence.

Difference Between the Pre-test and Post-test Performance in Trigonometric Ratios of Students Under the Experimental Group

Table 3. Difference between the Pre-test and Post-test Performance in Trigonometric Ratios of Students Under the Experimental Group.

Experimental Group	Test Statistics (t)	p-value	Decision for H_o	Interpretation
Pre-test	-56.602	<0.001	Reject H_o	Significant
Post test				

Table 3 shows the difference between the pre-test and post-test performance in Trigonometric Ratios of students in the experimental group. The paired-samples t-test revealed a statistically significant difference between the pre-test and post-test scores, $t(19) = -56.602$, $p < .001$. Since the p-value was lower than the 0.05 level of significance, the null hypothesis was rejected. This finding indicates that the students' performance significantly improved following the implementation of the Problem-Based Learning (PBL) approach.

Beyond statistical significance, the magnitude of the improvement was also substantial. Based on the reported t value and the sample size of 20 students, the corresponding paired-samples effect size was calculated as Cohen's $d_x \approx 12.65$, indicating an exceptionally large within-group effect. This result demonstrates that the improvement was not merely statistically detectable but also substantial in magnitude. The effect-size estimate should, however, be interpreted as a derived statistic based on the reported t value and sample size and should be verified against the original dataset before final publication.

The substantial improvement may be explained by the characteristics of PBL, in which students encounter problems that require them to understand the situation, identify relevant mathematical concepts, develop solution strategies, and justify their answers. Wati and Yerizon (2024) specifically identified PBL as a suitable approach for trigonometry because it places contextual problem solving at the center of learning and supports the development of mathematical problem-solving skills.

The finding is further supported by Fererde et al. (2024), whose study demonstrated that contextualized mathematical modeling improved students' conceptual understanding and problem-solving skills in trigonometry. Their findings suggest that when learners are given opportunities to connect mathematical concepts with realistic situations, they can develop stronger understanding and improve their ability to apply mathematical procedures to problems.

The present result therefore provides empirical support for the effectiveness of PBL in improving students' performance in Trigonometric Ratios. The very large within-group effect indicates that students experienced considerable learning gains during the four-week intervention. Nevertheless, because a paired-samples analysis does not by itself isolate the effect of PBL from other possible influences occurring over time, the comparison between the experimental and control groups provides the stronger basis for evaluating the relative effectiveness of the PBL approach.

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Difference Between the Post-test Performance in Trigonometric Ratios of Students in the Experimental and Control Groups

Table 4. Difference Between the Post-test Performance in Trigonometric Ratios of Students in the Experimental and Control Groups.

Groups	Test Statistics (t)	p-value	Decision for H_o	Interpretation
Control	-5.437	<0.001	Reject H_o	Significant
Experimental				

Table 4 presents the difference between the post-test performance in Trigonometric Ratios of students in the experimental and control groups. The independent-samples t-test revealed a statistically significant difference between the two groups, $t(38) = -5.437$, $p < .001$. Since the p-value was lower than the 0.05 level of significance, the null hypothesis was rejected. This finding indicates that the post-test performance of the experimental and control groups differed significantly after the intervention.

The direction of the group means indicates that students exposed to PBL performed better than those who received the Lecture Method. The experimental group obtained a post-test mean of 34.25 (SD = 3.45), compared with 27.20 (SD = 4.60) for the control group. Thus, the experimental group had a mean advantage of 7.05 points over the control group.

The magnitude of this between-group difference was also substantial. Based on the reported t value and equal group sizes of 20 students, the estimated independent-groups Cohen's d was approximately 1.72, representing a very large effect. This indicates that the difference between the PBL and Lecture Method groups was not only statistically significant but also educationally meaningful in magnitude. As with the within-group effect size, this value is derived from the reported test statistic and sample size and should be checked against the original dataset before publication.

The result provides stronger evidence for the effectiveness of PBL because the experimental group outperformed a comparison group that received conventional instruction. The finding is consistent with Wati and Yerizon (2024), who identified PBL as a relevant instructional approach for trigonometry because it engages learners in contextual problem solving and supports mathematical problem-solving development.

The finding also corresponds with Fererde et al. (2024), who reported that contextualized mathematical modeling instruction enhanced students' conceptual understanding, problem-solving skills, and ability to apply trigonometric knowledge to real-world situations. In the context of the present study, the PBL approach may have helped students connect trigonometric concepts with concrete problem situations, thereby encouraging them to select appropriate ratios, apply mathematical procedures, interpret results, and communicate solutions.

Overall, the results indicate that PBL was associated with significantly higher post-test performance than the Lecture Method. The statistically significant difference, combined with the large estimated effect size, provides evidence that PBL had a meaningful positive effect on students' achievement in Trigonometric Ratios within the conditions of the present experiment.

CONCLUSIONS

Based on the findings of the study, the following conclusions were formulated:

The control group demonstrated learning gains. Students taught through the Lecture Method improved from Low Mastery in the pre-test to Moving Towards Mastery in the post-test, indicating that conventional instruction contributed to improved performance in Trigonometric Ratios.

The experimental group demonstrated substantial improvement. Students exposed to the PBL approach increased their performance from Low Mastery in the pre-test to Moving Towards Mastery in the post-test, with a statistically significant and very large within-group effect.

PBL produced significantly higher post-test performance than the Lecture Method. The experimental group obtained a significantly higher post-test performance than the control group, with a large between-group effect, indicating that PBL provided an advantage over conventional instruction under the conditions of the study.

PBL is a promising instructional approach for Trigonometric Ratios. The findings indicate that problem-centered, contextualized, and learner-active instruction can support students' development of conceptual understanding and problem-solving skills in trigonometry.

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