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Research Article

# Effect of problem-based learning approach on students' achievement in trigonometry

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## ABSTRACT

This study investigated the effect of the problem-based learning ap-proach on students' achievement in Trigonometry in Senior High Schools in the Hohoe Municipality of Volta region in Ghana. The re-search was a mixed method that employed a quasi-experimental non-equivalent comparison group design to compare the achievements of students exposed to a problem-based learning approach and that of the traditional approach. A convenient sampling technique was used to select two Senior High Schools in the Hohoe Municipality which served as comparison and experimental groups respectively. Data was collected using instruments such as questionnaires, trigonometric achievement tests, and semi-structured interviews. A sample of 94 students comprising of 45 in the comparison group and 49 in the ex-perimental group was used for the study. The findings revealed that the problem-based learning approach is very effective for teaching and learning of trigonometry since it promoted students' active participa-tion in the instructional process, content mastery and improved their creative thinking and independent problem-solving skills.

**Keywords:** problem-based learning; senior high school students; achievement; trigonometry

## 1. INTRODUCTION

The importance of mathematics education is crucial for the welfare of people. Effective mathematics instruction provides students with several advantages, including the development of their critical thinking, reasoning, and problem-solving skills. The issues with the Ghanaian educational system are very broad in kind, and they include issues with teaching mathematics. The mathematics achievement of Senior High School students has recently received more attention. If students are to become the problem solvers of the future, they must be trained to transcend beyond simple memorizing of facts and equations and low level comprehension. This is because modern technology and scientific advances are being experienced on a global scale. The teaching methods such as lectures, demonstration among others used in many Senior High Schools have not brought about the expected learning outcomes in the development of trigonometric concepts among Senior High School (SHS) students. This has resulted in SHS students' low achievement in trigonometry in the West African Examination Council (WAEC) Examination. The Chief Examiner's report of the West African Examination Council (WAEC, 2016, 2018) on SHS Core Mathematics 2 outlined students' difficulties in solving trigonometric problems. Among the discoveries made includes students demonstrating weaknesses in understanding and solving trigonometric problems. There is also empirical evidence that many Senior High School students in Ghana have serious difficulties when solving trigonometric problems. They make a series of errors in the process (Mensah, 2017).

Recent studies (Kaharuddin, 2018; Lozinski, Poon & Spano, 2017; Masitoh & Fritriyani, 2018) conducted from other countries on some mathematics topics found that the PBL approach improved students' learning and understanding, and their achievement level in the subject. Many students in Ghana have a very difficult time solving arithmetic problems, especially those involving trigonometry. They make numerous mistakes throughout the process (Mensah, 2017). According to Gyan, Ayiku, Atteh, and Adams (2021), comprehending trigonometry is a must for understanding fields like architecture, physics, surveying, and engineering branches that have a substantial impact on human existence. One of the constructivist methods is having students participate in the conception of concepts. Bukari (2019) describes problem-based learning as a constructivist pedagogical approach to instruction in which students work together in smaller groups to find solutions to difficult problems. PBL encourages students to become self-directed learners, critical thinkers, and effective problem solvers, which helps them retain mathematical concepts and their applications to real-world situations for the rest of their lives (Bukari & Asiedu-Addo, 2019).

Teaching students to retain mathematical concepts as well as to understand the reasons behind and processes involved in their development is one efficient strategy to integrate PBL in the classroom (Iji, Emiakwa & Utubaku, 2015). Therefore, giving students a trigonometry problem does not guarantee that they will be able to answer it. Nevertheless, the steps followed by the students to reach their conclusion correct or not-implied that the intended concepts and theories had been learned. One of the most well-liked curriculum improvements in education has been the use of problem-based learning. This is because the method is thought of as the model of multidisciplinary studies and helps students to have a clearer mind, and be adaptable to various ways of thinking (Johari, Nor Hasniza & Mokhtar, 2013). This study investigated the effect of the problem-based learning approach on Senior High School students' achievement in trigonometry.

## 1.1 Research Questions

The study sought to answer the following questions:

1) What difficulties do SHS students encounter in trigonometry in the Hohoe Municipality?.
2) What effect does problem-based learning have on SHS students' achievement in trigonometry in the Hohoe Municipality?
3) How do SHS students perceive the effectiveness of the problem-based learning approach in teaching and learning trigonometry in the Hohoe Municipality?.

## 1.2 Research Hypotheses

**$H_0$**: There is no significant difference between the mean scores of students in the experimental group and the mean scores of students in the Comparison group in the post-test

**$H_1$**: There is a significant difference between the mean score of students in the experimental group and the mean scores of students in the comparison group in the post-test.

## 2. RESEARCH METHOD

This study used both quantitative and qualitative data in a mixed-method approach. Mixed methods were used in the study's quasi-experimental (non-equivalent comparison group) design to gather data. To gather various, complementary data on the same subject for integration and interpretation to satisfy the study's overall content goal, a mixed-method approach was adopted (Creswell & Clark, 2017). For this research study, mixing quantitative and qualitative data was done to better comprehend the results and to use the advantages of both types of data (Cohen, Manion & Morrison, 2018; Creswell, 2013). On the other hand, this study also included the collection of qualitative data. With the help of interviews, the researchers were able to gain a thorough grasp of the SHS students' understanding of trigonometry during the teaching and learning processes as well as how the PBL approach stimulates them to learn from their points of view. The study's desire to modify the independent variable and examine its impact on the dependent (trigonometric achievement) variable justifies the use of a quasi experimental design. Additionally, the researchers provide intervention and gauge the effects it has (Cohen, Manion & Morrison, 2018)

## 2.1 Sample and Sampling Technique

The researchers selected two intact classes of ninety-four (94) students from the third-year classes as the sample from Hohoe SHS A and SHTS B. From this sample, forty-nine (49) students belonged to the experimental group in SHTS B, and forty-five (45) students belonged to the comparison group in Hohoe SHS A. A convenient sampling technique was used to select two Senior High Schools in Hohoe for the study. This sampling technique was used to select these two schools because of the researchers' easy access to both schools. Additionally, given the study's focus was on a topic from the mathematics curriculum, final year students were chosen using the purposive sample technique. The goal of this study was to improve their comprehension of the ideas and get them ready for their final exam. Again, purposive sampling was used to choose students from the experimental group who took part in the study's interview. This was based on the student's availability and willingness to engage in the study at the time of the interview (Creswell & Clark, 2017; Patton, 2015).

## 2.2 Research Instruments

Pre- and post-tests made up the trigonometry achievement test, questionnaire and semi-structured interview were used for data gathering. With the aid of the Core Mathematics curriculum objectives, these items were carefully chosen from Senior High School core mathematics textbook recommendations and previous exam questions (Ministry of Education, 2010). A 3-point Likert scale questionnaire with six (6) closed-ended questions were used to elicit responses from the students in the two groups. An open-ended semi-structured interview was used to get their input. According to McLeod (2014), the use of open-ended questions in semi-structured interviews has the advantage of assisting researchers in gathering qualitative data by enabling participants and the interviewer to have a thorough discussion. The purpose of the interview was to learn how students viewed PBL's efficiency in trigonometry teaching and learning. Additionally, to ascertain whether PBL activities had enhanced self-confidence, investigational skills, and topic comprehension, as well as whether they had boosted individual engagement in group activities and raised individual concentration.

## 2.3 Validity

The extent to which an instrument measures what it is designed to measure is considered the instrument's validity (Creswell, 2014). The Senior High School mathematics curriculum and certified textbooks by the Ghana Education Service were consulted in the test item creation to assure the validity of the Trigonometric Achievement Test. Past WAEC trigonometry exam questions were also taken into account. To assure their content validity, the experts in mathematics education cross-checked the questionnaire and subject questions in the interview guides and made adjustments as well as input.

## 2.4 Reliability

The researchers used a test-retest strategy to assess the reliability of the trigonometry achieve-ment test and questionnaire in this study. The test-retest method of determining reliability, according to Creswell (2012), entails giving the same test to the same individuals twice, separated by a significant amount of time. The test-retest dependability of the instruments increases with closer results. In this study, the researchers gave the trigonometry achievement test and the questionnaire to the pilot school's students, then gave them to the same students again a month later. The outcomes were used to change the instruments. The study's instruments were then adjusted and enhanced. Using SPSS, the correlation coefficient of test-retest reliability of the TAT and questionnaires between two sets of instrument responses was determined. The reliability of the trigonometry achievement test and the questionnaire had correlation coefficients of 0.82 and 0.89, respectively. Since both reliability values were more than 0.5, the two instruments were very dependable and might aid in answering the research questions.

## 2.5 Treatment

In this study, a quasi-experimental design was employed. To teach the experimental group trig-onometry, the researchers created models based on PBL instructions. Additionally, new lessons on the same trigonometry were developed to teach the comparison group using the conventional method. The lesson plans for the experimental and comparison groups both followed the precise objectives, content, teaching and learning activities and evaluation exercises for trigonometry in the Senior High School Core Mathematics curriculum in Ghana. Following the pre-test in January–March 2020, the treatment lasted for eight (8) weeks. Each group received two lessons throughout the initial week. There were 60 minutes in each lesson. To familiarize students with the methodology, the experimental group's first lesson consisted of introducing PBL and trigonometry to the class. As part of the teaching and learning activities carried out throughout the instructional sessions, the students were also put into smaller groups of five. According to the SHS Core Mathematics curriculum, the following lessons from the first to the eighth week were intended to help the students understand the fundamentals of trigonometry. The lessons covered the following topics: (1) Tangent, sine, and cosine of acute angles; and (2) trigonometric ratios of 300, 450, and 3600. (3) Using calculators to read the sine, cosine, and tangent of angles between 00 and 3600 (4) Reverse trigonometric ratios (5) Angles of elevation and depression (6) Using trigonometric ratios (Ministry of Education, 2010). The comparison group received orderly instruction using the usual teaching method from the researchers, while the experimental group received orderly instruction using the PBL methodology.

The lesson for the treatment of the experimental group was based on the Problem-Based Learning Cycle developed by Othman, Salleh, and Sulaiman (2013). The problem-based learning cycle involves meeting the problem; problem analysis; discovery and reporting; solution presentation, reflection, and evaluation. This problem-based learning cycle was chosen because it fosters student participation and teamwork in the creation of information, offers students a variety of possibilities for problem-solving, and helps students remember what they have learned. The comparison group was instructed to use the traditional approach, which emphasized the fluency of the procedure when resolving trigonometric problems. This class emphasized memorization of the steps needed to solve trigonometric problems. The researcher concluded by highlighting the pattern of procedures required in each question for students to recall after discussing sample questions, identifying solutions, and summarizing. The comparison group's students spoke with the researchers about their struggles with trigonometry during the educational time. The researchers made it easier for students to memorize the many steps of the concepts to address their issues. In addition, the PBL instruction was used to teach the comparison group to get a sense of the new approach and also use it in their West African Senior High School Certificate Exams since they were preparing for their final year exams.

# 3. RESULTS AND DISCUSSION

## 3.1 Research Question 1

### What difficulties do SHS students encounter in trigonometry?

The results of the presentation was done in two ways. First, a descriptive analysis of pre-test scripts of all the 94 sampled students was done to identify difficulties faced by students in solving trigonometric problems. The second way was students' perception of trigonometric concepts and this was investigated through the administration of a closed-ended questionnaire to elicit students' responses from the options.

Based on the **Table 1**, on pre-test item 1, a closer look at each of the three difficulties under this category shows that 39 students out of the 94, constituting 41.5% of the sample for this study easily analyzed the diagram to form a right-angled triangle, whereas 36 had difficulty and could not, repre-senting 38.3% of the sample. In addition, 38 stu-dents out of the 94, constituting 40.5% of the sample for this study could easily use the basic trigonometry equation, whereas 37 students had difficulty and were not able to use the basic trigonometric equation, representing 39.4% of the sample. Concerning correct answers, through the use of correct algebraic calculation, 27 students out of the 94 constituting 28.7% were able to get the final answer. Forty-eight representing 51.1% of the sample could not get the correct answer and 19 out of 94 representing 20.2% were not able to attempt item 1 at all. On pre-test item 3, students had difficulty applying trigonometric concepts to real-life problems and solving them. In all, 3 students, constituting 3.2% of the sample for this study were able to solve the real-life problem in trigonometry, whereas 57 students out of 94, representing 60.6% had difficulty and could not solve the real-life problem completely. A total of 34 students out of 94, representing 36.2% could not even attempt the task.

Based on these results, it was clear that students had difficulties understanding trigonometric diagrams to make meaningful analyses for them to employ the appropriate algebraic calculation to solve the task. Also, the majority of students memorized the procedures due to a lack of understanding and not solving enough problems on the topic. This made it difficult for them to solve real-life trigonometric problems. Hence, they ended up having difficulties solving trigonometric problems by committing basic arithmetic errors and use of inappropriate procedures.

**Table 1**. Students' difficulties in the Pre-test

| Item | Difficulties | Correct (f %) | Incorrect (f %) | No attempt (f %) |
|---|---|---|---|---|
| 1. | Difficulty in analyzing the diagram to form a right-angled triangle | 39(41.5) | 36(38.3) | 19(20.2) |
| | Difficulty in using basic trigonometric equation | 38(40.5) | 37(39.4) | 19(20.2) |
| | Difficulty in performing the correct algebraic calculation | 27(28.7) | 48(51.1) | 19(20.2) |
| 2. | Difficulty in understanding trigonometric information to sketch the required diagram | 33(35.1) | 37(39.4) | 24(25.5) |
| | Difficulty in performing the correct algebraic calculation | 9(9.6) | 61(64.9) | 24(25.5) |
| 3 | Difficulty in applying trigonometry to real-life problems | 3(3.2) | 57(60.6) | 34(36.2) |

**Table 2**. Students' perception of trigonometric concepts

| Students' perception of trigonometric concepts | Agree (f %) | Disagree (f %) | Undecided (f %) |
|---|---|---|---|
| The teacher used step-by-step presentations to teach trigonometry concepts for I to understand | 9(9.6) | 72(76.6) | 13(13.8) |
| Terms in trigonometric topics difficult to understand | 78(83.0) | 11(11.7) | 5(5.3) |
| Trigonometry involves memorization of formulae without understanding | 64(68.1) | 22(23.4) | 8(8.5) |
| I have a challenge in learning trigonometry because the concepts are abstract | 53(56.4) | 35(37.2) | 6(6.4) |
| Lack of self-confidence to learn and solve trigonometric problems | 69(73.4) | 19(20.2) | 6(6.4) |
| Real-life trigonometric problems are difficult to understand | 81(86.2) | 10(10.6) | 3(3.2) |

**Table 2** shows that 9 students, constituting 9.6% of the sample for this study agreed that teacher used step-by-step presentation for them to understand the trigonometric concepts, whereas 72 disagreed, representing 76.6% of the sample and 13 were undecided, representing 13.8% of the sample. In addition, 78 students, constituting 83% of the sample for this study agreed that terminologies in trigonometric topics were difficult to understand, whereas 11 disagreed, representing 11.7% of the sample, and 5 students were undecided, representing 5.3% of the sample. Furthermore, 64 students, constituting 68.1% of the sample agreed that trigonometry involves memorization of formulae without understanding, whereas 22 disagreed on this, representing 23.4% of the sample, and 8 were undecided, representing 8.5% of the sample. Also, 53 students agreed that they have a challenge in learning trigonometry because the concepts are abstract, constituting 56.4% of the sample, whereas 35 representing 37.2% of the sample disagreed and 6 were undecided, representing 6.4% of the sample. On the issue of lack of self-confidence to learn and solve trigonometric problems, 69 students constituting 73.4% of the sample agreed on it, whereas 19 disagreed, representing 20.2% of the sample and 6 representing 6.4% of the sample were undecided. Finally, the real-life trigonometric problems are difficult to understand, 81 students agreed, con-stituting 86.2%, whereas 10 disagreed, representing 10.6% of the sample and 3 representing 3.2% of the sample were undecided.

Based on the results, a lot of students believed that their mathematics teachers did not use the appropriate steps during instructional processes to help them understand trigonometric concepts. It was also revealed by the results that the trigonometric topic was difficult to understand due to its abstractness and therefore, students just memorize the formulae without understanding. Finally, these results confirmed the difficulties they had in solving real-life problems in trigonometry which the basic cause was a lack of understanding of trigonometric concepts as shown in **Table 2**.

## 3.2 Research Question 2

**What effect does problem-based learning have on SHS students' achievement in trigonometry in the Hohoe Municipality?**

The findings from the semi-structured interview with five students who were arbitrarily chosen from the experimental group are presented in this section. These codes were provided to students to protect their identities throughout the interview: S1, S2, S3, S4, and S5. The themes from the interview guide were used to help in the transcription and analysis of the interview material. The following is a presentation of the interview data:

**Question**: What is your view about trigonometry as a topic in the mathematics syllabus when it was first taught?.
This was the response from S1:

*"Trigonometry is a difficult topic and I do not like it at all. I did not understand the concepts because the mathematics teacher rushed through the trigonometry claiming that we have been taught Geometry in the previous lesson which serves as a foundation and this makes the topic difficult for me to understand."*

When S2 was asked the same question, S2 said:

*"With regards to trigonometry, when the teacher came to class, he only talked about the concepts without involving us, put examples on the board, and solved them for us. So, I found it difficult to learn and understand the topic.*

S5 in response to the same question said:

*"I used to have the feeling that trigonometry is difficult but now l have a change of mind because of the current understanding I have about it."*

**Question**: How is your overall experience learning trigonometry now?
This was the answer given by S3:

*"At first, it was not easy learning and solving trigonometric problems. But now the current trigonometry learning activities are my best experiences ever because the teacher uses good instructional strategies to help us concentrate and enjoy the learning period. This helps me to develop a better understanding of trigonometry."*

Responding to the same question, S4 remarked:

*"The trigonometric activities are very interesting. I learn from those activities which encourage me to think and analyze the problems before I start to solve them. Now, I can say that my understanding has improved."*

S2 in response to the same question said:

*"I now understand the trigonometric concepts. Therefore, my performance will be good in it."*

**Question**: Do you feel the new instructional strategy is useful in teaching and learning trigonometry? Why?
S1 in response to this question said:

*"Yes! This new strategy allows us to share ideas in groups and come out with our solutions. This helps us to be involved in the instructional process."*

In response to the same question, S3 responded:

*"Yes! The group discussion and presentation in the class helps us to have the self-confidence to learn and understand the topic."*

S4 responded to the same question:

*"Yes, group discussion and presentation, and searching for information concerning the topic make all of us partake in the learning process."*

**Question**: What difference did the PBL approach make in your learning process of trigonometry as compared to your teachers' method?
In answering this question, S3 remarked:

*"When I was involved in doing something, it was easy to remember as compared to you telling me how to do it. Therefore, being part of PBL activities helped me to have a better understanding than just listening to the concepts which used to be the case."*

S5 in response to this same question said:

*"PBL is practical therefore, all of us are involved in the teaching and learning process."*

Responding to the same question, S1 said:

*"It improved my understanding of the trigonometric concepts more than the previous method."*

**Question**: What are the teaching and learning activities used to learn trigonometry through PBL that you like? Why?
Response from S1:

*"Group discussion, collaborative work, and presentation. They help to promote communication skills and self-confidence in me."*

In answering the same question, S2 said:

*"The search for information to answer the questions through group activities and sharing of ideas promote understanding and mastery of the topic."*

**Question**: Would you prefer that the PBL approach be used by mathematics teachers for every mathematics topic? Why?
S6 nodded his head and said:

*"Yes! If this approach is used for all mathematics topics, it will be of great help for us to understand all the topics."*

This was the response of S2:

*"Yes! This will encourage me to be involved in all teaching and learning processes of every topic and it promotes smooth learning."*

According to their comments, the students thought trigonometry was a challenging subject. The majority of the students believed that this was a result of the instructional strategies employed by the mathematics teachers while teaching and mastering the topics. Additionally, they stated their happiness that the PBL approach, which combines learning through discussion and group activities, kills boredom. Additionally, students felt that group projects, investigations, and presentations were successful in fostering communication skills, concept mastery, and increased self-confidence among them. Students also advised that the PBL methodology be used for the remaining mathematics topics. This will encourage students to study mathematics and gain a deeper understanding of it.

## 3.3 Research Question 3

How do SHS students perceive the effectiveness of the problem-based learning approach in teaching and learning trigonometry in the Hohoe Municipality?. This section presents the results of the Trigonometric Achievement Test (TAT) administered to the students within the period of carrying out this study. The results from both the pre-test and post-test are presented in **Table 3.**

### Pre-test scores of comparisson and experimental groups

The pre-test scores of experimental and control groups were analyzed and compared to determine if there existed any significant difference in the scores before treatment. **Table 3** shows the mean, standard deviation, maximum, and minimum of the pre-test scores between the two groups.

**Table 3**. Descriptive statistics of pre-test scores of comparison and experimental groups

| Group | N | Mean | Std Dev | Maximum | Minimum |
|---|---|---|---|---|---|
| Comparison | 45 | 4.67 | 4.6 | 19 | 00 |
| Experimental | 49 | 4.10 | 4.8 | 15 | 00 |

Based on the **Table 3**, the results illustrate a mean score of 4.67 for the control group and 4.10 for the experimental group. The minimum scores of the control and experimental were 00. Furthermore, the comparison and experimental groups scored maximum marks of 19 and 15 respectively. Looking at the mean scores of the groups would suggest that the control group performed better (mean = 4.67) than the experimental (4.10). To verify whether the difference in mean scores between the two groups was statistically significant, an independent sample t-test was performed at a 95% confidence interval. This result was shown in **Table 4**.

**Table 4**. Independent sample t-test of pre-test scores of comparisson and experimental groups

| Group | N | Mean | Std Dev. | T-value | Df | P- value |
|---|---|---|---|---|---|---|
| Comparison | 45 | 4.67 | 4.6 | 0.585 | 92 | 0.560 |
| Experimental | 49 | 4.10 | 4.8 | | | |

Based on the **Table 4**, the result from the independent sample t-test performed on the pre-test scores of the two independent groups revealed that there was no statistically significant difference between the control group (M = 4.67, Std D = 4.6) and experimental group (M =4.10, Std D = 4.8) conditions; $t(92) = 0.585$, $P = 0.560 > 0.05$. This result suggests that both control and experimental groups were at the same level in terms of conceptual understanding of trigonometry before intervention was done.

### Post-test scores for comparisson and experimental groups

Treatment was done for each group and a post-test was administered to measure participants' level of change in achievement compared to the pre-test. This part presents the results from the post-test scores for both groups.

**Table 5**. Descriptive statistics of post-test scores of comparisson and experimental groups

| Group | N | Mean | Std. Dev. | Maximum | Minimum |
|---|---|---|---|---|---|
| Comparison | 45 | 10.71 | 8.5 | 30 | 2 |
| Experimental | 49 | 15.84 | 7.7 | 30 | 4 |

Based on the **Table 5**, the results illustrate a mean score of 10.71 for the control group and 15.84 for the experimental group. The minimum score of the control and experimental groups were 02 and 04 respectively. Also, both groups scored a maximum mark of 30. Comparing the mean scores of the comparison group from Table 4.4 (Mean = 4.67) and Table 4.6 (Mean = 10.71), and an experimental group from Table 4.4 (Mean = 4.10) to Table 4.6 (Mean = 15.84) suggested that participants in both groups improved in their performance in the post-test. This is evidence that the performance of participants in the groups improved after treatment. To establish whether the difference in the pre-test and post-test scores within each group was statistically significant, paired sample t-test was conducted to compare the pre-test and post-test scores. The results are shown in **Table 6**.

**Table 6**. Paired sample t-test scores on the post-test and pre-test

| Group | N | Mean | Mean Diff | Std. Dev. | t-value | Df | p-value |
|---|---|---|---|---|---|---|---|
| Comparison | | | | | | | |
| Pre-test – Post-test | 45 | 4.67<br>10.71 | 6.04 | 7.3 | 5.54 | 44 | 0.000 |
| Experimental | | | | | | | |
| Pre-test- Post-test | 49 | 4.10<br>15.84 | 11.74 | 6.6 | 12.49 | 48 | 0.000 |

The analysis presented in **Table 6** shows that within the comparison group there was an increase in students' achievement scores in trigonometry from pre-test to post-test, conditions; t (44) = 5.54, p = 0.000< 0.05. This increase indicates that to some extent the traditional method and teacher influence increased students' achievement in trigonometry concepts. Also, the pre-test and post-test scores for the experimental group show a great improvement in students' performance in the trigonometric concepts after they have been exposed to the PBL approach, conditions; t (48) = 12.49, p = 0.000 < 0.05. Thus, the activities of the PBL approach have increased students' performance and conceptual understanding of the topic greatly. This research question focuses on the effectiveness of a problem-based learning approach in the n acquisition of trigonometric concepts compared to traditional instruction on students' achievement. In answering this research question, the following hypothesis was used for the study:

$H_0$: There is no significant difference between the mean score of students exposed to PBL and the mean score of students without PBL.

$H_1$: There is a significant difference between the mean score of students exposed to PBL and the mean score of students without PBL.

However, to ascertain the significance of this effect and change, the researcher conducted independent samples t-test on the post-test scores of both the control and experimental groups. Table 7 illustrates analysis from the results of the independent sample t-test.

**Table 7**. Independent sample t-test of post-test scores of the experimental and comparison groups

| Groups | N | Mean | Std Dev | t-value | Df | P-value | Eta squared |
|---|---|---|---|---|---|---|---|
| Comparison | 45 | 10.71 | 8.5 | 3.06 | 92 | 0.003 | 0.144 |
| Experimental | 49 | 15.84 | 7.7 | | | | |

Based on the results presented on the **Table 7** the independent sample t-test revealed that there was statistically significant difference between the comparison group (M= 10.71, SD= 8.5) and experimental group (M= 15.84, SD= 7.7) conditions; t (92) = 3.06, p = 0.003 < 0.05. This is an indication that the experimental group which was exposed to the PBL approach during the teaching and learning of trigonometry concepts outperformed the comparison group. The eta squared of 0.144 showed a large effect size which indicated that 14.4% of the variance in the post-test scores of the TAT (dependent variable) is influenced by the instructional approach (independent variable). Based on Cohen's rules of thumb on the magnitude of eta-squared interpretation done by Miles and Shelvin (2001), an eta-squared value of 0.01 (1%) has a small effect size, eta-squared values of 0.06 (6%) have medium effect size and eta squared 0.14 (14%) has large effect size. This result showed that the difference between the mean score achievement on the post-test of the students that experienced the PBL approach and those who experienced the traditional approach was large. Therefore, the use of the PBL approach in trigonometry produced a significant improvement in students against the traditional approach.

Three challenges prevented students from successfully resolving the problems. Therefore, it is difficult to analyze the diagram to create a right-angled triangle, difficult to use basic trigonometric equations, and difficult to perform the necessary algebraic calculations to get the solution. Due to their lack of knowledge, some students were unable to even attempt the question. The findings of this study support the general results found in the related literature by (Aminudim, Nusantara, Parta, Rahardjo & Subanji, 2019; Gur, 2009; Rohimah & Prabawanto, 2019; Tatlah, Amin &Anwar, 2017; Usman & Hussani, 2017). In their studies, these researchers found that students struggled to recall both their previous and new understanding of trigonometric concepts, which made it difficult for them to solve trigonometric problems and left them lacking in procedural abilities. Additionally, because they struggle with basic trigonometric equations, students wind up remembering the concept and technique without understanding it. According to the results, several students struggled to comprehend trigonometric concepts to draw the required diagram and instead drew unnecessary ones. Additionally, students encountered difficulties while applying the proper techniques to the problems. All of these resulted from a misunderstanding of terminology and incorrect definitions brought on by memorizing the steps or a process for solving trigonometric problems. These conclusions are strongly supported by past research studies (Gur, 2009) which discovered that definition, conceptual misunderstanding, and technical mechanical faults were to blame for pupils' struggles with trigonometry problems in different research. When students were attempting to solve mathematical problems, these caused incorrect use of equations and order of operations.

The findings showed that practically every student had trouble comprehending and resolving problems in real-life situations. This problem resulted from students' inability to complete enough math problems to better understand the concepts and math teachers' inability to connect trigonometric concepts to practical applications so that students would be familiar with them. This result is consistent with earlier research (Charles-Ogan & George, 2015; Numedina & Rafidaya, 2019), which identified some factors, including a lack of problem-solving skills in mathematics and a lack of familiarity with real-world trigonometric questions, as contributing to students' struggles with trigonometric problems. The respondents also concurred that learning trigonometry was difficult since the concepts were abstract and that it required memorizing formulae without understanding. The results of this study's responses are in line with those of a study done by Nabie, Akayuure, Ibrahim-Bariham, and Sofo (2018) on pre-service teachers' perceptions and knowledge of trigonometric concepts in two colleges of education in the Northern Region of Ghana. In that study, it was discovered that pre-service teachers thought the trigonometric concepts were abstract and so they memorized them without understanding when learning. Finally, students believed that understanding real-world trigonometric problems were challenging and that they lacked the confidence to grasp and solve trigonometric problems. This showed that students lacked confidence in their ability to learn about and solve problems with trigonometry since they did not understand the concepts. Students also struggled to comprehend the material they needed to learn to answer the issues, and their lack of familiarity with real-world trigonometric activities also contributed to the difficulties they faced with trigonometry. The results of this study are consistent with those of earlier studies (Aminudin, Nasantara, Parta, Rahardjo, Asari & Subanji, 2019; Nurmeidina & Rafidayah, 2019), which discovered that students lack skepticism toward mathematical problems, they struggle to comprehend the problem required to complete the tasks, and they are unfamiliar with real-life trigonometric problems. As a result, when learning trigonometric concepts, students become perplexed.

Trigonometry is one of the more challenging subjects at the SHS level, according to the replies provided by the participants in the interview, which are listed under the presentation of the results. The abstract nature of the problem and the instructional strategy used by the mathematics teachers to teach and learn the material, in the students' eyes, was to blame for this. Again, based on their answers to the interview questions, it was clear from the results that the experimental group of students was driven to learn trigonometry and comprehend the concepts. They believed that the PBL method of teaching and learning offered an environment where they could work in groups to discuss ideas, conduct research, and come up with answers. This sparked students' interest in the subject, helped them understand the material and helped them develop their confidence as learners. As a result, they developed into independent problem-solvers, self-directed learners, and critical thinkers in the classroom, and they suggested the PBL technique be utilized for additional mathematical disciplines. The findings of this study supported those of numerous other studies (Kaharuddin, 2018; Lozinki, Poon & Spaco, 2017; Mushlihuddin, Nurafifa & Irvan, 2018; Olaoye & Adu, 2015; Tandililing, 2015), all of which found that the PBL approach to mathematics encourages group participation, active learning, and conceptual understanding of the concepts.

The results of the independent samples t-test revealed that, before treatment, there was no statistically significant difference between the achievement levels of participants in comparison groups in their acquisition of trigonometric concepts. This demonstrated that before treatment began, both groups had mastered the same degree of trigonometric concepts. Results from the paired samples t-test of the scores of the comparison and experimental groups revealed that experimental group members who were exposed to the PBL strategy improved more from the pre-test to the post-test than the comparison group. Additionally, the results of the independent samples t-test revealed a significant difference in the post-test performance between individuals who had been exposed to the PBL technique and those who had been exposed to the traditional strategy in the comparison group. The fact that the two groups' achievement levels were different suggested that the experimental group outperformed the comparison group on the post-test. The outcome created an eta squared of 0.144 (14.4%), a considerable effect. This showed that there was a significant difference in the mean achievement scores between the students who used the PBL strategy and those who used the traditional strategy on the post-test. In comparison to the traditional approach, using the PBL approach in trigonometry results in a considerable improvement in student performance. Due to the usage of PBL during the treatment period, trigonometry performance and achievement improved. This result is in line with that of (Abdullah, Tarmizi & Abu, 2010; Bukari & Asiedu-Addo, 2019; Iji, Emiakwu & Utubaku, 2015; Olaoye & Adu, 2015), who discovered that PBL enhanced students' learning, conceptual comprehension, and accomplishment in mathematics.

## 4. CONCLUSION

The results of this paper showed that teachers dominated classroom interaction activities during teaching and learning trigonometry at Senior High Schools. This gave students limited opportunities to take an active part in the lesson such as sharing ideas on the concepts among themselves. Mathematics teachers gave much information to the students to absorb without much contribution from the students which did not encourage conceptual understanding. Mathematics teachers should have allowed students to do much of the work during teaching and learning trigonometric concepts for a better understanding of the topic. Finally, the major contribution of this study was the knowledge about the effect of the problem-based learning approach on SHS students' achievement in trigonometry. In this study, the experimental group was given instruction based on the PBL approach while the control group was instructed by the traditional approach. Students in both groups showed increments in their post-test results of TAT as compared to pre-test results. However, students in the experimental group achieved a better understanding of the trigonometric concepts than that in the control group. It can be stated that PBL instruction of trigonometric concepts had a positive effect on SHS students' achievement. The involvement of the students in the lessons by PBL led to the understanding of the concepts and therefore, improved students' performance in the post-test.

## AUTHOR'S CONTRIBUTIONS

The authors discussed the results and contributed to from the start to final manuscript.

## CONFLICT OF INTEREST

There are no conflicts of interest declared by the authors.

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