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Effect of Problem Based Learning Instructional Strategy on Students' Academic Achievement in Mathematics in Somolu Lagos State, Nigeria

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ABSTRACT

The study investigated the effect of problem based learning instructional strategy on students' academic achievement in mathematics. It is a 2 x 2 x 3 pre-test, post-test quasi experimental factorial design. The population comprised of all senior secondary two students (SSII) in Somolu Local Government Area of Lagos State. Proportionate sampling technique was used to select six (6) equivalent co-educational senior secondary schools that are distinctively located from one another within the Local Government area. Random sampling technique was used to select one hundred and twenty-three (123) students as sample. Problem Solving Achievement Test in Mathematics (PSATM) was the tool used for data collection. It was an 8 item essay test poised to test the students' ability to solve and interpret results in mathematics using the Polya problem solving approach. The tool was subjected to both face and content validity by lecturers in mathematics department. The modified copy was administered on sample outside and a reliability index of 0.54 was gotten. Firstly, the tool was administered on the sampled students since it was an intact class. It was re-arranged before re-administering after the treatment for three weeks. Descriptive statistics (mean and standard deviation), T-test and Analysis of Co-Variance (ANCOVA) were employed to analyse the data collected. Results revealed that students taught mathematics using problem based learning instructional strategy achieved more than the conventional group. The high ability students were significantly better than the average students while the average ability students were significantly better than the low ability students. In addition, both male and female students were positively affected by the approach. Recommendation made were that secondary school teachers should incorporate problem based learning instructional strategy in the lessons. Professional bodies should organize workshops and seminars on how to effectively use problem based instructional strategy in the classroom.

Keywords: Problem Based Learning, Mathematics, Academic Achievement, Gender.

INTRODUCTION

Mathematics is a vital tool, key to the study of other sciences and pre-requisite for success in life. The study of quantity, structure, space, and change is actually what mathematics is all about. It evolved via the study of the form and motion of the physical item, counting calculations, measurement, and logical reasoning. The subject is indispensable to the national goals and objectives as its quality is linked with the needed pursuit of Science and Technology. Quality in teaching is needed for the attainment of standard and standard ensure accountability which implies improved achievement. Hence, the Federal Government of Nigeria through the National Policy on Education (2004) made mathematics compulsory at the basic and post basic level of learning.

Despite that, students persistently have low achievement in mathematics. Adeyemi (2018) defined achievement as a student's current academic position and the completion of objectives. Its aim is to assist the teachers as well as students to evaluate how well they have comprehended a particular concept. Among the determining factor for students' achievement is the way through which teaching is conveyed to the learners. This shows the importance of instructional strategy in the teaching learning exercise (Opeisa, Odupe & Salami, 2018).

The performance of students remains poor despite the development and use of many instructional strategies. A lot of reasons have been attributed to this. Researchers lamented the poor state of mathematics instruction in our secondary schools. Abiodun et.al. (2022) asserted that the most frequently used method of teaching mathematics in Nigeria secondary schools is the teacher centered strategy. The teacher-centered mode of teaching is widely used in schools (Minarni *et. al.,* 2016, Onasanya, 2021). The students' passive involvement in the lesson accompanied with the abstract nature of mathematics might be the cause of the low achievement in the subject. Kurumeh & Iji (2009) asserted that if students are opportune to experience Mathematics aesthetically during Mathematics lessons, their fear and sense of difficulties in Mathematics will diminish. Additionally, one of the causes of low achievement in mathematics is a lack of conceptual comprehension. Students believe that mathematics is a memory game in which formulas, rules, and techniques for solving problems must be memorised by heart (Umar & Ibrahim, 2018). According to research, most students lack a fundamental comprehension of the subject being taught, which prevents them from applying what they learnt in the classroom to other contexts outside of it. Suitable instructional approaches are required to identify ways to accomplish the desired instructional outcomes. Strategy that emphasizes hand on activities, problem solving, critical thinking and collaborative learning should be employed (Garcia- Higuera & Panamericana, 2019). Therefore, investigating PBLIS is critical as a learning approach that may raise secondary school students' academic achievement in mathematics

PBLIS is a classroom instructional approach that organizes mathematics instruction around problem solving activities and enable students more opportunities to discover important concepts. It is an active learning pedagogy in which students learn mathematics through experience of solving open ended questions. According to Schmidt, Rotgans & Yew (2011), the goals of PBLIS is to develop in the students' flexible knowledge, effective problem solving skills, self-directed learning effective collaboration skills and intrinsic motivation. In this type of approach, students interpret the problem, assemble required information, identify possible solutions, evaluate options and present the conclusions rather than seeking a single correct answer. It is activity based and student centered approach as they learn about the subject through experience of solving an open ended question.

PBLIS in this study was integrated using the Polya problem solving approach. Polya (1984) stated that problem solving is a process starting from the minute the students are faced with the problem until the end when the problem is solved. Polya problem solving approach has four steps which are:

i. Understanding the problem
ii. Devising a plan to solve the problem
iii. Implementing the plan
iv. Reflecting on the problem.

In this study, SS II students learnt and were encouraged to solve mathematics exercises following the Polya problem solving stages.

Statement of the problem

Academic achievement in mathematics in both internal and external examinations has been recorded poor despite the vital roles mathematics play in our daily lives. Mathematics educators, instructors, parents, students, non-governmental organizations, and actually the entire country are quite concerned. The germane issues affecting performance can be detected through the critical examination of students' selection of questions at the Senior School Certificate Examination (SSCE) and their general performance on the questions selected. The West African Examination Council's (WAEC) Chief Examiner annually identify performance gaps and provide potential solutions in an effort to boost results. The Examiner's reports between 2015 and 2020 on mathematics examinations revealed consistently that students could not present their work orderly and logically; inability to present given information using an appropriate diagram; misread graphs and had inappropriate geometrical construction. By implication, student's poor performance in mathematics is a sign of the subject's difficulty, which been attributed to the prominent method used in instructional delivery of lessons. The conventional method where the teacher assumes the dominant role of the teaching/learning process while the students are recipients of information and passive listeners are widely used in the classrooms. In the light of this, this paper focuses on the effect of Problem Based Learning Instructional Strategy on the Academic Achievement of Students in Mathematics.

Purpose of the study

The study is specifically set to:

1) measure academic achievement of students taught mathematics using problem based learning instructional strategy and students taught using conventional strategy.
2) determine which instructional strategy suits the students better between the problem based learning instructional strategy and conventional strategy.
3) generate further literature on the methods highlighted.

Research questions

1) The following research questions were formulated to guide the study:
2) What are the mean achievement scores of students taught mathematics using problem based instructional strategy and students taught using conventional strategy?
3) What are the mean achievement scores of the high, average and low ability students taught mathematics using problem based instructional strategy?
4) What are the mean achievement scores of the male and female students who were taught mathematics using problem based instructional strategy?

Research Hypotheses

The following hypotheses were tested at 0.05 level of significance

1) There is no significance difference between the academic achievement of students taught mathematics using problem based instructional strategy and students taught using conventional strategy
2) There is no significance difference in the academic achievement of the high, average and low ability student taught

mathematics using problem based instructional strategy

3) There is no significance difference between the academic achievement of the male and female students who were taught mathematics using problem based instructional strategy

Significance of the study

The study's findings are anticipated to be helpful to the following education stakeholders: students, teachers, schools and parents.

It would make students appreciate the principles underlying learning and procedural steps by bringing into focus numerous exercises that are needed for them to excel in mathematics thus, alleviating their fear and changing their attitude positively towards the subject. It would also change their attitude cognitively (thinking ability) and affectively (feelings). Additionally, it would help students to explore and manipulate mathematical concepts in a context that piques their interest. Altogether, it would make the students efficient in problem-solving which may also improve their academic achievement

Teachers would be motivated by the findings to increase the number of hands-on activities, real-world situations, and to give students opportunity to participate actively in the lesson. It would assist the teachers in consciously identifying students with learning difficulties and to adopt the appropriate teaching strategy. The study's conclusions would be helpful to the school by actively introducing mathematical concepts, and procedures through a variety of appropriate experiences and instructional strategies, so boosting students' accomplishment. Parents would soon be pleased with the pupils as the school began to report better performances. The study's findings would be helpful to parents as well since they would help their children succeed at higher levels by helping them learn mathematics easily.

METHODOLOGY

(i) Research design

The study employed a 2 x 2 x 3 pre-test, post-test control group quasi-experimental design.

(ii) Population of the study

The target population consisted of the entire Senior Secondary School II Students (SS2) of senior secondary schools in Somolu Local Government Area of Lagos State.

(iii) Sample and Sampling Techniques

Proportionate Sampling technique was used to select six (6) schools out of nineteen (19) existing senior secondary schools in Somolu Local Government Area of Lagos State. The schools were distinctively located from each other. Three of the schools were used as experimental group while three were used as control group. Intact classes were used in all the schools. One hundred and twenty-three SS11 students were randomly selected as sample.

(iv) Instruments used for data collection

The instrument used for data collection is the Problem Solving Achievement Test in Mathematics (PSATM). It was an 8 item essay type test where the respondents followed the steps in polya problem solving approach to solve each item in the test. Marks were awarded to each step of the polya problem solving approach.

(v) Validity of the instrument

Problem Solving Achievement Test in Mathematics (PSATM) was validated by senior lecturers in the mathematics department. The modified copy was used to collect data.

(vi) Reliability of the Instrument

Data collected was subjected to Kuder Richardson 20 (K-R 20) for Problem Solving Achievement Test in Mathematics (PSATM). The calculated value was r = 0.54.

(vii) Method of Data Analysis

Descriptive Statistics (Mean and Standard Deviation), T-test and Analysis of Co-Variance (ANCOVA) were used to analyse the data collected.

RESULTS/FINDINGS

This section presents the results of data analysis using descriptive and inferential statistics. The three research questions were answered using the descriptive statistics of mean and standard deviation. Null hypothesis 1 and 2 were tested with T-test while null hypothesis 3 was tested with Analysis of Covariance (ANCOVA). All hypotheses were tested at 0.05 level of significance.

(i) Research Question One: What are the mean achievement scores of students taught mathematics using problem based instructional strategy and students taught using conventional strategy? The computed mean scores before and after treatment were shown in Table 1.

Table 1: Mean Difference of Mathematics students taught with PBLIS and those taught with Conventional Approach.

	Treatment Group	N	Mean	Standard Deviation	Difference Mean Gain	
					PBLIS	Conventional
Pretest	PBLIS	63	13.78	1.237	13.79	2.96
	Conventional	60	10.37	2.504		
Posttest	PBLIS	63	27.57	3.430		
	Conventional	60	13.33	1.068		

The two groups had no major difference in their achievement before the treatment as shown in the table above. The mean difference is 3.41. after the treatment in which the experimental group was taught with PBLIS, the mean difference rose to 13.79. the score of the students in the control group did not differ much between the pretest and post- test. The mean difference was 2.96. The mean achievement score of students in the experimental group increased from 13.78 to 27.57 with a mean difference of 13.79. The use of PBLIS has a major positive effect on the achievement of students.

(ii). Research Question Two: What are the mean achievement scores of the high, average and low ability student taught mathematics using problem based instructional strategy? The computed mean scores of students taught mathematics using PBLIS based on their abilities as shown in Table 2.

Table 2: The mean achievement score and standard deviation of the problem based instructional strategy group of low, average and high ability of respondents.

Score Level	N	Mean	Std. Deviation
Low 15 - 24	16	23.19	0.655
Avg. 25 - 29	20	26.50	1.100
High 30 – 35	27	30.96	1.506
Total	63	27.57	3.430

The table presents the mean achievement scores and standard deviations for students of varying ability levels (low, average, and high) taught mathematics using a problem-based instructional strategy (PBLIS). The combined mean achievement score for all 63 students was 27.57, with a standard deviation of 3.430, indicating the total variability in scores across all ability levels. The results demonstrate a clear progression in mean scores from low to high ability students, suggesting that PBLIS was effective across all ability levels, with higher ability students achieving higher mean scores. Additionally, the higher variability in scores among high ability students suggests that while PBLIS was generally effective, it allowed for a broader

range of performance outcomes within this group.

(iii). Research Question Three: What are the mean achievement scores of the male and female students who were taught mathematics using Problem Based Instructional Strategy? The mean scores of students taught mathematics using PBLIS based on gender as shown in Table3.

Table 3: Descriptive Analysis of post score of male and female respondents taught using problem based instructional strategy.

	Gender	N	Mean	Std. Deviation	Std. Error Mean
PBLIS	Male	26	26.12	3.536	0.694
	Female	37	28.59	2.995	0.492

The descriptive analysis of the post-test scores for male and female students taught mathematics using the Problem Based Instructional Strategy (PBLIS) indicates a difference in mean achievement scores between the genders. According to Table 3, male students (N=26) have a mean score of 26.12 with a standard deviation of 3.536 and a standard error mean of 0.694. Female students (N=37), on the other hand, exhibit a higher mean score of 28.59, with a standard deviation of 2.995 and a standard error mean of 0.492. These results suggest that female students achieved higher average scores than their male counterparts when taught using PBLIS.

(iv). Null Hypothesis 1:

H_{01}: There is no significance difference between the academic achievement of students taught mathematics using Problem Based Instructional strategy and students taught using Conventional strategy.

Table 4: T-test Statistics result between students taught mathematics with PBLIS and those taught with Conventional Approach

Groups	N	Mean	Std	df	t	Sig	Remark
PBIS	63	27.57	3.430	121	30.759	.000	Sig.
Conventional	60	13.33	1.068				

T-test results in Table 4 shows there is significant difference in the achievement of students taught mathematics using PBLIS than those taught mathematics using Conventional approach ($t(63) = 30.76$, $p < 0.05$), this is because the p-value of 0.001 is less .05 significance level. Hence, H01 is rejected. This implies that students gained significantly when taught with PBLIS in relation to those taught with Conventional method

(v). Null Hypothesis 2:

H_{02}: There is no significance difference in the academic achievement of the high, average and low ability student taught mathematics using problem based instructional strategy.

Table 5: ANCOVA Analysis Results of students' Score level when taught with PBLIS

Source	Type III Sum of Square	Df	Mean Square	F	Sig.	Partial Eta Square
Corrected Model	641.728[a]	3	213.909	143.905	.000	.880
Intercept	363.495	1	363.495	244.538	.000	.806
Pretest	0.699	1	0.699	0.471	.495	.008
Score level	631.600	2	315.800	212.451	.000	.878
Error	87.701	59	1.486			
Total	48621.000	63				
Corrected Total	729.429	62				

R Squared = .880 (Adjusted R Squared = .874)

The ANCOVA analysis presented in Table 5 aims to determine if there is a significant difference in the academic achievement of high, average, and low-ability students when taught mathematics using a problem-based instructional strategy (PBLIS). The results show that the overall model is highly significant ($F = 143.905$, $p < .001$), indicating that the predictors used in the model explain a substantial portion of the variance in the students' scores. Specifically, the score level, which represents the students' ability group (high, average, or low), shows a significant effect ($F = 212.451$, $p < .001$), with a large partial eta squared value of .878. This suggests that the differences in academic achievement across the three ability groups are highly significant when taught using PBLIS.

Moreover, the intercept is also significant ($F = 244.538$, $p < .001$), demonstrating that the overall level of achievement in the sample is substantial. However, the pretest scores do not significantly contribute to the model ($F = 0.471$, $p = .495$), indicating that initial differences in students' prior knowledge do not significantly affect the post-intervention scores. The R Squared value of .880 (Adjusted R Squared = .874) indicates that 88% of the variance in academic achievement can be explained by the model, highlighting the effectiveness of the problem-based instructional strategy in influencing students' performance. The analysis refutes the research hypothesis's assertion by demonstrating significant differences in academic achievement among high, average, and low-ability students taught with PBLIS.

(vi) Null Hypothesis 3:

H_{03}: There is no significance difference between the academic achievement of the male and female students who were taught mathematics using problem based instructional strategy.

Table 6: T Test analysis results of students' gender when taught mathematics with PBLIS

Groups	N	Mean	Std	df	t	Sig	Remark
Male	26	26.12	3.536	61	3.001	.004	Sig
Female	37	28.59	2.995				

The t-test yielded a t-value of 3.001 for male students and a corresponding p-value (Sig) of 0.004. Typically, if the p-value is less than a predetermined significance level of 0.05, the null hypothesis is rejected, suggesting that the observed difference in means is statistically significant. In this case, the p-value associated with male students is less than 0.05, indicating that the observed difference in mean scores between male and female students taught with PBIS is statistically significant. Therefore, based on the above analysis, the null hypothesis that there is no significant difference in mean scores between male and female students taught with PBIS is rejected.

DISCUSSION

Findings from the statistics shows that that the problem-based instructional strategy had a significantly greater impact on students' mathematical achievement compared to the conventional method. The findings align with Ogunsola et al. (2021) who reported that PBLIS strategies foster deeper understanding and long-term retention of mathematical concepts, leading to higher achievement scores. It also supported the findings of Wijnia et al. (2024) that shows PBLIS enhances student engagement and motivation, which are critical factors in academic success. It contrasts with conventional teaching methods, which often rely on rote learning and passive reception of information, potentially limiting students' ability to apply mathematical concepts in novel situations (Nilimaa, 2023).

The study's findings indicate a clear stratification in achievement scores across the ability levels. The high ability group demonstrated the highest performance, reflecting their capacity to engage deeply

with the problem-solving tasks presented in the PBLIS framework. The average ability group reflected a strong understanding and application of the mathematical concepts taught through PBLIS. The low ability group indicated that their scores were tightly clustered around the mean, suggesting a uniform response to the instructional strategy. The findings are consistent with Arviani et al., (2023) who reported that PBLIS can be particularly beneficial for high-ability students by challenging them to think critically and engage in higher-order problem-solving. However, it also provides support structures that can help lower-ability students improve their understanding of fundamental concepts (Hmelo-Silver & Chinn, 2021). The differential performance across ability levels may also be linked to the varying levels of prior knowledge and cognitive readiness that students bring to the learning environment. High-ability students are often better equipped to handle the open-ended, inquiry-based nature of PBL, which requires a strong foundation in basic mathematical principles (Schmidt et al., 2022). Despite these differences, the overall positive performance across all ability groups underscores the flexibility and adaptability of PBLIS in catering to diverse learning needs. The findings suggest that while high-ability students may gain the most from this approach, average and low-ability students also make meaningful progress, thereby supporting the notion that PBLIS can be an effective strategy for inclusive education (Hayes & Bulat, 2017).

The findings based on gender reveal that female students outperformed their male counterparts in the PBLIS group. The observed gender differences in achievement scores may be influenced by several factors. Research has shown that female students often exhibit higher levels of motivation and engagement in problem-based learning environments compared to their male counterparts (Chen et al., 2023). This heightened engagement can lead to better academic outcomes, as students are more likely to invest effort and persist in solving complex problems. Furthermore, the supportive and collaborative nature of PBLIS may particularly benefit female students, who often thrive in environments that encourage teamwork and communication (Lakkala et al., 2021). This instructional strategy aligns with the social constructivist framework, which posits that learning is enhanced through interaction and dialogue (Vygotsky, 1978). Female students, who generally exhibit stronger social and communicative skills, may find PBLIS more conducive to their learning style, thereby explaining their higher achievement scores.

Findings from the inferential statistics indicated that students taught using PBLIS performed significantly better than those taught using conventional methods. This finding is consistent with the findings of Ogunsola et al. (2021) who reported that students in PBLIS environments not only develop a deeper understanding of mathematical concepts but also exhibit higher achievement levels compared to those in traditional learning settings. Similarly, it also corroborated the findings of Zhang & Ma (2023) demonstrated that PBLIS is associated with significant gains in student achievement across various educational contexts, including mathematics. The substantial difference in achievement scores can be attributed to the active learning processes inherent in PBLIS. Problem-based learning emphasizes critical thinking, collaboration, and the application of knowledge to real-world problems, which are key factors in improving student learning outcomes (Tawfik et al.,2021).

These findings are consistent with recent research that highlights how different ability levels respond variably to instructional strategies, including problem-based learning instructional strategy (PBLIS). For instance, research by Wijnia et al. (2024) indicates that PBL can be particularly beneficial for high-ability students, who tend to thrive in environments that challenge their critical thinking and problem-solving skills. This is likely due to their stronger foundational

knowledge, which enables them to engage more deeply with complex problems. However, the significant differences in achievement across ability levels also suggest that average and low-ability students may not benefit from PBLIS to the same extent as their high-ability peers. This aligns with findings by Romine et al. (2019), who argue that while PBL encourages deeper learning, it may also present challenges for students with weaker prior knowledge or lower cognitive readiness.

The findings based on gender reveals that there is a significant difference in the academic achievement of male and female students when taught mathematics using PBLIS. These findings align with contemporary research that examines gender differences in educational outcomes, particularly in the context of active and problem-based learning environments. Several studies have noted that female students often outperform male students in collaborative and problem-based learning settings due to differences in learning styles and engagement levels. For example, a study by Abdulrahman et al. (2023) found that female students tend to exhibit higher levels of intrinsic motivation and engagement in problem-based learning tasks, which in turn leads to better academic performance. Moreover, the supportive and interactive nature of PBLIS may cater more effectively to the learning preferences of female students, who often thrive in environments that emphasize collaboration and communication. Research by Zahedi et al. (2021) supports this, suggesting that female students benefit more from pedagogical approaches that foster a sense of community and collective problem-solving, which are central elements of PBLIS. On the other hand, male students, while benefiting from PBLIS, may not engage with the same level of depth or persistence as their female counterparts. Studies have shown that male students may prefer more structured and competitive learning environments, which contrasts with the open-ended and exploratory nature of PBLIS (Lim et al., 2020). This difference in engagement could partially explain the lower mean scores observed among male students in this study. PBLIS is effective in improving academic achievement for both genders, it is crucial to consider how different students may respond to this instructional strategy. The finding also corroborates with the finding of Badru (2016) who revealed that female students had better performance than the male students with respect to achievement in mathematics.

CONCLUSION

The following conclusions have been made based on the findings of the study:

1. PBLIS is more potent in learning mathematics than the conventional method.
2. Female students had improved achievement than the male students when taught mathematics using PBLIS.
3. Students' achievement based on scoring levels were positively improved when PBLIS is used in learning mathematics.

Recommendation

Based on the conclusion of the study, the following recommendations were made:

1. Mathematics teachers should adopt PBLIS always in other to improve students' achievement in Mathematics.
2. Support and inspiration should be given to mathematics educators by offering conducive learning environment, laboratory and quality teaching resources.

Declaration by Authors

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