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Effect of problem-based learning strategy on the learning outcomes of senior secondary school students in Mathematics

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Abstract

Background: Problem-based learning (PBL) has been identified as an effective instructional strategy, particularly in enhancing student outcomes in various subjects, including mathematics. However, its impact on senior secondary school students' mathematics achievement and attitudes in Ogun State, Nigeria, remains underexplored.

Aims: This study aims to investigate the effects of PBL on the mathematics achievement and attitudes of senior secondary school students in the Ijebu Ode area of Ogun State, Nigeria. Additionally, it examines the influence of gender on students' attitudes towards mathematics.

Method: A sample of 100 students was randomly selected from two senior secondary schools, divided into an experimental group and a control group. The experimental group received instruction through PBL, while the control group followed traditional teaching methods. Six hypotheses were tested at a significance level of 0.05. Data were collected using a teaching guide on PBL, the Mathematics Achievement Test (MAT), and the Mathematics Attitude Scale, with reliabilities of 0.82 and 0.88, respectively. Analysis of Covariance (ANCOVA) was used to analyze the data.

Results: The findings revealed a significant positive effect of PBL on both the achievement and attitudes towards mathematics among the senior secondary school students. Additionally, gender was found to significantly influence students' attitudes towards mathematics.

Conclusion: The study concludes that PBL significantly enhances both mathematics achievement and attitudes among senior secondary school students in Ijebu Ode, Ogun State, Nigeria. It recommends that schools integrate student-centered teaching methods, including PBL, into their curricula and encourage teachers to adopt these strategies.

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INTRODUCTION

Mathematics, as an intriguing subject, has the potential to cultivate creativity and critical thinking skills. According to Kazeem (2021), mathematics is viewed as a way of thinking and organizing one's expression. However, many students perceive mathematics as uninteresting and devoid of meaning, leading to fear, anxiety, and disengagement. This perception is often attributed to the lack of a mathematics laboratory and unengaging teaching methods that fail to relate to real-world applications (Ali et al., 2010; Estonanto & Dio, 2019; Haerudin et al., 2021). Over the years, there has been a notable decline in academic achievement among secondary school students, with less than half of the students typically passing local and external mathematics examinations at the credit level or higher (Asanre et al., 2019). This decline is further highlighted by the 2022 WAEC results in mathematics for Ogun State, which revealed a decrease compared to previous years. Out of 1.6 million candidates who sat for the examination in 2022, 76.36% had credits in five subjects including English and mathematics, yet students had a decline of 5% in their performance compared to 2021, when the performance was 81.1%. This indicates a looming challenge in producing skilled

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and knowledgeable graduates in the country, which could have serious implications for the future. The WAEC chief examiners reported several areas of weakness in the candidates that might have led to their poor performance, including poor interpretability of questions, inability to apply mathematical principles correctly, and insufficient knowledge of various mathematical concepts (Mabena et al., 2021; Mazana et al., 2020). This underscores the need for effective teaching methods to address these issues.

Mathematical achievement is defined as the competency demonstrated by students in mathematics, quantified by scores on mathematics achievement tests. Achievement in mathematics is crucial for academic success and serves as a determinant of success in numerous professions. The assessment of students' academic achievement typically involves examinations or continuous assessment methods, with ongoing debates about the most effective testing approaches (Kazeem, 2021). According to Asanre et al. (2019), students' mathematics achievement is significantly influenced by their attitudes. Thomas and Gbenro (2014) reported that attitudes towards mathematics encompass general feelings of liking or disliking, inclinations to participate in or abstain from mathematical activities, and opinions on whether mathematics is beneficial. Koyuncu and Donmez (2018) opined that attitudes are among the factors that teachers consider crucial in determining the failure rates of mathematics learners. More broadly, attitudes towards mathematics are seen as a combination of cognitive, emotional, and behavioral responses that allow learners to develop their skills based on their experiences, knowledge, and emotions (Mensah et al., 2013; Li & Schoenfeld, 2019). Understanding the role of attitudes in mathematical achievement is essential, but another critical factor that must be considered is gender.

The issue of gender cannot be overlooked when discussing students' attitudes and achievements in mathematics at the senior secondary school level. Yazachew (2013) reported that female students exhibit poorer attitudes, lower achievement, and reduced self-efficacy in mathematics and science compared to male students. Females also tend to underestimate their talents in these subjects. Additionally, Lindberg et al. (2010) determined that there is very little gender disparity in students' mathematics achievement. Abiodun et al. (2024) emphasized that secondary school students need to perform well in mathematics to achieve future success in their academic and professional aspirations. They further stressed that the National Policy on Education (NPE) has advocated for the inclusion of problem-solving methods in the mathematics curriculum in Nigeria to provide students with high-quality mathematical skills. These problem-solving methods encourage active cognitive engagement. The teaching method for mathematics encourages students to actively engage in cognitive processes and apply their learning to practical situations, thus enhancing their overall educational experience.

Problem-based learning (PBL) is an educational approach that utilizes real-world issues to engage students in solving authentic problems, thereby preparing them for future workplace challenges (Deep et al., 2019). In PBL, collaborative group learning is emphasized, enabling students of diverse proficiency levels, including both high and low achievers, to work together. This approach aims to cultivate deep understanding, build knowledge, and develop crucial skills such as teamwork, leadership, communication, and motivation (Kazeem, 2021). Fatade et al. (2013) concluded that PBL represents a pedagogical alternative that diverges from the linear, complete, and transmissive logic of knowledge. Instead, it fosters active student participation, promotes the integration of knowledge, and encourages lifelong learning. Kazeem (2021) stressed that PBL serves as a pedagogical alternative that disrupts the linear, comprehensive, and transmissive nature of knowledge. Instead, it fosters active student involvement, promotes the integration of knowledge, and encourages ongoing education. Kazeem further emphasized that PBL is an inquiry-based learning method that empowers students to acquire and process new information by engaging with ill-structured problems that lack sufficient information for straightforward resolution. Given the substantial benefits associated with PBL, it is important to examine its impact on students' academic achievements and attitudes.

Hence, this study aimed to provide evidence on the effect of PBL on the academic achievements and attitudes of senior secondary school students in mathematics. Various researchers have investigated the impact of PBL. For example, Limann et al. (2022) studied the effect of PBL on students' achievement in trigonometry in senior high schools in the Hohoe Municipality of the Volta region in Ghana. Similarly, Emefo et al. (2023) examined the effect of a PBL strategy on senior

secondary 2 students' achievement in geometry, considering the effect of gender in Bichi, Kano State. They analyzed the difference in the mean achievement scores. Bukari and Addo (2019) investigated the effect of PBL on college of education students by examining their probability achievement and attitude toward the use of PBL. Additionally, Nese and Nese (2014) studied the differences in the pretest and posttest mean scores between the control and experimental groups regarding the achievement, attitude, and retention of fifth-grade students in Turkey. Melek (2016) conducted a meta-analysis on the effects of PBL on the attitudes of students in Turkey, comparing the findings of various studies. While these studies have provided valuable insights into the benefits of PBL, they have primarily focused on different regions, subjects, and educational levels. This study, however, specifically examines the main and interaction effects of PBL and gender on both academic achievement and attitudes towards mathematics among senior secondary school 1 students in Ijebu Ode, Ogun State, Nigeria. These studies highlight the potential of PBL in various educational settings. Collectively, these researchers have shown that PBL is a valuable concept in the teaching and learning process, utilizing different methods ranging from qualitative to quantitative and mixed methods.

METHOD

Research Design

This study makes use of a pretest, posttest, and control group quasi experimental study, as it applies independent variables to a specific sample to observe their impact on the variable of interest. Based on the hypotheses, both the experimental and control groups underwent two tests: a pretest and a posttest.

Participants

The population for this study included public senior secondary school Students in the Ijebu Ode local government area of Ogun State, Nigeria. The sample included a total of 100 students from an intact class of two public secondary schools purposively selected due to study criteria such as coeducational school, government approval and availability for the research. Each school contributed a total of 50 students to both the experimental and control groups. The selected students consisted of 42 males and 58 females. The students who participated were all in senior secondary school one (SSS1).

Instruments

The instruments used in the study were the Mathematics Achievement Test (MAT) and the Mathematics Attitude Scale (MAS). For the MAS, the response options provided for the respondents included a Likert scale, which offered respondents the following options: strongly agree (SA), agree (A), strongly disagree (SD), and disagree (D). The questionnaire, which allowed respondents to express how much they agreed or disagreed on the raised items, was used to answer questions about both favour and unfavour statements related to student's attitudes towards mathematics and the mathematics achievement test (MAT). were an objective session of 25 multiple-choice questions from A to D, with one correct answer and three distracters, designed to evaluate students' academic achievement in mathematics. These questions were drawn from a senior secondary school mathematics textbook to cover the following areas in mathematics: word problems leading to mathematics equations (10 questions), simultaneous equations involving indices (7 questions) and quadratic equation (8 questions), which are topics to which the student has been exposed. It was developed to cover students' knowledge, comprehension and application levels. Both instruments were validated by experts in the departments of educational psychology and mathematics education who evaluated the questionnaire's validity using face and content validity. The reliability was determined using a different sample from another local government, and the reliability coefficient was 0.88 for the MAS using the Cronbach alpha coefficient and 0.82 for the MAT using the split half method. The problem-based learning intervention class was taught mathematics content on word problems leading to mathematics equations such as linear and quadratic equations, and simultaneous equations involving indices by the researchers for five weeks in the experimental group while research assistance helped in overseeing the control group using conventional teaching methods. Both the Mathematics Achievement Test (MAT) and the Mathematics Attitude Scale (MAS)

were administered by the researcher to the respondents before and after the intervention as a pretest and posttest, respectively, to ensure proper completion.

Data Collection and Analysis

The selected schools were visited by the researcher and permission was obtained from the school authority. Then, the goal of the study was explained to the respondents, and emphasis was placed on the significance. After informing the participants that their responses would remain private, the researcher ensure that the instruments are correctly filled out with the assistance of research assistants. The instruments collected were transferred to data coding sheets. The responses from the questionnaire were coded; as SA = 4, A = 3, D = 2 and SD = 1. The codes generated from the responses were computed for each participant. Additionally, each item of the MAT was scored fourth for a total possible score of 100. The MAT score for each participant was also computed. The data were analysed using both descriptive statistics (mean and standard deviation) and inferential statistics; specifically, ANCOVA was utilized to analyse the hypotheses at a significance level of 0.05.

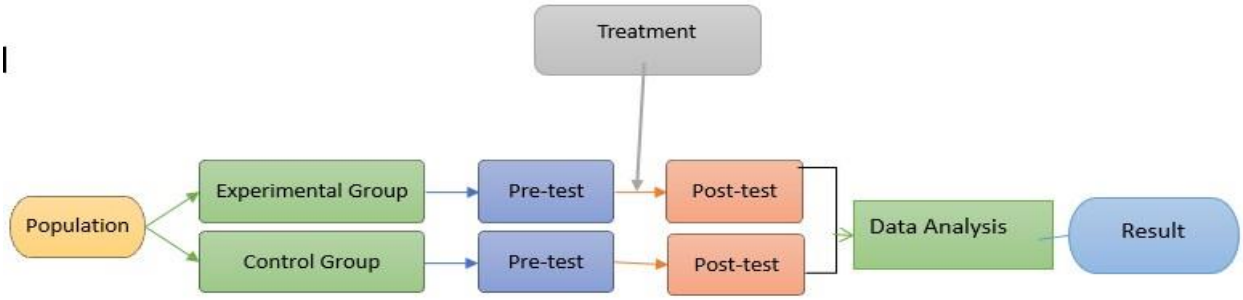

Figure 1. Flow Chart of the Method

RESULTS AND DISCUSSION

Descriptive Results of Pre and Posttest Students' Achievement and Attitudes in Mathematics.

Table 1. Pre and Posttest Students' Mean and Standard Deviation Scores for Both the Experimental and Control Groups

	N	Pre - achievement scores		Post -achievement score	
		Mean	S.D	Mean	S.D
Experimental	50	19.125	6.41	35	26.7
Control	50	18.000	4.90	19	5.93

According to Table 1, the experimental group exhibited a mean pretest achievement score of 19.125 and a mean posttest achievement score of 35. Conversely, the control group exhibited a mean pretest achievement score of 18 and a mean posttest achievement score of 19:

Table 2. Pre and Posttest Students' Mean and Standard Deviation Scores for Both the Experimental and Control Groups on Attitudes Towards Mathematics

Group	N	Pre attitude scores		Post attitude score	
		Mean	S.D	Mean	S.D
Experimental	50	14.40	6.341	16.28	7.456
Control	50	11.28	4.335	14.12	7.178

Table 2 shows that the experimental group had a mean pretest attitude score of 14.40 and a mean posttest attitude score of 16.28. This indicates an improvement in students' attitudes towards mathematics after being taught using the problem-based learning (PBL) approach. Conversely, the control group had a mean pretest attitude score of 11.28 and a mean posttest attitude score of 14.12. Although both groups showed improvement, the experimental group demonstrated a more substantial increase, suggesting the greater efficacy of PBL in enhancing students' attitudes. The

comparison highlights that PBL not only aids in academic performance but also significantly boosts students' positive perceptions of mathematics.

Testing of Hypothesis

Hypothesis 1: There is no significant effect of teaching strategy, PBL, on the mathematics academic achievement of senior secondary school students.

Table 3. Two-way analysis of covariance (ANCOVA) was conducted to analyse students' achievement scores, considering treatment, gender, and their interaction

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected Model	827.052	3	275.684	11.134	.000
Intercept	8963.019	1	8963.019	362.000	.000
Covariate	403.016	1	403.016	104.005	.000
Strategy	731.000	1	731.000	33.724	.000
Gender	53.839	1	53.839	3.434	.147
Strategy * gender	50.535	1	50.535	2.041	.160
Error	1138.948	46	24.760		
Total	10944.000	50			
Corrected Total	1966.000	49			

R Squared = .576 (Adjusted R Squared = .421)

The ANCOVA of students' achievement scores presented in Table 3 indicates the effect of problem-based learning instruction on student achievement in mathematics was examined at a significance level of 0.05. The F value for treatment was 33.724, which was significant at .000 ($p < .05$), leading to the rejection of the null hypothesis. Consequently, it is concluded that there is a significant main effect of treatment (strategy) on students' mathematics achievement.

Hypothesis 2: There is no significant primary effect of gender on the mathematics academic achievement of senior secondary school students.

The null hypothesis is accepted as the F value for gender, which is 3.434, is not significant at .147 ($p > .05$). Therefore, it can be concluded that there is no significant main effect of gender on the mathematics achievement of senior secondary school students.

Hypothesis 3: There is no significant interaction effect between treatment (PBL) and gender on the mathematics academic achievement of senior secondary school students.

According to Table 3, the F value of 2.041 for the interaction effect of treatment and gender is not significant at . 160 ($p > .05$). Consequently, the null hypothesis is accepted, indicating that there is no significant interaction effect of treatment and gender on mathematics achievement secondary school students.

Table 4. Two-way analysis of covariance (ANCOVA) was conducted to analyse students' attitude scores, considering treatment, gender, and their interaction

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected Model	318.130[a]	3	106.043	4.020	.013
Intercept	13338.974	1	13338.974	505.685	.000
Strategy	52.473	1	52.473	12.989	.001
Gender	209.23	1	209.23	7.124	.009
Strategy * Gender	56.868	1	56.868	2.156	.149
Error	1213.390	46	26.378		
Total	14914.000	50			
Corrected Total	1531.520	49			

R Squared = .316 (Adjusted R Squared = .212)

Hypothesis 4: There is no significant primary effect of teaching strategy, PBL, on the attitudes towards mathematics of senior secondary school students.

According to Table 4, the ANCOVA of students' attitude scores indicates the effect of the problem-solving strategy on student mathematics achievement at a significance level of 0.05. The

null hypothesis is rejected due to the significant F value of 12.989 for treatment at .001 ($p < .05$). Consequently, it can be concluded that there is a significant main effect of strategy (PBL) on secondary school students' attitudes towards mathematics.

Hypothesis 5: There is no significant primary effect of gender on senior secondary school students' attitudes towards mathematics.

The null hypothesis is rejected due to the significant F value of 7.124 for gender at 0.009 ($p < .05$). Therefore, it can be concluded that there is a significant main effect of gender on secondary school students' attitudes towards mathematics.

Hypothesis 6: There is no significant interaction effect between treatment (PBL) and gender on the attitudes towards mathematics of senior secondary school students.

In Table 4, the F-value of 2.156 for the interaction effect of strategy (PBL) and gender is not significant at 0.149 ($p > .05$). Consequently, the null hypothesis is accepted, therefore, it is concluded that there is no significant interaction effect of strategy (PBL) and gender on secondary school attitudes toward mathematics.

Discussion of Findings

The findings indicated that the treatment, specifically the application of problem-based learning (PBL), significantly impacts the academic achievement of senior secondary school students in mathematics. This suggests that students who received instruction through the PBL approach achieved greater academic performance than those who did not receive this treatment. The observed difference in achievement scores underscores the efficacy of problem-based learning as a teaching approach for enhancing students' mathematical proficiency. The results corroborate the results of Emefo et al. (2023) and Limann et al (2022), who both concluded that students who were taught geometry and trigonometry using PBL had a greater mean achievement score than those who were taught using conventional approaches. This result also aligns with the conclusion of Liu (2018) and Abiodun et al (2024) that reported that using student centered teaching strategies can increase mathematics learning initiatives and increase interest among students. The findings indicate that gender does not significantly affect the mathematics academic achievement of senior secondary school students. This suggests that both male and female students attain comparable levels of academic performance in mathematics., regardless of their gender. The lack of a significant gender effect highlights the importance of recognizing and addressing individual differences and abilities rather than relying on gender stereotypes in regard to academic achievement in mathematics. It is crucial to recognize that variations in methodology, sample size, population characteristics, and other factors can lead to differing results across studies. While Asanre et al. (2022) may have observed a significant interaction effect between the medium of instruction and gender on students' achievement in mathematics, the present study did not yield similar results.

Moreso, the findings show a significant impact of treatment, particularly the incorporation of problem-based learning (PBL), on the attitudes of senior secondary school students towards mathematics. This suggests that students who are exposed to the PBL approach demonstrated a more positive disposition towards mathematics than did those who did not receive this treatment. The observed positive attitude towards mathematics among students in the exposed group highlights the effectiveness of the strategy in fostering a favourable perception of the subject. This finding underscores the importance of utilizing innovative and engaging instructional strategies, such as PBL, to promote positive attitudes towards mathematics among students. The findings of the present study are consistent with those of Asanre et al. (2022), who also concluded that instructional strategy significantly influenced secondary school students' attitudes towards mathematics. Additionally, these findiings align with the comparative study carried out by Melek (2016). The findings indicate that gender has an influence on senior secondary schools' students' attitude towards mathematics within Ijebu Ode, Ogun State, Nigeria. This finding is in accordance with the findings of Asanre et al (2022) and Ogunsola et al (2021) but negates the findings of Yazachew (2013), who reported that female students exhibit poorer attitudes, achievement and self-efficacy in mathematics and science than male students, and that females tend to underestimate their talents in the subjects. The findings indicate that there is no interaction effect of strategy and gender on the attitudes of senior secondary school students towards mathematics. This finding is corroborated by the research conducted by

Asanre et al. (2022). This implies that instructional strategy is not gender sensitive as it significantly increases the achievement of both genders.

CONCLUSION AND RECOMMENDATION

The findings of this study conclude that problem-based learning (PBL) strategies significantly impact senior secondary school students' academic achievement and attitudes towards solving word problems in mathematics in Ijebu Ode, Ogun State, Nigeria. The PBL intervention positively influenced both academic performance and students' attitudes towards mathematics, particularly in teaching word problems leading to mathematical equations. This suggests that modern teaching approaches can effectively instill the problem-solving skills and attitudes required in the 21st century. The strategy has proven effective in enhancing students' learning outcomes by improving knowledge construction, critical thinking skills, and quantitative abilities. It is hoped that this study will encourage educational stakeholders to adopt PBL as a teaching and learning method. Introducing PBL early in students' education, through dedicated time in the daily schedule for studying mathematics, can improve concentration and deepen understanding of mathematical content. Emphasis should be placed on ensuring students do not rely excessively on others' ideas, to prevent fostering a nonchalant attitude towards learning. Government and educational policymakers should structure curricula to accommodate student-centered learning approaches, and teachers should receive regular training on PBL. Moreover, school authorities should provide the necessary supervision and support to teachers to ensure the effective implementation of PBL. Further studies are recommended in other regions to verify these findings, given the limited sample size used in this study, which may not represent all secondary school students in Ogun State, Nigeria.

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AUTHOR CONTRIBUTIONS STATEMENT

The authors discussed the main and interaction effects of problem-based learning strategy and gender on academic achievement in and attitudes towards mathematics among senior secondary school 1 students in Ijebu Ode, Ogun State, Nigeria and all the authors contributed to finalizing the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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