Effect of Problem-Based Learning on Physics Achievement of Senior Secondary School Students in Nigeria

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Abstract
Physics remains one of the science subjects in which senior secondary school students in Nigeria consistently record poor achievement, a trend that has been linked partly to the continued dominance of teacher-centred, lecture-based instruction. This study examined the effect of problem-based learning (PBL) on the physics achievement of senior secondary school students and further investigated whether the effect differs by gender. A quasi-experimental, non-randomised pretest-posttest control group design was adopted. A sample of 128 Senior Secondary Two (SS2) physics students drawn from four intact classes in two co-educational secondary schools was assigned to an experimental group, taught selected mechanics topics using problem-based learning, and a control group, taught the same topics using the conventional lecture method, over a period of six weeks. Data were collected using a 40-item, four-option multiple-choice Physics Achievement Test (PAT) validated by experts in science education and measurement, with a Kuder-Richardson (KR-20) reliability coefficient of 0.84. Two research questions were answered using mean and standard deviation, while two null hypotheses were tested using Analysis of Covariance (ANCOVA) at the 0.05 level of significance. Findings showed that students taught physics using problem-based learning achieved significantly higher post-test scores than those taught using the lecture method, and that gender had no statistically significant effect on the achievement of students within the problem-based learning group. The study concludes that problem-based learning is a more effective instructional strategy than the conventional lecture method for improving physics achievement among senior secondary school students, and recommends that physics teachers be trained and supported to integrate problem-based learning into everyday classroom instruction.

Keywords: *problem-based learning, physics achievement, senior secondary school, quasi-experimental design, Nigeria*

1.0 Introduction

Physics occupies a central position among the science subjects offered at the senior secondary school level in Nigeria because of the role it plays in laying the conceptual foundation for careers in engineering, medicine, computing, and other technology-driven fields. The National Policy on Education identifies the production of scientifically literate citizens capable of applying scientific knowledge to solve everyday problems as one of the broad goals of secondary education, and

physics is expected to contribute directly to this goal by developing learners' capacity for logical reasoning, observation, and problem solving (Federal Republic of Nigeria, 2013).

Despite this important role, the academic achievement of Nigerian senior secondary school students in physics has remained a source of concern to teachers, parents, and policy makers. Reports on the West African Senior School Certificate Examination and the National Examinations Council have repeatedly shown that candidates' performance in physics falls short of expectation, and researchers have traced this trend to a combination of factors, including inadequate laboratory facilities, a shortage of qualified physics teachers, and, most persistently, continued reliance on teacher-centred lecture methods that reduce students to passive recipients of abstract formulae and definitions (Adeyemo, 2010; Aina & Akintunde, 2013).

The conventional lecture method, in which the teacher transmits information while students listen and take notes, has been criticised for its limited capacity to develop the reasoning and application skills that physics demands. Because concepts such as motion, force, and energy are often abstract and mathematically expressed, students taught mainly through lecture and note-dictation tend to memorise formulae without grasping the underlying principles, a situation that manifests as poor performance whenever they encounter unfamiliar or applied problems (Akinbobola & Afolabi, 2009). This has strengthened the case for student-centred, activity-based approaches that place learners at the centre of the instructional process and allow them to construct understanding through active engagement with real or realistic problems.

Problem-based learning is one such student-centred approach. Originally developed for medical education, PBL is an instructional strategy in which learners are first presented with an ill-structured, real-life problem and are then required to identify what they already know, determine what they still need to learn, and work collaboratively to research, apply, and evaluate possible solutions, with the teacher acting as a facilitator rather than a dispenser of information (Barrows & Tamblyn, 1980). Because it requires learners to actively construct knowledge rather than passively receive it, PBL is grounded in constructivist learning theory, and its proponents argue that it produces deeper conceptual understanding, stronger problem-solving skills, and better retention than traditional expository teaching (Hmelo-Silver, 2004).

A number of studies within Nigeria have investigated the effectiveness of problem-based and closely related problem-solving strategies in physics instruction, generally reporting that learners exposed to these strategies outperform those taught conventionally. Enyeneokpon (2012), for example, found that Nigerian Certificate in Education pre-service teachers exposed to problem-based learning achieved significantly higher scores in physics and acquired stronger science process skills than their counterparts taught by the conventional lecture method. Related problem-solving interventions have similarly been reported to produce significant gains in senior secondary school students' physics achievement when compared with lecture-based instruction. However, much of the existing Nigerian literature on activity-based strategies in physics has concentrated on general problem-solving, guided-discovery, or project-based approaches, while classroom-based experimental evidence that isolates the effect of the structured problem-based learning cycle on senior secondary physics achievement remains comparatively limited. It is this gap that the present study sought to address.

1.1 Statement of the Problem

Physics teaching in many Nigerian senior secondary schools continues to be dominated by the lecture method, in which teachers explain concepts and solve sample problems on the chalkboard while students copy notes with little opportunity for independent inquiry or application. This

approach has been associated with the persistently low achievement scores recorded by students in internal and external physics examinations, weak retention of physics concepts, and declining interest in physics-related courses at the tertiary level. While problem-based learning has been advocated as a viable alternative capable of reversing this trend, Nigerian classroom-based experimental evidence that isolates its specific effect on senior secondary school students' physics achievement, and on whether such an effect is influenced by the gender of the learner, remains comparatively scarce. It was against this background that the present study set out to determine the effect of problem-based learning on the physics achievement of senior secondary school students in Nigeria.

1.2 Objectives of the Study

The Objectives of this study was to:

1. determine the effect of problem-based learning on the academic achievement of senior secondary school students in physics, compared with the conventional lecture method; and
2. determine the influence of gender on the physics achievement of students taught using problem-based learning.

1.3 Research Questions

The following research questions guided the study:

1. What is the difference between the mean achievement scores of students taught physics using problem-based learning and those taught using the conventional lecture method?
2. What is the difference between the mean achievement scores of male and female students taught physics using problem-based learning?

1.4 Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

HO1: There is no statistically significant difference between the mean post-test achievement scores of students taught physics using problem-based learning and those taught using the conventional lecture method.

HO2: There is no statistically significant difference between the mean post-test achievement scores of male and female students taught physics using problem-based learning.

1.5 Significance of the Study

The findings of this study are expected to benefit physics teachers by providing empirical justification for adopting problem-based learning as a routine instructional strategy rather than an occasional classroom activity. Curriculum planners and teacher-education institutions may find the results useful in designing pre-service and in-service training programmes that build teachers' capacity to design and facilitate problem-based lessons. Students stand to benefit from improved conceptual understanding and problem-solving competence, while the study also adds to the relatively limited body of Nigerian experimental literature that isolates the effect of structured problem-based learning, as distinct from general activity-based or project-based methods, on senior secondary physics achievement.

1.6 Scope of the Study

The study was delimited to Senior Secondary Two (SS2) physics students in selected co-educational secondary schools and focused specifically on mechanics topics, namely linear

motion, force and Newton's laws of motion, and work, energy and power, as prescribed in the senior secondary physics curriculum. The independent variable was mode of instruction (problem-based learning versus the conventional lecture method), the dependent variable was physics achievement, and gender was treated as a moderating variable.

2.0 Literature Review

2.1 Theoretical Framework

This study is anchored on constructivist learning theory, which holds that learners actively construct knowledge and understanding through experience and reflection rather than passively receiving information transmitted by a teacher. Dewey (1938) argued that genuine learning occurs when learners engage with real, purposeful experiences rather than with content presented in isolation from application, an idea that underlies the use of authentic problems as the starting point of instruction in PBL. Vygotsky's (1978) social constructivist perspective further emphasises that learning is enhanced through social interaction and collaborative problem solving within a learner's zone of proximal development, providing the theoretical justification for the small-group, collaborative structure of problem-based learning, in which peers and a facilitating teacher scaffold one another toward deeper understanding. Together, these positions suggest that when students are confronted with a realistic physics problem and supported to investigate, discuss, and construct their own explanations, they are more likely to develop durable conceptual understanding than when they are simply told the correct formula and procedure.

2.2 The Concept of Problem-Based Learning

Problem-based learning is commonly described as an instructional approach that begins instruction with a problem to be solved rather than with the presentation of content to be learned. Barrows and Tamblyn (1980), who pioneered the approach in medical education, characterised it as learning that results from the process of working toward the understanding or resolution of a problem, with the problem encountered first, before any preparatory study or teaching has occurred. Hmelo-Silver (2004) identified the essential features of PBL as including an authentic, ill-structured problem that anchors the entire learning cycle, student-centred inquiry in which learners determine their own learning needs, small-group collaboration, and a teacher who facilitates rather than directs the learning process. In a typical PBL cycle, as adapted for secondary school physics instruction, learners are presented with a realistic scenario, such as designing a safety barrier capable of withstanding a given impact force, and are guided to identify the facts already known, formulate learning issues, generate and test hypotheses, carry out independent and group research, and finally apply what they have learned to propose and justify a solution. This cycle, illustrated in Figure 1, is cyclical rather than linear, since reflection at the end of one problem often generates new questions that feed into subsequent learning.

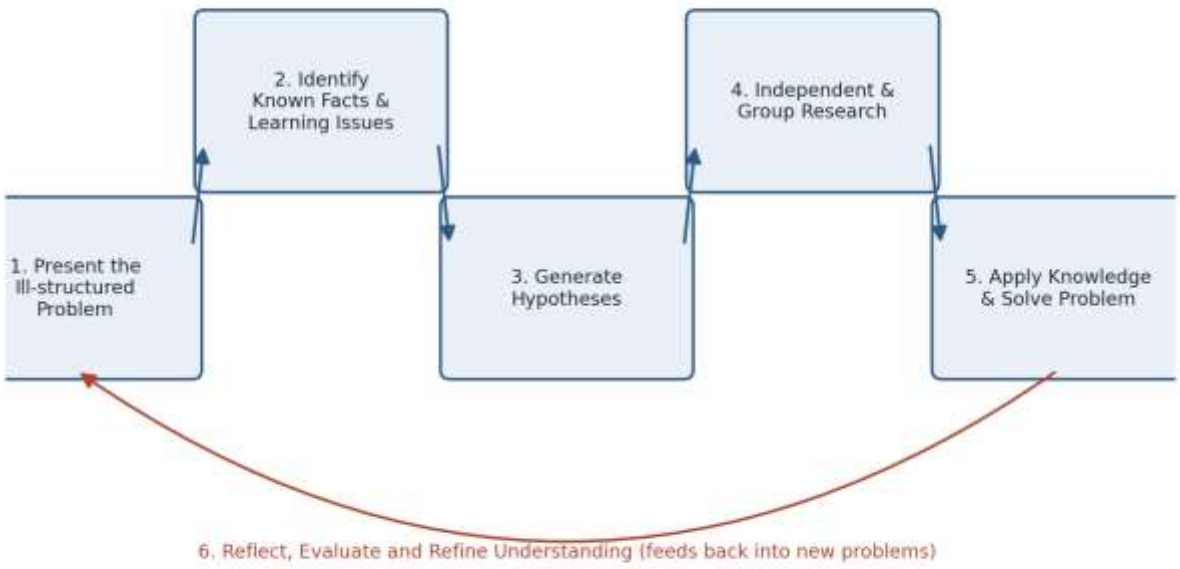


Figure 1: The Problem-Based Learning Instructional Cycle

2.3 Empirical Studies on Problem-Based Learning and Physics Achievement

Several studies have examined the effect of problem-based and related problem-solving strategies on students' achievement in physics. Enyeneokpon (2012) investigated the effect of problem-based learning on the achievement of Nigerian Certificate in Education pre-service teachers in physics and their acquisition of science process skills, using a quasi-experimental design involving pre-service teachers drawn from colleges of education in south-western Nigeria. The treatment group, exposed to problem-based learning, recorded significantly higher achievement scores than the control group taught by the conventional lecture method, and the strategy was also found to significantly enhance science process skills. This finding supports the theoretical expectation that engaging learners with realistic problems, rather than presenting them with ready-made content, deepens both conceptual understanding and procedural competence.

At the secondary school level, studies applying related structured problem-solving strategies have similarly reported significant achievement gains for experimental groups compared with control groups taught conventionally, alongside improved retention of physics concepts over time. Studies examining project-based learning, a closely related student-centred strategy, have likewise reported significant effects of the approach on secondary school students' physics achievement, with the effect sometimes found to interact with contextual factors such as school location. Taken together, this body of evidence points consistently in one direction: instructional strategies that require students to engage actively with problems, rather than to passively absorb content, tend to produce stronger achievement outcomes in physics than the conventional lecture method.

Beyond achievement, some studies have explored the influence of gender on the effectiveness of problem-based learning. Findings on this question have been mixed; while a few studies report that male students outperform their female counterparts under activity-based instruction, a larger number find no statistically significant gender difference once students are exposed to the same

student-centred strategy, suggesting that problem-based learning may narrow, rather than widen, gender-related gaps in physics achievement (Akinbobola, 2009). This inconsistency in the literature partly motivated the inclusion of gender as a variable of interest in the present study.

2.4 Summary of Literature Reviewed

The literature reviewed shows general agreement that the conventional lecture method contributes to poor achievement in physics because it does not sufficiently engage learners in the active reasoning and application that the subject demands, and that student-centred strategies grounded in constructivist theory, including problem-based learning, tend to produce superior achievement outcomes. However, most of the Nigerian studies specifically on problem-based learning in physics have focused on pre-service teachers or on the closely related problem-solving and project-based strategies, leaving a relative gap in classroom-based experimental evidence involving senior secondary school students taught with the structured PBL cycle. The present study was designed to help close this gap, while also examining whether the effect of the strategy is moderated by gender.

3.0 Methodology

3.1 Research Design

The study adopted a quasi-experimental, non-randomised pretest-posttest control group design. Intact classes were used, since random assignment of individual students to groups was not administratively feasible in the participating schools. One intact SS2 physics class in each of the two participating schools was randomly assigned to the experimental group and taught using problem-based learning, while the other intact class in each school served as the control group and was taught the same content using the conventional lecture method. Both groups sat for the same instrument as a pretest before treatment commenced and as a post-test at the end of the six-week instructional period.

3.2 Population of the Study

The population of the study comprised all Senior Secondary Two (SS2) physics students in public co-educational secondary schools in the study area during the academic session in which the study was conducted.

3.3 Sample and Sampling Technique

A multi-stage sampling procedure was used to select the sample. First, two co-educational secondary schools were purposively selected on the basis of having at least two streams of SS2 physics classes and comparable facilities. Second, within each school, one intact class was randomly assigned to the experimental group and the other to the control group by a simple balloting technique. This yielded a total sample of 128 SS2 physics students, comprising 64 students in the experimental group (34 males, 30 females) and 64 students in the control group (32 males, 32 females), as summarised in Table 1.

Table 1: Distribution of Sample by Group and Gender

Group	Male	Female	Total	%
Experimental (PBL)	34	30	64	50.0
Control (Lecture)	32	32	64	50.0
Total	**66**	**62**	**128**	**100.0**

3.4 Instrumentation

The instrument used for data collection was a researcher-designed Physics Achievement Test (PAT), consisting of 40 multiple-choice items, each with four options, covering linear motion, force and Newton's laws of motion, and work, energy and power. The same instrument, with items re-ordered, was used as both pretest and post-test. Content validity was established by three experienced physics teachers and two science education lecturers, who reviewed the items against the senior secondary physics curriculum for relevance, clarity, and appropriate cognitive level. The instrument was trial-tested on 40 SS2 physics students in a school outside the study sample, and reliability was estimated using the Kuder-Richardson formula 20 (KR-20), yielding a coefficient of 0.84, which was considered adequate for a cognitive achievement test of this nature.

3.5 Experimental Procedure

Before treatment commenced, regular physics teachers in the two participating schools who taught the experimental groups were trained over two sessions on the principles and procedure of problem-based learning, including how to design ill-structured problems, facilitate small-group discussion, and guide learners without supplying ready answers. Both groups were pretested using the PAT one week before treatment began. Over the following six weeks, the experimental group was taught the specified mechanics topics using the PBL cycle, in which each topic was introduced through a realistic problem scenario, and students worked in small groups to identify learning issues, research relevant concepts, test possible solutions, and present and defend their conclusions, with the teacher facilitating rather than lecturing. The control group was taught the same topics over the same period using the conventional lecture method, in which the teacher explained concepts, solved illustrative examples, and assigned exercises. At the end of the six weeks, both groups were post-tested using the same instrument, with items re-arranged to reduce the possibility of recall.

3.6 Method of Data Analysis

Research questions were answered using mean and standard deviation of the achievement scores. The two null hypotheses were tested using Analysis of Covariance (ANCOVA), with pretest scores used as covariate to control for any pre-existing differences between the groups, at the 0.05 level of significance. All computations were performed using the Statistical Package for the Social Sciences (SPSS).

4.0 Results

4.1 Research Question 1

What is the difference between the mean achievement scores of students taught physics using problem-based learning and those taught using the conventional lecture method?

Table 2: Mean and Standard Deviation of Pretest and Post-test Achievement Scores

Group	N	Pretest Mean	Pretest SD	Post-test Mean	Post-test SD
Experimental (PBL)	64	24.60	5.12	61.30	8.47
Control (Lecture)	64	23.90	5.34	38.70	7.63

Table 2 shows that the experimental and control groups had comparable pretest mean scores of 24.60 and 23.90 respectively, indicating that the two groups were fairly equivalent in physics achievement before treatment. At post-test, however, the experimental group taught with problem-based learning recorded a considerably higher mean score of 61.30 compared with 38.70 for the control group taught by the conventional lecture method, a difference of 22.60 points, as illustrated in Figure 2.

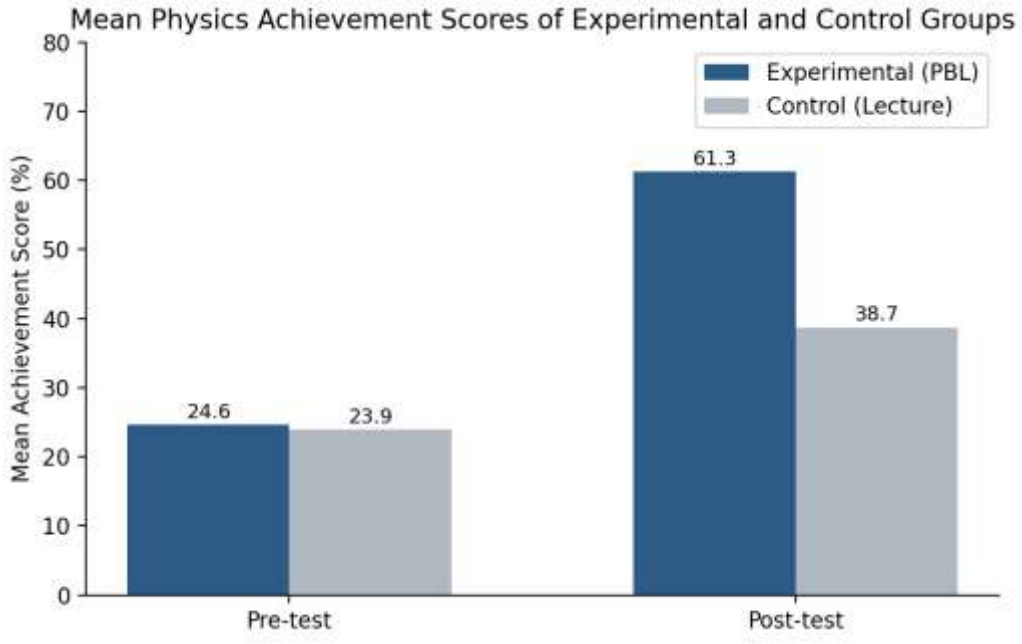


Figure 2: Mean Pretest and Post-test Achievement Scores of the Experimental and Control Groups

4.2 Research Question 2

What is the difference between the mean achievement scores of male and female students taught physics using problem-based learning?

Within the experimental group, male students recorded a post-test mean score of 62.0 while female students recorded a post-test mean score of 60.4, a difference of only 1.6 points, suggesting a minimal gender gap in achievement under problem-based learning, as shown in Figure 3.

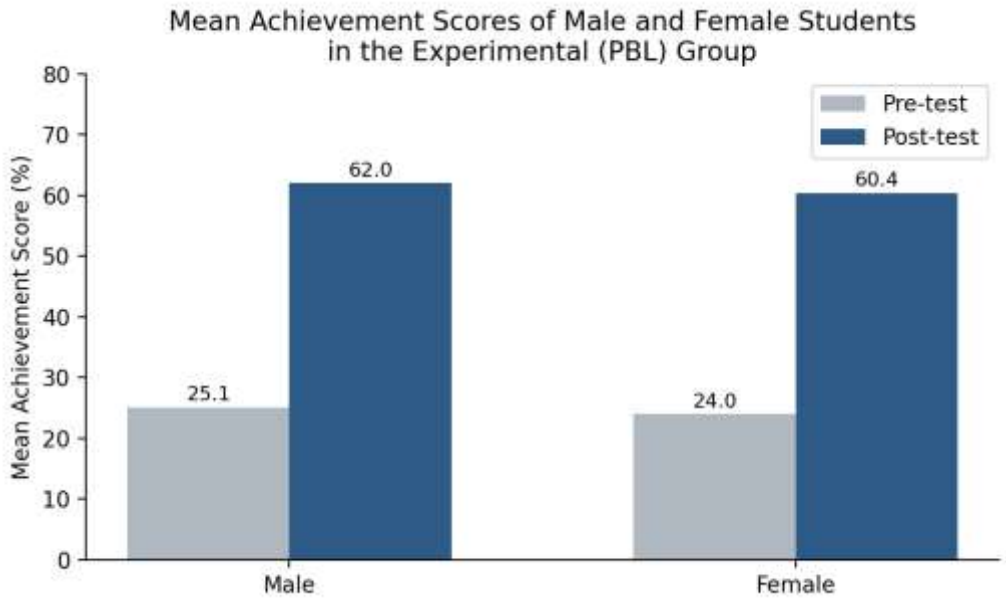


Figure 3: Mean Pretest and Post-test Achievement Scores of Male and Female Students in the Experimental Group

4.3 Hypothesis 1

HO1: There is no statistically significant difference between the mean post-test achievement scores of students taught physics using problem-based learning and those taught using the conventional lecture method.

Table 3: ANCOVA Summary of Post-test Achievement Scores by Group (Method)

Source	Type III SS	df	Mean Square	F	Sig.
Pretest (covariate)	612.40	1	612.40	10.86	.001
Group (Method)	5324.18	1	5324.18	94.38*	.000
Error	7047.05	125	56.38		
Total	512,904.00	128			

**Significant at $p < 0.05$*

As shown in Table 3, the ANCOVA result indicates a statistically significant effect of instructional method on students' post-test physics achievement scores, $F(1, 125) = 94.38$, $p = .000$, which is less than the 0.05 significance level, after controlling for pretest scores. The null hypothesis (HO1) is therefore rejected. This confirms that students taught physics using problem-based learning achieved significantly higher scores than those taught using the conventional lecture method.

4.4 Hypothesis 2

HO2: There is no statistically significant difference between the mean post-test achievement scores of male and female students taught physics using problem-based learning.

Table 4: ANCOVA Summary of Post-test Achievement Scores by Gender (Experimental Group Only)

Source	Type III SS	df	Mean Square	F	Sig.
Pretest (covariate)	58.21	1	58.21	0.94	.336
Gender	76.53	1	76.53	1.24	.270
Error	3762.88	61	61.69		
Total	246,528.00	64			

Not significant at $p > 0.05$

As shown in Table 4, the ANCOVA result indicates no statistically significant effect of gender on the post-test physics achievement scores of students in the experimental group, $F(1, 61) = 1.24$, $p = .270$, which is greater than the 0.05 significance level. The null hypothesis (HO2) is therefore retained, indicating that male and female students benefited comparably from the problem-based learning intervention.

5.0 Discussion of Findings

The finding that students taught physics using problem-based learning achieved significantly higher post-test scores than those taught using the conventional lecture method is consistent with constructivist theory, which holds that learners develop deeper and more durable understanding when they actively construct knowledge through engagement with realistic problems rather than passively receiving transmitted information (Dewey, 1938; Vygotsky, 1978). The result also aligns with Enyeneokpon (2012), who reported that pre-service teachers exposed to problem-based learning significantly outperformed those taught by the conventional lecture method in physics achievement, as well as with the broader pattern in the Nigerian literature showing that activity-based and problem-solving strategies consistently produce stronger achievement outcomes than lecture-based instruction (Akinbobola & Afolabi, 2009).

A plausible explanation for this outcome is that the problem-based learning cycle compels students to grapple with the practical implications of physics concepts before they are formally taught the underlying theory, which appears to promote more meaningful encoding of information than a sequence in which the theory is presented first and application is treated as an afterthought. The collaborative, small-group structure of PBL may also have contributed to the observed gains by allowing students to clarify misconceptions through peer discussion and to receive more immediate, targeted feedback than is typically possible in a lecture-format classroom.

The finding of no statistically significant difference between male and female students' achievement within the problem-based learning group suggests that the strategy created a comparably supportive learning environment for both sexes. This is consistent with reports that once students are exposed to the same student-centred, activity-based strategy, gender-related achievement gaps that are sometimes observed under conventional instruction tend to narrow or disappear (Akinbobola, 2009). This result reinforces the argument that observed gender differences in physics achievement in Nigerian classrooms may be more a function of instructional method and unequal opportunities for active participation than of any inherent difference in ability between male and female learners.

6.0 Conclusion

This study set out to determine the effect of problem-based learning on the physics achievement of senior secondary school students in Nigeria and to examine whether that effect is moderated by gender. The findings showed that students taught using problem-based learning achieved significantly higher scores than those taught using the conventional lecture method, and that the achievement gains associated with problem-based learning were not significantly different between male and female students. It is therefore concluded that problem-based learning is a more effective strategy than the conventional lecture method for improving senior secondary school students' achievement in physics, and that it offers a gender-equitable pathway to improved performance in the subject.

7.0 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Physics teachers should be trained, through pre-service and in-service professional development programmes, in the design and facilitation of problem-based learning lessons, including how to construct authentic, curriculum-aligned problem scenarios.
2. Curriculum planning authorities and school administrators should provide the instructional time, resource materials, and manageable class sizes that problem-based learning requires, since the strategy is more time- and resource-intensive than the conventional lecture method.
3. Physics textbooks and instructional materials developed for the senior secondary curriculum should incorporate realistic, ill-structured problems that teachers can adapt for problem-based lessons, rather than presenting content solely as ready-made theory followed by exercises.
4. Given the gender-equitable outcome observed in this study, teachers and policy makers should consider problem-based learning as a strategy for narrowing gender-related achievement gaps in physics and other science subjects.
5. Further studies should be conducted across a wider range of schools, physics topics, and geographical zones, using larger and, where feasible, randomly assigned samples, to strengthen the generalizability of these findings.

8.0 Limitations of the Study

This study was limited by its use of a quasi-experimental design with intact classes rather than full random assignment of individual students, which, despite the statistical control provided by ANCOVA, cannot completely rule out the influence of pre-existing group differences. The study was also restricted to two schools and to selected mechanics topics, and the six-week treatment period, while sufficient to demonstrate an effect, was not long enough to assess the long-term retention of the achievement gains recorded. Future researchers are encouraged to address these limitations through longitudinal designs covering a broader range of physics topics and school contexts.

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