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Effect of Problem-based Learning Strategy on Senior Secondary Two Students' Achievement in Geometry in Bichi, Kano State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

This study focused on investigating the effect of Problem-Based Learning (PBL) strategy on Senior Secondary Two (SS2) students' achievement in geometry in Bichi, Kano State, Nigeria. The study adopted a quasi-experimental design with pretest-posttest control group. A population of 256 SS2 students and a sample of 60 SS2 students from two secondary schools participated in the study. The treatment group was exposed to PBL for a period of eight weeks totaling to 20 hours, while the control group received the lecture teaching method. The research instrument used was Geometry Achievement Test (GAT). The data were analyzed with the Analysis of Covariance (ANCOVA) statistic at 0.05 level of significance. The findings revealed that there

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was a significant difference in the achievement of experimental group when compared with control group. It was concluded that problem-based learning is effective in the teaching and learning of geometry. It was recommended that teachers of Senior Secondary Two classes should adopt problem-based learning strategy in the teaching and learning of Geometry.

Keywords: Problem-based learning; mathematics student; achievement and geometry.

1 Introduction

Achievement in mathematics can be defined as the competency shown by the student [1]. Its measure is the score on an achievement test in mathematics. The key to success in many professions is dependent on achievement in mathematics as mathematics is seen as an essential part of academic achievement in the modern era. Mathematics achievement also deals with students' scores in either teacher-made test or standardized test administered by examining bodies. Achievement is useful, especially in deciding whether a student has passed or failed mathematics after being tested. The poor achievement in mathematics and geometry in particular has been a source of worry to stakeholders like parents, principals, school administrators, researchers and curriculum planners. For instance, parents are worried because their children cannot secure admission into higher institutions without a credit pass in mathematics. Principals are not encouraged by the poor achievement because it would affect enrolment of students into the schools.

Geometry is a branch of mathematics that features in the Senior Secondary Certificate Examination (SSCE) in mathematics on a yearly basis. Geometry deals with the properties, measurement and relations of points, lines, angles, surfaces and shapes. The shapes could either be two-dimensional such as rectangles, squares, triangles, rhombuses, circles, kites, and trapezium or three-dimensional such as cubes, cuboids, cylinders, spheres, pyramid and cone. Some of these shapes are used by engineers in construction of bridges, houses, dams, tunnels and highway systems. Thus geometry plays an important role in construction. Besides, it is fundamental in learning school subjects such as Physics, Chemistry, Fine and Applied Arts where for example it is applied in calculation of simple harmonic motion, chemical bonding and cloth design.

Questions in geometry have been a major problem to senior school students in Nigeria. In Nigeria, a significant portion of the test items in external examinations consist of geometry questions. The WAEC mathematics exams for the years 2021 and 2022 clearly demonstrate this. There are 75% and 58%, respectively, of geometry-related problems in the objective/essay section of the questions for the years 2021 and 2022. This indicates that 75% of questions in 2021 and 58% of questions in 2022 were difficult for students to answer. The majority of candidates would not be able to pass mathematics with a credit, making it impossible for them to get into Nigeria's higher education institutions if the trend is not stopped. This is evident with the WAEC Chief Examiners' reports for a time span of twelve years (2011-2022) [2] which consistently point at geometry as the aspect of mathematics that students experience the greatest difficulty. The reports within the time span revealed that as a result of the difficulty involved in geometry, majority of students avoided geometry questions (WAEC Chief Examiners Reports, 2011, 2015 & 2019), obtained poor results after attempting the questions [2] and demonstrated poor knowledge of its application (WAEC Chief Examiners Reports, 2013-2019). Moreover, WAEC Chief Examiners report from 2011-2022 in Nigeria shows the analysis of students' achievement. According to the reports, some areas of the syllabus that were poorly attempted by the candidates include geometry and representation of information in diagrams. In 2021, for instance, the report indicated that students exhibited weakness in solving problems in geometry. Furthermore in 2022, the report showed that candidates were unable to solve problems on geometry, cyclic quadrilaterals, circle theorems, angle of elevation and depression. The area of geometry was like a recurring decimal which was poorly attempted by the candidates in majority of the years examined. The analysis also showed that questions on geometry appear in both the core and elective parts of the questions set by examination bodies and if students continues to show weakness in the aspect of geometry it will affect the final score which they will get at the end. Consequently only few students will obtain a credit pass in mathematics and will not be qualified to gain admission into tertiary institutions. In Nigeria, higher education admission seekers are expected to get credit passes in five subjects relevant to their chosen courses of study, including mathematics. The WAEC Chief Examiners report also revealed that in 2011, 40.35% of the candidates obtained a credit pass in Mathematics while 59.65% had no credit in Mathematics. Furthermore, in 2013, the analysis revealed that 41.44% of the candidates passed the subject at credit level,

31.30% in 2014, 34.18% in 2015, 38.68% in 2016, 40.78% in 2017, 50.05% in 2018, 35.82% in 2019 and 34.75% in 2020. In 2021 and 2022 there was improvement in the percentage pass of 81.70% and 76.36% respectively but still geometry question in the core part of the question was reported as one aspect of students weakness. Based on this, it is evident that students' achievement in mathematics is low given that a large number of candidates did not obtain credit in mathematics. Except this problem is mitigated it would be difficult for students to obtain good grades in mathematics. Students need to improve their achievement in geometry which will also help them to achieve good grades in mathematics in both internal and external examinations.

Several causes have been identified by mathematics educators and researchers for poor achievement of students in mathematics and geometry in particular. Suleiman and Hammed [3], posited that "non implementation and utilization of research findings by mathematics teachers, ineffective mathematics curriculum, students negative attitudes towards mathematics, poor self-concept and methods employed by teachers are responsible for students' poor achievement in mathematics and geometry in particular". Furthermore, Hassidov (2019) and Isack [4] revealed that "teaching method employed by teachers is a factor affecting students' achievement in mathematics. Teachers are the most important single determinant of what takes place in the classroom. This is so because teachers are the originators of strategies used in teaching mathematics in the classroom. Teacher's failure to use appropriate and stimulating teaching strategies could be responsible for students' poor achievement in mathematics. This point to the fact that good teaching helps students to learn effectively but bad teaching would lead to poor learning and achievement".

Research evidences [5,6], suggested that mathematics instruction today, still follows the traditional or conventional method of acquisition of knowledge where the teacher controls the instructional process. This method involves lecturing about mathematical concepts. It is a situation where a teacher uses his knowledge to explain about the subject or concept being learned while the students pay attention. This method of instruction makes students passive instead of active learners. The process also involves simple regurgitation of facts. This method of teaching has been identified as being ineffective as it contributes to poor achievement of students in mathematics (Paris, 2014). Hence, there is need for teachers to use modern method of teaching such as Problem-Based Learning (PBL) strategy.

"The PBL is a classroom strategy that organizes mathematics instruction around problem solving activities and affords students more opportunities to discover important concepts" [7]. PBL is a method of teaching where the teacher helps students to focus on solving problems within a real-life context. This method is based on the ideals of constructivism and student-centred learning. Prem [8] opined that "the method is used to bridge the gap between student's procedural fluency and conceptual understanding. Concepts are clearly understood by the students instead of memorizing the procedure to a particular problem. Study in the Problem-Based Learning supports the cognitive-learning theory of some constructivists Psychologists like Vygotsky who believes that impact of group reinforces and rewards learning. He further believed that individuals should construct knowledge and learning process based on previous experience. Studies in the Problem- Based Learning showed positive effect on students' learning". For instance, the finding of Padmavathy and Mareesh [9] showed that "students in PBL classroom achieved better than their counterpart in conventional classroom and problem-based learning had effects on the teaching of mathematics and it improved the ability of students to use mathematical concept in real life". Result of the study conducted by Ogunsola, Adelana and Adewale [10] revealed that "problem-based learning approach enhanced students' academic performance in Mathematics and it also revealed that gender has no main effect on the academic performance of students". In a similar study, Bedemo [11] carried out "study on the effect of problem-based learning on students' achievement and attitude in physics. The result of the study showed that students developed positive attitude towards problem-based learning, their academic achievement and attitude towards mechanics were positively correlated".

Studies on the problem-based learning also showed mixed results. The result of the study conducted by Pinter [12] on "the effects of problem-based learning on mathematics anxiety, self-efficacy and mathematics achievement of elementary students showed that the implementation of the problem-based learning approach does have a significant effect on students' mathematics anxiety, self-efficacy and mathematics achievement". Crowley [13] could not find any evidence to maintain the superiority of Problem-based learning over traditional method of teaching. The studies reviewed in problem-based learning did not identify a single direction of mathematics achievement of gender (male and female students) as a moderating variable despite strong indication by Ezeudu and Obi [14] on personality indicated that male students on the average are more assertive,

active and intelligent especially in topics like geometry while female students are more extroverted and perform better in languages.

Despite the relevance of problem-based learning, there is paucity of empirical studies on its effects on senior school students' achievement in geometry in Bichi Educational Zone of Kano State, Nigeria. It is important to study the effects of problem-based learning on students' achievement in mathematics in general and geometry in particular. This study, therefore seeks to find out the effects of problem-based learning strategy on senior school students' achievement in geometry. The study also seeks to determine the extent to which the use of PBL strategy affects the students' achievement in geometry based on gender.

1.1 Purpose of the study

The purpose of this study is to determine the effect of problem-based learning strategy on senior secondary two students' achievement in geometry in Bichi, Kano State, Nigeria. The specific objectives of the study are to:

1. Determine the difference between the achievement mean scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method.
2. Determine the difference between the achievement mean scores of SS2 male and female students taught geometry with problem-based learning strategy.

1.2 Research questions

The following research questions guided the study:

1. What is the difference between the achievement mean scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method?
2. What is the difference between the achievement mean scores of SS2 male and female students taught geometry with problem-based learning strategy?

1.3 Hypotheses

The following hypotheses were tested at 0.05 level of significant.

1. There is no significant difference between the achievements mean scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method.
2. There is no significant difference between the achievement mean scores of SS2 male and female students taught geometry with problem-based learning strategy.

2 Methods

2.1 Design of the Study

The study employed the non-randomized pre-test, post-test quasi experimental research design. According to Awotunde and Ugodulunwa (2004) quasi experimental research design is an empirical interventional study used to estimate the causal impact of an intervention on target population without random assignment. The choice of the quasi experimental research design for the study was ideal because there was no randomization of participants for the experimental and control groups.

2.2 Population of the Study

The population for the study consisted of 256 SS2 students in public secondary schools in Bichi Educational Zone, Kano. The choice of SS2 students was because geometry is treated in their curriculum.

2.3 Sample and sampling technique

The sample for the study was drawn from two single sex schools (male and female). The sample consists of 60 SS2 mathematics students comprising 28 males and 32 females. The experimental group had 32 students (15 males and 17 females) while the control group had 28 students (13 males and 15 females).

The multistage sampling technique was used to select a representative sample based on the population of public schools in the study area. The male and female schools used were randomly selected using balloting method. Simple random sampling technique was used to categorise the classes into experimental and control groups.

2.4 Instrument for data collection

The instrument used for data collection was Geometry Achievement Test (GAT). The GAT consisted of three sections: A, B, and C. Section A solicited for the bio-data of the students, such as name of school, student's code and gender. Section B consisted of 50 objective questions with four options, A, B, C and D for each question in which students was instructed to select the correct option that best answers the question. Section C consisted of four essay questions in which students were instructed to answer all.

2.5 Validation of the instrument

The content validity of Geometry Achievement Test (GAT) was carried out by three experts; two from Mathematics Education unit and one from Research Measurement and Evaluation unit, all from the faculty of Education, University of Jos. The instrument evaluation guide filled by all experts showed the appropriateness of the items of the instruments in terms of comprehensiveness, adequacy, suitability and relevance to the study. After the expert judgments, some of the items were modified based on their comments to arrive at the final draft used for the data collection.

2.6 Reliability of the instrument

The reliability of the objective test was established using Kuder-Richardson (KR) Formula 21. The KR-21 formula is used to measure internal consistency of a test especially when there is only a single administration of the test and items are dichotomously (0 or 1) scored. Result showed that the correlation coefficient of the objective part of GAT is 0.794. This reliability value (0.794) is high enough and it equally lends credence to its high content validity.

For the essay part of GAT, the internal consistency of the reliability of essay part was established using Cronbach alpha method. The use of the Cronbach alpha method was because essay test items are continuously and not dichotomously expressed. The procedure yielded a reliability coefficient of 0.759. This reliability value (0.759) is equally high enough and also lends credence to the content validity of the essay test.

2.7 Method of data collection

The experiment was conducted during the normal school periods following the school timetable which lasted for 8 weeks using the regular mathematics teacher who was trained for the proper implementation of the research procedure. The researchers prepared eight lesson notes in chord property, circle theorems, bearings and angles of elevation and depression for the control and experimental group. The Problem Based Learning strategy in geometry was used for treatment group whereas the lecture method was used for the control group. Before the experiment, subjects in the treatment and control groups were given the pre-test. At the end of the experiment, the researchers with the help of the class mathematics teacher administered the post-test to the subjects in the two groups. The pre-test and post-test were the same except in the re-organization of the questions. The scripts were marked and recorded using the same marking guide.

2.8 Method of data analysis

Research questions were answered using mean and standard deviation while the hypotheses were tested using Analysis of Covariance (ANCOVA) at 0.05 level of significance.

3 Results

3.1 Research question one

What is the difference between the achievement mean scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method?

Table 1. Mean achievement scores of students taught geometry with problem-based learning strategy and those taught with the lecture method

Teaching Method	N	Pre-test		Post-test		Mean Gains
		Mean	SD	Mean	SD	
Problem-Based Learning	32	42.21	8.50	63.34	12.31	21.13
Lecture Method	28	42.74	8.54	50.89	12.69	8.15
Mean differences		**0.53**		**12.45**		**12.98**

N= 60

Result in Table 1 indicates that the problem-based learning strategy group had a mean Pre-test Score of 42.21, and standard deviation of 8.50; a mean post-test score of 63.34 and a standard deviation of 12.31 with a mean gain in score of 21.13. Similarly, the lecture method group had a mean pre-test score of 42.74 and a standard deviation of 8.54, a mean post-test score of 50.89 and a standard deviation of 12.69. It could be seen that the standard deviation of the lecture method group is higher both in pre-test and post-test meaning the scores are widely spread. The mean gain in score of the lecture method group is 8.15. Table 1 equally shows the mean differences at the pre-test and post-test which are 0.53 (in favour of the lecture method group) and 12.45 (in favour of the problem based group). The higher mean gain in score of students taught with problem-based learning strategy (21.13) indicated that students taught with problem-based learning strategy achieved more than students taught with lecture method. This means that the problem-based group did better in the post-test than the lecture method group. On the whole, the group means gain in score difference is 12.98 and it is in favour of the problem-based group. Thus, problem-based learning strategy has relative effect on students' achievement in geometry with a group mean difference of 12.98.

3.2 Research question two

What is the difference between the achievement mean scores of SS2 male and female students taught geometry with problem-based learning strategy?

Table 2. Mean difference between achievement mean scores of ss2 male and female students taught geometry with problem-based learning strategy

Groups Method	N	Pretest		Post-test		Mean gain
		Mean	SD	Mean	SD	
Male	15	43.38	8.59	64.93	11.14	21.55
Female	17	41.26	8.42	61.94	13.44	20.68
Mean Difference		**2.12**		**2.99**		**0.87**

N=32

Result presented in Table 2 showed that in the problem-based learning strategy group, the males had a mean pre-test score of 43.38 with a standard deviation of 8.59, a mean post test score of 64.93 with standard deviation of 11.14 and a mean gain in score of 21.55. The females on the other hand had a mean pre-test score of 41.26

with a standard deviation of 8.42, a post-test score of 61.94 with a standard deviation of 13.44, and a mean gain in score of 20.68. At the pre-test level, it is evident that the standard deviation of male students is higher than that of females meaning male students scores are more spread than those of females while at the post-test the reverse is the case. Also, the mean difference between the male and female pre-test scores is 2.12 in favour of the males, while the mean difference between the male and female post-test scores is 2.99 in favour of the males. The mean difference between the male and female gain score is 0.87 in favour of the males. It could be concluded that the male students achieved higher than the females in both the pre-test and post-test.

3.3 Hypothesis one

There is no significant difference between the achievements mean scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method.

Table 3. Summary of analysis of covariance (ANCOVA) for the mean achievement score of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method

Variation Source	Sum of Squares	Df	Mean Sum of Squares	F-Ratio	p-value	Decision
Corrected Model	8511.795[a]	2	4255.898	85.144	.000	
Intercept	1329.660	1	1329.660	26.601	.000	
Pretest	6196.759	1	6196.759	123.973	.000	**S**
Group	1804.852	1	1804.852	36.108	.000	
Error	2849.138	57	49.985			
Total	209966.000	60				
Corrected Total	11360.933	59				

R Squared = .749 (Adjusted R Squared = .740)
S= Significant

Result of data analysis presented in Table 3 shows that the probability value associated with the calculated value of F (36.108) for the mean achievement scores of SS2 students taught geometry with problem-based learning strategy and those taught with the lecture method is 0.000. Since this value (0.000) is less than the 0.05 alpha when tested at 0.05 level of significance, the null hypothesis is rejected. Hence, the study concludes therefore that there is a significant difference between the achievement mean scores of SS2 students taught Geometry with problem-based learning strategy and those taught with the lecture method.

3.4 Hypothesis two

There is no significant difference between the achievement mean scores of SS2 male and female students taught geometry with problem-based learning strategy.

Table 4. Summary of analysis of covariance (ANCOVA) for the mean achievement scores of male and female students taught geometry with problem-based learning strategy

Source of variation	Sum of Squares	Df	Mean Square	F-Ratio	P-value	Decision
Corrected Model	2893.833[a]	2	1446.916	23.242	.000	
Intercept	1791.687	1	1791.687	28.780	.000	
Pretest	2822.489	1	2822.489	45.338	.000	
Group	38.076	1	38.076	.612	.441	**NS**
Error	1805.386	29	62.255			
Total	133097.000	32				
Corrected Total	4699.219	31				

. R Squared = .616 (Adjusted R Squared = .589)
***NS** = Not Significant*

The analysis in Table 4 reveals the F- calculated value of (0.612) and p-value of 0.441. Since this p-value is greater than the 0.05 alpha when tested at 0.05 level of significance, the null hypothesis which states that there is

no significant difference between the achievements means scores of SS2 male and female students taught Geometry with problem-based learning strategy is thereby upheld. It implies that there is no significant difference between the achievements means scores of SS2 male and female students taught geometry with problem-based learning strategy.

4 Discussion

The findings from this study indicated that students taught geometry with problem-based learning strategy achieved more than students taught geometry with lecture method. The findings of this study is in agreement with the findings by Padmavathy and Mareesh [9] which showed that students in PBL classroom achieved better than their counterpart in conventional classroom and problem-based learning had effects on the teaching of mathematics and it improved the ability of students to use mathematical concept in real life. This is also in consonance with the findings of Ogunsola, Adelana and Adewale [10] who also showed that problem-based learning approach enhanced students' academic performance in Mathematics. The implication of this study is that mathematics teachers should go for the teaching method that will provide students with ability to interpret, reason, analyze and synthesize the mathematical problems.

Summary of data analysis also revealed that the achievement of the male students in geometry is higher than the female students in the experimental group but the test of significance revealed that the difference is not statistically significant.

5 Conclusion

Based on the findings of the result, there is a positive effect of problem- based learning strategy on students' achievement in learning geometry. Both male and female students performed equally well when exposed to problem-based learning strategy.

6 Recommendations

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

1. Mathematics teachers should teach the students using problem-based learning strategy so that teaching and learning of geometry will be student centred.
2. The Government in collaboration with curriculum planners should integrate problem-based learning in geometry topic.
3. Education managers should regularly organize seminars and workshops for training of teachers on problem-based learning strategy.

Competing Interests

Authors have declared that no competing interests exist.

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