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RESEARCH PAPER

Effect of Problem-Based Learning Approach on Students' Academic Performance in Senior Secondary Mathematics

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Abstract

Conventional teaching method alone cannot enhance the mathematical creativity and thinking skills needed in the 21st Century. Therefore, modern teaching methods are needed to facilitate students' problem-solving skills. This study examined the effect of the problem-based learning (PBL) approach on students' academic performance in senior secondary Mathematics. The pretest-posttest control, quasi-experimental design, was adopted in the study. An intact class of Senior Secondary School (II) Mathematics students (108) from two randomly Selected Senior Secondary schools in Akinyele Local Government Area, Oyo State, Nigeria, were used selected. Four null hypotheses were formulated and tested using Analysis of Covariance at the alpha level of 0.05. Results revealed that problem-based learning approach enhanced students' academic performance in Mathematics ($F1, 108= 7.130$; $p = (.009) < .05$). It also revealed that gender has no main effect on the academic performance of students ($F1, 108= .051$; $p = (.821) > .05$). In addition, there was no significant interaction effect of PBL and gender on students' academic performance in Mathematics ($F1, 108= .000$; $p = (.985) > .05$), and; there is a significant main effect of PBL on the quantitative ability of students ($F1, 108= 6.756$; $p = (.010) < .05$). It was recommended that stakeholders in education and the government need to train and retrain teachers on adopting the PBL approach in Mathematics classrooms to enhance students' academic performance.

Keywords: Problem-based learning (PBL); Students' academic performance; Mathematics; Quantitative ability; Gender

INTRODUCTION

Globally, attempts are being made by educators and other stakeholders in education to ensure that students learn without difficulty. These attempts are being made bearing in mind that poor performance by students can mar the expectations that educated citizens are the pride of any nation.

The history of education is full of efforts to make learning more active, effective, and productive. However, to date, some of the challenges to effective learning still persist (Adegbemile, 2011). An aspect of education that is so vital to the development and any nation is science education. Science, as it is generally believed, is the bedrock on which technological advancement is built. According to Usman (2010), science involves intellectual activities engaged in by humans to discover the natural world they live in. Therefore, it is an indispensable tool leveraged for advancement by both developed and developing nations of the world (Feynman, 2011). The aspect of science that is of concern in this study is Mathematics. Due to its central role in education, Mathematics has been said to be the mother of all sciences. In Nigeria, Mathematics is a compulsory subject that must be taken and passed at the primary and secondary school levels. Mathematics and its applications are part of daily life to make life better. Thus, the development of students' understanding of Mathematics and its applications is one of the objectives of Mathematics education. Moreover, the teaching and learning of Mathematics have become important now more than ever as science and technological developments and advancements keep increasing daily (Sahin, 2010).

Due to the importance attached to the knowledge of Mathematics and how such knowledge can aid the scientific and technological development of any nation, educators and other stakeholders in education have been clamouring for modern approaches to the teaching and learning of the subject. This is because as important as the subject is, it is still plagued by setbacks that still negatively impact students' academic performance. According to Abdullaha, Tarmizia, and Abub (2010), students taught the concepts of Mathematics using conventional or traditional are preoccupied with exercises, rules, and equations that need to be learned, but are of limited use in unfamiliar situations such as solving real-life problems. Some of the factors responsible for students' poor performance in Mathematics among secondary school students have been identified. Still, chief among these challenges are teachers' factors such as poor teaching methods and poor content knowledge. Others are lack of relevant and updated textbooks, lack of or poor Mathematics laboratory, poor motivation on the part of both teachers and students etc. Chief among the problems is the problem of poor teaching methods on which all others rest. Teachers' continued use of traditional or conventional approaches in teaching Mathematics has affected students negatively for a long time. The traditional or conventional teaching method is a strategy in which students passively absorbed what the teacher, who is standing at the front of the classroom, says to them. This approach has not been favoured by many and has been criticized for being lecture-based instruction and teacher-centred instructional methods (Zakaria & Iksan, 2007).

Modern methods of teaching have shifted from conventional methods, and Mathematics should not be left out. Students-centred learning which also affords them active participation in their learning processes in which the teacher is merely a facilitator of learning remains the focal point of contemporary Mathematics education. Hence, active learning involves learners taking responsibility for their learning; are given the opportunity to make decisions about various dimensions of their learning process and also to perform self-regulation. One modern teaching approach that has been shown to possess these qualities and which can be applied in teaching

Mathematics is problem-based learning (PBL) (Bouwma-Gearhart, Stewart, & Brown, 2009; Miller, Streveler, Yang, & Santiago, 2009).

Problem-based learning (PBL) was chiefly developed from Barrow's problem-based learning model. PBL was developed by Barrows for medical students at McMaster University in the early 1970s by creating scenarios where students could apply learned skills to a real-life problem-solving scenario (Tarmizia, Ahmad, & Bayat, 2010). PBL is an instructional method that fosters learning and also develops 21st-century competencies and skills in students through problem-solving and integration and application of knowledge in real-world settings (Bell, 2010; Capraro & Slough, 2013). Lee and Kwan (2014) posited that one of the constructivist approaches which disproved the use of conventional methods of teaching is the problem-based learning (PBL). This is because the PBL approach is an innovative, student-centered and self-directed approach method which affords students the opportunity to solve real-life problems in order to encourage learning (Shin & Azman, 2014). It is an approach that is often used to assist learners' to enhance interactions and higher-level thinking by using ill-structured problems that are highly relevant to a subject area and employ a student-centered approach. Typically, the problem is described as an ill-structured (or messy) problem, since it is open-ended and there is not solely one solution to the problem. In this approach, learners are encouraged to engage with problems and to seek the knowledge needed to develop a possible solution for the problem. Consequently, PBL is an instructional strategy that may effectively increase learners' motivation and retention of information as they actively use critical thinking skills to solve problems (Tarmizia et al., 2010). PBL is a student-centered teaching approach that enables students to become active participants in solving problems, answering questions, cooperating in learning, working in teams on problems or projects, and taking on more of the responsibility for learning (Ates & Eryilmaz, 2011). Also, the approach encourages learners to take the initiative for their own knowledge acquisition (Lee, Mann, & Frank, 2010).

Empirical reports on PBL, reported by Hsieh and Knight (2008) and Kuruganti, Needham, and Zundel (2012), revealed that PBL assists in bridging the gap between theory and practice which is in contrast to the conventional lecture-based approach. Also, the study of Fatade, Mogari, and Arigbabu (2013) reported significant differences between the mean achievements of students instructed using the PBL approach and the mean achievements of students taught using the conventional method. In addition, reports stated that students taught using the PBL approach performed better to the highly interactive mode through which students were challenged, through questions that engendered critical thinking on the assigned problems. This study also considers gender and quantitative ability as moderating variables reported as factors affecting performance in Mathematics. Omosewo (2012) reported no significant difference in the academic performance of male and female students in Mathematics. Male and female students need encouragement to make use of hands-on and heads-on senses. These skills are required in the problem-based learning approach. The male students taught using PBL did not significantly perform better than female students taught using the same method (Etiubon & Ugwu, 2016). This corroborates Omosewo (2012), who reported no significant difference in the academic performance of male and female students instructed using the PBL approach. The PBL approach also utilizes real-life learning problems as its main learning objectives (Cooper & Carver, 2012), hence, students are exposed to an ill-structured real-life problem to solve (Schmidt, 2012), thereby, increasing logical thing and enchaining learning. Aliyu (2017) examined the use of the PBL approach and reported significant improvement in the students' knowledge and organization. This study is among the first studies on PBL in the Nigerian context.

Quantitative ability is the ability of students to execute tasks related to the handling of numbers; it is students' ability to solve numerical and mathematical problems accurately and in less time (Adesanya, 2015). Quantitative ability is synonymous with numerical aptitude, mathematical ability, and figural ability, all of which are essential mathematical skills. According to Anazia (2019), quantitative and verbal skills come into play because candidates are expected to answer computational questions, as well as present answers in a logical and analytical manner. Also, candidates are expected to use appropriate terms, draw relationships between concepts, and interpret information/data clearly. Quantitative ability implies that students are able to separate concepts in its constituent parts (Eleje & Esomonu, 2018) and relate abstract concepts to various phenomena. Johnson, McClintock, and Hornbein (2017) observed that one part of quantitative reasoning is the process of quantification, which involves understanding that some attributes can be measured, finding an appropriate unit of measure, and understanding the relationship of the attributes and the unit. Quantitative reasoning is explained as the way the students analyze a situation and incorporate it into a quantitative structure which is set up by a network of quantities and relationships between these quantities. It is these relationships between quantities that is the most important content in quantitative reasoning (Nunes, Bryant, Evans, Bell, & Barros, 2012). Teaching children how to include the inversion principle. Unodiaku (2014) reported that quantitative skills are important at initiating and maintaining dominance in developed nations. High-level quantitative abilities in Mathematics assist students who are scientifically and mathematically sound to take up careers that will bring about advanced scientific and technological development. Also, Ke and Grabowski (2007) reported that modern approaches to teaching and learning Mathematics have a significant effect on students' quantitative abilities. Hackenberg, and Lee (2016) reported that quantitative reasoning is a foundation for students to be able to develop other kinds of reasoning, such as algebraic reasoning.

Several studies in Nigeria have attempted to study the effect of PBL on students' academic performance in Mathematics. The need to ensure that mathematics education is given to students using the appropriate method while also instilling problem-solving skills in students is the gap that the study attempted to fill. Specifically, the study determined the main effect of the problem-based learning (PBL) approach on the academic performance of senior secondary school students in Mathematics. It also determined the main effect of gender on senior secondary students' academic performance in Mathematics. In addition, it determined the interaction effect of the problem-based learning (PBL) approach and gender on senior secondary students' academic performance in Mathematics. Finally, the study examined the main effect of the PBL approach on students' quantitative abilities, in Akinyele Local Government Area, Oyo State, Nigeria.

Statement of the Problem

The belief that Mathematics is an uninteresting and hard subject to learn and pass persists. Because of this, students are always afraid, worried and anxious to learn mathematics and, therefore, mostly negatively affect the subject. Added to this wrong notion about Mathematics is the challenge of ineffective teaching methods used by teachers. While several factors affect the teaching and learning of Mathematics, chief amongst them is the approach or method used by teachers in delivering the contents of mathematics to their students. Previous studies in Mathematics show that the conventional teaching method is gaining less relevance in the 21st Century classrooms. Because of this, modern approaches, of which PBL one and is fast gaining relevance due to its

ability to instill problem-solving skills in students is one. Based on empirical reports, the Mathematician of the 21st Century cannot be raised using the conventional method. Hence, modern approaches have to be embraced. Hence, this study attempted to fill this gap in addition to ensuring that Mathematics education is given to students using the right and modern approach while also instilling problem-solving skills required of the 21st Century workplace in students in Akinyele Local Government Area of Ibadan, Oyo State, Nigeria. It is because of this that this investigated the effect of problem-based learning approach on students' academic performance in senior secondary schools Mathematics in Akinyele Local Government Area of Oyo State.

Hypotheses

The study tested the following hypotheses:

Ho1: There is no significant main effect of problem-based learning (PBL) approach on senior secondary students' academic performance in Mathematics.

Ho2: There is no significant main effect of gender on senior secondary students' academic performance in Mathematics.

Ho3: There is no significant interaction effect of problem-based learning (PBL) approach and gender on senior secondary students' academic performance in Mathematics.

Ho4: There is no significant main effect of problem-based learning (PBL) approach on students' quantitative ability.

METHODOLOGY

The study adopted the pretest-posttest control group quasi-experimental design. The population of the study comprised all Senior Secondary II Mathematics students in Akinyele Local Government Area, Oyo State. The study sample was composed of one hundred and eight (108) intact classes of SS II Mathematics students from two randomly selected senior secondary schools in Akinyele LGA. The two senior secondary schools were selected using the simple random sampling technique. Treatment conditions were assigned to the schools using the Balloting method.

Three categories of instruments were used for data collection in the study and, they were titled "Teacher's Guide on Problem-Based Learning Approach (TGPBLA)", "Teacher's Guide on Conventional Teaching Method (TGCTM), and "Mathematics Achievement Test (MAT)". The Teacher's Guide on the Problem-Based Learning Approach (TGPBLA) was self-developed by the researchers and served as a lesson note which guided the teacher in facilitating the experimental group. The Teacher's Guide on Conventional Teaching Method (TGCTM) was also self-developed and served as the lesson note used in teaching the control. The face and content validity of the TGPBLA and TGCTM was ensured by the researchers some experienced Mathematics experts. Their constructive suggestions were incorporated into the final instruments. The Mathematics Achievement Test (MAT) was also self-developed by the researchers. The questions in MAT were based on the topic taught during the experiment. It contained thirty (30) items with multi-choice responses. The instrument of the MAT was carried out using the test-retest method. Twenty (20) of the instrument were administered twice to selected students from another school who were not part of the initial sample.

The data collected were collated were and analyzed using the Cronbach Alpha reliability coefficient and the reliability coefficient yielded was 0.85, which showed that the instrument was reliable. To experiment with the selected schools, relevant permissions were obtained from the heads of the selected schools. The Mathematics teachers were also contacted and briefed before the conduct of the study to solicit their cooperation during the exercise.

Pre-test Stage – In this stage, Mathematics Achievement Assessment Test (MAT) was administered on both experimental and control groups to determine their entry knowledge on the topic selected for the experiment. In each school, the exercise lasted for 1 hour.

i. Procedure for the Application of Treatment (PBL) on the Experimental Group – In this stage, the students were assigned problems to solve. They were given a week to solve the problems. They thereafter presented their findings to the facilitator (the teacher). The Teacher's Guide on the Problem-Based Learning Approach (TGPBLA) guided the conduct of the facilitator throughout this stage. The whole exercise lasted for three weeks.
ii. Procedure for the Application of Conventional Teaching on the Control Group – In this group students were taught the selected Mathematics topic using the conventional teaching method. In this stage, the Teacher's Guide on Convectional Teaching Method (TGCTM) served as a guide to the teacher. The whole exercise teaching lasted for three weeks.

Post-test Stage – In this stage, the Mathematics Achievement Test (MAT) was administered to both the experimental and control groups to get their performances after the exercise. The data collected were analyzed using ANCOVA at a 0.05 level of significance.

RESULTS AND DISCUSSION

HO_1: There is no significant main effect of problem-based learning (PBL) approach on senior secondary students' academic performance in Mathematics.

Table 1. Tests of Between- Subjects Effects (Treatment).

Source	Type III Sum of Squares	df	Mean Square	F	Significant
Corrected Model	74.747[a]	4	18.687	1.945	.108
Intercept	1319.840	1	1319.840	137.406	.000
Pretest	11.563	1	11.563	1.204	.275
Treatment	68.485	1	68.485	7.130	.009
Academic Performance	.300	1	.003	.000	.050
Error	989.355	103	9.605		
Total	39183.000	108			
Corrected Total	1064.102	107			

a.R^2= .070; R^2_{adj}= .034

Table 1 shows the result of the test of hypothesis one, which states that there is no significant main effect of PBL strategy on senior secondary students' academic performance in Mathematics. The results of analysis of covariance (ANCOVA) ($F_{1, 108}$= 7.130; p = (.009) < .05) as shown in the Table, show that there is a significant main effect of treatment (problem-based learning (PBL) approach) on senior secondary students' academic performance in Mathematics. This shows that

treatment is effective for the teaching and learning of Mathematics in senior secondary schools. This implies that problem-based learning approach is effective for improving students' academic performance in Mathematics.

HO_2: There is no significant main effect of gender on senior secondary students' academic performance in Mathematics.

Table 2. Tests of Between- Subjects Effects (Gender).

Source	Type III Sum of Squares	df	Mean Square	F	Significant
Corrected Model	74.747[a]	4	18.687	1.945	.108
Intercept	1319.840	1	1319.840	137.406	.000
Pretest	11.563	1	11.563	1.204	.275
Treatment	68.485	1	68.485	7.130	.009
Gender	.493	1	.493	.051	.821
Error	989.355	103	9.605		
Total	39183.000	108			
Corrected Total	1064.102	107			

a.R^2= .070; R^2_{adj}= .034

Table 2 shows the result of hypothesis two, which states that there is no significant main effect of gender on senior secondary students' academic performance in Mathematics. The results of analysis of covariance (ANCOVA) ($F_{1, 108}$= .051; p = (.821) > .05) in the Table, reveals that there is no significant main effect of gender on senior secondary students' academic performance in Mathematics. The result shows that gender is not a factor in students' academic performance in Mathematics; hence, it does not significantly affect performance in Mathematics in senior secondary schools. Based on this finding, the stated null hypothesis is not rejected. The result implies that gender does not significantly affect students' academic performance in Mathematics in senior secondary schools.

HO_3: There is no significant interaction effect of the problem-based learning (PBL) approach and gender on senior secondary students' academic performance in Mathematics.

Table 3. Tests of Between- Subjects Effects (Treatment * Gender).

Source	Type III Sum of Squares	df	Mean Square	F	Significant
Corrected Model	74.747[a]	4	18.687	1.945	.108
Intercept	1319.840	1	1319.840	137.406	.000
Pretest	11.563	1	11.563	1.204	.275
Treatment	68.485	1	68.485	7.130	.009
Gender	.493	1	.493	.051	.821
Treatment * Gender	.003	1	.003	.000	.985
Error	989.355	103	9.605		
Total	39183.000	108			
Corrected Total	1064.102	107			

a.R^2= .070; R^2_{adj}= .034

In Table 3 above, the result shows the analysis of covariance (ANCOVA) ($F_{1, 108}$= .000; p = (.985) > .05), which reveals that there is no significant interaction effect of PBL strategy and gender on senior secondary students' academic performance in Mathematics. This implies that the treatment (problem-based learning approach) and gender combined did not significantly affect students' academic performance in Mathematics.

HO_4: There is no significant main effect of the problem-based learning (PBL) approach on students' quantitative ability.

Table 4. Tests of Between- Subjects Effects (Quantitative Ability).

Source	Type III Sum of Squares	df	Mean Square	F	Significant
Corrected Model	74.747[a]	4	18.687	1.945	.108
Intercept	1319.840	1	1319.840	137.406	.000
Pretest	11.563	1	11.563	1.204	.275
Treatment	68.485	1	68.485	7.130	.009
Quantitative Ability	467.353	1	467.353	1.133	.000
Error	989.355	103	9.605		
Total	39183.000	108			
Corrected Total	1064.102	107			

a.R^2= .074; R^2_{adj}= .035

In Table 4 above, the result of the analysis of covariance (ANCOVA) ($F_{1, 108}$= 1.133; p = (.000) < .05), shows that there is a significant main effect of problem-based learning (PBL) approach on students' quantitative abilities in Mathematics. Based on this result, the stated null hypothesis was rejected. This shows that the treatment (problem-based learning (PBL) approach) influences students' quantitative abilities. The result implies that the treatment positively predicts students' quantitative ability in Mathematics in senior secondary schools.

The first hypothesis of the study states that there is no significant main effect of the problem-based learning (PBL) approach on senior secondary students' academic performance in Mathematics. However, because of the result of the analysis (F1, 108= 7.130; p = (.009) < .05), the hypothesis was not accepted. This shows that the problem-based learning (PBL) approach (treatment) is practically effective for teaching and learning Mathematics in senior secondary schools. The finding supports Hsieh and Knight (2008) and Kuruganti et al. (2012) that PBL assists in bridging the gap between theory and practice that contrast to the conventional lecture-based approach. Also, the study of Fatade et al. (2013) reported significant differences between the mean achievements of students instructed using the PBL approach and the mean achievements of students taught using the conventional method. In addition, it has been reported that students taught using the PBL approach performed better to the highly interactive mode through which students were challenged through questions that engendered critical thinking on the assigned problems. Etiubon and Ugwu (2016) reported that PBL in Mathematics facilitated students' understanding of the concept of Mathematics which they attached to the highly interactive stimulating way that questions were used to challenge students' critical thinking on assigned tasks. According to them, PBL makes learners take responsibility for their learning and become independent learners who can continue to learn in their whole lifetime.

Hypothesis two of the study states that there is no significant main effect of gender on senior secondary students' academic performance in Mathematics. This hypothesis was not rejected because the result shows (F1, 108= .051; p = (.821) > .05), implying that there is no significant main effect of gender on senior secondary students' academic performance in Mathematics. The result means that gender does not in any way predict students' academic performance in Mathematics. This supports Omosewo (2012) who reported no significant difference in the academic performance of male and female students in Mathematics. Male and female students need encouragement to make use of hands-on and heads-on senses as required by the problem-based learning approach. Also, male students taught using PBL did not significantly perform better than female students who were taught using the same method (Etiubon & Ugwu, 2016).

The third hypothesis of the study states that there is no significant interaction effect of the problem-based learning (PBL) approach and gender on senior secondary students' academic performance in Mathematics. Given the finding from the analysis (F1, 108= .000; p = (.985) > .05), the hypothesis was not rejected but accepted to be true. Therefore, it was concluded that with interaction effect, the problem-based learning (PBL) approach and gender have no significant effects on senior secondary students' academic performance in Mathematics. The result implies that the treatment and gender combined do not predict or affect students' learning and academic performance in Mathematics. This aligns with the report of Omosewo (2012) who reported no significant difference in the academic performance of male and female students taught using the PBL approach. This is also as male students taught using the PBL method did not significantly perform better than female students taught using the same method (Etiubon & Ugwu, 2016).

The last hypothesis of the study states that there is no significant main effect of the problem-based learning (PBL) approach on students' quantitative ability. However, based on the finding (F1, 108= 1.133; p = (.000) < .05), the null hypothesis was rejected and, an alternative hypothesis was accepted that there is a significant main effect of problem-based learning (PBL) approach on students' quantitative abilities in Mathematics. Hence, treatment positively predicts students' quantitative ability in Mathematics in senior secondary schools. The study supported Ke and Grabowski (2007) who reported that modern approaches to teaching and learning of mathematics significantly affect students' quantitative ability. Hackenberg, and Lee (2016) also reported that quantitative reasoning is a foundation for students to be able to develop other kinds of reasoning, such as algebraic reasoning.

CONCLUSION

Based on the findings of the study, it was concluded that using the problem-based learning (PBL) approach is effective for improving students' performance in Mathematics. This is because the approach has been proved effective and rewarding in enhancing students' mastery of Mathematics concepts. It is also helpful in enhancing knowledge construction and critical thinking. Also, it was concluded that PBL effectively improves problem-solving skills and enhances their quantitative abilities. However, just as gender did not affect students' academic performance in Mathematics, gender and PBL combined did not as well. Concerning the findings, it is recommended that the Government and other stakeholders in education train and retrain teachers regularly on effective use of PBL for Mathematics classrooms. It is believed that when teachers are versed in its utilization, students' academic performance will be adequately improved and students' will likely get to like the subject than what presently obtains. Also, officials of the Ministry of Education in

charge of the Mathematics curriculum are advised to develop or restructure the Mathematics curriculum to accommodate the techniques of PBL so that time is not wasted in the classroom while trying to fit the process into the present classroom. By inculcating the approach in the curriculum, teachers of Mathematics can better plan on how to use the approach daily without wasting time and resources. Finally, teachers are advised to always ensure that during the process of using the PBL, they act as facilitators only. This will ensure that students utilize the approach well, and in turn, this will assist them in becoming both independent and collaborative learners. Also, it will allow them to become critical thinkers which is one of the hallmarks of the PBL approach.

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