IMPACT OF PROBLEM-BASED LEARNING MODEL ON STUDENTS' ACADEMIC ACHIEVEMENT IN MATHEMATICS

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Abstract

This study examined the impact of the problem-based learning model on students' academic achievement in Mathematics in Junior Secondary Schools in Edo South Senatorial District, Edo State, Nigeria**.** Two research questions were answered in this study. The population of the study was 7,802 Junior Secondary School Students. The study was a descriptive survey using the quasi-experimental design using the pre-test and post-test. The sample size of the study was 780 students. The research instrument was the 2023 Basic School Certificate Examination Mathematics multiple-choice (Paper II). The data collected were analysed using the independent sample t- test. The findings of the study showed among others that there is a significant difference in the achievement scores of students taught mathematics using the problem-based learning model and those taught mathematics using the conventional method in favour of the problem-based learning model. Introducing Problem-based learning into the school system for teaching mathematics at all levels was recommended.

Key Words: Problem-based; Mathematics; Learning; academic achievement, problem-solving

Introduction

Mathematics is one of the main subjects in high school because it is an important subject that allows human beings to understand the world they live in and estimate the unknowns. Mathematical proficiency significantly impacts the economic prosperity of societies (Lipnevich et al., 2011). Moreover, it plays a pivotal role in the scientific and technological advancement of nations (Enu et al., 2015). The reason lies in mathematics being a fundamental skill for comprehending various disciplines, including Engineering, Sciences, Social Sciences, and even the Arts (Patena & Dinglasan, 2013; Phonapichat, et al., 2014). Abe and Gbenro (2014) emphasize that mathematics serves a multifaceted purpose in science and technology, permeating all aspects of scientific inquiry, technological applications, and business enterprises. Consequently, mathematics assumes a central role in educational curricula, recognizing its paramount importance.

Mathematics is essential in almost all fields: measurement in fashion, angles in sports, technology and economics. Mathematics is not just computing, but a tool to understand structures, relationships and patterns to produce solutions to complex real-life problems. The importance of mathematics is based on the fact that it requires students to acquire thinking skills, especially in problem-solving. It facilitates problem-solving even in real-life situations (Akinmola, 2014). The use of mathematics in everyday life activities is essential, which is why it requires ways and methods through which mathematical knowledge can be impacted. However, the acquisition of problem-solving skills is low in the world (Novita et al., 2012). This low level of mathematical problem-solving ability among students is a function of the teacher's teaching approach or mode of instruction (Sipayung & Anzelina, 2019).

Imasuen (2016) observed that teachers rely on conventional approaches, where they present mathematics as something abstract, so it does not make sense to students. Now it has become a kind of masquerade that generates fear and anxiety among the students. Students still consider Mathematics to be the most challenging and confusing subject (Escarez & Ching, 2022), especially when it comes to problem-solving (Nurjamaludin et al., 2021). It has been observed that mathematics performance in the world is low (Iman, 2016; Roman, 2019). This poor performance is the result of using ineffective teaching techniques and learning approaches that inhibit students' ability to learn mathematics (Lauren et al., 2018). Students who learn mathematics using real-world activities and intervention will display a high level of knowledge and skills in critical thinking and collaboration (Brau, 2020). Learning mathematics requires innovation and creativity on the part of teachers and students; however, it is observed that this is still at its lowest point (Syahputra & Surya, 2017).

For mathematics to be meaningful and realistic for students there must be a change in the mode of teaching. The provision of high-quality education that emphasizes problem-solving and makes students globally

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competitive can only be achieved through learning mathematics (Dinglasam et al., 2023). Achieving this implies that problem-based learning must be applied effectively. Therefore, the 2020 World Economic Forum emphasized the use of problem-based learning, which involves problem-solving, as one of the most in-demand skills, and gave a five-year lag. PBL as a learning strategy organizes mathematics teaching around problem-solving activities at the same time, providing students with opportunities to think critically, present their creative ideas, and communicate mathematically with other students. The problem-based learning (PBL) model is based on the theory of constructivism and creates opportunities for students to become effective problem solvers in their profession and for subsequent career success (Mazumder, 2014). Problem-based learning focuses on problems on which students can build their knowledge and develop research and thinking skills at a higher level. The PBL model is developed and designed to help students develop broad knowledge and be able to apply the knowledge obtained in effective problem-solving (Mundilarto, 2017). Problem-solving is one of the main objectives of mathematics courses. It addresses some of the key points for students (Gök & Silay, 2010).

Problem-based learning is a type of learning that involves problems that allow students to design an inquiry activity through problem-solving (Aidoo et al., 2016). It is a teaching method that uses students' everyday experiences as a starting point for their learning (Kosim & Tirta, 2020). As an instructional method, it helps students use the open inquiry approach to learn how to apply scientific knowledge in real-life situations (Ketpichainarong, et al., 2010), unlike the traditional method where students become passive in the teaching process that does not promote problem-solving or cognitive skills (Ronis, 2008). Problem-based learning involves an experiential learning process that is comprised of data collection, research, observations, explanations, and conclusions (Bell, 2010). When students engage in learning through the inquiry process, it allows them to develop self-confidence. Inquiry learning seems to contribute to the understanding of scientific concepts (Aidoo, et al., 2016) that can be applied in the context of everyday life. Students' engagement in inquiry learning will bring about tremendous improvement in their understanding and learning mathematics.

The use of problem-based learning has been found to improve students' self-regulation skills, thereby improving academic performance (Sungur & Tekkaya, 2006). Students can explore other ways of learning by using problem-based learning. Using the PBL strategy in teaching also helps stimulate students' understanding of how to find information linked to the problem, increasing their thinking ability. The teacher only guides the students throughout the learning process while the students take responsibility for their learning to find a solution (Aidoo, et al., 2016). Additionally, it motivates students to learn and develop independent skills that allow them to solve problems and face challenges in real-life situations. Using problem-based learning holds students accountable for their work; and can allow teachers to monitor students' understanding and development of self-regulated learning (Karabulut, 2002). In addition, it creates active learning (Muraray-Harvey et al., 2013), emphasizes broader teaching and learning activity processes, creates opportunities to develop significant knowledge, skills and attitudes related to collaborative learning, to build cooperative knowledge; helps students establish explicit relationships between attitudes toward cooperation and the achievement of learning outcomes; and identify specific collaborative skills required by students and obtained through group collaboration. It is based on the premise that learning involves the construction of new knowledge that will be acquired through solving the proposed problem, which is supported by the theory of cognitive science. Cognitive science theory states that prior knowledge about something can determine the nature and amount of information that students can process and elaborate to be assimilated (Regehr & Norman cited in Rézio et al., 2021). The most unique thing about PBL is that it brings each new problem with a challenge; learning achievement is recognized when a student can solve a new problem similar to the previous one, but the solution is presented differently.

Problem-based learning as student-centered pedagogical learning involves students being divided into smaller groups to discuss a challenging problem and find a solution to the problem. Students are given a complex problem to solve and the necessary guidelines that will help them solve it (Alexander et al., cited in Aidoo, et al., 2016). Students work in smaller groups to critically discuss the problem and possible ways to explore and reflect on the problem and content (Aidoo, et al., 2016). Students in a problem-based learning classroom try to search for information, access learning material, and share ideas while working in small groups. One of the teacher's functions is to guide students through questions that will direct them to find possible solutions to the problem. Students reflect on the problem through the inquiry process by applying strategies that lead to the problem (Amador et al., cited in Aidoo et al., 2016). Students in the group go through several steps to solve the

problem through observations, predictions, and drawing conclusions based on assumptions (Bell, 2010). The steps involved in PBL according to Sidabutar and Surya (2017) are (1) understand the problem, (2) make plans (3) implement plans and (4) re-examine the problem-solving process again. This is a replica of the scientific ways of acquiring knowledge.

Greenwald cited in Aidoo et al (2016), stated that when implementing problem-based learning, students should be asked open-ended questions that relate to the problem, find possible solutions through problem-solving activities, analyze data using guided questions and finally evaluate their problem-solving ability and critical thinking ability of the students as a way to know how much knowledge the students have acquired. The PBL has been around for two decades and started at McMaster University School of Medicine. Since its inception, PBL has been used in many undergraduate and graduate programs, such as medicine (Azer et al. 2013, Doherty et al. 2018), nursing (Choi et al. 2014), social work and education (Wong & Lam, 2007), law (Wijnen et al. 2017), architecture (Armitage et al., 2015), economics (Harum et al., 2012), business (Smith, 2005) , science (Akcay, 2009) and engineering (Van Barnveld & Strobel, 2009). It has also been applied in primary and secondary education (Wilder, 2015; Siew & Mapeala, 2016; Li & Stylianides, 2018). The use of PBL is gaining momentum in other fields such as medicine, engineering, mathematics, language assessment, and many more. Murshid et al. (2022) stated that the use of PBL should be recommended for teaching and learning and should be adopted by everyone. The PBL has been used in several countries such as Denmark, the United States, the United Kingdom, the Netherlands, Asia and Europe. Its usage has brought about tremendous improvement in the learning of mathematics. Hence, it has led to geographical and academic dissemination of scientific production on its methodology (Pinho et al., 2015).

Several researchers have affirmed the effectiveness of problem-based learning in the classroom. For example, Cockrell et al. (2000) concluded that PBL was effective compared to other pedagogical approaches as it facilitates students' critical thinking and problem-solving skills. It also allows students to apply theory to practice (Cooke & Moyle, 2002). Aaron et al. (2002) found higher test scores for students who enrolled in problem-based learning classes compared to the traditional method. Gallagher, et al., cited in Aidoo et al., (2016) reported that problem-based learning was successful in teaching ecosystems in fifth-grade science and had higher performance on test scores compared to traditional instruction. Zhou et al., (2013) concluded that problem-based learning improves students' analytical skills and their ability to personalize learning. Students can evaluate and infer the learned content while drawing reasonable conclusions. With this, a habit of mind is promoted among students, which increases scientific literacy among students. According to Aidoo, et al., (2016), students who enrolled in problem-based learning achieved higher scores on national examinations in the United Kingdom and a significant number of students who were taught in a problem-based school passed the national standardized test three times more than students who received problem-based instruction from traditional schools. These findings confirmed that problem-based learning has significant impacts on students' problem-solving skills and attitudes toward learning. Hmelo-Silver cited in Aziz et al (2014) opined that problem-based learning increases the level of thinking skills of students by requiring them to think critically about a problem and analyze data to find solutions. On the other hand, PBL encourages students to research to satisfy their needs for knowledge and then link the new knowledge to their thinking and decision-making processes.

PBL contributes to students' learning of specific ideas and skills used to simplify abstract concepts by providing multiple ways to create a classroom climate where all students participate in problem-solving. This approach places greater emphasis on procedures that involve the mind, psychology, and creativity of students, as they directly participate in the exploration of the situation being investigated through the research method (Etiubon & Ugwu, 2016). According to Malinowski and Johnson (2001), students who work with ill-structured problems are more likely to develop a significant body of knowledge about the content, regulate their thinking, and make meaningful use of it when necessary, using problem-based learning. Karabulut and Bayraktar (2018) also posited that PBL allows students to develop active learning, problem-solving skills, and understanding-based field knowledge. This makes students take responsibility for their learning and become independent learners who can continue learning throughout their lives.

Gender is one of the demographic characteristics that could have a substantial effect on student learning. Typically, in Western and African settings, male students tend to dominate discussions, while female students are more accommodating than dominant (Wrigley-Asant et al., 2023). Exploring the views of male and female students on their initial experience of interprofessional problem-based learning, Reynolds (2003) notes that problem-based learning made a positive and welcome

contribution to learning for both genders, indicating that learning Problem-based can support both learning styles. Women tend to be more sensitive to interpersonal dynamics in problem-based learning and their commitment and participation depend on feeling comfortable and positively connected with their colleagues (Alajmi, 2014). The results of some research on the influence of gender on students' academic performance remain inconclusive. Goldstein (2009) opined that male students show higher academic performance when participating in learning activities that involve practice and calculation than their female counterparts. Moronfolla (2012) found that female students find it difficult to draw graphs and do problems that involve calculations.

Statement of Problem

One of the reasons why students perform poorly in mathematics is that they consider mathematics to be abstract because it involves the development of problem-solving skills (Arbo et al., 2022). It is widely considered an abstract topic to be studied (Fritz, 2019), and is only considered "genius" (Rattan et al., 2012). These conceptions have generated fear and anxiety and even loss of interest in learning it, which has caused failures and school dropouts. However, learning mathematics opens up more opportunities for students (Li & Scoenfeld, 2019). You cannot do mathematics without acquiring problem-solving skills, that is, without problems there is no mathematics (Klerlen & Hervey, 2017).

Teaching methods are a vital aspect of the learning environment. It is the form or technique with which a concept is taught that varies from one subject to another. The teaching method that a teacher uses improves or hinders learning. The most common and oldest teaching method is the conventional teaching method. A conventional teaching method is a teaching method that helps students focus on memorization compared to other teaching methods. Students' proficiency in understanding mathematical concepts in school largely determines their learning performance. Academic achievement or performance is the result of a teaching and learning process. Consequently, for the best possible academic performance in mathematics to be realized, students need to continually exchange ideas, experiences, knowledge and skills through a discussion approach, to facilitate effective teaching and learning of mathematics. To do this, it is necessary to focus attention on the problem-based learning model, which will help students to be more active in the teaching and learning process. Problem-based learning is one of the learning models designed to help students develop their thinking skills, problem-solving and intellectual abilities, learn the roles of adults by experiencing them through simulated real situations, and become independent learners (Arends, 2008). It is also observed that adequate attention has not been given to the problem-based learning model in Nigeria and Edo State in particular. In light of the above, the researcher, therefore, investigated the impact of the problem-based learning model on the academic performance of students in Mathematics in Edo South Senatorial District, Nigeria.

Research Questions

The following research questions were raised to guide the study:

1. What is the difference in the achievement scores of students taught mathematics using the Problem-Based Learning model and those taught mathematics using the conventional method?
2. What is the difference in the achievement of male and female students taught mathematics using the Problems Based Learning model?

Hypotheses

The following null hypotheses were formulated from the above research questions and were tested at a significance level of 0.05:

1. There is no significant difference between the achievement scores of students taught mathematics using problem-based learning models and those taught mathematics using conventional methods.
2. There is no significant difference between male achievement scores and female achievement scores using the Problems-Based Learning model.

Methods

The study was a descriptive survey which adopted the quasi-experimental design using the pre-test and post-test. The design was appropriate because there was control and manipulation of the subjects, but there was little or no randomization. The population of the study consists of one hundred and thirty-seven (137) public Junior Secondary School with 7,802 students in Edo South Senatorial District, Edo State Nigeria. The sample size of the study was seven hundred and eighty (780) students selected from sixty-eight (68) public Junior Secondary Schools in Edo South Senatorial District, Edo State Nigeria. The multistage sampling procedure was used. The research instrument was the 2023 Basic School Certificate Examination Mathematics multiple-choice (Paper II) developed by the National Examination Council (NECO). The validity of the instrument was not

ascertained since the questions were constructed and standardized by NECO and within the validity period of three years. However, the reliability of the instrument was ascertained using the Kuder-Richardson formula 20, (K20) and it gave an index of 0.92. The tests (pretest and posttest) were administered to the students within the time, stipulated by the researchers and the respective mathematics teachers in the schools sampled. The data collected were analysed using the independent sample t-test at 0.005 level of significance.

Results

Table 1: Independent Sample T-Test of the Difference in the Achievement Scores of Students Taught Mathematics Using the Problem-Based Learning Model and those Taught Mathematics using the Conventional Method

Methods	N	Mean	Standard deviation	t-value	p-value	Remark
Conventional	390	90.10	3.30	5.734	0.000	Significant
Problem-Based Learning	390	107.28	2.37			

Table 1 shows a t-value of 5.734 and a p-value of 0.000. Testing at an alpha level of 0.05, the p-value is less than the alpha level. Therefore, the null which states that "there is no significant difference in the achievement scores of students taught mathematics using the problem-based learning model and those taught mathematics using the conventional method" is rejected. Consequently, there is a significant difference in the achievement scores of students taught mathematics using the problem-based learning model and those taught mathematics using the conventional method. The problem-based learning model seems to be better than the conventional method of teaching mathematics.

Table 2: Independent Sample T-Test of the Difference in the Achievement Scores of Male and Female Students Taught Mathematics Using a Problem-Based Learning Model and Those Taught Mathematics Using the Conventional Method

Sex	N	Mean	Standard deviation	t-value	p-value	Remark
Male	320	58.60	13.30	-0.313	0.755	Not Significant
Female	460	58.77	12.37			

Table 2 shows a t-value of -0.313 and a p-value of 0.755. Testing at an alpha level of 0.05, the p-value is greater than the alpha level. Therefore, the null there is no significant difference in the achievement scores of male and female students taught mathematics using the problem-based learning model and those taught mathematics using the conventional method is retained.

Discussion of Findings

Analysis of the first hypothesis indicates that there is a significant difference in the achievement scores of students who were taught mathematics using the problem-based learning model and those who were taught mathematics using the conventional method. The problem-based learning model seems to be better than the conventional method of teaching mathematics. The students obtained very good results after PBL was applied in mathematics teaching. It shows that students' problem-solving and thinking skills improved when the PBL instruction method was used in teaching Mathematics (Aidoo et al., 2016). As a good instructional strategy, it motivates students to understand and reflect on the content they have been exposed to and helps them develop their critical thinking and problem-solving skills (Zhou et al., 2013). With this, Problem-Based Learning can improve analytical skills through data evaluation and inferences (Zhou et al., 2013). In a typical problem-based learning classroom, students solve problems as they progress through the inquiry process in a real-life context. When students engage in problem-based learning, teachers encourage them to explore possibilities, invent alternative solutions, collaborate with other students, test ideas and hypotheses, review their thinking, and present their best solutions. Hands-on activities provide students with opportunities to engage in exploration and draw meaningful conclusions (Zhou et al., 2013).

The second hypothesis sought to identify whether there is a significant difference in the achievement scores of male and female students who were taught mathematics using problem-based learning models and those taught using the conventional model. The findings show no significant differences in the performance scores of male and female students on the test after being exposed to the problem-based learning approach to teaching mathematics. This is an indication that sex is not a determining factor in students' assimilation of ideals when taught with PBL. Reynolds (2003) notes that problem-based learners made positive and well-received contributions to learning for both genders, indicating that problem-based learners can support both learning styles, and can benefit both sexes.

Conclusion

From the findings of this study, it was concluded that problem-based learning is student-centred, which prepares students to relate scientific concepts to real-life situations and can be adopted for teaching and learning mathematics and other subjects. The use of problem-based learning as a teaching and learning strategy can improve student performance and also an effective approach to teaching and learning mathematics. Furthermore, student performance in mathematics using problem-based learning is not dependent on the sex of the students.

Recommendations

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

1. Problem-based learning should be introduced into the school system by the government and other stakeholders in the educational sector for teaching mathematics at all levels.
2. Problem-Based Learning should be used by teachers as an alternative option for the implementation of learning mathematics and any other subjects
3. Seminars and workshops should be organised by the Ministries of Education to train the teachers so as to have a better understanding of the model and its application.

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