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Effect of STEM Problem-Based Learning on Achievement in Basic Science among Secondary School Students

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Abstract

This study was carried out to examine the effect of STEM Problem Based Learning on students' achievement in Basic Science. This is in consideration of the fact that the Nigerian National Policy on Education provides that for a student to study any of the core science subjects at the Senior secondary school level, he must have to score a credit pass in Basic Science at Junior Secondary School level. Without a credit pass in any of the science subjects that make up Basic Science (Biology, Chemistry and Physics), a student cannot study any of the course in science, technology, engineering or mathematics at the tertiary education level. Unfortunately, literatures show that there is massive failure of students in Basic Science especially at the Basic Education Certificate Examination. This study is guided by three research questions and three research hypotheses. The population for this study is junior secondary school form 2 students of Nsukka local government area of Enugu State in Nigeria. The study used random sampling technique to sample schools and employed pre-experimental research design. The sample was sub-divided into two: low ability learners and high ability learners. Data was collected at two different periods (pretest and post-test) using an achievement test constructed by the researchers. The analysis was carried out using ANCOVA, Independent Sample T-test and Paired Sample T-test using IBM SPSS version 23. The results of the analysis showed that STEM PBL is a good strategy that can be used to increase students' achievement in Basic Science.

Keywords: *Basic Science, Achievement, STEM, Problem-Based Learning, Low ability learners, High ability learners.*

INTRODUCTION

In Nigeria, junior secondary school students do not perform as well as is expected of them in Basic Science so as to be talented and intelligent to find solution to the scientific difficulties of the nation in this period that every nation is advancing scientifically and technologically (Ajagun, 2018). Research studies are indicative of the fact that Nigerian students do not perform well in internal and external examinations when it has to do with BasicScience and some other science related subjects such as Further Mathematics, Chemistry, Biology and Mathematics (Ajagun, 2018). This is further corroborated by WAEC (2022), which presented a low performance rate in science subjects. The result of the junior secondaryschool students in Basic Science is also very poor. This can be observed from the Basic Science results of junior secondary schools in Enugu South Local Government Area of Enugu State, Nigeria (Ozaji, 2021).

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This worry is as a result of the growing understanding that Nigeria as a country could not advance as speedily as she wished to without suitable means of scientific and technologicalmanpower at all levels in her employed populace. Ochuba (2019) argued that the situation of Basic science at the basic education level was of great consequence. This is for the reason thatthe performance at this level affects the quality and quantity of admission in sciences into institutions of higher learning in the country.

Basic science curriculum for junior secondary form 2 that has been developed using theprinciples of Social Constructivism learning approach is different from the others (Oyedeji, 2020). In this curriculum, the role of teachers and pupils in the classroom, the approach to assessment and evaluation as well as to the teaching techniques have been radically changed. In spite of all these curriculum development changes in Basic science there are many researchstudies that report concept difficulties and misconceptions in Basic science topics in the junior secondary form 2 curriculum. The following examples can be given for the topics of pulley, kinetic theory, pneumatic machines, wheel and axel (Oyedokun, 2020), wheel and axel, pneumatic machine, work, energy and power, crude oil and petrol chemicals (Oyedeji, 2020), kinetic theory, pulley, thermal energy, pneumatic machines (Adedayo, 2018), crude oil and petrol chemicals, pulley, pneumatic machine, wheel and axel, kinetic theory and thermal energy(Akinsola, 2023). From the above list of difficult topics, pulley, pneumatic machines, wheel and axel appeared consistently. It is on this premise that the present study has chosen to study students' achievement in these topics in Basic Science.

It is necessary to have a look at the Basic Education Certificate Examination (BECE) results for Nsukka Local Government Area of Enugu State, Nigeria within the past few years in other to understand the reason for this study. In 2017, only 3,125 students representing 38.30% of students who sat for BECE obtained credit in Basic Science in the zone (Enugu StateMinistry of Education, 2017). By 2018, 37.17% representing 2,118 of the students that sat for BECE were able to obtain credit pass in Basic Science in the zone (Enugu State Ministry of Education, 2018). In 2019 and 2020, the results were no better since only 2,630 students representing 38.92% (Enugu State Ministry of Education, 2019b) and 2,853 representing 29.37% (Enugu State Ministry of Education, 2020) obtained credit and above respectively. The Basic Science results for 2021, 2022 and 2023 were even worse than the previous years (Enugu State Ministry of Education, 2021, 2022, 2023).

According to Ayo (2019), Nigerian students' achievement in science has declined since 2017. Ezeokpo (2022), has called on teachers, parents and educators to do something about thecontinued decline of students' achievement in science. Ajogwu, Esomugha, Ojoloha, and Bashir (2021) noted that the trend of poor students' achievement in Basic Science if not properly addressed will hinder the achievement of Sustainability Goals in Nigeria. Mong and Ertmer (2023) noted that STEM PBL approach is a potentially good approach in science instruction. He further argued that teachers should incorporate investigation, questioning, predicting, explaining and observation into their teaching. Memorization and rote learning killinitiative and does not allow learners to apply knowledge in a different situation, but STEM PBL grants students the opportunity to explore, investigate information and transfer their learning to a similar situation. STEM PBL encourages and promotes students' involvement in the learning process thereby giving students control over their learning (Altshuler & Bosch, 2019). When students get involved in the collection of data, analysis of data and participate in solving process, they acquire new knowledge which they can still apply to solve more problems(Bleicher, 2022).

Achievement in Basic Science is defined as a student's ability to achieve some premeditated goals in responding to academic questions on Basic Science topics (York, Gibson,& Rankin, 2023). Achievement in Basic Science is likely to improve when a good instructionalapproach like STEM PBL is employed by teachers in the teaching and learning of the subject.In this study, a student's achievement in Basic Science is defined as the student's academic ability or level of knowledge in providing positive responses to

questions or quiz or tests in Basic Science and being able to use those responses or knowledge to solve real-life problem situations. There are many variables that can impact successfully on student achievement in Basic Science, but the most critical is classroom instruction (Diseth, 2018). Classroom instruction isthe most important factor that impacts student achievement (Galyon, Blondin, Yaw, Nalls, & williams, 2020).

One of the reasons that is adduced for mass failure in Basic Science is that some of the topics are very difficult for students to understand. Literatures by Mong and Ertmer (2023) suggested that STEM PBL can be used to teach difficult topics. This is because, it is believed that STEM PBL help learners to probe into the topic, examine issues in the problem, try to develop a means or model for solving the problem, carry out some research into the problem, analyse, interpret information gathered on the problem, use mathematical thinking, and evaluate and disseminate or communicate information. The researchers want to investigate theEffect of STEM PBL on the Academic Achievement of Junior Secondary form 2 Students in Enugu South Local Government Area of Enugu State.

Research Objectives

Given the growing emphasis on differentiated instruction and the effectiveness of STEM-based pedagogies in enhancing science achievement across diverse learner profiles, this study sets out to explore the role of STEM Project-Based Learning (STEM PBL) in addressing variations in student performance based on ability levels. Specifically, the research is guided by the following objectives:

1. Considering the implementation of STEM PBL in Basic Science classrooms, will there be a significant difference in the mean achievement test scores between low ability and high ability learners?
2. In light of the instructional intervention using STEM PBL, will there be a significant improvement between the pretest and post-test achievement scores of low ability learners in Basic Science?
3. With the adoption of STEM PBL methodology, will there be a significant improvement between the pretest and post-test achievement scores of high ability learners in Basic Science?

RESEARCH METHOD

Hypotheses

The following hypotheses were formulated at $\alpha = 0.5$ to guide the study:

- H_{o1} There will be no significant difference on the mean achievement test score in Basic Science between Low ability and High ability learners who were taught using STEM PBL on Post-test after controlling for the effect of Pretest.
- H_{o2} There will be no significant difference in the mean achievement test scores in Basic Science pretest and post-test of low ability students who were taught using STEM PBL.
- H_{o3} There will be no significant difference in the mean achievement test scores in Basic Science pretest and post-test scores of high ability students who were taught using STEM PBL.

Research Design

This study used pre-experimental research design. In a pre-experimental design, a singlegroup of subjects or participants or two or more groups of subjects or participants are studied after some treatment presumed to cause change have been administered (Choo, Clarke, & Little,2019). Though pre-experiments adhere to some fundamental stages employed in conducting experimental studies, pre-experimental research designs may either fail to comprise a pretest, a control group or comparison group, or both pretest and control group; no randomization of subjects or participants are utilized to control for extraneous variables (Goldkuhl, 2020).

In this study, there is one group of students which is sub-divided into two. The participants were classified into two sub-groups: low ability learners and high ability learners.This is because research has revealed that the problem of low achievement in Basic Science isworse with low ability learners (Fong, Kim, Davis, Hoang, & Kim, 2021). According to Mei and Pajares (2020) low ability students perform very low academically because they do not find it easy to internalize and retain information that they have learnt.

The two sub-groups received the same intervention which is STEM PBL. There was a pre-test, which was administered at the beginning of the experiment. There was a post-test, which was administered after thirteen weeks of treatment to the two sub-groups. The treatmentended before the post-test.

Sample and Sampling Technique

There are two independent variables in this study; a primary independent variable whichis STEM PBL and a secondary independent variable which is students' ability. The dependentvariable in this study is achievement in Basic Science test scores.

This study was carried out in secondary schools in Enugu South Local Government Area of Enugu State, Nigeria. From the population of thirty schools, the researcher used randomsampling to compose one school. After composing the school, it was found out that for form 2there are three classes of high ability learners and two classes of low ability learners. Hence, the researcher, used stratified random sampling to compose one class from the three high abilityclasses and one other class from the two low ability classes. This is because the classes were already classified into low ability and high ability. The researcher needed one low ability classand one high ability class. One of the characteristics of pre-experimental studies is the absence of randomisation of subjects. As a result, intact classes were used for this study. The sample size is 70 students.

Group A which is high ability class has 35 participants while group B which is low ability class has 35 participants, giving a total of 70 participants. The experiment lasted for twelve weeks. The students and teacher that took part in the study made out time after school dismissal. The two classes that were used for the experiment received the same intervention. The intervention ended before the post-test. There was no contamination effect because both low ability and high ability learners received the same intervention which was administered bythe same teacher to both groups.

Ezeugwu & Ezeugwu, (2024) in a study of senior secondary form 2 physics students inEnugu State pointed out that, differential ability test helps to discover the learner's strengths and weaknesses, so the suitable instructional goals, intervention strategies, and progress monitoring can be formed. The differential ability tests has for a long time been used in grouping students into different ability classes in some schools in Enugu State (Enugu State Ministry of Education, 2019). Nnamani (2023) pointed out that differential ability tests are veryeffective in classifying students into low ability and high ability

classes. Differential ability tests assess abilities involved in thinking: reasoning, perception, memory, verbal and mathematical ability, and problem solving (Ogbuefi & Onyenaturuchi, 2021).

In other to confirm the differences in ability of the two groups, the researchersadministered Cattel Free Cultural Test to low ability and high ability learners. It is found that the mean score of intelligence test of high ability students is significantly higher compared withlow ability students who participated in the study. The result of independent samples t-test showed that there is a significant difference on the mean score of Cattell Free Cultural Intelligence test between low ability and high ability students $p < 0.05$ (Table 1). The result which is exhibited by independent samples t-test support the justification made in this research,which define low ability and high ability students are divided based on the classification madeusing differential ability test by the Enugu State Ministry of Education.

Table 1. Independent Samples T-Test for Cattell Free Test

Independent Samples T-Test						
	F	Sig.		t	df	Sig. (2-tailed)
IntelCattell	Equal variances Assumed	.22	.64	25.89	68	.00
	Equal variances			25.89	67.99	.00

Data Analysis

ANCOVA, paired sample t-test and independent sample t-test were used to analyse thedata that were collected from this study. The result of One-way ANCOVA, Paired sample t- test and Independent sample t-test on the research questions and hypotheses are as follows:

The result of inferential statistical analysis to study the effect of STEM PBL on achievement in Basic Science test scores. The statistical analysis is conducted in order to answer research question (1), (2), and (3) as follows.

A one-way between-groups analysis of covariance (ANCOVA) was conducted to compare theeffect of STEM PBL on the achievement in Basic Science test scores of high ability and low ability learners, Table 2. For the purpose of analysis, the independent variable was the students'ability, and the dependent variable consisted of students' pre-test scores and post-test scores. Participants' scores on the pretest were used as the covariate in this analysis.

Table 2 *Tests of Between-Subject Effects for Research Question 1*

Source	Type III Sumof Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	846.36	2	423.18	7.17	.00	.18
Intercept	3067.82	1	3067.82	51.99	.00	.44
Pretest	204.30	1	204.30	3.46	.07	.05
Group	108.38	1	108.38	1.84	.18	.03
Error	3953.59	67	59.01			
Total	357386.00	70				
Corrected Total	4799.94	69				

After adjusting for pretest scores, there was no statistically significant differencebetween the two groups (high ability and low ability learners) on the post test scores on the achievement in Basic Science test scores, F (1, 69) = 1.84, p = .18, partial eta squared = .03, Table 2. Therefore, for Ho1 the decision failed to be reject.

Consequently, a paired-samples t-test was conducted to evaluate the impact of the intervention (STEM PBL) on achievement in Basic Science test scores of low ability learners,Table 3. There was a statistically significant change in achievement in Basic Science test scoresof low ability learners from pretest (M = 57.71, SD = 10.49) to post-test (M = 78.71, SD = 7.81),t (34) = -13.85, p < .05. Therefore, the hypothesis Ho2 is rejected.

Table 3 Paired-Sample T-Test for Achievement in Basic Science Test of Low Ability Learners

	Paired Differences					
Low Ability	Pretest/Post-test scores ASM	Mean	SD	t	df	Sig. (2-tailed)
		-22.00	9.40	-13.85	34	.00

Hence, from paired-samples t-test conducted to evaluate the impact of the intervention (STEM PBL) on achievement in Basic Science test scores of high ability learners, Table 4, there was a statistical significant change in achievement in Basic Science test scores of high ability learners from pretest (M = 74, SD = 6.05) to post-test (M = 83.83, SD = 8.08), t (34) = -7.94, p < .05. Therefore, hypothesis Ho3 failed to reject.

Table 4 *Paired-Sample T-Test for Achievement in Basic Science Test of High Ability Learners*

	Paired Differences					
High Ability	Pretest/post-test scoresof ASM	Mean	SD	t	df	Sig(2-tailed)
		-9.83	7.33	-7.31	34	.00

Moreover, a one-way between-groups analysis of covariance was conducted to compare the effectiveness of STEM PBL on the low ability and high ability learners. For the purpose ofanalysis, the independent variable was students' ability, and the dependent variable consisted of post-test scores on the achievement in Basic Science test which was administered immediately after the intervention. From Table 5, after adjusting for pretest scores, there was asignificant difference between the two groups on the post-test scores, F (1, 69) = 10.03, p = .10, partial eta squared = .03. Therefore, from Table 5, there is a significant difference in the increase of achievement in Basic Science test scores between low ability and high ability learners who were taught using STEM PBL after controlling for the effect of pretest.

Table 5 *Test of Between-Subject Effect*

Source	Type III Sumof Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	334.84	2	167.42	9.57	.00	.22
Intercept	8968.36	1	8968.36	512.59	.00	.88
PretestAchievement	4.78	1	4.78	.27	.60	.00
Group	175.48	1	175.48	10.03	.10	.03
Error	1172.25	67	17.50			
Total	515450.00	70				
Corrected Total	1507.09	69				

a. R Squared = .222 (Adjusted R Squared = .199)

Consequently, the ANCOVA results show that there is no significant difference after controlling for the pretest, Table 2. However, the result of paired-sample t-test, Table 3 showsa significant positive effect for low ability learners while Table 4 shows a significant positive effect for high ability learners. The result of the paired-sample t-test between low and high ability learners shows a significant increase from pretest to post-test for both low and high ability learners. This means that the intervention gives the same positive effect to both low andhigh ability learners with a significant increase from pretest to post-test. Therefore, the hypothesis$H_{O}3$ failed to reject.

This shows that both the low ability and high ability learners benefited equally from the intervention as each of the two groups recorded significant positive increase in post-test scores over and above the pretest scores. Implying that STEM PBL has helped to increase the achievement in Basic Science test scores of the low ability and high ability learners over the period. Therefore, the mean achievement in Basic Science post-test score of low ability learnersis smaller compared to the mean achievement in Basic Science post-test score of high ability learners. The mean achievement in Basic Science post-test score of low ability learners is higherthan their mean achievement pretest scores. Likewise, the mean achievement in Basic Sciencepost-test score of high ability learners is higher than their mean pretest score. Based on the results of this analysis, null hypotheses $H_{O}1$, $H_{O}2$ and $H_{O}3$ of no significant difference in achievement in Basic Science test scores of low ability and high ability learners is failed to berejected.

Findings

In this section, the researcher discussed the implication of the research findings for teachers of Basic Science, for the learners of Basic Science, for the Secondary Education Administrators, for the Curriculum Planners and learning theories.

This study has been able to show that STEM PBL has a positive effect on theachievement in Basic Science test score. Whereas, state or federal guidelines or standards frequently dictate the topics, skills or ideas covered by the curriculum, the teacher can give insight or make suggestions with regards to the categories of instructional or teaching materials,teaching activities or hands-on activities and topics, skills and ideas that may have to be included in the curriculum. The teacher can determine whether a hands-on activity will be appropriate for a stipulated lesson time and whether or not the activity will

give students opportunity for active participation. On the other hand, students should actively participate in all hands-on activities in the class since active participation enables them to learn more. They should keep themselves busy with their homework and assignments.

While curriculum experts, educational administrators or supervisors and educational agencies occupy themselves with countless man-hours of planning, developing and producingthe curriculum, the teacher as the instrument of implementing the curriculum knows exactly what topics, ideas, skills or subject matter that should be included in the curriculum (Dogan, Pringle, & Mesa, 2023). The teachers deal directly with the learners or students who are the main benefactors of the curriculum.

Teachers need to understand that enhancing the quality of teaching is one of the best ways to increase learner attainment in schools (White & Harrison, 2022). Learners require to have access to high-quality teaching like STEM PBL that aids achievement, independence andengagement in learning in other to facilitate the development of active cognitive skills of learners. Previous studies have shown that learners have better performance when the teachingmethod is more involving for the learners (Nian-Shing, Shing, Wei, & Liu, 2021).

Conclusively, teachers should not lose sight of using STEM PBL in teaching Basic Science and other science related topics and ideas because not only that the approach gives thelearner the opportunity of active involvement, but it facilitates and increases the learners' achievement Basic Science. It is therefore recommended by this study that Basic science teachers should use STEM PBL approach in their teaching for effective learning to take place.

CONCLUSION

Students have to always be challenged and confronted with assignments, tasks and questions that are relevant to the skills, aptitudes, knowledge and competences little above theirpresent or existing level of mastery and understanding. This arouses their interest, motivates them and builds on their prior, previous or earlier successes and achievement to improve the students' confidence (Davis, Athey, & Vandevender, 2015). Robnett, Chemers, and Zurbriggen(2015) further asserted that teaching is good only when it progresses ahead of development. This is how instruction or teaching plays an exceptionally significant role in development.

Many students struggle with their achievement in Basic Science. In Enugu State, morethan two thirds of students do not obtain credit pass in Basic Science. This study has used STEM PBL to improve the achievement test scores in Basic Science. The implementation of STEM PBL in the classroom can only realise its full potentials if used on the right level, at theright time and in the right way, with appropriate support from the teachers.

The findings recommend that STEM PBL as a teaching approach should be incorporated in the school curriculum since it is an inventive, innovative and effective approachfor teachers to improve learners' academic performance or achievement. STEM PBL should explicitly, specifically and unambiguously be integrated or incorporated into Basic Science lessons for maximum improvement of the learners' Basic Science achievement. In this study, STEM PBL improved the Basic science achievement of both the low ability and high ability learners. From the findings, STEM PBL is very effective in the classroom. Conclusively therefore, STEM PBL can increase and retain learners' Basic science achievement.

Limitation and Further Research

A limitation of this study is the small sample size, which might not represent the wider group of secondary school students. The research took place in just one location, making it hard to apply the findings to other areas with different educational settings. The design of the study did not consider

individual differences in prior knowledge or learning styles, which may affect how effective STEM problem-based learning is. The intervention was of a short duration, and the long-term effects on students' achievement in basic science were not looked at. The study used self-reported data from students and teachers, which may have biases like social desirability or recall bias. The methods for assessing achievement may not have fully captured all aspects of student learning and understanding. External factors, such as students' home life and extracurricular activities, were not controlled, which might have affected the results. The focus was mainly on academic achievement, without looking at other possible outcomes like motivation or attitudes toward science.

Future research could look at the effects of STEM problem-based learning in various science fields to see if the impacts are similar. Future studies could also examine how sustainable the learning gains from STEM problem-based learning are and how it affects students' future academic choices.

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