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THE INFLUENCE OF ROBOTICS-ENHANCED INSTRUCTIONAL STRATEGY ON SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN PHYSICS IN ABEOKUTA SOUTH METROPOLIS

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A**bstract:**
This study investigated the influence of educational robotics as an instructional strategy on the academic achievement of secondary school students in physics within Abeokuta South Metropolis, Nigeria. Despite the recognized importance of physics education to technological advancement, students' performance in physics examinations had been consistently poor. The study adopted a quasi-experimental design and purposive sampling technique, a Physics Achievement Test (PAT) was administered as a pretest and posttest to 120 Senior Secondary School 2 students from two different schools (60 from each school) with treatment groups exposed to robotics-enhanced instruction using the mBot. Data analysis employed mean, standard deviations, and Analysis of Covariance (ANCOVA) to test the null hypotheses. The findings revealed that students taught with mBot performed better than those without it. Gender differences in academic achievement were not significant. The study underscored the effectiveness of educational robots in enhancing physics education and called for its integration into the curriculum, teacher training, and the promotion of gender equality in Science Technology Engineering and Mathematics (STEM) education. Implementing these recommendations could contribute to improved academic outcomes and foster technological advancement in Nigeria.

Keywords: Educational robotics, Robotics-enhanced instruction, Academic achievement, Physics Achievement Test (PAT), Analysis of Covariance (ANCOVA), Quasi-experimental design

Introduction

The importance of science education, particularly physics, in driving a country's technological advancement is widely recognized. Physics, the study of natural occurrences and the interaction between matter and energy, is crucial for understanding various phenomena and technological innovations (Udoh, 2012). Despite its significance, the performance of Senior Secondary School students in physics examinations, such as the West African Senior School Certificate Examination (WASSCE) and the National Examination Council (NECO), has been consistently poor (The Nation Newspaper, October 27th, 2016) . Factors contributing to this trend include socio-cultural and economic backgrounds, inadequate instructional materials, unqualified teachers, and ineffective pedagogical methods (Akintoye & Salau, 2020).

In response to these challenges, educational robotics has emerged as a promising approach to enhance physics education. Robotics provides hands-on, interactive learning experiences that stimulate students' interest and facilitate the comprehension of complex physics concepts

(Guastella & D'Amico,2020). However, the integration of robotics into the Nigerian secondary school curriculum has been limited, primarily due to skepticism among government officials regarding its potential impact on technological advancement (Fabiyi, Abdulmalik & Tiamiu, 2016) Despite this, robotics offers numerous benefits, including the development of problem-solving skills, creativity, and teamwork (Zhang & Zhu, 2022**)**

The mBot, an entry-level robot, has gained popularity in secondary schools for its versatility and ease of use. Equipped with sensors and motors, the mBot enables students to explore concepts such as speed, friction, optics and Simple Harmonic Motion (SHM). The use of RGB LEDs allows students to experiment with light intensity and color mixing, enhancing their understanding of optics (Fior, Fonda & Canessa, 2024**)**. Research has shown that robotics-assisted teaching

strategies can improve students' academic performance, computational skills, motivation, and social interaction (Atmatzidou & Demetriadis, 2016). However, the impact of such strategies on gender differences in physics education remains unclear. While male students typically outperform their female counterparts in physics, robotics may offer a more inclusive and engaging learning environment for both genders (Akinbobola & Afolabi, 2012)

Statement of Problem

The ongoing challenge of poor academic performance in Physics among secondary school students poses significant concerns to stakeholders. This issue not only hampers the country's potential to achieve development but also impacts students' access to high-demand courses like engineering and medicine. It also affects their success and productivity in these fields, contributing to a lag in critical sectors such as health and construction. While previous researches have pointed to factors like teacher shortages and ineffective teaching methods as key contributors, limited attention has been given to robotics as a potential solution. This study aims to address this gap by investigating the impact of robotics-enhanced teaching methods on students' Physics achievement at the senior secondary level in Abeokuta South Local Government area of Ogun State. Addressing this issue is crucial for Nigeria's economic progress, given the pivotal roles of Physics in various fields such as engineering, computer science, and biomedical studies.

Hypotheses

The following null and alternate hypotheses were formulated and tested at a significance level of 5%

Ho1: There is no significant main influence of educational robotics as instructional strategy on academic achievement of students in physics.

Ho2: There is no significant influence of gender using educational robotics as instructional strategy on academic achievement of students in physics.

Theoretical Review

The theoretical framework for this study is based on the principles of constructivism, constructionism, and design-based learning.

Constructionism Theory

Constructionism is based on constructivism and emphasizes a hands-on approach to learning as well as self-direction. Constructivism "tends to underestimate the relevance of individual preferences or styles in human learning and development, as well as the role of context, uses, and media". Constructionism, on the other hand, is more contextual and pragmatic than constructivism; it acknowledges the importance of contexts, individual minds and their preferred representation, artifacts, and learning through hands-on experience (Bers, 2017).

Design Based Learning Theory

Design Based Learning (DBL) includes two distinct cycles: (1) design/redesign cycle, and (2) investigation and exploration cycle. The first cycle (i.e. design/redesign cycle) includes the following procedures: learners play with tools to understand the challenges, they engage in a problem based learning in order to define what should be investigated, finally, the learners plan a design, and then construct, test, and analyze it. In the second cycle, students refine the problem and establish a hypothesis, then design, conduct, and analyze an investigation before presenting and sharing it. As part of a Design-Based Learning project, students benefit from employing robotics for scientific problems. It strengthens the connection between content and real-world applications for pupils (Sahin, Ayar & Adiguzel, 2014).

Empirical Review of Literature

Suleman, Hussain, Din and Iqbal (2017) carried out a study on effects of Computer-Assisted Instruction (CAI) on students' academic achievement in physics at secondary level, it was found out that Computer-Assisted Instruction (CAI) significantly improved the achievements of the students in Physics. Similarly, Sullivan and Bers (2016) found an increased interest in STEM education, a greater appreciation for collaboration, and a more positive attitude toward problem solving among kids who participated in a robotics programme. The study of Esportuno and Gerardo (2014) on the influence of

robotics-aided lessons on students' physics achievement revealed that the post-test scores of students who were exposed to robotics-aided instruction was higher than that of the non-robotics aided lessons. Chatzopoulos, Papoutsidakis, Kalogiannakis and Psycharis (2020) while working on the use of educational robotics for the teaching of physics and its relation to self-esteem found out that there is a big improvement concerning the self-esteem as well as the learning outcome after the teaching-learning sequence using the educational robotics. Sobremisana (2017) investigated 'The use of physics innovative device for improving students, motivation and performance in learning selected concepts in physics', it was revealed that the group taught with the Physics innovative device performed significantly better than those taught in the traditional method and also the use of Physics innovative device generally improved students' understanding of concepts and led to higher academic achievements. However, there appears to be no review on the impacts of robotics-aided teaching strategy on the performance of students on gender bases. This study attempted to illuminate this aspect.
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Methodology

Research Design

The study made use of a quasi-experimental design since the study is set out to establish a cause-and-effect relationship between the independent variable (robotics enhanced teaching strategy) on the dependent variable (students' academic achievement in senior secondary Physics). Two treatment groups (control and experimental groups) were pretested, administered with a treatment, and post-tested.

T1: O1 X O3
T2: O2 O4
T1 : Treatment Group 1
T2 : Treatment Group 2
O1O2 : Pretest Scores
O3O4: Posttest Scores
X: Treatment

Sample and Sampling Techniques

The stimulus instrument (the mBot) is not a regular device in most schools in Abeokuta South, hence the researcher deployed purposive sampling technique to identify and select specific participants from senior secondary schools who could best represent the study's population. The researcher chose two comparable intact classes of SSS 2 students that offered Physics in four different schools in Abeokuta South Local Government Area of Ogun State. These classes consisted of 120 students of which 68 are males and 52 are females, with an average age of 16 years. Two of the schools are equipped with the mBot robot, thus, the classes in these school serve as the experimental groups while the remaining two classes from the two other schools without the mBot robot are the control classes.

Stimulus Instruments

The mBot robot and the Teacher's instructional guide are the stimulus instruments. The mBot is a STEAM teaching and learning educational robot designed to teach programming to students. The following functional parts of the robot are adapted and utilized for teaching some physics concepts:

i. The ultrasonic sensor which is the eye of the mBot and enables the robot to know the distance from an object.
ii. The wheels connected to the motors which enable the robot to move in a preferred direction.
iii. The controller Mcore which is the main control board for the mBot integrates various onboard sensors such as the buzzer, light sensors, RGB LED, etc.

Response Instrument

Physics Achievement Test (PAT) constituted the response instrument. The PAT was a teacher-made test constructed by the researcher covering three topics in Physics (Motion, Momentum, and Additive Mixture of Colour). It consisted of 30 multiple choice items administered as the pretest and posttest to participants in both the experimental group and control group at the start and end of the treatment.

Hypotheses Testing
At alpha = 0.05% significant level

Hypothesis 1
There is no significant mean effect of educational robotics as instructional strategy on academics achievement of students in Physics

Table 1: Effects of Treatment on Pre-Test
Tests of Between-Subjects Effects
Dependent Variable: pretest scores
a. R Squared = .011 (Adjusted R Squared = .003)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	9.075[a]	1	9.075	1.344	.249
Intercept	16216.875	1	16216.875	2400.842	.000
Groups	9.075	1	9.075	1.344	.249
Error	797.050	118	6.755		
Total	17023.000	120			
Corrected Total	806.125	119			

There is no statistically significant effect between the groups (experimental method and control method) on the pretest at p = 0.249

Table 2**: Effects of Treatment on Post-Test**
Tests of Between-Subjects Effects
Dependent Variable: post-test scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	371.008[a]	1	371.008	68.236	.000
Intercept	47322.408	1	47322.408	8703.537	.000

Groups	371.008	1	371.008	68.236	.000
Error	641.583	118	5.437		
Total	48335.000	120			
Corrected Total	1012.592	119			

R Squared = .366 (Adjusted R Squared = .361)

There is statistically significant effect between the groups (experimental method and control method) on the post-test at p= 0.000

Table 3: Effect of Treatment on Total Score
Tests of Between-Subjects Effects
Dependent Variable T_ SCORES

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	264.033[a]	1	264.033	12.950	.000
Intercept	118944.033	1	118944.033	5833.660	.000
Groups	264.033	1	264.033	12.950	.000
Error	2405.933	118	20.389		
Total	121614.000	120			
Corrected Total	2669.967	119			

a. R Squared = .099 (Adjusted R Squared = .091)

There is a statistically significant effects between the groups (experimental method and control method) on the TOTAL SCORES (post-test + pre-test) at p =0.000.

Considering the three cases, the null hypothesis is rejected and the alternative hypothesis is accepted. The experimental group taught with the robotics-enhanced strategy has higher adjusted score than the control group taught with the traditional method. This implies that robotics-enhanced strategy is a more effective teaching strategy. This finding aligned with the work of who worked on the influence of robotics-aided lessons on Franklie, Esportuno, Bobby and Gerardo (2014) students' physics achievement. They found out that the achievement scores of students in post-test of robotics-aided

instruction were high while those under the non-robotics-aided instruction were average.

Hypothesis 2

There is no significant mean effect of gender on the achievement of students, using educational robotics as instructional strategy

Table 4. Effect of Gender on Academic Achievement (Pre-Test)

Dependent Variable: pretest scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3.411E-13[a]	1	3.411E-13	.000	1.000
Intercept	14415.000	1	14415.000	2110.057	.000
Gender	.000	1	.000	.000	1.000
Error	806.125	118	6.832		
Total	17023.000	120			
Corrected Total	806.125	119			

a. R Squared = .000 (Adjusted R Squared = -.008)

There is no significant effect of gender on the pretest at p = 1.00

Table 5: Effect of Gender on Academic Achievement (Post-Test)
Tests of Between-Subjects Effects

Dependent Variable: post-test scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	6.017[a]	1	6.017	.705	.403
Intercept	42400.417	1	42400.417	4970.568	.000
Gender	6.017	1	6.017	.705	.403
Error	1006.575	118	8.530		
Total	48335.000	120			
Corrected Total	1012.592	119			

a. R squared = .006 (Adjusted R Squared = -.002)

Table 6: Effect of Gender on Academic Achievement (Total Scores)

Tests of Between-Subjects Effects

Dependent Variable: T_SCORES

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	6.017[a]	1	6.017	.267	.607
Intercept	106260.417	1	106260.417	4706.819	.000
Gender	6.017	1	6.017	.267	.607
Error	2663.950	118	22.576		
Total	121614.000	120			
Corrected Total	2669.967	119			

a. R Squared = .002 (Adjusted R Squared = -.006)

There is no statistically significant effects of gender on the TOTAL SCORES(post-test + pre-test) at P=0.607, hence the null hypothesis is accepted

Considering the three cases, the null hypothesis was accepted and alternative hypothesis rejected. This means that at 0.05 level of significance, there was no significant difference in the achievement between male and female when taught with the robotics-enhanced strategy. This implied that the robotics-enhanced strategy is best used to teach both male and female students

Summary

This study explored the impact of integrating educational robotics, specifically the mBot, as an instructional strategy on the academic achievement of Senior Secondary School students in physics in Abeokuta South Metropolis, Nigeria. Using a quasi-experimental design, the research involved 120 students, divided into experimental and control groups, with the former receiving robotics-enhanced instruction. The findings indicated a significant improvement in the physics performance of students taught using robotics compared to traditional teaching methods. The study found no significant gender differences in academic achievement, suggesting that robotics-enhanced strategies were equally effective for both male and female students. The study advocated for the integration of educational robotics into the curriculum and highlighted its potential to enhance physics education and promote gender equality in STEM fields.

Conclusion

Following the results obtained from the analysis of data collected, the following conclusions were arrived at:

Appropriate teaching strategies are effective means of conveying information so that learning can take place. Educational tools such as mBot and other low-cost robots should be used for teaching and learning as they can help improve students' performance in Physics. Physics students taught using robotics-enhanced instructional strategies performed better than those taught using traditional methods. There is no gender bias in physics performance among upper secondary students.

Recommendations

The study's recommendations are as follows:

1. Implementation of low-cost robotics and supplementary software in schools to enhance student engagement, improve learning outcomes, and foster better understanding of real-world problems.
2. Promote gender equality in Physics education to ensure both male and female students view Physics as crucial for technological advancement.
3. Integration of robotics for teaching and learning into the curriculum.
4. Establishment of robotics clubs, and organization of robotics competitions in schools, facilitated by trained professionals, to enhance students' skills and interest in robotics.

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