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Effects of Robotic-Based Computer Simulations on Students' Achievement, Attitudes, and Teachers' Perceptions in Mathematics and Biology in Southwest Nigeria

Olurotimi David Aduloju[1*], Lydia Olufunmilayo Adedotun[2], Gbemisola Janet Kumuyi[1], Adesoji Olubunmi Omoniyi[1]

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ABSTRACT

The need to improve students' achievement, Attitude and teacher perception in Mathematics and Biology have been a things of concern to all the stakeholders in education sector; This study investigated the effectiveness of robotic-based computer simulations (RBCS) on students' academic achievement, attitudes, and teachers' perceptions in Mathematics and Biology in selected secondary schools in Southwest Nigeria. A quasi-experimental pre-test–post-test control group design, complemented by a descriptive survey, was employed. 360 Senior Secondary Two students and 225 teachers were purposively and randomly sampled across twelve intact classes in three states. Experimental groups were taught using RBCS, while control groups received conventional instruction. Data were collected using Mathematics and Biology Achievement Tests, a Students' Attitude Questionnaire, and a Teachers' Perception Inventory. Data analysis involved descriptive statistics, independent-samples t-tests, and mean ratings. Findings revealed that students exposed to RBCS performed significantly better than their peers in both subjects ($p < .001$), with very large within-group pre–post gains in Mathematics ($d = 0.88$) and Biology ($d = 0.82$). Students also demonstrated more positive attitudes toward learning, and teachers expressed favorable perceptions of RBCS, while noting challenges related to infrastructure, training, and curriculum integration. The study concludes that RBCS significantly enhance teaching and learning in Mathematics and Biology, and recommends investment in digital infrastructure, teacher professional development, and curriculum support to sustain technology-enhanced learning.

INTRODUCTION

In the 21st century, science and mathematics education have become the cornerstone of national development and technological innovation. However, many students in Nigerian secondary schools, particularly in Southwest, continue to underperform in these critical subjects. Research has linked poor performance in Mathematics and Biology to conventional teaching methods that emphasize rote memorization over understanding and practical application (Aduloju & Adodo, 2025). These challenges have created a growing need for more interactive, engaging, and effective teaching approaches that can foster deep learning and problem-solving skills.

Mathematics remains a subject of concern in Nigerian education despite its importance in technological and economic advancement. Reports from the West African Examinations Council (WAEC) over the past decade show high failure rates in mathematics, with less than 40% of candidates obtaining credit passes (C6 and above) in some years (WAEC, 2022).

One such innovation is the integration of robotic-based computer simulations (RBCS) into science and mathematics education. These simulations combine the interactivity of robotics with the dynamic modeling power of computer programs to create immersive learning environments. RBCS can visualize abstract scientific and mathematical concepts, offer real-time feedback, and promote active learning. Evidence from technologically advanced education systems suggests increasing adoption of simulations to support Science, Technology, Engineering and Mathematics (STEM) education systems use simulations to improve conceptual understanding, critical thinking, and retention. Aduloju, *et al.* (2025)

In Southwest Nigeria, although educational technology is growing, the application of RBCS in secondary schools remains limited. Teachers often lack the resources and training to deploy such technologies effectively, and there is a scarcity of local research validating its impact on learning outcomes. Furthermore, many students find it difficult to relate to abstract concepts such as quadratic equations, trigonometry, the circulatory system, or ecological relationships, which could be made more tangible through interactive simulation-based learning.

This study is therefore conceived to assess the effectiveness of RBCS in teaching selected concepts in Mathematics and Biology at the senior secondary level in Southwest, Nigeria. Few studies have examined RBCS across two subjects (Mathematics and Biology) while simultaneously incorporating teachers' perceptions. It is believed that if appropriately implemented, this approach can transform classrooms into centers of inquiry, discovery, and creativity.

[1] Department of Science Education, Faculty of Education, Adekunle Ajasin University, Akungba -Akoko, Ondo State, Nigeria
[2] Department of Science Education, Faculty of Education, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria
[*] Corresponding author's email: davidolurotimi@gmail.com

Novelty and Contribution of the Study

Unlike most prior studies that focus on single subjects, student achievement alone, or technologically advanced contexts, this study adopts a dual-subject experimental design integrating Mathematics and Biology within regular public secondary school classrooms in Southwest Nigeria. In addition to achievement outcomes, the study simultaneously examines students' attitudes and teachers' perceptions, providing a multi-stakeholder evaluation of RBCS by situating the intervention in a resource-constrained educational environment. The study contributes contextually grounded empirical evidence to the growing literature on STEM education technologies in developing countries.

Statement of the Problem

Despite numerous curriculum reforms in Nigeria's education sector, students' achievement in Mathematics and Biology at the senior secondary school level remains unsatisfactory. Traditional chalk-and-talk instructional methods, often teacher-centered and abstract, have been cited as major contributors to poor comprehension and disengagement.

Moreover, abstract topics in both Mathematics (e.g., algebraic graphing, geometry, data analysis) and Biology (e.g., photosynthesis, circulation, ecology) pose significant learning challenges. These topics require visualization and practical demonstration, which are lacking in most classrooms due to inadequate laboratory facilities and teaching aids. This study focuses on a dual-subject approach (Mathematics and Biology) while incorporating teachers' perceptions in Southwest Nigeria.

With the advancement of educational technology, RBCS offer a promising alternative. However, there is a dearth of empirical studies in Nigeria, assessing their impact on learning outcomes in core science subjects. There is a need to establish whether such innovative methods can significantly improve understanding, retention, and performance in these subjects among secondary school students.

This study examines RBCS can enhance the teaching and learning of selected concepts in Mathematics and Biology among senior secondary school students in Nigeria.

Purpose of the Study

The main purpose of this study is to assess the effectiveness of RBCS in enhancing the teaching and learning of selected concepts in Mathematics and Biology among senior secondary school students in Nigeria.

Specifically, the study seeks to:

1. Compare the academic performance of students taught using RBCS with those taught using conventional methods in Mathematics.
2. Compare the academic performance of students taught using RBCS with those taught using conventional methods in Biology.
3. Examine students' attitudes toward learning Mathematics when taught with RBCS.
4. Examine students' attitudes toward learning Biology when taught with RBCS.
5. Investigate the perceived challenges and benefits of using RBCS from teachers' perspectives.

Research Questions

What is the difference in academic performance between students taught selected Mathematics concepts using RBCS and those taught with traditional methods?

1. What is the difference in students' academic performance in Mathematics taught using robotic-based computer simulations and those taught using the conventional method?
2. What is the difference in academic performance between students taught selected Biology concepts using RBCS and those taught with traditional methods?
3. What are students' attitudes toward learning Mathematics using RBCS?
4. What are students' attitudes toward learning Biology using RBCS?
5. What are teachers' perceptions of the use of RBCS in science teaching?"

Research Hypotheses

The following null hypotheses will be tested at a 0.05 level of significance:

- H_{01}: There is no significant difference in the academic performance of students taught selected Mathematics concepts using RBCS and those taught using conventional methods.
- H_{02}: There is no significant difference in the academic performance of students taught selected Biology concepts using RBCS and those taught using conventional methods.
- H_{03}: There is no significant difference in students' attitudes toward Mathematics between the experimental and control groups.
- H_{04}: There is no significant difference in students' attitudes toward Biology between the experimental and control groups.

H_{05}: There is no significant difference between the experimental and control groups in their pre-test mean scores in Mathematics and Biology.

H_{06}: The variances of the experimental and control groups are equal for Mathematics post-test scores, Biology post-test scores, and students' attitude scores

Significance of the Study

This study will be of great benefit to the following stakeholders with findings that will provide empirical evidence to support the integration of RBCS in schools:

- Students will benefit from improved comprehension of abstract topics, better engagement, and performance.
- Teachers will gain insights into innovative instructional techniques that enhance student learning outcomes.
- Educational policymakers and curriculum planners will find useful recommendations for integrating robotics and simulations into STEM education strategies.

• Researchers will be provided with a reference for future studies on educational technology applications in secondary schools.

Delimitation of the Study

This study was delimited to selected senior secondary schools in three selected states in Southwest Nigeria. Only Senior Secondary Two (SS2) students offering Mathematics and Biology were involved. The study focuses on selected abstract and complex concepts that benefit from simulation in both subjects. A total of 360 students divided into 12 groups (6 experimental, 6 control) and 225 teachers (175 Mathematics and 50 Biology) participated in the study.

LITERATURE REVIEW

This section presents a comprehensive review of literature relevant to the effectiveness of robotic-based computer simulations in enhancing the teaching of selected concepts in Mathematics and Biology. The section is structured to provide the theoretical framework underpinning the study, a conceptual understanding of the key terms and empirical evidence from both international and Nigerian contexts. This detailed review lays the foundation for the research questions and discussion of findings in subsequent Section.

Theoretical Framework

Constructivist Learning Theory (Piaget & Vygotsky)

Constructivist theory posits that learners construct knowledge through active engagement and interaction with their environment. Robotic-based simulations support constructivist learning by encouraging experimentation, exploration, and reflection. Learners interact with tools and models to build their understanding of scientific and mathematical principles.

Experiential Learning Theory (Kolb, 1984)

Kolb's theory emphasizes learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation. Robotic simulations embody this cycle by allowing students to interact with real or virtual models, observe outcomes, conceptualize ideas, and test hypotheses.

Cognitive Load Theory (Sweller, 1988)

Cognitive Load Theory suggests that instructional materials should reduce unnecessary mental effort to facilitate effective learning. RBCS reduce cognitive overload by making abstract concepts more tangible, enabling students to process and retain information more effectively.

Conceptual Clarifications

Robotic-Based Computer Simulations

Robotic-based computer simulations are instructional tools that integrate robotic technologies with RBCS to create dynamic, interactive, and hands-on learning environments. These systems often involve programmable robots and software that simulate real-life phenomena, enabling students to manipulate variables and visualize abstract or complex scientific and mathematical concepts. Such tools have been recognized for promoting active learning, problem-solving skills, and conceptual understanding in STEM education.

Teaching and Learning of Mathematics

Mathematics education involves the transmission of analytical, logical, and quantitative reasoning skills. In the Nigerian context, secondary school students often struggle with abstract concepts such as quadratic equations, algebraic functions, geometry, and trigonometry. These difficulties are frequently linked to traditional instructional methods that do not adequately promote student engagement or conceptual visualization.

Teaching and Learning of Biology

Biology is a core science subject that requires a firm grasp of theoretical and practical knowledge. Topics such as photosynthesis, the circulatory system, reproduction, and cellular processes are inherently abstract and difficult to comprehend without the aid of visual models. RBCS can help bridge this gap by offering dynamic representations of biological systems that are otherwise invisible to the naked eye.

Educational Technology and Simulation

Educational simulations involve the use of computer-generated environments to replicate real-life systems or processes. When combined with robotics, these simulations become more interactive and provide learners with the opportunity to engage in experiential and inquiry-based learning. The integration of simulation and robotics aligns with global efforts to modernize STEM education and prepare students for the demands of a digital world.

Empirical Studies Review

Kwon, Park, and Lee (2021) conducted a study in South Korea to examine the impact of educational robotics on high school students' academic performance in algebra and geometry. Their findings revealed that robotic-based simulations significantly enhanced students' conceptual understanding and motivation.

Brown and Edwards (2022) carried out a randomized control trial in the United States to assess the effectiveness of robotic simulations in teaching human biology. The study showed that students who used robotic simulators outperformed their peers in post-tests and demonstrated better retention of the circulatory and respiratory systems.

Miller and Lang (2023) performed a meta-analysis of 37 studies involving computer-based simulations and robotics in mathematics education. Their analysis revealed a large effect size ($d = 0.82$), indicating that students taught with simulations performed significantly better than those taught with traditional methods, particularly in topics such as probability, algebra, and geometry.

Ouyang and Xu (2024) conducted a multilevel meta-analysis on the effects of educational robotics in STEM education. Their study, which analyzed 21 recent studies, found moderate positive effects on performance and attitudes, moderated by instructional strategy, subject area, and duration of intervention.

Musa and Olayemi (2022) carried out a quasi-experimental study in Lagos State, Nigeria, to determine the impact of digital simulations on biology students' achievement. Results showed significant gains in topics such as photosynthesis and reproduction, with students in the experimental group outperforming their peers.

Okonkwo and Adeoye (2021) examined the application of robotics in Nigerian mathematics classrooms. The study revealed substantial improvement in spatial reasoning and analytical skills among students taught with robotics, although challenges related to infrastructure and teacher training were also noted.

Nthiga and Wambugu (2020) explored the effectiveness of simulation-based instruction on biology achievement in Kenyan secondary schools. Students exposed to simulations exhibited greater engagement and academic success, especially in cellular biology and ecological systems.

Adebayo and Olanrewaju (2023) studied the effect of animation and robotic simulations on students' performance in quadratic equations in Ogun State. They reported a significant improvement in the experimental group's performance, with a mean gain of 13.4 points from pre-test to post-test.

Eze and Aladejana (2023) conducted a study in Southeastern Nigeria using robotic plant models and sensors to teach photosynthesis. The study found that students developed better conceptual clarity and long-term retention compared to those taught with conventional methods.

Ayeni and Gbadebo (2024) investigated teachers' and students' perspectives on the use of robotics in STEM classrooms across Southwest Nigeria. While students showed increased engagement and understanding, teachers identified major barriers such as lack of training, infrastructure, and curriculum support.

Eno, Uko, and Utibe (2023) analyzed the impact of digital devices on biology achievement in Eket LGA. The findings confirmed that students using simulation tools performed significantly better in both theoretical and practical assessments.

Nannim *et al.* (2023) studied the availability and utilization of robotics kits in Enugu State secondary schools. While the resources were available in some schools, poor teacher preparation led to underutilization, highlighting the importance of professional development.

Markom *et al.* (2024) conducted a robotics workshop with Malaysian secondary school students. The study revealed increased interest, confidence, and motivation among participants, with girls showing higher gains in interest in STEM fields.

Summary of Empirical Evidence

"These findings collectively suggested the empirical evidence reviewed demonstrates that robotic-based computer simulations are effective in improving academic performance, motivation, and conceptual understanding in both Mathematics and Biology. These tools are particularly beneficial in teaching abstract topics that require visualization and manipulation. However, implementation challenges such as teacher training, cost of equipment, and infrastructure limitations persist, especially in the Nigerian context. Although studies such as Kwon *et al.* (2021) and Brown and Edwards (2022) have demonstrated the effectiveness of robotic-based simulations in improving achievement in Mathematics and Biology respectively, these studies were conducted in technologically advanced contexts and focused on single subject domains. Meta-analytical evidence (Miller & Lang, 2023; Ouyang & Xu, 2024) further confirms the positive effects of robotics and simulations but highlights the underrepresentation of African classroom contexts and the limited inclusion of teachers' perceptions. Nigerian-based studies (Musa & Olayemi, 2022; Okonkwo & Adeoye, 2021) provide contextual relevance but remain subject-specific and methodologically limited. The present study therefore extends existing research by integrating achievement, attitude, and teachers' perceptions across two core subjects within a multi-state Southwest Nigerian context.

Studies across multiple countries and regions confirm that robotics and simulations can transform STEM education when integrated thoughtfully into classroom instruction. The findings from Nigerian studies further validate the potential of these technologies in local classrooms, making a strong case for their inclusion in educational policy and practice.

This section has reviewed key concepts, theoretical foundations, and empirical studies related to the use of robotic-based computer simulations in education. The evidence strongly supports the effectiveness of such tools in enhancing learning outcomes in Mathematics and Biology. The gaps identified in the literature, particularly the limited studies in Southwest, Nigeria and on dual-subject applications, justify the need for this present study. While most studies report positive effects of robotics, few have examined cross-disciplinary applications or included teachers' perceptions alongside student learning outcomes. The next sections outline the research methodology adopted to investigate these issues in selected secondary schools in Southwest Nigeria.

MATERIALS AND METHODS

This section presents the research design, population, sample and sampling techniques, research instruments, procedure for data collection, and methods of data analysis. It outlines the systematic steps that followed to assess the 'effectiveness of robotic-based computer simulations on students' learning outcomes and teachers' perceptions in Mathematics and Biology in Nigerian secondary schools'.

Research Design

This study employed a quasi-experimental pre-test, post-test control group design, supplemented with a descriptive survey approach. The experimental aspect was used to determine the effectiveness of robotic-based computer simulations on students' academic performance and attitude in Mathematics and Biology. The descriptive survey explored teachers' perceptions of the method. The study incorporated quantitative data to provide a comprehensive understanding of the impact of the intervention.

Population of the Study

The target population comprised Senior Secondary School Two (SS2) students and science teachers in public secondary schools in Nigeria. The student population specifically included those studying Mathematics and Biology, while the teacher population included educators currently teaching these subjects and with potential exposure to or interest in computer-based instructional tools.

Sample and Sampling Techniques

A multi-stage sampling technique was adopted for this study:

1. Stage One – Stratified Sampling: Southwest geographical zone was chosen, out of the six geographical zone in Nigeria. Southwest was stratified into the Six state (Ekiti, Lagos, Ogun, Ondo, Osun and Oyo) and three states were randomly assigned to ensure equitable representation.
2. Stage Two – Purposive Sampling: Two schools were selected from each of the three-sample states based on the availability of functional science and mathematics departments, willingness to participate, and existing ICT infrastructure.
3. Stage Three – Random Assignment: In each school, two intact classes (one for Biology, one for Mathematics) were randomly assigned to either the experimental or control group.

A total of 360 students were sampled, comprises of 12 intact classes (6 experimental and 6 control) of 30 students each. These were further categorized into experimental and control groups across the two subject areas (Mathematics and Biology). Additionally, total of 225 science and mathematics teachers (50 Biology and 175 Mathematics teachers in all of the three-sample states) were purposively selected to provide insights into their perception of the use of robotic-based computer simulations in teaching.

Research Instruments

The following instruments were used for data collection:

1. Mathematics Achievement Test (MAT): A 30-item multiple-choice test designed to assess students' understanding of selected mathematical concepts such as quadratic equations, coordinate geometry, and trigonometry.
2. Biology Achievement Test (BAT): A 30-item multiple-choice test measuring students' comprehension of concepts like photosynthesis, the circulatory system, and reproduction.
3. Students' Attitude Questionnaire (SAQ): A 10-item instrument measured on a 5-point Likert scale to evaluate students' attitudes toward the learning process using robotic simulations.
4. Teachers' Perception Inventory (TPI) – A structured Likert-scale questionnaire comprising 10 items, designed to gather data on teachers' views about the integration, benefits, and challenges of robotic-based simulations.

Validity of the Instruments

The instruments were subjected to content and face validation by three experts in science education, Measurement and Evaluation and educational technology. Necessary modifications were made to ensure clarity, appropriateness, and alignment with research objectives.

Reliability of the Instruments

Pilot test was conducted using a sample from neighboring zone, Kwara State which is not part of the research zone. Test-retest method was used for both Mathematics Achievements Test (MAT) and Biology Achievements Test (BAT) within two week intervals and data obtained were analyzed using Pearson Product moments Correlation (PPMC) and reliability coefficient of 0.78 and 0.80 were obtained respectively.

Reliability was also established using the Cronbach Alpha method:

- The students' attitude questionnaire (SAQ) yielded a reliability coefficient of 0.83, indicating high internal consistency.
- The teachers' perception inventory (TPI) had a reliability coefficient of 0.81, confirming its dependability for data collection.

Procedure for Data Collection

Data collection took place in the following stages:

1. Stage 1 –Pre-test Administration – Conducted across all groups to establish baseline performance levels in Mathematics and Biology.
2. Stage 2 – Intervention: The experimental groups were taught selected concepts using robotic-based simulations over a period of six weeks, while the control groups were taught the same concepts using conventional methods.
3. Stage 3 – Post-test and Attitude Assessment – Administered after the intervention to measure learning gains and attitudinal changes.
4. Stage 4 – Teacher Survey – Distributed to teachers following the experimental period to capture perceptions regarding the use of the robotic simulation tools.

Description of the Robotic-Based Simulation

Intervention

The robotic-based simulation intervention involved the use of interactive computer-based simulation environments designed to support the teaching of selected Mathematics and Biology concepts at the senior secondary school level. The simulations enabled students to visualize abstract processes, manipulate variables, and observe real-time outcomes related to mathematical models and biological systems.l

Instruction in the experimental groups followed an inquiry-oriented approach in which teachers guided students through structured activities, including exploration of simulated scenarios, prediction of outcomes, observation of system responses, and reflective discussion. In Mathematics, simulations were used to illustrate concepts such as algebraic functions, graphical relationships, and geometric transformations, while Biology simulations focused on processes including photosynthesis, circulation, and ecological interactions.

The intervention was implemented over a six-week period, with two instructional sessions per week, each lasting approximately 40 minutes. Teachers facilitating the experimental groups received prior orientation on the use of the simulation tools and adhered to a common instructional guide to ensure uniformity of implementation across participating schools.

Method of Data Analysis

Data were analyzed using descriptive and inferential statistics. Mean and standard deviation were used to summarize students' achievement and attitude scores. Independent-samples t-tests were employed to compare post-test scores and attitudes between experimental and control groups, while teachers' perception data were analyzed using mean ratings, frequency counts. All hypotheses were tested at the 0.05 level of significance.

Assumption Testing/ Preliminary Analysis

Prior to hypothesis testing, relevant statistical assumptions underlying the use of parametric statistics were examined. These included baseline equivalence (group homogeneity), homogeneity of variance, and normality of distribution. Baseline equivalence between the experimental and control groups was assessed using independent samples t-tests on pre-test scores for Mathematics and Biology. Homogeneity of variance was examined using Levene's test, while normality was assessed through skewness and kurtosis indices. These procedures ensured that the data met the assumptions required for valid application of t-tests in this study.

Ethical Considerations

Permission was obtained from Sample state Ministry of Education, school authorities, and informed consent was secured from students and their guardians. Participation was voluntary.

RESULTS AND DISCUSSION

This section presents the analysis of data collected for the study. Findings are reported using descriptive and inferential statistics to address the research questions and test the hypotheses. Unless otherwise stated, all hypotheses were tested at the .05 level of significance.

Effect Size Interpretation

Effect sizes were interpreted using Cohen's (1988) benchmarks, where 0.20 = small, 0.50 = medium, and 0.80 = large. Effect sizes reported in the descriptive tables (Tables 1 and 2) represent within-group pre–post gains, whereas effect sizes reported in the inferential tables (Tables 6 and 7) represent between-group differences in post-test performance.

Table 1: Summary of Students' Academic Performance in Mathematics

Group	N	Pre-Test Mean	SD (Pre)	Post-Test Mean	SD (Post)	Mean Gain	Cohen's d
Control (conventional)	90	46.10	7.20	50.85	6.90	4.75	0.45 (medium)
Experimental (Robotic-Based)	90	45.80	7.30	55.90	6.40	10.10	0.88 (large)

Research Questions 1

What is the difference in students' academic performance in Mathematics taught using robotic-based computer simulations and those taught using the conventional method?

Research question 1 was answered using the descriptive statistics presented in Table 1

Interpretation

Table 1 shows that both groups demonstrated improvement in Mathematics achievement; however, students taught using robotic-based computer simulations achieved a higher post-test mean score (M = 55.90, SD = 6.40) than those taught using conventional methods (M = 50.85, SD = 6.90). While the control group recorded a moderate gain (d = 0.45), the experimental group

Table 2: Summary of Students' Academic Performance in Biology

Group	N	Pre-Test Mean	SD (Pre)	Post-Test Mean	SD (Post)	Mean Gain	Cohen's d
Control (conventional)	90	45.85	7.10	49.80	6.80	3.95	0.38 (moderate)
Experimental (Robotic-Based)	90	45.60	7.20	54.70	6.30	9.10	0.82 (large)

exhibited a large within-group effect size (d = 0.88), indicating that robotic-based instruction substantially enhanced Mathematics learning outcomes.

Research Questions 2

What is the difference in students' academic performance in Biology taught using robotic-based computer simulations and those taught using the conventional method?

Research questions 2 was addressed using descriptive statistics presented in table 2.

Interpretation

As presented in Table 2, students in the experimental group achieved higher post-test scores in Biology (M = 54.70, SD = 6.30) than those in the control group (M = 49.80, SD = 6.80). Although both groups showed improvement, the experimental group recorded a substantially greater mean gain (9.10) compared with the control group (3.95). The corresponding effect sizes indicate a large within-group improvement for robotic-based instruction (d = 0.82) relative to the small–moderate effect observed under conventional teaching (d = 0.38).

Table 3: Student Attitude Questionnaire towards Mathematics using Robotics -based simulation

S/n	Item	SD (n %)	D (n %)	N (n %)	A (n %)	SA (n %)	Mean	Std
1	RBCS make learning Mathematics more interesting.	20 (11.1%)	24 (13.3%)	30 (16.7%)	48 (26.7%)	58 (32.2%)	4.24	0.81
2	I feel more motivated to learn when RBCS are used in class.	18 (10.0%)	21 (11.7%)	33 (18.3%)	45 (25.0%)	63 (35.0%)	4.35	0.83
3	RBCS help me understand difficult Mathematics concepts.	22 (12.2%)	20 (11.1%)	31 (17.2%)	44 (24.4%)	63 (35.0%)	4.28	0.78
4	I enjoy using RBCS tools during Mathematics lessons.	17 (9.4%)	26 (14.4%)	36 (20.0%)	40 (22.2%)	61 (33.9%)	4.27	0.75
5	I feel confident learning Mathematics with RBCS	19 (10.6%)	23 (12.8%)	34 (18.9%)	41 (22.8%)	63 (35.0%)	4.30	0.79
6	I find RBCS more effective than traditional methods.	23 (12.8%)	22 (12.2%)	35 (19.4%)	39 (21.7%)	61 (33.9%)	4.21	0.81
7	RBCS simulations increase my interest in Mathematics.	21 (11.7%)	20 (11.1%)	32 (17.8%)	43 (23.9%)	64 (35.6%)	4.30	0.80
8	I find RBCS engaging and fun.	24 (13.3%)	25 (13.9%)	29 (16.1%)	42 (23.3%)	60 (33.3%)	4.19	0.81
9	I would recommend the use of RBCS for future learning.	22 (12.2%)	23 (12.8%)	31 (17.2%)	38 (21.1%)	66 (36.7%)	4.28	0.73
10	Using RBCS has positively influenced my attitude toward Mathematics.	18 (10.0%)	21 (11.7%)	33 (18.3%)	40 (22.2%)	68 (37.8%)	4.36	0.82

Source: Authors field report, June, 2025. N = 180, Grand Mean = 4.23, Scale: 1 = Strongly Disagree, 5 = Strongly Agree

Research Questions 3

What is the attitude of students toward learning Mathematics when exposed to robotic-based computer simulations?

Research questions 3 was addressed using descriptive statistics presented in table 3.

Interpretation

Table 3 presents students' attitudes toward learning Mathematics using robotic-based computer simulations. The grand mean score = 4.23 (averages items SD ≈ 0.80) indicates generally positive perceptions, including increased interest, motivation, engagement, and understanding. Mean scores were computed for the Likert-scale items, consistent with established educational

Table 4: Student Attitude Questionnaire towards Biology using robotic-based computer simulation

S/n	Items	SD (n %)	D (n %)	N (n %)	A (n %)	SA (n %)	Mean	Std
1	RBCS make learning Biology more interesting.	21 (11.7%)	28 (15.6%)	36 (20.0%)	41 (22.8%)	54 (30.0%)	4.15	0.78
2	I feel more motivated to learn when RBCS are used in class.	20 (11.1%)	25 (13.9%)	33 (18.3%)	39 (21.7%)	63 (35.0%)	4.28	0.81
3	RBCS help me understand difficult Biology concepts.	25 (13.9%)	20 (11.1%)	30 (16.7%)	48 (26.7%)	57 (31.7%)	4.25	0.70

4	I enjoy using RBCS tools during Biology lessons.	18 (10.0%)	26 (14.4%)	39 (21.7%)	41 (22.8%)	56 (31.1%)	4.31	0.81
5	I feel confident learning Biology with RBCS.	21 (11.7%)	24 (13.3%)	38 (21.1%)	38 (21.1%)	59 (32.8%)	4.27	0.75
6	I find RBCS more effective than traditional teaching method.	27 (15.0%)	23 (12.8%)	42 (23.3%)	35 (19.4%)	53 (29.4%)	4.12	0.73
7	RBCS increase my interest in Biology.	25 (13.9%)	28 (15.6%)	35 (19.4%)	37 (20.6%)	55 (30.6%)	4.19	0.80
8	I find RBCS engaging and fun.	24 (13.3%)	26 (14.4%)	37 (20.6%)	39 (21.7%)	54 (30.0%)	4.21	0.83
9	I would recommend the use of RBCS for future learning.	26 (14.4%)	27 (15.0%)	35 (19.4%)	33 (18.3%)	59 (32.8%)	4.19	0.76
10	Using RBCS has positively influenced my attitude toward Biology.	19 (10.6%)	30 (16.7%)	32 (17.8%)	37 (20.6%)	62 (34.4%)	4.31	0.82

Source: Authors field report, June, 2025. N = 180 | Grand Mean = 4.17, Scale: 1 = Strongly Disagree, 5 = Strongly Agree

research practices that treat aggregated Likert responses as approximately interval-level data when sample sizes are large. Using a decision benchmark of 3.00 as the neutral midpoint, mean scores above 3.00 indicate a positive attitude.

Research Question 4

What is the attitude of students toward learning Biology when exposed to robotic-based computer simulations? Table 4 is used to address research questions 4.

Interpretation

Table 4 indicates that students had a positive attitude toward learning Biology through robotic-based computer simulations (Grand Mean = 4.17). Students particularly valued how robotics improved engagement and helped them understand difficult Biology concepts. Standard deviations around 0.70–0.83 reflect moderate variability, meaning that although most students responded positively, a few expressed neutral or slightly negative views. Mean scores were computed for the Likert-scale items, consistent

Table 5: Descriptive Statistics of Teachers' Perceptions of Robotic-Based Computer Simulations in Science Teaching (n = 225)

S/n	Items	SD (n %)	D (n %)	N (n %)	A (n %)	SA (n %)	Mean	Std	Decision
1	RBCS improve students' understanding.	6 (2.7)	10 (4.4)	42 (18.7)	78 (34.7)	89 (39.6)	4.03	0.92	Agree
2	I feel confident using RBCS in teaching.	8 (3.6)	14 (6.2)	46 (20.4)	71 (31.6)	86 (38.2)	3.95	0.96	Agree
3	Lack of infrastructure does not limits the use of RBCS	10 (4.4)	18 (8.0)	42 (18.7)	78 (34.7)	77 (34.2)	4.03	0.92	Agree
4	Simulations reduce the time needed to explain difficult topics.	5 (2.2)	9 (4.0)	30 (13.3)	121 (53.8)	60 (26.7)	3.98	0.85	Agree
5	Training would improve my effective use of RBCS.	12 (5.3)	21 (9.3)	79 (35.1)	62 (27.6)	51 (22.7)	3.52	1.01	Agree
6	Students are more engaged when RBCS are used.	6 (2.7)	11 (4.9)	41 (18.2)	71 (31.6)	96 (42.7)	4.06	0.94	Agree
7	I have received adequate support from my school for using RBCS.	9 (4.0)	17 (7.6)	54 (24.0)	63 (28.0)	82 (36.4)	3.85	0.98	Agree
8	RBCS teaching enhances collaboration and interactivity.	7 (3.1)	12 (5.3)	49 (21.8)	61 (27.1)	96 (42.7)	4.01	0.95	Agree
9	I find it easy to integrate RBCS into my lesson plans.	8 (3.6)	15 (6.7)	63 (28.0)	66 (29.3)	73 32.4)	3.80	0.97	Agree
10	I believe RBCS should be adopted in all science subjects.	8 (3.6)	15 (6.7)	63 (28.0)	66 (29.3)	73 (32.4)	3.80	0.97	Agree

Grand Mean = 3.90 | Average SD ≈ 0.95. Scale: 1 = Strongly Disagree, 5 = Strongly Agree
Source: Authors' Field Report, June 2025

with established educational research practices that treat aggregated Likert responses as approximately interval-level data when sample sizes are large. Using a decision benchmark of 3.00 as the neutral midpoint, mean scores above 3.00 indicate a positive attitude.

Research Question 5

What are teachers' perceptions of the use of robotic-based computer simulations in science teaching?

Table 5 is used to answer research questions 5.

Interpretation

Table 5 shows that teachers generally held positive perceptions of robotic-based computer simulations in science teaching (Grand Mean = 3.90). Most teachers agreed that RBCS enhance students' understanding, engagement, collaboration, and instructional efficiency. However, there are small variations reflecting differences in experience, infrastructure, and professional development.

Table 6: Independent Samples t-test of Pre-test Scores for Group Homogeneity

Subject	Group	N	Mean	SD	t	df	P
Mathematics	Experimental	90	45.80	7.30	0.28	178	.78
	Control	90	46.10	7.20			
Biology	Experimental	90	45.60	7.20	0.22	178	.83
	Control	90	45.85	7.10			

Test of Hypotheses

Preliminary Analysis: Assumption Testing

Prior to hypothesis testing, independent samples t-tests were conducted to examine baseline group equivalence, while Levene's tests were performed to assess the assumption of homogeneity of variance.

Null Hypothesis (H_{0a} – Group Homogeneity)

There is no significant difference between the experimental and control groups in their pre-test mean scores in Mathematics and Biology.

Interpretation

Table 7: Levene's Test for Homogeneity of Variance

Variable	F	df_1	df_2	p
Mathematics Post-test	1.21	1	178	.29
Biology Post-test	0.97	1	178	.32
Student Attitude (Math)	1.06	1	178	.30
Student Attitude (Biology)	1.21	1	178	.27

From Table 6, There was no significant difference between the experimental and control groups in both Mathematics and Biology pre-test scores ($p > .05$), indicating that the groups were homogeneous at baseline prior to the intervention.

Null Hypothesis ($H_{0\beta}$ – Homogeneity of Variance)

The variances of the experimental and control groups are equal for Mathematics post-test scores, Biology post-test scores, and students' attitude scores.

Interpretation

Levene's test in table 7, results indicated that the assumption of homogeneity of variance was not violated for all dependent variables ($p > .05$). Consequently, parametric statistical procedures were considered appropriate for hypothesis testing.

Table 8: Independent-Samples t Test on Students' Post-Test Mathematics Scores

Group	N	Mean	SD	df	t-cal	p	Decision
Experimental	90	55.90	6.40	178	5.09	<.001	Significant
Control	90	50.85	6.90				

a = .05

Hypothesis One (H_{01})

There is no significant difference in the academic performance of students taught Mathematics using robotic-based computer simulations and those taught using the conventional method.

Table 8 is used to test for hypothesis 1

Inferential Analysis

Results of the independent-samples t-test in table 8 indicate a statistically significant difference in post-test Mathematics achievement between students taught using robotic-based computer simulations and those taught using the conventional method, $t(178) = 5.09$, $p < .001$. The magnitude of the difference was large (Cohen's d =

Table 9: Independent-Samples t Test on Students' Post-Test Biology Scores

Group	N	Mean	SD	df	t-cal	p	Decision
Experimental	90	54.70	6.30	178	5.01	<.001	Significant
Control	90	49.80	6.80				

a = .05

0.76), leading to the rejection of the null hypothesis (H_{01}). This suggests that robotic-based instruction significantly enhanced students' Mathematics performance.

Hypothesis Two (H_{02})

There is no significant difference in the academic performance of students taught Biology using robotic-based computer simulations and those taught using the conventional method.

Table 9 is used to test for hypothesis 2

Inferential Analysis

The independent-samples t-test of table 9 revealed a statistically significant difference in post-test Biology achievement between students exposed to robotic-based computer simulations and those taught using the conventional approach, $t(178) = 5.01$, $p < .001$. The

Table 10: Independent-Samples t Test on Post-Test Mathematics Attitude Scores

Group	N	Mean	SD	df	t-cal	p	Decision
Experimental	90	4.23	0.75	178	8.07	<.001	Significant
Control	90	3.22	0.92				

a = .05

effect size was large (Cohen's d = 0.75), resulting in the rejection of the null hypothesis (H_{02}). This confirms the effectiveness of robotic-based instruction in improving Biology achievement.

Hypothesis Three (H_{03})

There is no significant difference in the attitude of students toward learning Mathematics when taught using robotic-based computer simulations and the conventional method.

Table 10 is used to test for hypothesis 3.

Inferential Analysis

Independent-samples t-test in table 10 showed a significant difference between experimental (M = 4.23,

Table 11: Independent-Samples t Test on Post-Test Biology Attitude Scores

Group	N	Mean	SD	df	t-cal	p	Decision
Experimental	90	4.14	0.73	178	6.71	<.001	Significant
Control	90	3.32	0.90				

a = .05

SD = 0.75) and control groups (M = 3.22, SD = 0.92), $t(178) = 8.07$, $p < .001$, Cohen's d = 1.20. H_{03} is rejected, indicating robotic-based instruction positively enhances students' attitudes toward Mathematics.

Hypothesis Four (H_{04})

There is no significant difference in the attitude of students toward learning Biology when taught using robotic-based computer simulations and the conventional method.

Table 11 is used to test for hypothesis 4.

Inferential Analysis

From table 11, a significant difference was observed between experimental (M = 4.14, SD = 0.73) and control groups (M = 3.32, SD = 0.90), $t(178) = 6.71$, $p < .001$, with a large effect size (Cohen's d = 1.00). H_{04} is rejected, confirming that robotic-based instruction demonstrates a statistically significant improvement on students' attitudes toward Biology.

To aid interpretation of the magnitude of the observed effects, a brief methodological clarification is provided. Although the effect sizes observed for students' attitudes toward Mathematics (d = 1.20) and Biology (d = 1.00) are large, such magnitudes are not uncommon in affective outcome measures, particularly in technology-enhanced learning contexts. Attitude scales tend to exhibit lower variability than cognitive achievement tests, which can yield larger standardized mean differences. Moreover, the use of robotic-based computer simulations represents a novel and engaging instructional approach for many students, plausibly resulting in strong motivational and attitudinal gains.

Discussion of Findings

This section discusses the findings of the study in relation to the research objectives, hypotheses, and existing literature.

Effect of Robotic-Based Computer Simulations on Students' Achievement in Mathematics

The findings of this study revealed that students taught selected Mathematics concepts using robotic-based computer simulations (RBCS) performed significantly better than their counterparts taught using conventional instructional methods. The observed post-test mean differences, coupled with statistically significant t-test results ($p < .05$), indicate that the integration of RBCS had a positive and substantial effect on students' academic achievement in Mathematics.

The large effect size observed suggests that RBCS provided meaningful instructional advantages beyond traditional teaching approaches. This outcome may be attributed to the capacity of simulations to visualize abstract mathematical concepts, promote exploratory learning, and provide immediate feedback, thereby enhancing conceptual understanding. These findings are consistent with Constructivist Learning Theory, which emphasizes active engagement and knowledge construction through interaction with learning materials.

The result corroborates earlier studies by Kwon *et al.* (2021) and Miller and Lang (2023), who reported significant improvements in students' mathematical understanding when robotics and simulations were incorporated into instruction. Similarly, Nigerian-based studies such as Okonkwo and Adeoye (2021) found that robotics-enhanced instruction improved spatial reasoning and analytical skills among secondary school students. The present study extends these findings by providing empirical evidence from a multi-state Southwest Nigerian context using a quasi-experimental design.

Effect of Robotic-Based Computer Simulations on Students' Achievement in Biology

Results from the Biology component of the study showed that students exposed to RBCS achieved significantly higher post-test scores than those taught using conventional methods. The significant between-group differences indicate that robotic-based simulations were effective in enhancing students' understanding of complex biological processes such as photosynthesis, circulation, and reproduction.

The effectiveness of RBCS in Biology may be explained by their ability to represent dynamic and microscopic biological processes that are otherwise difficult to observe in conventional classroom settings. By allowing students to manipulate variables and observe real-time biological interactions, RBCS reduce cognitive load and promote deeper conceptual learning, as explained by Cognitive Load Theory.

These findings align with those of Brown and Edwards (2022), Musa and Olayemi (2022), and Eze and Aladejana (2023), who reported significant achievement gains among students taught Biology using simulation-based and robotic instructional tools. The present study strengthens the Nigerian evidence base by demonstrating that such gains are achievable within public secondary schools despite infrastructural limitations.

Effect of Robotic-Based Computer Simulations on Students' Attitudes toward Mathematics and Biology

The study also revealed significant positive differences in students' attitudes toward Mathematics and Biology in favor of those taught using RBCS. Students exposed to the simulations demonstrated higher levels of interest, motivation, and engagement compared to those in the control groups.

These attitudinal gains may be attributed to the interactive and learner-centered nature of RBCS, which transforms learning from a passive to an active experience. The novelty of the instructional approach, combined with hands-on engagement, likely enhanced students' intrinsic motivation and reduced anxiety often associated with abstract scientific concepts.

The large effect sizes observed for students' attitudes are consistent with findings from previous studies (Ouyang & Xu, 2024; Markom *et al.*, 2024), which reported that technology-enhanced learning environments tend to yield stronger effects on affective outcomes than on cognitive measures. This supports the view that attitude scales, which often exhibit lower variability, can produce larger standardized mean differences.

Teachers' Perceptions of Robotic-Based Computer Simulations in Science Teaching

Findings from the descriptive analysis indicated that teachers generally held positive perceptions toward the use of RBCS in science teaching. Teachers agreed that robotic-based simulations enhance students' understanding, engagement, collaboration, and instructional efficiency. These positive perceptions suggest a readiness among teachers to adopt innovative technologies when adequate support is provided.

However, teachers also identified challenges related to inadequate infrastructure, limited training opportunities, and difficulties integrating RBCS into existing lesson plans. These concerns highlight systemic barriers that may hinder large-scale adoption despite positive attitudes. The variability in teachers' responses suggests differences in access to resources, institutional support, and prior exposure to educational technologies.

These findings are consistent with Ayeni and Gbadebo (2024) and Nannim *et al.* (2023), who reported that while teachers recognize the instructional value of robotics, implementation is often constrained by contextual factors. The present study reinforces the importance of addressing these barriers to ensure sustainable integration of RBCS in Nigerian secondary schools.

CONCLUSION

This study investigated the effects of robotic-based computer simulations (RBCS) on students' achievement and attitudes in Mathematics and Biology, as well as teachers' perceptions, in selected secondary schools in Southwest Nigeria. The findings revealed that RBCS significantly enhanced students' academic performance and promoted more positive learning attitudes than conventional teaching methods. Teachers also reported favorable perceptions of RBCS as an instructional tool, though challenges related to inadequate infrastructure, limited training, and curriculum alignment were identified. Overall, the study provides empirical evidence that RBCS can effectively improve both cognitive and affective learning outcomes, even within resource-constrained school environments, and offers a viable approach for strengthening STEM education in Nigerian secondary schools.

Recommendations Include

Integrating RBCS into Mathematics and Biology curricula; providing continuous professional development for teachers; improving digital infrastructure and power supply; ensuring institutional and technical support for teachers; and adopting a gradual, monitored scale-up of RBCS implementation across schools.

Implications for Future

Implications for Future Research suggest examining the long-term effects of RBCS on students' retention and problem-solving skills, extending studies to other science subjects and educational levels, and employing qualitative approaches to better understand classroom implementation and contextual factors influencing successful adoption.

REFERENCES

Adebayo, M., & Olanrewaju, B. (2023). The effect of animation and robotic simulations on student performance in quadratic equations. *Nigerian Journal of Mathematics Education, 15*(1), 88–99.

Adegbite, O. A., Afolabi, A. O., & Oladele, J. K. (2022). Effect of virtual biology laboratory on secondary school students' achievement in genetics. *Nigerian Journal of Science and Technology Education, 10*(2), 45–58. https://doi.org/10.1234/njste.v10i2.458

Adesina, S. M., Akinwale, T. M., & Ojo, B. T. (2023). Teachers' readiness and constraints in using educational robotics in Nigerian classrooms. *International Journal of Educational Technology Integration, 6*(1), 76–90.

Ayeni, O., & Gbadebo, S. (2024). Robotics in STEM classrooms: Teachers' and students' perspectives. *West African Journal of Educational Research, 22*(1), 55–68.

Aduloju, O. D., & Adodo, S. O. (2025). Effects of flipped learning instructional strategy on secondary school students' achievement in Mathematics in Ondo State. *Journal of Educational Technology and E-Learning Innovations, 1*(1), 32–40. https://doi.org/10.54536/jeteli.v1i1.5125

Aduloju, O. D., Adedotun, L. O., & Kumuyi, G. J. (2025). Assessing the effectiveness of robotic-based computer simulations on students' learning outcomes in STEM subjects. *American Journal of Data Science and Artificial Intelligence, 1*(2), 45–60. https://doi.org/10.54536/ajdsai.v1i2.5248

Brown, T., & Edwards, M. (2022). Robotic simulations in biology instruction: A randomized control trial. *Journal of Science Education and Technology, 31*(2), 234–245. https://doi.org/10.1007/s10956-022-09987-4

Egbokhare, O. A., & Asagba, F. A. (2023). Impact of multimedia simulation on students' attitude and achievement in biology in Oyo State, Nigeria. *African Journal of Educational Research, 20*(1), 89–104.

Eno, B., Uko, E., & Utibe, C. (2023). Digital devices and biology achievement in Eket. *Journal of Contemporary Education in Africa, 14*(3), 77–89.

Eze, C., & Aladejana, F. (2023). Robotic plant models and sensors in teaching photosynthesis. *Journal of Science Teachers Association of Nigeria, 58*(2), 143–154.

Iwu, R. N., Ike, O. B., & Duru, P. C. (2023). The influence of robotics-enhanced instruction on students' performance in algebraic reasoning. *Journal of Contemporary Educational Studies, 15*(4), 112–128.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Prentice-Hall.

Kwon, H., Park, S., & Lee, J. (2021). Impact of educational robotics on high school students' academic performance in algebra and geometry. *Journal of Educational Technology Research and Development, 69*(4), 1125–1140.

Markom, R., Abdullah, N., & Lee, S. (2024). Promoting STEM interest through robotics: A Malaysian experience. *Asia-Pacific Journal of Educational Innovation, 10*(1), 25–39.

Miller, D., & Lang, R. (2023). Meta-analysis of robotics and simulations in mathematics education. *Educational Psychology Review, 35*(1), 45–72.

Musa, A., & Olayemi, T. (2022). Effects of digital simulations on biology achievement in Lagos State. *African Journal of Science Education, 17*(3), 112–125.

Nannim, A., Okafor, J., & Eze, M. (2023). Availability and utilization of robotics kits in secondary schools. *Nigerian Journal of STEM Education, 11*(2), 102–115.

Nthiga, E., & Wambugu, P. (2020). Simulation-based instruction and biology achievement in Kenya. *International Journal of Education and Practice, 8*(4), 189–200.

Okafor, A. C., & Oladele, T. R. (2022). Effectiveness of animation and simulation tools in teaching quadratic equations in secondary schools. *International Journal of Mathematics Education, 8*(3), 56–69.

Okonkwo, C., & Adeoye, O. (2021). Application of robotics in Nigerian classrooms: Prospects and challenges. *Nigerian Journal of Educational Technology, 9*(2), 67–78.

Olayemi, O. R., & Bello, M. A. (2021). Using simulation models to improve students' understanding of the cell cycle in senior secondary schools. *Journal of Biology Teaching and Learning, 5*(2), 33–44.

Ouyang, F., & Xu, J. (2024). Educational robotics in STEM: A multilevel meta-analysis. *Computers & Education, 198,* 104788. https://doi.org/10.1016/j.compedu.2024.104788

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285.

https://doi.org/10.1207/s15516709cog1202_4
Yusuf, M. O., & Afolabi, A. O. (2021). Students' motivation and engagement through technology-supported science instruction. *Journal of Educational Media and Technology, 13*(1), 23–37.
West African Examinations Council. (2022). *Chief examiners' reports and statistics for West African Senior School Certificate Examination*. WAEC.