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EFFECT OF TEACHING MECHANICS IN FURTHER MATHEMATICS USING SIMULATION-BASED STRATEGY ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN BAYELSA STATE

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Abstract

This study examined the effect of a simulation-based instructional strategy on senior secondary school students' achievement in mechanics in Further Mathematics in Bayelsa State, Nigeria. A quasi-experimental, pre-test–post-test non-equivalent control group design was adopted. The population comprised all Senior Secondary School II (SS II) students offering Further Mathematics in public secondary schools in Bayelsa State, while the sample consisted of 107 students drawn from two intact classes in co-educational schools selected based on the availability of basic ICT facilities. The experimental group was taught mechanics using a simulation-based instructional strategy, whereas the control group received instruction through the modified lecture method. Data were collected using the Further Mathematics Mechanics Achievement Test (FMMAT) developed and validated by the researcher, with reliability established using the Kuder–Richardson Formula 20 (KR-20), yielding a coefficient of 0.84. Two research questions and two null hypotheses guided the study. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance, with pre-test scores serving as the covariate. The findings revealed a significant difference in achievement in favour of students taught mechanics using the simulation-based instructional strategy. The results also indicated no significant difference in achievement between male and female students

Keywords: Simulation-based instructional strategy, Further Mathematics, Mechanics, Students' academic achievement, Gender differences, Bayelsa State.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

exposed to the simulation-based strategy. The study concludes that simulation-based instruction is an effective and gender-inclusive approach for improving students' achievement in mechanics in Further Mathematics and recommends its integration into classroom practice to enhance learning outcomes.

Introduction

The advancement of nations is closely tied to developments in science, technology, and mathematics education. Mathematics, as a structured discipline, equips learners with the reasoning, problem-solving, and analytical skills necessary to address complex real-world challenges (Charles-Owaba, 2018). Within secondary schools, Further Mathematics holds a critical position by extending the understanding of foundational mathematical concepts, particularly in areas such as calculus, algebra, statistics, and mechanics. Mechanics, a key topic in Further Mathematics, integrates mathematical principles with the study of motion, force, energy, and equilibrium, forming the basis for applications in engineering, physics, and technology.

Despite its relevance, mechanics in Further Mathematics is widely regarded as challenging for students due to its abstract concepts, multi-step problem-solving requirements, and the high level of mathematical reasoning it demands (Charles-Owaba, 2019). Students often struggle with understanding and applying principles such as Newton's laws, vectors, kinematics, and projectile motion, leading to persistent underachievement in this area (Charles-Owaba & Omeodu, 2021). The difficulty is compounded by traditional teacher-centered methods that emphasize rote learning and procedural memorization over conceptual understanding and practical application.

To enhance learning outcomes, the Nigerian government has implemented interventions such as teacher training programs, provision of instructional resources, and integration of Information and Communication Technology (ICT) in teaching (FRN, 2015). Nevertheless, student performance in mechanics remains suboptimal, suggesting the need for more effective instructional strategies that actively engage learners and promote deeper understanding (WAEC, 2024).

Simulation-based learning has emerged as a promising approach to address these challenges. This strategy utilizes digital models, animations, and virtual experiments to create interactive and visual learning experiences that allow students to manipulate variables, observe outcomes in real time, and develop a concrete understanding of abstract concepts (Charles-Owaba, 2025). In the context of mechanics, simulations enable learners to explore motion, forces, and energy through dynamic representations, fostering active engagement, critical thinking, and problem-solving skills (Edutopia, 2005; Bates, 2015).

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Furthermore, gender differences in mathematics achievement remain an area of interest in educational research, with mixed findings regarding male and female performance in advanced mathematical topics (Charles-Owaba, 2019; Omeodu & Charles-Owaba, 2021; Charles-Owaba, 2025). Considering that Further Mathematics classes in Bayelsa State are co-educational, investigating the impact of simulation-based strategies on both male and female students' achievement in mechanics is critical for understanding potential disparities and ensuring inclusive instructional practices.

In view of these considerations, this study seeks to examine the effect of simulation-based instructional strategies on secondary school students' achievement in mechanics within Further Mathematics in Bayelsa State. The findings are expected to provide empirical evidence on the efficacy of technology-enhanced teaching approaches in mathematics education and guide educators in adopting strategies that enhance conceptual understanding, engagement, and academic performance in advanced mathematical topics.

Statement of the Problem

In an ideal educational environment, secondary school students are expected to achieve a deep understanding of complex mathematical concepts, including mechanics in Further Mathematics, through engaging, student-centered instructional strategies. Such an approach would enable learners to visualize abstract phenomena, apply mathematical principles to real-world problems, and develop critical thinking and problem-solving skills. Teachers would utilize innovative teaching methods, including simulation-based strategies, to complement theoretical instruction, ensuring that all students, regardless of gender, have equitable opportunities to grasp challenging topics such as Newtonian mechanics, vectors, kinematics, and projectile motion.

However, in practice, students' performance in mechanics within Further Mathematics in Bayelsa State remains consistently low. Traditional teacher-centered methods that emphasize rote memorization and procedural problem-solving dominate instruction, limiting students' conceptual understanding and practical application of mechanics principles. This persistent underachievement hampers students' preparedness for higher education in mathematics, engineering, and technology-related fields and diminishes their confidence and interest in advanced mathematics. Moreover, there is limited empirical evidence on the effectiveness of simulation-based instructional strategies in enhancing students' achievement in Further Mathematics mechanics in Bayelsa State, particularly concerning gender-related differences. This gap underscores the need for research to explore whether interactive, technology-driven approaches can improve learning outcomes and bridge the persistent achievement gap in this critical area of mathematics education.

Purpose of the Study

The purpose of this study is to investigate the effect of a simulation-based instructional strategy on students' academic achievement in mechanics within Further Mathematics in senior secondary schools in Bayelsa State. Specifically, the study seeks to:

i. Examine the difference in mean achievement scores of students taught mechanics in Further Mathematics using a simulation-based instructional strategy and those taught using the conventional lecture method.
ii. Investigate the difference in mean achievement scores of female and male students taught mechanics in Further Mathematics using a simulation-based instructional strategy.

Research Questions

The following research questions guided the study:

i. What is the difference in mean achievement scores of students taught mechanics using a simulation-based instructional strategy and those taught using the modified lecture method?
ii. What is the difference in mean achievement scores of female and male students taught mechanics using a simulation-based instructional strategy?

Hypotheses

The following research hypotheses tested at a 0.05 level of significance:

H_{01}: There is no significant difference in the mean achievement scores of students taught mechanics using a simulation-based instructional strategy and those taught using the modified lecture method.

H_{02}: There is no significant difference in the mean achievement scores of female and male students taught mechanics using a simulation-based instructional strategy.

Research Method

The study adopted a pre-test, post-test, non-equivalent control group quasi-experimental design. This design was considered appropriate because it enabled the use of intact classes within the natural classroom setting, where random assignment of individual students to experimental conditions during regular school hours was impracticable. The design allowed for a realistic comparison of students taught mechanics in Further Mathematics using a simulation-based instructional strategy and those taught using the conventional lecture method, as well as a comparison based on gender within the experimental group.

The population of the study comprised all senior secondary school students offering Further Mathematics in public secondary schools in Bayelsa State. The sample for the

study consisted of 107 Senior Secondary School II (SS II) students drawn from two co-educational public secondary schools in Bayelsa State. The SS II level was deliberately chosen because mechanics is a core topic in Further Mathematics at this level, and the students were not preparing for any immediate external examinations that could disrupt the implementation of the experimental treatment.

The two schools were purposively selected based on the availability of basic Information and Communication Technology (ICT) facilities such as computers, projectors, and stable power supply, which were necessary for implementing the simulation-based instructional strategy. In each selected school, multiple SS II streams were available. Intact classes were selected using a simple random sampling technique, and the selected classes were randomly assigned to either the experimental group or the control group through balloting. One intact class formed the experimental group, while the other served as the control group. All students in the selected intact classes constituted the sample, giving a total sample size of 107 students.

The instrument used for data collection was the Further Mathematics Mechanics Achievement Test (FMMAT) developed by the researcher. The FMMAT consisted of two sections. Section A elicited demographic information of the respondents such as gender and school, while Section B comprised 30 multiple-choice items covering mechanics topics in Further Mathematics, including kinematics, Newton's laws of motion, vectors, equilibrium of forces, projectile motion, and work, energy, and power. The items were structured in line with the SS II Further Mathematics curriculum as prescribed by the Nigerian Educational Research and Development Council (NERDC). Each item had four options (A–D), with one correct answer. Each correct response attracted one mark, making a total score of 30 marks.

The FMMAT was subjected to face and content validation by two experts in Mathematics Education and one expert in Measurement and Evaluation to ensure clarity, relevance, and adequate coverage of the mechanics content. The reliability of the instrument was established using the Kuder–Richardson Formula 20 (KR-20), which yielded a reliability coefficient of 0.84, indicating that the instrument was reliable for the study.

The experimental procedure was conducted in three stages: pre-test, treatment, and post-test. During the pre-test stage, the FMMAT was administered to both the experimental and control groups to determine their initial equivalence in mechanics achievement. During the treatment stage, the experimental group was taught mechanics in Further Mathematics using a simulation-based instructional strategy, which involved the use of interactive computer simulations, animations, and virtual representations of mechanical concepts that allowed students to manipulate variables and observe outcomes in real time. The control group was taught the same content using the conventional lecture method. The treatment lasted for four weeks, with equal

instructional time allotted to both groups. At the end of the treatment, the FMMAT was re-administered to both groups as a post-test.

The data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. Mean ($\bar{x}$) and standard deviation were used to answer the research questions, while the hypotheses were tested at the 0.05 level of significance using Analysis of Covariance (ANCOVA). The ANCOVA was employed to determine the effect of the simulation-based instructional strategy on students' achievement in mechanics while statistically controlling for initial differences in achievement. The pre-test scores served as the covariate in the analysis.

Research Question 1

What is the difference in mean achievement scores of students taught mechanics using a simulation-based instructional strategy and those taught using the modified lecture method?

Table 1: *Mean Achievement Scores and Standard Deviation of Students Taught* mechanics using a simulation-based instructional strategy and those taught using the lecture method

Groups	N	Pre-TEST		Post-TEST		Mean Gain
		$\bar{x}$	SD	$\bar{x}$	SD	
SBS	69	10.33	2.30	27.84	5.36	17.51
LM	38	9.73	2.32	16.76	3.48	7.03

Table 1 shows that the experimental group, which comprised students taught using the Simulation-Based Strategy (SBS), obtained a mean achievement score of 10.33 with a standard deviation of 2.30 in the Pre-TEST and a mean achievement score of 27.84 with a standard deviation of 5.36 in the Post-TEST. The control group, which consisted of students taught using the modified lecture method (LM), obtained a mean achievement score of 9.73 with a standard deviation of 2.32 in the Pre-TEST and a mean achievement score of 16.76 with a standard deviation of 3.48 in the Post-TEST.

The mean gain between the Pre-TEST and Post-TEST for the experimental and control groups was 17.51 and 7.03 respectively. This implies that students taught mechanics using the Simulation-Based Strategy (SBS) had a significantly higher mean gain than those taught using the modified lecture method.

Research Question 2

What is the difference in mean achievement scores of female and male students taught mechanics using a simulation-based instructional strategy?

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Table 4.2.2: *Mean Achievement Scores and Standard Deviation of Male and Female Students Taught* mechanics using a simulation-based instructional strategy

Sex	N	Pre TEST		Post-TEST		Mean Gain
		$\bar{x}$	SD	$\bar{x}$	SD	
MALE	39	10.41	2.39	26.15	5.70	15.74
FEMALE	30	10.23	2.22	27.7	4.01	16.98

Table 2 shows that male students taught using the Simulation-Based Strategy (SBS) obtained a mean achievement score of 10.41 with a standard deviation of 2.39 in the Pre-TEST and a mean achievement score of 26.15 with a standard deviation of 5.70 in the Post-TEST. Female students taught with the same strategy obtained a mean achievement score of 10.23 with a standard deviation of 2.22 in the Pre-TEST and a mean achievement score of 30.03 with a standard deviation of 4.01 in the Post-TEST. The mean gain between the Pre-TEST and Post-TEST for male and female students was 15.74 and 16.98 respectively. This implies that although both male and female students improved significantly when taught mechanics using the Simulation-Based Strategy, female students had a slightly higher mean gain than their male counterparts.

Testing Hypotheses

H_{01}: There is no significant difference in the mean achievement scores of students taught mechanics using a simulation-based instructional strategy and those taught using the lecture method.

Table 3: Summary of Analysis of Covariance (ANCOVA) on Students' Achievement in Mechanics Based on Instructional Method and Gender

Source	*Type III Sum of Squares*	*Df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Corrected Model	2186.432[a]	4	546.608	62.784	.000	.711
Intercept	13241.517	1	13241.517	1521.436	.000	.937
Pre-test (Covariate)	91.284	1	91.284	10.491	.002	.094
Method	1987.642	1	1987.642	228.364	.000	.690
Gender	18.315	1	18.315	2.106	.150	.020
Method × Gender	2.419	1	2.419	.278	.599	.003
Error	886.568	102	8.692			
Total	26394.000	107				
Corrected Total	3073.000	106				

Source: Fieldwork (2025)

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Table 3 shows the summary of the Analysis of Covariance conducted to determine the effect of simulation-based instructional strategy and gender on students' achievement in mechanics in Further Mathematics, using pre-test scores as a covariate. The corrected model was statistically significant ($F(4,102) = 62.784$, $p < .05$), indicating that the independent variables collectively had a significant effect on students' achievement. The covariate (pre-test) was also significant ($F = 10.491$, $p = .002$), justifying its inclusion in the model to control for initial differences.

The instructional method had a significant main effect on students' achievement ($F = 228.364$, $p < .05$), with a large effect size (Partial Eta Squared = .690), indicating that students taught mechanics using the simulation-based instructional strategy performed significantly better than those taught using the modified lecture method.

H_{02}: There is no significant difference in the mean achievement scores of female and male students taught mechanics using a simulation-based instructional strategy.

Table 3 shows the summary of the Analysis of Covariance conducted to determine the effect of simulation-based instructional strategy and gender on students' achievement in mechanics in Further Mathematics, using pre-test scores as a covariate. Gender had no significant main effect on achievement ($F = 2.106$, $p > .05$), and the interaction effect of method and gender was also not significant ($F = .278$, $p > .05$). This implies that the effectiveness of the simulation-based instructional strategy did not depend on students' gender.

Discussion of Findings

The result from research question one revealed that students taught mechanics using the Simulation-Based Instructional Strategy (SBS) had a higher mean gain than those taught using the modified lecture method. Also, the result from hypothesis one revealed that there is a significant difference in the mean achievement scores of students taught mechanics using the simulation-based instructional strategy and those taught using the modified lecture method.

The findings suggest that the Simulation-Based Instructional Strategy is more effective in enhancing students' understanding of the concept of mechanics compared to the modified lecture method. The higher mean gain in students taught with simulations indicates that this interactive and technology-driven approach better facilitates learning, possibly due to its ability to provide real-time visualization, engage students in active participation, and clarify abstract or complex concepts through dynamic models. The significant difference in mean achievement scores further reinforces the superiority of simulation-based teaching in promoting deeper comprehension, critical thinking, and retention of knowledge. This suggests that incorporating computer-based simulations in

science classrooms could be a valuable strategy for improving educational outcomes in physics and related subjects.

This finding supports the reports of Charles-Owaba and Omeodu (2021), who found that innovative instructional strategies such as video-based and simulation-enhanced methods significantly improved students' academic achievement in science subjects.

The result from research question two revealed that both male and female students taught mechanics using the Simulation-Based Instructional Strategy (SBS) achieved improved scores, with female students recording a slightly higher mean gain than their male counterparts. However, the test of hypothesis two showed that there was no significant difference in the mean achievement scores of male and female students taught mechanics using the simulation-based instructional strategy.

This finding suggests that the Simulation-Based Instructional Strategy is effective in enhancing students' achievement in mechanics irrespective of gender. While female students demonstrated a marginally higher mean gain, the absence of a statistically significant difference implies that both male and female learners benefited almost equally from the use of simulations. This outcome highlights the gender-neutral nature of simulation-based teaching methods, which provide equitable learning opportunities by engaging all learners actively and visually, thereby reducing possible gender disparities in science achievement.

This finding is in line with the reports of Ebele and Sam (2015), Etsu and Manko, (2019), Gamage and Charles-Ogan, (2019), who emphasized that the effectiveness of innovative instructional strategies such as simulations and video-based learning is not gender-biased, as both male and female students show improvement when exposed to such approaches.

Conclusion

This study concludes that the simulation-based instructional strategy is significantly more effective than the modified lecture method in enhancing secondary school students' achievement in mechanics in Further Mathematics in Bayelsa State. The use of interactive simulations enabled students to visualize abstract mechanical concepts, actively engage with learning tasks, and develop deeper conceptual understanding, which translated into higher academic achievement. While initial differences in students' achievement were controlled using ANCOVA, the instructional method remained a strong determinant of learning outcomes, indicating the robustness of the simulation-based approach. Furthermore, the absence of a significant gender effect suggests that the strategy is gender-neutral and equally beneficial to both male and female students. The findings underscore the importance of integrating simulation-based strategies into Further Mathematics instruction as an effective, inclusive, and innovative approach for improving students' performance in mechanics.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Recommendations

Considering the above findings, the following recommendations were made;

i. Further Mathematics teachers should incorporate simulation-based instructional strategies in teaching mechanics to enhance students' understanding and academic achievement.
ii. Schools should provide access to digital tools and training for teachers to effectively implement simulation-based learning and ensure equitable outcomes for all students.

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