



EFFECT OF USE OF COMPUTER SIMULATIONS ON STUDENTS' ACHIEVEMENT IN BASIC SCIENCE IN ENUGU EDUCATION ZONE, NIGERIA

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Abstract

This research examined the effect of use of computer simulations in instructional delivery on students' achievement in Basic science in Enugu Education Zone of Enugu state. The study was guided by two research questions and three null hypotheses. A pretest-posttest non-equivalent control group quasi-experimental design was employed. Population of the study consisted of all Junior Secondary School Two (JSS2) students enrolled in public secondary schools within the Enugu Education Zone, from which 120 students was sampled using purposive and random sampling techniques. Data were collected using the Basic Science Achievement Test (BSAT), which was validated by three experts. The reliability of the CAT was determined using the Kuder-Richardson Formula 20, resulting in a reliability coefficient of 0.84. The experimental group was taught specific Basic science concepts using Computer simulations, while the control group received instruction on the same concepts through the traditional lecture method (LM). Data were analysed using mean, standard deviation, and analysis of covariance (ANCOVA). The results indicated that the use of computer simulation in instructional delivery significantly improved students' achievement compared to the lecture method. No significant influence of gender on students' achievement in Basic science was observed. Based on these findings, it was recommended that schools should integrate computer simulations into teaching, particularly Basic science, to improve student performance through interactive, experiential learning.

Keywords: Achievement, Basic Science, Computer Simulations, Instruction,

Introduction

The rapid evolution of educational technology has revolutionized pedagogical approaches, with computer simulations emerging as a transformative tool in science education. Computer simulations, defined as dynamic, interactive digital models that replicate real-world scientific phenomena, allow learners to visualize abstract concepts, manipulate variables, and engage in experiential learning within a risk-free virtual environment (de Jong, Linn, & Zacharia, 2013). In the context of Basic Science, a foundational subject that equips students with essential scientific knowledge and inquiry skills, simulations hold significant promise in bridging the gap between theoretical instruction and practical understanding. Research indicates that simulations enhance conceptual mastery by enabling students to observe cause-



and-effect relationships, conduct virtual experiments, and receive immediate feedback, thereby promoting deeper cognitive engagement (Rutten, van Joolingen, & van der Veen, 2012). Despite these advantages, the empirical evidence on the efficacy of computer simulations in improving students' achievement in Basic Science remains inconclusive, particularly in developing educational contexts Nigeria, where infrastructural limitations and resistance to technological integration persist (Ofoegbu, Asogwa, & Okechukwu, 2021). While some studies report substantial gains in science achievement following simulation-based instruction (Smetana & Bell, 2012), others suggest that its effectiveness is contingent upon factors such as instructional design, teacher competency, and students' prior knowledge (Akpan & Andre, 2000). This discrepancy underscores the need for context-specific research, particularly in the Enugu Education Zone, where traditional lecture methods dominate science classrooms, potentially limiting students' opportunities for active learning.

A critical yet underexplored dimension in this discourse is the moderating influence of gender on the relationship between computer simulations and academic achievement in Basic Science. Gender disparities in science achievement have been widely documented, with studies attributing these differences to sociocultural factors, varying levels of self-efficacy, and differential engagement patterns between male and female students (Halpern *et al.*, 2007). For instance, research suggests that male students often exhibit greater confidence and participation in hands-on science activities, whereas female students may face stereotype threats that undermine their performance (Wang & Degol, 2013). However, proponents of technology-enhanced learning argue that simulations, by virtue of their interactive and visually stimulating nature, may mitigate gender-based disparities by fostering an inclusive and equitable learning environment (Lau & Yuen, 2013). Some studies have found that female students, in particular, benefit from the structured guidance and reduced anxiety associated with virtual experimentation, leading to improved outcomes in science (Honey & Hilton, 2011). Conversely, other research indicates that gender differences persist even in simulation-based learning, with males outperforming females in tasks requiring spatial reasoning and abstract problem-solving (Uttal *et al.*, 2013). Given these conflicting findings, there is a pressing need to investigate whether and how gender influences the effectiveness of computer simulations in Basic Science instruction, particularly in the Nigerian educational landscape, where gender dynamics in STEM participation remain a persistent concern (Okeke, 2019).

Furthermore, existing studies on simulation-based learning in science education have predominantly been conducted in Western contexts, with limited attention to sub-Saharan



Africa, where disparities in technological access, teacher preparedness, and curricular alignment may yield divergent outcomes (Hennessy, Harrison, & Wamakote, 2010). In Nigeria, for instance, while the National Policy on Education advocates for technology integration in schools, implementation remains inconsistent due to infrastructural deficits and insufficient teacher training (Federal Ministry of Education, 2013). This gap in localized research necessitates an investigation into how computer simulations can be effectively harnessed to enhance Basic Science achievement in the Enugu Education Zone, where students' performance in national science assessments has been suboptimal (West African Examinations Council, 2022). Additionally, prior studies have largely overlooked the interplay between gender and instructional technology in science education, leaving unanswered questions about whether simulations can serve as an equalizing force or inadvertently reinforce existing disparities. By examining gender as a moderator variable, this study sought therefore, to provide nuanced insights into how male and female students differentially benefit from simulation-based instruction, thereby informing targeted pedagogical strategies.

In light of these gaps, this study aims to assess the effect of computer simulations on students' achievement in Basic Science in the Enugu Education Zone while exploring the moderating role of gender. The findings would contribute to the broader discourse on technology-enhanced science education by offering empirical evidence on the contextual applicability of simulations in a developing educational setting. Moreover, by elucidating gender-specific effects, the study seeks to provide actionable recommendations for policymakers and educators seeking to promote equitable and effective science instruction.

Purpose of the Study

Specifically, the study sought to determine the:

1. Mean achievement scores of students taught Basic science using computer simulation and those taught using the traditional lecture method.
2. Mean achievement scores of male and female students taught Basic science using computer simulation and those taught using the traditional lecture method.
3. Interaction effects of teaching methods and gender on students' academic achievement in Basic science.



Research Questions

1. What are the mean achievement scores of students taught Basic science using computer simulation and those taught using the traditional lecture method?
2. What are the mean achievement scores of male and female students taught Basic science using computer simulation and those taught using the traditional lecture method?

Hypotheses

1. There is no statistically significant difference in the mean achievement scores of students taught Basic science using computer simulation and with those taught using the traditional lecture method.
2. There is no statistically significant difference in the mean achievement scores of male and female students taught Basic science using computer simulation and with those taught using the traditional lecture method.
3. There is no significant interaction effect of teaching methods and gender on students' academic achievement in Basic science.

Methods

The study utilized a quasi-experimental research design, specifically the non-equivalent control group pretest-posttest design. This design was considered suitable because randomization of subjects into experimental and control groups was not feasible, as the study was conducted in intact classes within their natural school settings. The design allowed the researcher to compare the performance of a group taught with computer simulation (experimental group) and another taught with conventional methods (control group), using both pretest and posttest scores to measure the treatment effect.

The population of the study consisted of all Junior Secondary School Two (JSS2) students enrolled in public secondary schools within the Enugu Education Zone. A sample of 120 students was drawn from four co-educational public secondary schools using purposive sampling. The selection criteria included availability of computer laboratories, presence of qualified Basic Science teachers, and willingness of the school authorities to participate in the study. Two schools were randomly assigned to the experimental group, and the other two to the control group. The experimental group consisted of 64 students while the control group consisted of 56 students, all taught by their regular subject teachers under the supervision of the researcher.



The instrument for data collection was the Basic Science Achievement Test (BSAT), a researcher-developed test comprising 50 multiple-choice questions. The test items were drawn from topics covered in the JSS2 Basic Science curriculum such as “Changes and Its Effects,” “Energy,” and “Simple Machines,” which are considered suitable for simulation-based instruction. The face and content validity of the BSAT were established by three experts. To determine the reliability of the BSAT, a trial testing was conducted on 30 JSS2 students in a school outside the study area but with similar characteristics. The reliability coefficient was computed using the Kuder-Richardson Formula 20 (KR-20) appropriate for dichotomously scored items. The result yielded a reliability coefficient of 0.84, which was considered high and acceptable for educational research.

The experimental procedure lasted for six weeks. Prior to the intervention, both experimental and control groups were administered the BSAT as a pretest. The experimental group received instruction using computer simulation packages, which provided interactive and visual demonstrations of scientific concepts. The control group, on the other hand, was taught the same concepts using conventional teaching methods, primarily lecture and textbook-based instruction. Both groups were taught by their regular subject teachers to maintain consistency in instructional delivery and reduce teacher-related biases.

To ensure uniformity, the researcher developed lesson plans for both groups, which were strictly followed throughout the study. The teachers were also trained prior to the intervention on how to use the computer simulations and how to follow the instructional procedures without deviation.

Data collection involved the administration of the BSAT as both a pretest and posttest. The instruments were administered under uniform conditions with the help of trained research assistants to minimize test administration errors and ensure consistency across schools. For data analysis, mean and standard deviation were used to answer the research questions. Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance.

Results

Table 1: Mean Achievement scores of Students taught Basic Science using Computer Simulation (CS) and Lecture Method (LM)

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
CS	64	13.14	3.07	35.11	6.22	21.97
LM	56	12.95	3.16	22.98	3.92	10.03



According to Table 1, students who were taught Basic science using computer simulation achieved a pretest mean score of 13.14 and a posttest mean score of 35.11, resulting in a mean gain of 21.97. In contrast, students taught Basic science using the lecture method (LM) had a pretest mean score of 12.95 and a posttest mean score of 22.98, with a mean gain of 10.03. The pretest scores of students taught with lecture method were more heterogeneous, as indicated by a standard deviation of 3.16, compared to those taught with Computer simulation, who had a standard deviation of 3.07. However, in the posttest, students taught with computer simulation showed greater variability in their scores, with a standard deviation of 6.22, while those taught with LM had a more uniform performance, reflected by a standard deviation of 3.92. Students taught using computer simulation had higher gained mean than those taught using lecture method.

Table 2: Mean Achievement scores of Male and Female Students taught Basic Science using Computer Simulation (CS) and Lecture Method (LM)

Method	Gender	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
CS	Male	27	12.15	3.29	32.96	5.56	20.81
	Female	37	13.86	2.72	36.68	6.27	22.81
LM	Male	14	13.93	3.52	23.07	4.76	9.14
	Female	42	12.62	3.00	22.95	3.66	10.33

As shown in Table 2, male students taught Basic science using computer simulation achieved a pretest mean score of 12.15 and a posttest mean score of 32.96, resulting in a mean gain of 20.81. In comparison, female students taught with computer simulation had a pretest mean score of 13.86 and a posttest mean score of 36.68, with a mean gain of 22.81. Table 2 further indicated that male students taught Basic science using the lecture method (LM) had a pretest mean score of 13.93 and a posttest mean score of 23.07, yielding a mean gain of 9.14. Similarly, female students taught with LM had a pretest mean score of 12.62 and a posttest mean score of 22.95, with a mean gain of 10.33. Overall, both male and female students taught with computer simulation demonstrated higher mean gain scores compared to their counterparts taught with LM. Specifically, male students in the CS group outperformed those in the LM group, and female students in the CS group also achieved greater gains than those in the LM group.

Table 3: ANCOVA Test of Significance of Difference in the Mean Achievement Score of Students taught Basic science using Computer Simulation and Lecture Method

Source	SS	df	Mean Square	F	Sig.	Decision
Corrected Model	4981.456 ^a	4	1245.364	53.275	.000	
Intercept	2638.463	1	2638.463	112.870	.000	
Pretest	373.660	1	373.660	15.985	.000	
Method	3588.588	1	3588.588	153.516	.000	Sig.
Gender	70.548	1	70.548	3.018	.085	Not Sig.
Method * Gender	25.059	1	25.059	1.072	.303	Not Sig.
Error	2688.244	115	23.376			
Total	111746.000	120				
Corrected Total	7669.700	119				

Table 3 shows that the instructional approach had a significant effect on students' achievement in Basic Science, as evidenced by $F(1, 115) = 153.516$ and a P-value less than 0.05. This result leads to the rejection of the null hypothesis and confirms that students taught using computer simulation performed significantly better than those taught through the lecture method. Additionally, Table 3 indicates that gender did not have a statistically significant effect on students' achievement in Basic Science, with $F(1, 115) = 3.018$ and P greater than 0.05. This implies that the null hypothesis for gender is retained, suggesting no meaningful difference in achievement between male and female students regardless of the teaching method used. Furthermore, the table reveals no significant interaction between instructional method and gender on students' achievement in Basic Science, as shown by $F(1, 115) = 1.072$ and $P > 0.05$. This suggests that the effectiveness of the instructional method on students' achievement does not vary by gender, as illustrated in Figure 1.

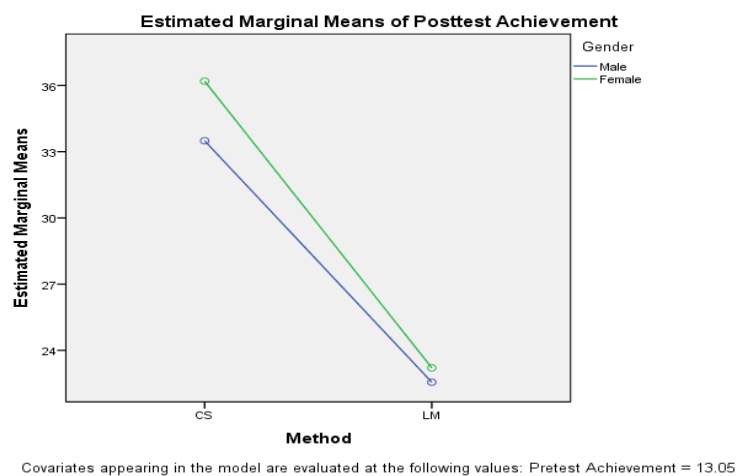


Figure 1: Plot of interaction effect of instructional methods and gender on students' achievement in Basic science

The interaction effect of instructional methods and gender on students' Basic science achievement, depicted in Figure 1, is both non-significant and ordinal. This indicates that the impact of instructional methods did not vary according to gender, making them gender-biased.

Discussion

The study's findings reveal several important insights into the effectiveness of computer simulations compared to traditional lecture methods, as well as the role of gender in academic achievement. Firstly, students who were taught using computer simulations performed significantly better than those taught through the lecture method. This suggests that interactive, technology-based learning tools may enhance understanding and retention of material more effectively than passive lecture-based instruction. The immersive and engaging nature of simulations likely provides students with hands-on experience, fostering deeper comprehension and application of concepts, which translates into higher achievement levels.

The findings of this study align with and contrast against several existing research studies on instructional methods and gender differences in academic achievement. A significant body of research supports the conclusion that computer simulations enhance learning outcomes compared to traditional lecture methods. For instance, a meta-analysis by Smetana and Bell (2012) found that simulations and interactive technology significantly improved student achievement in science education by allowing learners to manipulate variables and visualize abstract concepts, leading to deeper understanding. Similarly, Rutten, van Joolingen, & van der Veen (2012) demonstrated that simulation-based learning fosters active engagement and problem-solving skills, which are often lacking in passive lecture settings. These studies reinforce the current findings that computer simulations are more effective than lectures, likely due to their experiential and student-centered nature.

However, some studies suggest that the effectiveness of simulations may depend on subject matter and implementation. For example, a study by Merchant *et al.* (2014) found that while simulations improved conceptual understanding, they were not always superior to direct instruction for procedural knowledge. This contrasts slightly with the current study, which found a clear advantage for simulations, possibly indicating that the subject domain or instructional design plays a role in their effectiveness.

Additionally, the study found no meaningful difference in mean achievement between male and female students, regardless of the teaching method used. This indicates that gender does not play a significant role in determining academic success in this context, as both male



and female students performed similarly when exposed to the same instructional strategies. Furthermore, the effectiveness of the instructional method on students' achievement does not vary by gender, meaning that computer simulations and lectures impact male and female students equally. This finding challenges any assumptions that one gender might benefit more from a particular teaching approach, reinforcing the idea that both methods are equally accessible and effective for all students.

Regarding gender differences, the current study's finding that no meaningful achievement gap exists between male and female students aligns with much of contemporary educational research. Hyde (2005), in her *gender similarities hypothesis*, argued that males and females perform similarly in most academic domains, with only minor differences in specific contexts. Similarly, a large-scale study by Stoet and Geary (2013) found that gender disparities in STEM achievement were often overstated, with female students performing equally well when given equivalent learning opportunities. These findings support the conclusion that instructional effectiveness does not vary significantly by gender.

However, the study also notes that the interaction effect is gender-biased, which introduces a layer of complexity to these findings. While the overall achievement levels between genders were similar, the way male and female students interacted with the instructional methods may have differed. For instance, one gender might have engaged more actively with simulations, while the other might have adapted differently to lecture-based instruction, even if their final achievement scores were comparable. This bias in interaction effects suggests that while the outcomes are equitable, the underlying dynamics of how students engage with these teaching methods could vary by gender.

However, the observation of a gender-biased interaction effect introduces nuance. Some studies suggest that while achievement outcomes may be similar, engagement patterns can differ. For example, Cooper & Robinson (2014) found that female students often reported higher satisfaction with collaborative and inquiry-based methods (like simulations), whereas male students sometimes preferred competitive or independent learning structures. Additionally, research by Cheryan *et al.* (2017) on stereotype threat indicates that subtle biases in instructional design (masculine-coded interfaces in simulations) may influence participation without necessarily affecting final grades. This could explain why the current study detected an interaction effect despite equal achievement outcomes.

In contrast, some older studies (Wehrwein et al., 2007) argued that gender differences in learning preferences could lead to divergent outcomes in certain teaching modalities, but



these findings have been increasingly challenged by meta-analyses showing minimal performance gaps. The current study's results thus align more closely with modern research emphasizing equity in learning outcomes while acknowledging that gendered engagement patterns may persist beneath the surface.

The study highlights the superiority of computer simulations over lectures in boosting students' achievement, while also emphasizing that gender does not significantly influence overall academic performance. However, the gender-biased interaction effect implies that the learning experience itself may differ between male and female students, warranting further investigation into how these methods are perceived and utilized differently across genders. These findings have important implications for educators and curriculum designers, suggesting that incorporating technology-enhanced learning tools can benefit all students, regardless of gender, while also acknowledging the need to consider nuanced engagement patterns in instructional design.

Conclusion

The study underscores the superiority of computer simulations over lectures in boosting student achievement while reinforcing that gender does not determine academic success. However, the gender-biased interaction effect highlights the need for further investigation into how students of different genders experience and engage with various teaching methods. Educators should adopt simulation-based learning where appropriate but remain attentive to potential differences in student interaction to foster an inclusive and maximally effective learning environment. Ultimately, these findings advocate for a shift toward more interactive, technology-enhanced teaching strategies while dismissing outdated assumptions about gender-based learning differences. Future research should explore long-term retention, subject-specific variations, and socio-cultural factors that may influence how students respond to different instructional approaches.

Recommendations

1. Adopt simulation-based learning: schools should integrate computer simulations into teaching, particularly in Basic science, to improve student performance through interactive, experiential learning.
2. Ensure gender-responsive teaching practices: While no gender gap exists in achievement, educators should use inclusive strategies to promote equal engagement and avoid unconscious biases in instructional design.



3. Research engagement patterns: Further studies should explore how male and female students interact differently with teaching methods, using qualitative approaches to uncover hidden disparities in motivation and participation.

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