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EFFECT OF COMPUTER-ASSISTED INSTRUCTION ON SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN ATOMIC THEORY IN MINNA, NIGER STATE, NIGERIA

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Abstract

This study investigated the effect of computer-aided instruction (CAI) on senior secondary school students' achievement in atomic theory in Minna, Niger State, Nigeria. The persistent poor performance of students in atomic theory, a highly abstract topic in chemistry, has been a major concern for educators. The study determined whether CAI could improve students' academic achievement compared to conventional teaching methods. A quasi-experimental research design was adopted. The population comprised 1,850 senior secondary school students (615 females and 1,235 males) in Minna during the 2024/2025 academic session. A sample of 155 students was selected using simple random sampling. The Atomic Theory Achievement Test (ATAT) served as the data-collection instrument. The reliability coefficient of the ATAT, determined using the Kuder-Richardson 21 (K-R 21) formula, was 0.86. Four research

questions and four null hypotheses, tested at the 0.05 level of significance, guided the study. Data were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA). Findings revealed that students taught with computer-aided instruction achieved significantly higher in atomic theory than those taught using conventional methods. No significant gender difference in achievement was observed among students exposed to CAI, indicating that the instructional approach was equally effective for both male and female students. The study concludes that computer-aided instruction is an effective strategy for teaching Atomic Theory in chemistry. It recommends integrating CAI into chemistry instruction, providing adequate teacher training on CAI tools and simulations, and investing in secondary school technological infrastructure to enhance learning outcomes.

Keywords: Computer-Aided Instruction, Atomic Theory, Academic Achievement, Chemistry Education.

Introduction

Science is a systematic and organized endeavour that generates knowledge through observation, experimentation, and logical reasoning. It provides testable explanations and predictions about natural phenomena and the universe, serving as the foundation for understanding the world and driving technological and societal progress. Modern science is broadly categorized into three main branches (Clark, 2016; Adeyemi & Ogunleye, 2021). The natural sciences, which include physics, chemistry, biology, and biotechnology, focus on the laws governing matter, energy, and living systems. The social sciences investigate human behavior, social structures, and interactions through disciplines such as sociology, economics, and psychology. The formal sciences, encompassing mathematics, logic, and statistics, supply the analytical tools and frameworks essential for modeling and interpreting data across all scientific domains. Together, these branches underpin the applied sciences, which translate scientific knowledge into practical solutions in fields such as engineering, technology, agriculture, medicine, and environmental management.

Applied sciences play a vital role in addressing societal needs by converting fundamental scientific principles into

tangible innovations. These disciplines, including engineering, information and communication technology, agriculture, medicine, and environmental management, foster industrial development, economic growth, and improvements in human health and quality of life (Bakare et al., 2020). Science education, which equips learners with the requisite knowledge, skills, and competencies, is therefore central to national development. It underpins scientific and technological advancements applicable to critical sectors such as health, agriculture, information and communication technology, electronics, manufacturing, and construction (Adeyemi & Ogunleye, 2021; Okeke & Onwukwe, 2022). In recognition of this importance, the Nigerian government, through the National Policy on Education, mandates that at least 60% of admissions into conventional universities be allocated to science and science-related programs. This policy aims to produce a critical mass of scientifically trained graduates capable of advancing national development (Federal Republic of Nigeria, 2014; Okeke & Onwukwe, 2022).

Within science education, chemistry occupies a pivotal position. As a central discipline, it bridges theoretical understanding and practical application by enabling learners to comprehend the composition, structure, properties, and

transformations of matter. This knowledge forms the foundation for innovations in industry, healthcare, agriculture, energy, and environmental sustainability (Adeyemi & Ogunleye, 2021). Effective integration of chemistry in the curriculum thus develops both conceptual mastery and applied skills, producing graduates who can meaningfully contribute to technological advancement and national progress.

Chemistry is a natural science that investigates the properties, composition, structure, and transformations of matter, including the energy changes accompanying chemical reactions (Edomwonyi & Aava, 2024). It provides the foundation for understanding the material world and drives technological innovations in medicine, agriculture, manufacturing, environmental protection, energy, and information technology (Basarkod, Ersoy & Kurt, 2021).

In Nigeria, chemistry is taught at the secondary school level to develop scientific literacy, build essential skills, foster problem-solving abilities, and prepare students for tertiary education in science-related fields such as medicine, pharmacy, engineering, and biotechnology (Edomwonyi & Aava, 2024; Onwe, 2019). Mastery of

chemistry is vital for technological advancement and national development (De-Jong & Talanquer, 2018). Globally, computer-assisted instruction (CAI) has proven effective in enhancing science learning outcomes. CAI enables students to interact with abstract concepts through simulations, virtual experiments, and dynamic visualizations, thereby improving conceptual understanding and motivation (Basarkod, Ersoy & Kurt, 2021; Boopathy, Rajaguru, Krishnan & Mohamed, 2020). Despite its importance, students often find atomic theory difficult due to its abstract nature. Traditional teaching methods often lead to poor comprehension, negative attitudes, and low achievement (Plass, Milne & Bridges, 2019). Computer simulations offer a promising solution by providing interactive and concrete representations of atomic structures and processes (Van Joolingen, de Jong & Dede, 2018). In Nigeria, poor achievement in atomic theory persists. West African Senior School Certificate Examination (WASSCE) reports (2019–2025) show fluctuating credit pass rates (29.52%–38.84%) and a rising failure rate (F9) from 13.27% in 2019 to 28.18% in 2023, indicating low retention and understanding of key concepts such as electron configuration.

Table 1: West African Secondary School Certificate Examination Result in Niger State from 2019-2025

Year	Registered Candidates	Total Pass (A1–C6)	% Pass (A1–C6)	Total Pass (D7–E8)	% Pass (D7–E8)	Total Fail (F9)	% Fail (F9)
2019	7534	2610	34.64%	3924	52.08%	1000	13.27%
2020	10815	4201	38.84%	5114	47.29%	1500	13.87%
2021	11518	3707	32.18%	5811	50.45%	2000	17.36%
2022	10534	3110	29.52%	5124	48.64%	2300	21.83%
2023	8518	2607	30.61%	3511	41.22%	2400	28.18%
2024	7666	2223	29.00%	2987	39.00%	2451	32.00%
2025	6,232	1,745	28.00%	2,306	37.00%	2,181	35.00%

Source: Department of Educational Resource Center (ERC), Niger State Ministry of Education, Minna (2025).

Table 1 shows a worrying trend of declining student performance in WASSCE results in Niger State in atomic theory between 2019 and 2023. Credit-level pass rates (A1–C6) fluctuated, ranging from a high of 38.84% in 2020 to a low of 29.52% in 2022, with 30.61% recorded in 2024. While the proportion of students obtaining D7–E8 grades declined steadily, failure rates (F9) rose sharply from 13.27% in 2019 to 28.18% in 2023, more than doubling within the period. This consistent increase in failure rates signals a serious decline in performance and underscores the urgent need for effective instructional interventions in the teaching of atomic theory.

Achievement in education refers to the extent to which learners acquire intended knowledge, skills, and competencies as a result of instruction. In the context of

chemistry, achievement encompasses both a deep conceptual understanding of scientific principles and the ability to apply these principles to solve theoretical and practical problems (Khalid et al., 2021; Basarkod et al., 2021). It is a critical indicator of effective learning and serves as a foundation for students' progression to higher education and professional careers.

Students' low achievement in organic chemistry has often been associated with the continued reliance on conventional teaching methods. In response, instructional approaches such as Computer-Aided Instruction (CAI) have been explored as viable alternatives for improving learning outcomes. Evidence from classroom-based studies in Nigerian secondary schools indicates that students exposed to CAI tend to perform better than those taught through

traditional lecture methods, with improvements observed across both male and female students (Oluwole, Adesina, & Bello, 2020). Similarly, the need to improve students' performance in chemistry has led to the adoption of innovative instructional strategies, such as CAI. Findings from studies conducted in Nigerian secondary schools suggest that students taught using CAI achieve higher academic outcomes than those exposed to conventional teaching methods. For instance, Abdullahi, Yusuf, and Mohammed (2019) reported that students exposed to CAI performed significantly better than their counterparts taught through traditional approaches, highlighting CAI's potential to improve students' achievement in chemistry.

Gender is defined as a social construct that shapes the roles, expectations, and opportunities of males and females in society (Ezeani & Obasi, 2020), has been extensively examined as a potential factor influencing achievement in science subjects. However, research findings on gender differences in science achievement remain inconclusive. While some studies report that male students outperform females in certain science domains, others find no significant gender differences, especially when modern, interactive, and student-centered instructional strategies such as computer-aided instruction are employed (Afolabi et

al., 2022; Nwosu & Eze, 2020; Bello et al., 2022). These mixed results suggest that teaching methodology may be more influential than gender itself in determining learning outcomes. Therefore, this study determine the effect of computer-aided instruction on senior secondary school students' achievement in atomic theory in Minna, Niger State, with a focus on the role of gender

Statement of the Problems

Despite growing advocacy for integrating digital tools into science education, the use of computer-aided instruction (CAI) to teach complex chemistry concepts, such as atomic theory, CAI remains underexplored in Nigerian secondary schools. In Minna, Niger State, students continue to exhibit poor understanding of atomic theory, as evidenced by consistently low performance in senior secondary examinations. This persistent difficulty is largely attributed to the abstract nature of the topic and the limitations of conventional teacher-centered instructional methods.

Although CAI has the potential to improve visualization, conceptual understanding, and learner engagement, empirical evidence of its effectiveness in the Nigerian secondary school context, particularly in Minna, is limited. Most existing studies on CAI have been conducted in developed countries with

advanced technological infrastructure and well-resourced classrooms, raising questions about the applicability of their findings to resource-constrained Nigerian schools. Additionally, while gender has been identified as a possible factor influencing science learning outcomes, its role in students' achievement when using CAI in atomic theory remains insufficiently examined. In light of these gaps, this study investigated the effect of computer-aided instruction on senior secondary school students' achievement in atomic theory in Minna, Niger State, Nigeria.

Objective of the Study

The study determined the effect of computer-aided instruction on senior secondary school students' attitude and achievement in atomic theory in Minna, Niger State, Nigeria. Specifically, the study sought to;

- i. find out the academic achievement of senior secondary students when taught using computer-aided instruction and those taught using conventional methods.
- ii. ascertain the achievement of male and female senior secondary school students when taught atomic theory using computer-aided instruction.

Research Questions

The following research questions guided the study:

- i. What are the mean achievement scores of senior secondary students when taught atomic theory using computer-aided instruction and those taught using conventional methods?
- ii. What are the mean achievement scores of male and female senior secondary school students when taught atomic theory using computer-aided instruction?

Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

- H₀₁:** There is no significant difference in the mean achievement scores of senior secondary students taught atomic theory using computer-aided instruction and those taught using conventional methods.
- H₀₂:** There is no significant difference in the mean achievement scores of male and female senior secondary school students when taught atomic theory using computer-aided instruction.

Methodology

The study adopted a quasi-experimental research design with a non-randomized pretest–post-test control group. This design was considered appropriate because random assignment of subjects was not feasible, since the use of intact classes. The study consisted of one experimental group and one control group. The experimental group was taught atomic theory using computer-aided instruction, while the control group was taught the same content using the conventional teaching method.

The population of the study comprised 1,850 Senior Secondary School I (SS1) chemistry students from five selected public secondary schools in Minna, Niger State, during the 2024/2025 academic session. The study sample comprised 155 students selected via simple random sampling. First, two schools were randomly selected. Second, one intact SS1 chemistry class was randomly selected from each school. One class was assigned to the experimental group, while the other served as the control group.

Results

Research Question One

What are the mean achievement scores of senior secondary students when taught atomic theory using computer-aided instruction and those taught using conventional methods?

Data were collected using the Atomic Theory Achievement Test (ATAT), developed by the researcher. The instrument consisted of 30 multiple-choice items with four options (A–D), adapted from WAEC past questions. Each correct answer attracted 2 marks, giving a total score of 60. The instrument was used for both pretest and post-test to measure students' achievement in atomic theory.

The ATAT was validated by experts in science education to ensure clarity, relevance, and adequate coverage of the content area. The instrument's reliability was established through a trial test with SS2 students outside the study sample. The scores were analyzed using Kuder-Richardson Formula 21 (KR-21), which yielded a reliability coefficient of 0.86, indicating that the instrument was reliable. Data collected were analyzed using descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at a 0.05 level of significance.

Table 2: Mean Achievement Scores of Senior Secondary School Students Taught Atomic Theory Using Computer-Aided Instruction and Those Taught Using Conventional Methods

Group		Pretest	Posttest
Experimental	Mean	9.31	21.91
	N	75	75
	Std. Deviation	2.838	4.275
Control	Mean	7.67	16.95
	N	80	80
	Std. Deviation	1.888	2.783

Table 2 shows that the pretest mean score of the experimental group (students taught Atomic Theory using Computer-Aided Instruction) is 9.31 with a standard deviation of 2.838, while the posttest mean score is

21.91 with a standard deviation of 4.275. The pretest mean score for the control group (students taught using the conventional method) is 7.67 with a standard deviation of 1.888, while the posttest mean score is 16.95 with a standard deviation of 2.783.

Hypothesis One

There is no significant difference in the mean achievement scores of senior secondary students taught atomic theory using computer-aided instruction and those taught using conventional methods.

Table 3: ANCOVA Result of the Mean Achievement Scores of Senior Secondary Students Taught Atomic Theory Using Computer-Aided Instruction and those Taught Using Conventional Methods

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1135.346 ^a	2	567.673	48.480	.000	.389
Intercept	6136.565	1	6136.565	524.068	.000	.775
Pretest	184.305	1	184.305	15.740	.000	.094
Group	1127.252	1	1127.252	96.268	.000	.388
Error	1779.841	152	11.709			
Total	60941.000	155				
Corrected Total	2915.187	154				

Table 3 shows the ANCOVA result of the mean achievement scores of senior secondary students taught Atomic Theory using Computer-Aided Instruction and those

taught using Conventional Methods, since the $F(1,152) = 96.268$; and $P = 0.000$, $< \alpha = 0.05$, thus the hypothesis was rejected, implying that there was significant difference

in the mean scores of students' achievement when taught Atomic Theory using Computer-Aided Instruction and those taught using Conventional Methods. This is because

the p-value is less than the alpha level of 0.05, therefore leading to the rejection of the null hypothesis.

Research Question Two

What are the mean achievement scores of male and female senior secondary school students when taught atomic theory using computer-aided instruction?

Table 4: Mean Achievement Scores of Male and Female Senior Secondary School Students Taught Atomic Theory Using Computer-Aided Instruction

Gender		Pretest	Posttest
Male	Mean	9.30	22.10
	N	40	40
	Std. Deviation	2.866	3.747
Female	Mean	9.31	21.69
	N	35	35
	Std. Deviation	2.847	4.855

Table 4 shows that the pretest mean score for male students taught Atomic Theory using Computer-Aided Instruction is 9.30, with a standard deviation of 2.866, while the post-test mean score is 22.10, with a standard

deviation of 3.747. The pretest mean score of female students is 9.31 with a standard deviation of 2.847, while the post-test mean score is 21.69 with a standard deviation of 4.855.

Hypothesis Two

There is no significant difference in the mean achievement scores of male and female senior secondary school students when taught atomic theory using computer-aided instruction.

Table 5: ANCOVA Result of the Mean Achievement Scores of Male and Female Senior Secondary School Students Taught Atomic Theory Using Computer-Aided Instruction

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	351.730 ^a	2	175.865	12.654	.000	.260
Intercept	5301.539	1	5301.539	381.476	.000	.841
Pretest	348.526	1	348.526	25.078	.000	.258
Gender	3.037	1	3.037	.219	.642	.003
Error	1000.617	72	13.897			
Total	37345.000	75				
Corrected Total	1352.347	74				

Table 5 shows the ANCOVA result of the mean achievement scores of male and female senior secondary school students taught Atomic Theory using Computer-Aided Instruction, since the $F(1,72) = 0.219$; and $P = 0.642$, $> \alpha = 0.05$, thus the hypothesis was not rejected, implying that there was no

significant difference in the mean scores of male and female students' achievement when taught Atomic Theory using Computer-Aided Instruction. This is because the p-value is greater than the alpha level of 0.05; therefore, the null hypothesis is retained.

Discussion of Findings

The findings of this study on hypothesis three showed that there was a significant difference in the mean achievement scores of senior secondary students when taught Atomic Theory using Computer-Aided Instruction (CAI) and those taught using conventional methods. This finding aligns with previous studies by [Oluwole](#), Adesina, and Bello (2020), [Abdullahi](#), Yusuf, and Mohammed (2019), and Bala, Musa, and Ade (2024), which reported that CAI significantly enhances students' academic performance in chemistry. Similarly, Okafor and Nwokocho (2021) found that students exposed to CAI

outperformed their peers taught using traditional methods in inorganic chemistry, while Chukwu, Obi, and Eze (2021) observed comparable outcomes across different chemistry topics.

The improved achievement observed in students taught using CAI in this study could be attributed to the interactive and visual learning opportunities provided by the instructional method. CAI allows students to engage with atomic structures through animations, simulations, and virtual experiments, enabling them to visualize abstract concepts that are difficult to grasp through conventional lecture-based teaching.

This dynamic, learner-centered approach facilitates deeper understanding, reinforces key concepts, and provides immediate feedback, collectively enhancing students' mastery and retention of the content.

The findings of this study on hypothesis four showed that there was no significant difference in the mean achievement scores of male and female senior secondary school students when taught Atomic Theory using Computer-Aided Instruction (CAI). This result aligns with the findings of Okafor and Nwokocha (2021), Chukwu, Obi, and Eze (2021), Ibrahim and Salihu (2022), and Bala, Musa, and Ade (2024), who reported that CAI significantly improved students' academic achievement in chemistry, with no significant differences between male and female students. Similarly, Anyanwu (2020) and Okoro and Nwachukwu (2020) found that both male and female students benefited equally from CAI in biology and chemistry, demonstrating that gender did not affect students' performance when interactive, technology-driven instructional strategies were employed.

The lack of a significant gender difference in achievement may be attributed to the interactive and learner-centered features of CAI, which allow all students, regardless of gender, to visualize abstract concepts, engage in virtual experiments, and actively participate in the learning process. By providing equal opportunities for

exploration, simulation, and self-paced learning, CAI minimizes traditional gender-based disparities in science education. This suggests that CAI creates an equitable learning environment where both male and female students can achieve similarly in challenging topics such as Atomic Theory.

Conclusion

The findings of this study indicate the effect of Computer-Aided Instruction (CAI) on senior secondary school students' achievement in Atomic Theory in Minna, Niger State, Nigeria. The results show that students taught using CAI achieved higher academic achievement than those taught using the conventional method. This suggests that CAI influences students' understanding of Atomic Theory concepts. The study further reflects that the use of CAI as an instructional approach can support more interactive learning experiences in chemistry. These findings align with existing studies on the use of instructional technologies in science education and highlight the relevance of incorporating CAI into classroom instruction to improve learning outcomes in Atomic Theory.

Recommendation

Based on these findings, the study recommends, among others, that:

1. Schools should incorporate Computer-Aided Instruction as a regular teaching strategy for challenging topics, such as Atomic Theory, to enhance students' understanding and interest in chemistry.
2. Schools should ensure that both male and female students have equal access to CAI resources, as the study shows that the approach benefits all students regardless of gender.

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