



Effects of interactive multimedia-based science instruction on students' academic achievement, attitudes, and self-concept of rural secondary school students in Nigeria

Oluwanife Segun Falebita*

University of Zululand,
SOUTH AFRICA

Sukurat Aderonke Asimolowo

Federal University Oye Ekiti,
Nigeria

Article Info

Article history:

Received: April 02, 2026

Revised: May 15, 2026

Accepted: June 04, 2026

Keywords:

Academic Achievement;
Attitude; Interactive
multimedia-based;
Instruction; Self-Concept.

Abstract

Background: Despite ongoing efforts to improve science education, Biology achievement in many rural Nigerian secondary schools remains low, partly due to limited integration of technology-enhanced instructional approaches.

Aim: This study examined the effects of interactive multimedia-based Biology instruction on students' academic achievement, attitudes, and self-concept in rural secondary schools.

Method: A quasi-experimental pretest–posttest non-equivalent control group design was employed. Seventy-one Senior Secondary School I students from two purposively selected public secondary schools in Oye Local Government Area, Ekiti State, Nigeria, participated in the study. The experimental group received interactive multimedia-supported instruction incorporating animations, simulations, and visual presentations, while the control group received conventional instruction for six weeks. Data were collected using validated achievement, attitude, and self-concept instruments and analyzed using descriptive statistics and ANCOVA.

Results: The findings revealed that students exposed to interactive multimedia instruction achieved significantly higher academic performance, more positive attitudes toward Biology, and stronger self-concept than students taught through conventional methods ($p < .001$).

Conclusion: Interactive multimedia-based instruction effectively enhanced both cognitive and affective learning outcomes among rural secondary school students. The study highlights the potential of animation- and simulation-supported teaching to improve science learning in resource-constrained settings and recommends increased investment in digital instructional resources and teacher professional development.

To cite this article: Falebita, O. S., & Asimolowo, S. A. (2026). Effects of interactive multimedia-based science instruction on students' academic achievement, attitudes, and self-concept of rural secondary school students in Nigeria. *Journal of Advanced Sciences and Mathematics Education*, 6(2), 568-584.

INTRODUCTION

Recent national examination reports continue to show low pass rates in Biology among students in rural secondary schools in Nigeria, raising concerns about persistent inequities in science learning outcomes (Adeyele, 2024). Rural learners consistently perform below national averages due to limited instructional resources, inadequate laboratory exposure, and continued dependence on teacher-centered pedagogies (Olanrewaju et al., 2021; Rachel et al., 2025). Biology is particularly affected because many of its concepts, such as genetics, cellular processes, ecology, and physiology, require visualization and experiential learning for meaningful understanding. Yet, classroom instruction in many rural schools remains dominated by lecture-based approaches that emphasize memorization rather than conceptual engagement (E. O. Babalola & Omolafe, 2025; Usaini & Basiru, 2025). The limitations of conventional Biology instruction are not merely technological but pedagogical. Existing classroom practices often position students as passive recipients of

*Corresponding author:

Oluwanife Segun Falebita, University of Zululand, South Africa

falebitaO@unizula.ac.za ✉

information, limiting inquiry, interaction, and visual exploration of scientific phenomena. Studies conducted in African science classrooms indicate that instructional methods that combine visual representations, simulations, and learner interaction produce stronger conceptual understanding than lecture-oriented approaches (Adekunle et al., 2019; Ntaila & Mbaraka, 2023; Sefinat & Opeyemi, 2023). However, many schools that claim to integrate technology rely primarily on static PowerPoint presentations, which frequently replicate traditional teacher-centered instruction rather than transform learning processes (F. Babalola et al., 2025; Sefinat & Opeyemi, 2023). This suggests that the educational value of technology depends on the extent to which it supports active cognitive engagement.

The integration of interactive multimedia into science education represents a paradigm shift from traditional, teacher-centered pedagogy toward a more dynamic and learner-engaged instructional model. Interactive multimedia, characterized by the combination of text, moving images, video, and sound into a mutually supportive unit, has become a cornerstone of modern educational systems aimed at simplifying complex scientific concepts (Adeyele, 2024). In Nigeria, the adoption of these tools is driven by the need for innovative learning environments that can breakthrough traditional barriers to creative learning and provide advanced learning systems for subjects such as Physics, Biology, and Basic Science (Adeyele, 2024; Udu & Nmadu, 2023). This study conceptualizes interactive multimedia-based instruction as the integration of animations, visual presentations, projected instructional materials, and digital simulations designed to promote active learner engagement in Biology classrooms. The approach is theoretically grounded in the Cognitive Theory of Multimedia Learning, which posits that students learn more effectively when verbal and visual information are processed simultaneously through multiple cognitive channels. The study is also informed by constructivist learning theory, which emphasizes active knowledge construction through interaction and exploration. These frameworks suggest that multimedia-supported learning environments can enhance not only academic achievement but also learners' attitudes and academic self-concept by improving comprehension, confidence, and participation (Anwo et al., 2025; Udu & Nmadu, 2023; Usaini & Basiru, 2025).

Empirical evidence on multimedia learning in science education has produced generally positive but fragmented findings. Recent studies reported improvements in students' achievement and engagement following the use of simulation-based and animation-supported instruction in science subjects (Adekunle et al., 2019; Ugwuoke et al., 2023). However, many existing studies focused primarily on urban schools, isolated cognitive outcomes, or general ICT integration without examining psychosocial variables such as academic self-concept. Other studies relied on broad descriptions of "technology use" without clearly distinguishing between passive presentation tools and interactive multimedia applications. Consequently, evidence remains limited regarding how interactive multimedia instruction simultaneously influences students' achievement, attitudes, and self-concept in resource-constrained rural secondary schools. The rural context further strengthens the relevance of this investigation. In many rural schools in Nigeria, inadequate laboratory facilities and limited instructional resources restrict opportunities for practical science learning. Interactive multimedia tools may help bridge this gap by enabling students to visualize biological processes through simulations and animations that are otherwise difficult to demonstrate physically (Rachel et al., 2025). Despite this potential, empirical studies examining multimedia-supported Biology instruction in rural Nigerian secondary schools remain scarce.

This study addresses this gap by investigating the effects of interactive multimedia-based Biology instruction on students' academic achievement, attitudes toward Biology, and academic self-concept in rural secondary schools in Ekiti State, Nigeria. Unlike prior studies that examined only achievement outcomes or generalized ICT use, this study evaluates both cognitive and affective outcomes using a structured multimedia intervention grounded in established learning theory. The

study, therefore, contributes empirical evidence on the pedagogical value of interactive multimedia instruction for improving science learning in underserved rural educational settings. The present study addresses these gaps by examining the effects of interactive multimedia-based Biology instruction on students' academic achievement, attitudes toward Biology, and academic self-concept simultaneously within a rural secondary school context in Nigeria. Unlike prior studies that broadly examined technology use, this study focuses specifically on interactive multimedia instruction involving animations, visual presentations, simulations, and projected instructional materials grounded in CTML. By integrating cognitive and affective outcomes within a single theoretical framework, the study contributes empirical evidence on how multimedia-supported pedagogy can improve science learning in underserved educational environments.

LITERATURE REVIEW

This study is anchored in Mayer's Cognitive Theory of Multimedia Learning (CTML), which explains how learners process and retain information presented through combined verbal and visual channels (Mishra, 2025). CTML argues that meaningful learning occurs when instructional materials are designed to reduce cognitive overload and promote active cognitive processing by integrating words, images, animations, narration, and simulations (Cavanagh & Kiersch, 2022; Toh & Tasir, 2024). The theory is built on three core assumptions: dual-channel processing, which suggests humans have separate channels for visual and auditory information; limited working memory capacity, which acknowledges that each channel can only process a small amount of information at once; and active knowledge construction, where learners actively select, organize, and integrate new information (Cavanagh & Kiersch, 2022; Mayer, 2024). According to CTML, students learn more effectively when they can select relevant information, organize it into coherent mental structures, and integrate it with prior knowledge (Désiron et al., 2024; Toh & Tasir, 2024). The relevance of CTML to Biology education is particularly significant because many biological concepts are abstract, dynamic, and difficult to observe directly (Haruna & Lawan, 2025; Ntaila & Mbaraka, 2023). Processes such as cellular respiration, genetics, ecological interactions, and physiological mechanisms often require visualization for effective comprehension (Musa et al., 2025; Ntaila & Mbaraka, 2023). Interactive multimedia tools, including animations, simulations, and visual demonstrations, support conceptual understanding by translating abstract processes into observable representations (Adeyele, 2024; Ntaila & Mbaraka, 2023). Unlike conventional lecture-based approaches that rely heavily on verbal explanation, multimedia instruction aligns with CTML by simultaneously engaging visual and auditory cognitive systems, thereby improving comprehension, retention, and learner engagement (Mayer, 2024; Usaini & Basiru, 2025). CTML also provides a conceptual link between multimedia instruction and the outcome variables examined in this study. Effective multimedia environments can enhance academic achievement through improved cognitive processing (Adeyele, 2024; Haruna & Lawan, 2025), strengthen students' attitudes toward Biology by increasing engagement and interest (Udo & Inyang, 2022; Usaini & Basiru, 2025), and improve academic self-concept by fostering confidence and perceived competence during learning tasks (Ogunyebi, 2025; Udu & Nmadu, 2023). Thus, the theory offers an integrated explanatory framework connecting instructional design with both cognitive and affective learning outcomes (Ahmed et al., 2026; Offiong et al., 2026).

Recent empirical studies consistently indicate that interactive multimedia instruction improves students' academic achievement more effectively than conventional teacher-centered approaches (Adeyele, 2024; Ntaila & Mbaraka, 2023; Sefinat & Opeyemi, 2023; Wang, 2021). However, the effectiveness of multimedia instruction depends not merely on the availability of technology but also on the extent to which instructional design promotes cognitive engagement,

visualization, and active learning (Adeyele, 2024; Cavanagh & Kiersch, 2022; Toh & Tasir, 2024). This position aligns closely with Mayer's Cognitive Theory of Multimedia Learning, which posits that learners understand concepts more effectively when verbal explanations are integrated with relevant visual representations (Cavanagh & Kiersch, 2022; Mayer, 2024). Studies conducted in science education contexts across Africa generally report positive effects of multimedia-supported instruction on students' achievement (Bello et al., 2022; Ntaila & Mbaraka, 2023). For instance, Computer Assisted Multimedia Instruction has been shown to significantly improve student performance and retention in complex topics such as ecology in Northwestern Nigeria (Bello et al., 2022; Haruna & Lawan, 2025; Wang, 2021). Similarly, interactive multimedia instruction improved Biology achievement among secondary school students in Malawi and Ghana by presenting scientific concepts through multimodal representations that reduced abstraction (Miezhah & Whajah, 2023; Ntaila & Mbaraka, 2023). Further research reveals that students taught using multimedia facilities performed significantly better than those in conventional classrooms, particularly in environments facing significant digital infrastructure challenges (Moonasamy & Naidoo, 2024; Nkwocha, 2023). Animation-based instructional videos have also demonstrated effectiveness in enhancing achievement in rural and under-resourced schools by providing the necessary visual scaffolding (Musa et al., 2025; Rachel et al., 2025). Despite these positive findings, the literature reveals important pedagogical concerns: some classroom technologies, such as static PowerPoint presentations, often replicate traditional teacher-centered practices rather than transforming learning processes (Ajayi et al., 2023; Sefinat & Opeyemi, 2023). Consequently, differences in reported outcomes across studies may reflect variations in instructional design rather than technology itself (Ajayi et al., 2023; Nwuba et al., 2023; Toh & Tasir, 2024).

Students' attitudes toward Biology play a critical role in determining their motivation, classroom participation, persistence, and long-term interest in science-related careers (Getenet et al., 2024; Udo & Inyang, 2022; Usaini & Basiru, 2025). Research consistently shows that negative attitudes toward science subjects are often associated with passive instructional approaches that emphasize memorization rather than exploration and interaction (Ajayi et al., 2023; ElSayad et al., 2021; Udu & Nmadu, 2023). In contrast, multimedia-supported instructional environments create more engaging and participatory learning experiences that stimulate learners' curiosity and interest (Adeyele, 2024; Okela, 2024; Usaini & Basiru, 2025). Empirical studies support the argument that multimedia instruction positively influences students' attitudes toward science learning (Liang et al., 2021; Miezhah & Whajah, 2023; Usaini & Basiru, 2025). Recent findings indicate that Computer-Aided Instruction significantly enhances students' attitudes toward health-related science concepts compared to traditional methods (ElSayad et al., 2021; Usaini & Basiru, 2025). Similarly, animation-based instructional materials have been found to increase students' motivation and enthusiasm in rural classrooms by presenting concepts in visually appealing and interactive formats (Miezhah & Whajah, 2023; Rachel et al., 2025; Samane-Cutipa et al., 2022). These findings align with CTML, which suggests that meaningful multimedia experiences reduce cognitive difficulty and increase learner engagement through integrated processing (Getenet et al., 2024; Mayer, 2024; Toh & Tasir, 2024). However, the literature also suggests that not all forms of multimedia produce positive outcomes; technologies used primarily for teacher-led presentations may still reinforce passive structures (Sefinat & Opeyemi, 2023). In rural Nigerian schools, students' attitudes are often negatively influenced by inadequate laboratory resources and limited practical engagement (Kinta & Philip, 2025; Samane-Cutipa et al., 2022). Multimedia tools, including virtual simulations and digital videos, help address these limitations by making scientific concepts more accessible and relatable (Haruna & Lawan, 2025; Nkwocha, 2023). While prior studies indicate improvement in attitudes, limited research has examined this specifically within rural Biology classrooms while simultaneously

considering achievement and self-concept (Liang et al., 2021; Ogunyebi, 2025; Udo & Inyang, 2022; Usaini & Basiru, 2025).

Academic self-concept represents students' perceptions of their competence within a subject domain and is strongly associated with motivation and performance (Abiona & Falebita, 2020; Ahmed et al., 2026; Ogunyebi, 2025). Contemporary learning theories suggest that instructional environments supporting interaction, autonomy, and successful task completion can strengthen learners' self-perceptions (Anwo et al., 2025; Udu & Nmadu, 2023; Zheng, 2024). Multimedia learning environments contribute to positive academic self-concept by simplifying complex concepts, providing immediate feedback, and enabling self-paced exploration (Adeyele, 2024; Mensah et al., 2024; Toh & Tasir, 2024). Recent studies provide increasing evidence that multimedia-supported instruction positively affects students' confidence in science learning (Ahmed et al., 2026; Udu & Nmadu, 2023). Research involving interactive engagement pedagogies has shown superior gains in academic self-concept compared to traditional methods, creating a positive link between a student's perceived competence and actual success (Anwo et al., 2025; Mensah et al., 2024; Udu & Nmadu, 2023). Students exposed to multimedia applications often demonstrate greater confidence in mastering scientific concepts than their peers taught through conventional methods (Adeyele, 2024; Udu & Nmadu, 2023; Zheng, 2024). Animation-based instruction also supports differentiated learning among students with varying ability levels, thereby improving their perceptions of their own ability to succeed (Rachel et al., 2025; Yang, 2023). Despite these promising findings, important gaps remain; many studies primarily focus on academic achievement while paying limited attention to psychosocial outcomes like self-concept (Ahmed et al., 2026; Offiong et al., 2026). Furthermore, existing research rarely examines achievement, attitudes, and self-concept simultaneously within a single framework (Offiong et al., 2026; Ogunyebi, 2025). Research targeting interactive multimedia-supported Biology instruction in rural Nigerian secondary schools remains particularly limited, often focusing on urban contexts or isolated technologies without evaluating the holistic influence on both cognitive and affective outcomes (Offiong et al., 2026; Udo & Inyang, 2022; Udu & Nmadu, 2023).

METHOD

Research Design

This study employed a quasi-experimental pretest–posttest non-equivalent control group design to investigate the effects of interactive multimedia-based Biology instruction on students' academic achievement, attitudes, and self-concept. Two groups participated in the study: an experimental group that received multimedia-supported instruction and a control group that received conventional teacher-centered instruction. Both groups completed pretests and posttests to assess changes in the measured outcomes.

Participant

The participants consisted of 71 Senior Secondary School I (SSS I) students drawn from two purposively selected public secondary schools in Oye Local Government Area, Ekiti State, Nigeria. School selection was based on the availability of multimedia facilities required for the intervention. The experimental group comprised 38 students, while the control group consisted of 33 students. Intact classes were used to preserve the natural classroom setting.

Instrument

Data were collected using three validated instruments: the Biology Achievement Test (BAT), the Biology Attitudinal Scale (BAS), and the Biology Self-Concept Scale (BSCS). The BAT contained 20 multiple-choice items assessing students' Biology achievement. The BAS and BSCS each consisted of 10 Likert-scale items measuring students' attitudes toward Biology and their self-concept in the subject, respectively. Instrument validity was established through expert review, while reliability

coefficients obtained from a pilot study were 0.793 (BAT), 0.845 (BAS), and 0.812 (BSCS), indicating acceptable to high reliability.

Data Analysis

Descriptive statistics, including means and standard deviations, were used to summarize students' scores. Paired-sample t-tests were conducted to examine within-group differences between pretest and posttest scores, while independent-sample t-tests were used to compare posttest scores between groups. Additionally, Analysis of Covariance (ANCOVA) was employed to control for pre-existing group differences and determine the effect of the instructional treatment. Statistical significance was established at the 0.05 level.

Research Procedure

A pretest was administered to both groups before the intervention. The experimental group received six weeks of interactive multimedia-based instruction incorporating animations, simulations, visual presentations, and projected digital materials on ecological cycles, including the oxygen, water, carbon, and nitrogen cycles. The control group studied the same topics using conventional teaching methods involving verbal explanations, chalkboard illustrations, and textbooks. Following the intervention, both groups completed the posttest using the same instruments.

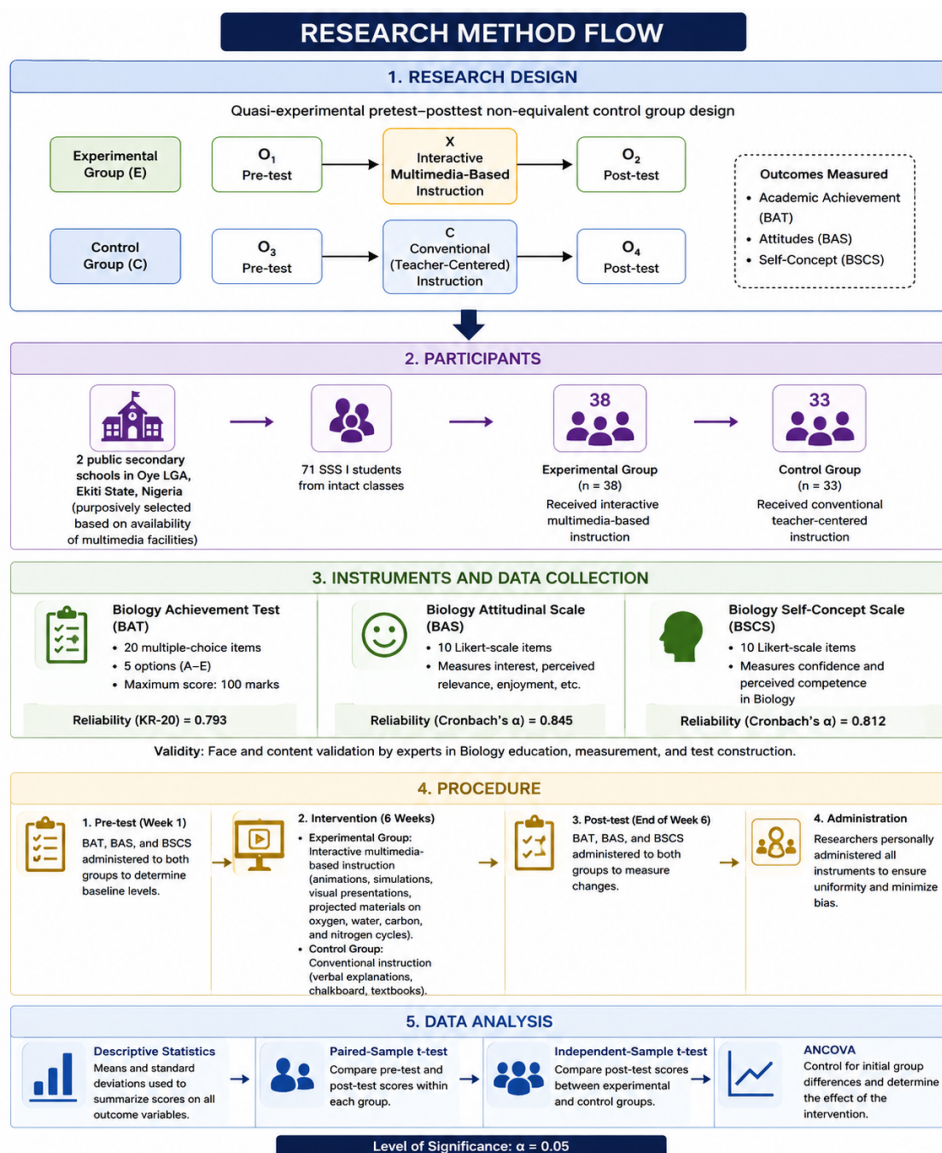


Figure 1. Research Method Flow.

RESULTS AND DISCUSSION

Results

Research Question 1: What is the effect of interactive multimedia-based Biology instruction on students' academic achievement in Biology?

In answering the question, the pretest and posttest mean scores of Biology students exposed to treatments were computed and compared. The result is presented in Table 1.

Table 1. Mean and standard deviation of pre-test and post-test scores of students in the experimental and control groups

Strategies	Test	N	Mean	S.D	Mean Diff.	PreTest Diff.	PostTest Diff.
Interactive multimedia-based Learning	Pretest	38	23.29	4.69	50.92	0.62	25.72
	Posttest		74.21	12.17			
Conventional	Pretest	33	23.91	5.08	24.57		
	Posttest		48.49	9.64			
Total		71					

The results in Table 1 reveal significant differences between the pre-test and post-test scores of students in the experimental and control groups. The experimental group, which utilized interactive multimedia-based learning strategies, had a pre-test mean score of 23.29 (SD = 4.69) and a post-test mean score of 74.21 (SD = 12.17). This resulted in a substantial mean difference of 50.92, indicating a marked improvement in student achievement following the intervention. Conversely, the control group, which employed conventional teaching methods, had a pre-test mean score of 23.91 (SD = 5.08) and a post-test mean score of 48.49 (SD = 9.64), yielding a mean difference of 24.57. Although this group also improved, the extent of the change was significantly less than that of the experimental group. These results highlight the effectiveness of interactive multimedia-based learning strategies in enhancing student understanding and achievement, as evidenced by the greater improvements in post-test scores compared to the control group. The effect of the instructional strategy on senior secondary school students' achievement in Biology is further presented graphically below in Figure 1.

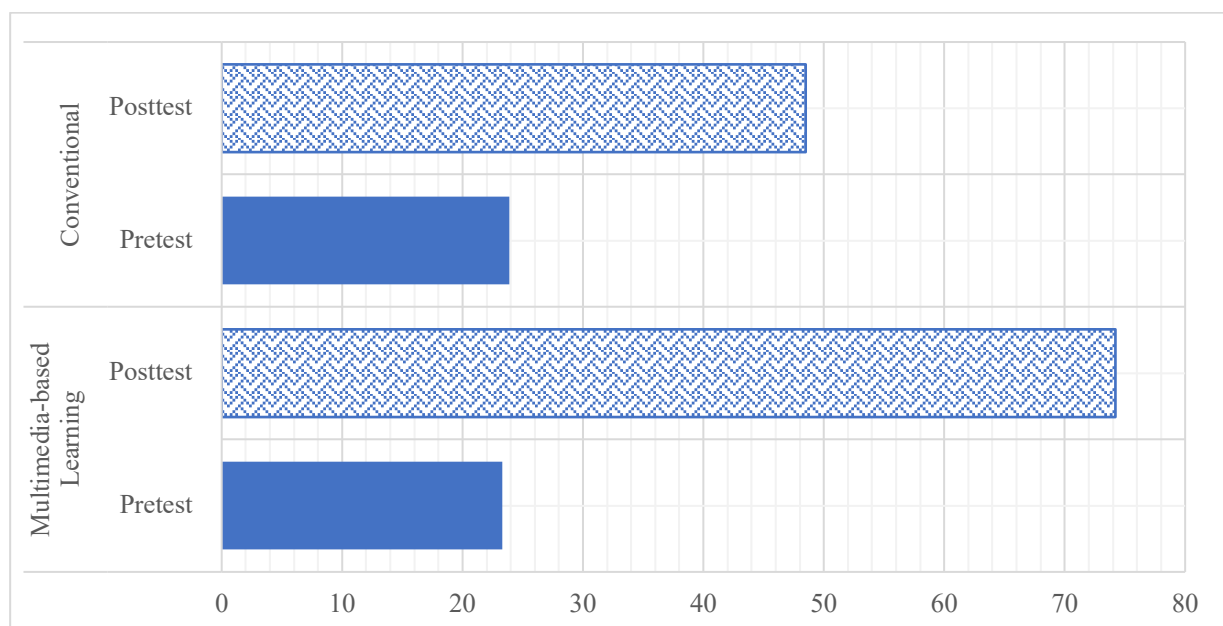


Figure 1: Bar chart showing Pre-test and Post-test mean scores of students in Biology in the Interactive multimedia-based and conventional groups

Research Question 2: How does interactive multimedia-based Biology instruction affect students' attitudes towards Biology?

To answer the question, the pre-attitude (Pre-ATT) and post-attitude (Post-ATT) mean scores of the Biology students exposed to treatments were computed and compared. The result is presented in Table 2.

Table 2. Mean and standard deviation of pre-attitude and post-attitude scores of students in the experimental and control groups

Strategies	Test	N	Mean	S.D.	Mean Diff.	Pre-ATT Diff.	Post-ATT Diff.
Interactive multimedia-based Learning	Pre-ATT	38	24.89	3.02	5.40	0.86	5.62
	Post-ATT		30.29	2.81			
Conventional	Pre-ATT	33	24.03	3.03	0.64		
	Post-ATT		24.67	2.57			
Total		71					

Table 2 presents the mean and standard deviation of pre-attitude and post-attitude scores for students in both the experimental and control groups. The experimental group, which engaged in interactive multimedia-based learning, had a pre-attitude mean score of 24.89 (SD = 3.02) and a post-attitude mean score of 30.29 (SD = 2.81). The resulting mean difference of 5.40 indicates a significant positive shift in student attitudes following the multimedia intervention. In contrast, the control group, utilizing conventional teaching methods, recorded a pre-attitude mean score of 24.03 (SD = 3.03) and a post-attitude mean score of 24.67 (SD = 2.57), resulting in a minimal mean difference of 0.64. This suggests that the conventional approach had little impact on improving student attitudes. These results show the effectiveness of interactive multimedia-based learning not only in enhancing knowledge but also in fostering a more positive attitude toward learning. The effect of the instructional strategy on senior secondary school students' attitude towards Biology is further presented graphically below in Figure 2.

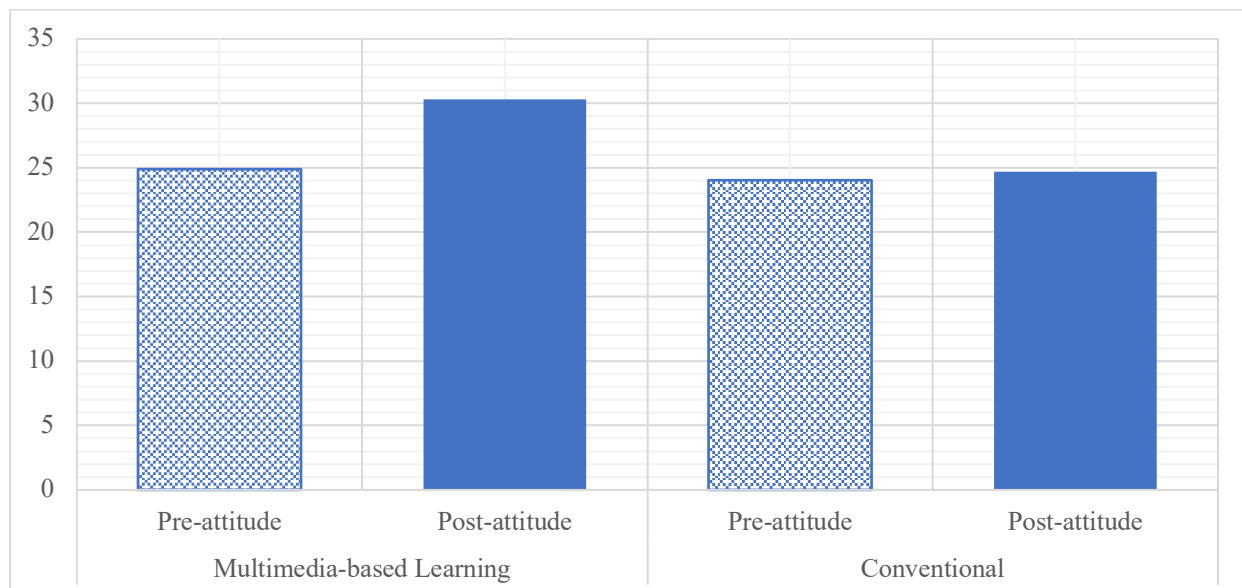


Figure 2: Bar chart showing pre-attitude and post-attitude mean scores of students in Biology in the Interactive multimedia-based and conventional groups

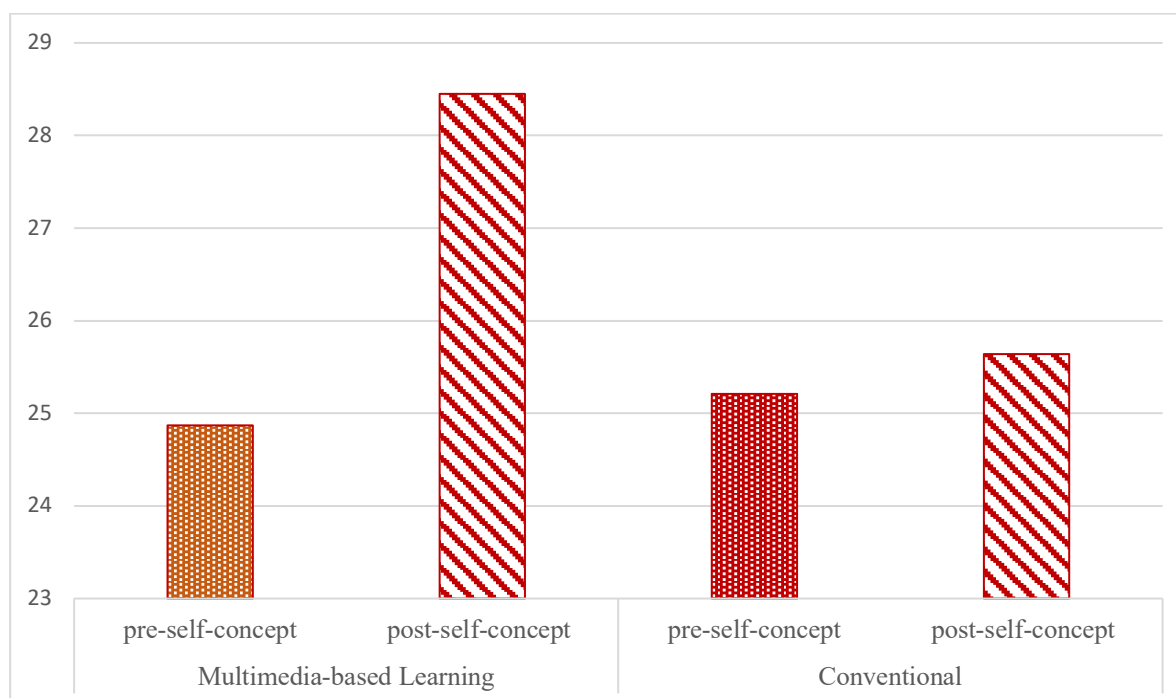
Research Question 3: What is the effect of interactive multimedia-based Biology instruction on students' self-concepts in Biology?

To answer the question, the pre- and post-self-concept mean scores of Biology students exposed to treatments were computed and compared. The result is presented in Table 3.

Table 3. Mean and standard deviation of pre-self-concept and post-self-concept scores of students in the experimental and control groups

Strategy	Test	N	Mean	S.D.	Mean Diff.	Pre-self-concept Diff.	Post-self-concept Diff.
Interactive multimedia-based Learning	pre-self-concept	38	24.87	2.17	3.58	0.34	2.81
	post-self-conc		28.45	2.62			
Conventional	pre-self-concept	33	25.21	2.64	0.43	0.34	2.81
	post-self-concept		25.64	2.91			
Total		71					

Table 3 displays the mean and standard deviation of pre-self-concept and post-self-concept scores for students in the experimental and control groups. The experimental group, which utilized interactive multimedia-based learning strategies, had a pre-self-concept mean score of 24.87 (SD = 2.17) and a post-self-concept mean score of 28.45 (SD = 2.62). This resulted in a mean difference of 3.58, indicating a notable improvement in students' self-concept after the intervention. On the other hand, the control group, which followed conventional teaching methods, recorded a pre-self-concept mean score of 25.21 (SD = 2.64) and a post-self-concept mean score of 25.64 (SD = 2.91), yielding a mean difference of only 0.43. This suggests that the conventional approach did not significantly enhance students' self-concept. These results underscore the positive impact of interactive multimedia-based learning on students' self-perceptions and confidence. The effect of the instructional strategy on senior secondary school students' self-concept in Biology is further presented graphically below in Figure 3.

**Figure 3:** Bar chart showing pre-self-concept and post-self-concept mean scores of students in Biology in the Interactive multimedia-based and conventional groups**Testing of Hypotheses**

Hypothesis 1: Interactive multimedia-based biology instruction does not have a significant effect on students' academic achievement in Biology.

The pretest and posttest scores were collected from students in the interactive multimedia-based learning and conventional groups to test the hypothesis. ANCOVA was used to compute the effects of the instructional strategies on students' achievement. The result is presented in Table 4.

Table 4. ANCOVA for the effect of interactive multimedia-based learning and conventional strategies on students' achievement in Biology

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11719.974 ^a	2	5859.987	47.328	<.001	.582
Intercept	11799.674	1	11799.674	95.300	<.001	.584
PRETEST	31.095	1	31.095	.251	.618	.004
GROUP	11563.691	1	11563.691	93.394	<.001	.579
Error	8419.463	68	123.816			
Total	295300.000	71				
Corrected Total	20139.437	70				

a. *R Squared* = .582 (*Adjusted R Squared* = .570)

Table 4 presents the results of the ANCOVA examining the effects of interactive multimedia-based learning and conventional strategies on students' achievement in biology. The pre-test scores did not show a significant difference ($F(1, 68) = .251, p = .618$), indicating that the initial achievement levels were homogeneous across groups. This homogeneity is crucial as it confirms that any observed differences in post-test scores can be attributed to the interventions rather than pre-existing disparities in knowledge. The treatments revealed a significant effect on student achievement ($F(1, 68) = 93.394, p < .001$), with a partial eta squared value of .579, suggesting a large effect size. Hence, the hypothesis is rejected. Therefore, interactive multimedia-based biology instruction has a significant effect on students' academic achievement in Biology. This indicates that the interactive multimedia-based learning strategy significantly improved students' academic achievement compared to conventional methods. The overall model accounted for 58.2% of the variance in post-test scores (R -squared = .582), underscoring the effectiveness of the teaching strategies. This strong model fit further supports the conclusion that interactive multimedia-based learning is beneficial for enhancing student achievement in biology.

Hypothesis 2: Interactive multimedia-based biology instruction does not have a significant effect on students' attitudes towards Biology.

The pre-attitude and post-attitude scores were collected from students in the interactive multimedia-based learning and conventional groups to test the hypothesis. ANCOVA was used to compute the effects of the instructional strategies on students' attitudes towards Biology. The result is presented in Table 5.

Table 5. ANCOVA for the effect of interactive multimedia-based learning and conventional strategies on students' attitude towards Biology

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	719.271 ^a	2	359.635	71.448	<.001	.678
Intercept	237.414	1	237.414	47.167	<.001	.410
PreATT	160.870	1	160.870	31.960	<.001	.320
GROUP	465.305	1	465.305	92.442	<.001	.576
Error	342.279	68	5.034			
Total	55445.000	71				
Corrected Total	1061.549	70				

a. *R Squared* = .678 (*Adjusted R Squared* = .668)

Table 5 provides the ANCOVA results examining the effects of interactive multimedia-based learning and conventional strategies on students' attitudes toward biology. The pre-attitude scores significantly influenced post-attitude scores ($F(1, 68) = 31.960, p < .001$), accounting for 32% of the variance (partial eta squared = .320). This suggests that students' initial attitudes were relevant to their subsequent attitudes. Notably, the treatment revealed a significant effect on attitudes ($F(1, 68) = 92.442, p < .001$), with a large effect size (partial eta squared = .576). Hence, the hypothesis is rejected. Therefore, interactive multimedia-based biology instruction has a significant effect on students' attitudes towards Biology. This indicates that the interactive multimedia-based learning strategy significantly enhanced students' attitudes toward biology compared to conventional teaching methods. The model explained 67.8% of the variance in post-attitude scores ($R^2 = .678$), highlighting the effectiveness of multimedia approaches in fostering positive attitudes among students.

Hypothesis 3: Interactive multimedia-based biology instruction does not have a significant effect on students' self-concepts in Biology.

To test the hypothesis, the pre-self-concept and post-self-concept scores were collected from students in the interactive multimedia-based learning and conventional groups. ANCOVA was used to compute the effects of the instructional strategies on students' self-concept. The result is presented in Table 6.

Table 6. ANCOVA for the effect of interactive multimedia-based learning and conventional strategies on students' Self-concept

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	371.512 ^a	2	185.756	43.099	<.001	.559
Intercept	39.472	1	39.472	9.158	.003	.119
PreSelfConcept	231.952	1	231.952	53.817	<.001	.442
GROUP	165.965	1	165.965	38.507	<.001	.362
Error	293.079	68	4.310			
Total	52965.000	71				
Corrected Total	664.592	70				

a. $R^2 = .559$ (Adjusted $R^2 = .546$)

Table 6 presents the ANCOVA results assessing the effect of interactive multimedia-based learning and conventional strategies on students' self-concept. The pre-self-concept scores significantly influenced the post-self-concept scores ($F(1, 68) = 53.817, p < .001$), suggesting that initial self-concept levels were homogeneous across groups. This homogeneity is vital, as it indicates that the differences in post-self-concept can be attributed to the interventions rather than pre-existing disparities. The treatments showed a significant effect on self-concept ($F(1, 68) = 38.507, p < .001$), with a partial eta squared value of .362, indicating a moderate effect size. Hence, the hypothesis is rejected. Therefore, interactive multimedia-based biology instruction has a significant effect on students' self-concepts in Biology. This suggests that the interactive multimedia-based learning strategy significantly enhanced students' self-concept compared to conventional methods. The model explained 55.9% of the variance in post-self-concept scores ($R^2 = .559$), highlighting the teaching strategies' effectiveness.

Discussion

The findings of this study suggest that the effectiveness of interactive multimedia-based Biology instruction extends beyond simple technology integration to the quality of cognitive engagement it creates during learning. Students exposed to animations, simulations, visual demonstrations, and projected instructional materials demonstrated stronger academic achievement, more positive attitudes toward Biology, and improved academic self-concept

compared with students taught through conventional teacher-centered instruction (Nkwocha, 2023; Yusuf & Afolabi, 2010). These outcomes collectively indicate that multimedia instruction may function not only as a content delivery tool but also as a pedagogical mechanism that reshapes how students experience and interpret Biology learning (Kiat et al., 2020; Ntaila & Mbaraka, 2023).

The improvement in academic achievement can be interpreted through the lens of Mayer's Cognitive Theory of Multimedia Learning, which argues that meaningful learning occurs when learners process verbal and visual information simultaneously through complementary cognitive channels (Mayer, 2024; Ugwuoke et al., 2023). In this study, multimedia instruction appeared to reduce the abstractness commonly associated with Biology concepts by transforming invisible or complex processes into observable and interactive representations. Rather than memorizing isolated facts through lecture-based instruction, students were able to visualize ecological cycles and biological interactions in real time, leading to better long-term retention of concepts (Bello et al., 2022; Haruna & Lawan, 2025). This finding supports studies reporting that interactive multimedia environments improve conceptual understanding in science education, particularly for complex topics such as genetics and reproduction (Kiat et al., 2020; Musa et al., 2025). However, the present findings also extend prior research by showing that the effectiveness of multimedia instruction is particularly relevant in rural classrooms where laboratory experiences are limited or unavailable (John, 2025; Rachel et al., 2025). Importantly, the findings challenge the assumption that any form of educational technology automatically improves learning outcomes. Prior studies have shown that some classroom technologies merely reproduce traditional teacher-centered teaching patterns when used passively. The significant gains observed in this study, therefore, appear to stem not from technology itself but from the interactive design of the instructional process (Köseoğlu & Efendioğlu, 2015). The use of animations, simulations, and visual explanations encouraged learner participation, visualization, and cognitive interaction with content, which conventional lecture methods rarely provide (Miezah & Whajah, 2023; Putri et al., 2024). This suggests that the pedagogical structure underlying multimedia instruction may be more important than the technology platform itself (Abdullah, 2023).

The findings regarding students' attitudes toward Biology further reinforce this interpretation. Students taught through multimedia-supported instruction demonstrated greater interest and engagement in Biology learning, suggesting that interactive learning environments may alter students' emotional and motivational responses to science subjects (Usaini & Basiru, 2025). In many conventional classrooms, Biology is frequently experienced as abstract and text-heavy, contributing to disengagement. By contrast, multimedia-supported lessons created visually stimulating and participatory learning experiences that likely increased curiosity and classroom involvement (Köseoğlu & Efendioğlu, 2015). Similar improvements in students' motivation and attitudes have been reported in studies involving animation-based and computer-assisted instruction (Rachel et al., 2025; Yusuf & Afolabi, 2010). Nevertheless, the present study adds nuance to the literature by demonstrating that positive attitudinal changes can occur even in resource-constrained rural schools when multimedia tools are deliberately designed to support interaction rather than passive presentation.

The relationship between multimedia instruction and academic self-concept is particularly noteworthy because this dimension has received limited attention in previous multimedia learning studies. The findings suggest that multimedia-supported instruction may strengthen students' perceptions of competence by making difficult concepts more understandable and accessible (Premalatha & Rani, 2025). Students who can successfully visualize and interact with scientific processes are more likely to perceive themselves as capable learners. This aligns with contemporary perspectives that academic self-concept develops through repeated experiences of successful learning and task mastery (Ahmed et al., 2026; Akata et al., 2025). In this study, multimedia

instruction appeared to create conditions that reduced cognitive frustration and increased learners' confidence in handling Biology tasks across varying ability levels (Adeyele, 2024; Rachel et al., 2025). The significance of this finding lies in its implication that multimedia instruction may influence long-term academic persistence in science not only through achievement gains but also through students' beliefs about their own abilities (Ntaila & Mbaraka, 2023; Ugwuoke et al., 2023).

At the same time, the findings should not be interpreted as evidence that multimedia instruction alone can resolve broader structural inequalities in rural science education. Challenges such as unstable electricity supply, inadequate digital infrastructure, and limited teacher training remain important constraints that may affect sustainability and scalability in under-resourced Nigerian schools (John, 2025; Rachel et al., 2025). Moreover, the effectiveness of multimedia instruction depends heavily on instructional quality, contextual adaptation, and teacher competence rather than technology availability alone (Abdullah, 2023; Nkwocha, 2023). Overall, this study contributes to the literature in three important ways. First, it integrates cognitive and affective outcomes by examining achievement, attitudes, and academic self-concept simultaneously within a single instructional framework. Second, it extends multimedia learning research into rural Nigerian secondary school contexts that remain underrepresented in empirical literature. Third, the study demonstrates that interactive multimedia instruction grounded in CTML can support meaningful Biology learning in resource-constrained classrooms when designed to promote active cognitive engagement rather than passive technology use.

Implications

The findings of this study have significant implications for both the theoretical and practical aspects of educational practices, particularly in Biology instruction in secondary schools. The interactive multimedia-based instructional approach has demonstrated a positive impact on students' academic achievement, attitudes, and self-concept in Biology, aligning with previous studies that emphasize the effectiveness of multimedia tools in promoting deeper cognitive engagement and understanding of complex concepts. By utilizing tools such as animations, simulations, and visual demonstrations, teachers can foster a more interactive and engaging learning environment, particularly in rural schools where resources and laboratory facilities are often limited. These results suggest that integrating multimedia instruction can bridge the gap between theoretical learning and practical understanding, offering an effective alternative to traditional methods, particularly in schools with insufficient access to physical resources. The study's findings also highlight the role of student-centered learning environments in enhancing student motivation and engagement. Teachers and educational institutions can adopt these multimedia strategies to create more participatory learning experiences, positively influencing students' attitudes toward subjects that are typically perceived as challenging, such as Biology. Moreover, the improvement in students' academic self-concept through multimedia learning reinforces the need for such instructional strategies in developing students' confidence and persistence in their studies.

Limitations and Suggestions for Future Research

Despite the promising results, this study has some limitations. The research was conducted in a specific context, focusing on secondary school students in rural Nigeria, which may limit the generalizability of the findings to other educational systems or regions. Additionally, the study primarily examined the impact of interactive multimedia-based instruction on Biology, and while this provides valuable insights into the field, the results may not be directly applicable to other subjects or disciplines. Furthermore, the study relied on a quantitative approach and did not include qualitative insights from students or teachers, which could provide a deeper understanding of how multimedia tools influence learning from the perspectives of the participants. The sample size, though adequate for statistical analysis, may also limit the robustness of the findings, particularly in

terms of demographic diversity, as students' backgrounds (such as access to technology outside of school) could have varied impacts on the effectiveness of multimedia instruction. Future studies could benefit from a more diverse sample and the inclusion of qualitative data to complement the quantitative findings. Future research should consider expanding the scope of this study by exploring the long-term effects of interactive multimedia-based instruction on students' academic success and engagement, including potential retention of knowledge over extended periods. Investigating the impact of gender and learning styles could also provide valuable insights into how different groups of students respond to multimedia learning tools, allowing for more personalized educational strategies. Moreover, it would be beneficial to conduct further studies in a cross-cultural context or in schools with varying levels of technological access, to examine whether the effectiveness of multimedia instruction is influenced by environmental factors. Additionally, future studies could incorporate a mixed-methods approach, combining quantitative data with qualitative interviews or surveys to gain a deeper understanding of students' experiences with interactive multimedia-based learning and its effect on their attitudes, self-concept, and academic performance. Lastly, the implementation of training programs for teachers on effectively using multimedia tools should be explored, ensuring that educators are well-equipped to integrate these technologies into their teaching practices and make the most out of digital learning resources.

CONCLUSION

This study found that interactive multimedia-based Biology instruction significantly boosts students' academic achievement, attitudes toward Biology, and self-concept in Biology, especially in rural secondary schools. The findings show that adding multimedia elements such as animations, simulations, and visual demonstrations can improve students' understanding of complex biological ideas and make learning more engaging and meaningful. By supporting multimodal learning and reducing dependence on traditional lecture methods, multimedia instruction offers an effective alternative for enhancing science education in places with limited laboratory facilities and instructional resources. The results, therefore, emphasise the potential of interactive multimedia-based teaching to improve both cognitive and emotional learning outcomes in Biology education in underserved areas.

AUTHOR CONTRIBUTIONS STATEMENT

Oluwanife Segun Falebita conceptualized the study, developed the research framework, research design, conducted data analysis, led the writing of the manuscript, and provided critical revisions. Sukurat Aderonke Asimolowo contributed to the data collection process, literature review development, and manuscript editing.

REFERENCES

- Abdullah, K. H. (2023). Divulging two decades of multimedia applications in biology education. *Jurnal Inovasi Pendidikan IPA*, 9(2), 177–191. <https://doi.org/10.21831/jipi.v9i2.57361>
- Abiona, G. O., & Falebita, O. S. (2020). Impact of Covid-19 pandemic on senior secondary school students' academic performance and self-concept in biology and mathematics in Northwestern Nigeria. *Journal of the Social Sciences*, 48(4), 2037–2051.
- Adekunle, S. E., A., S., & K, B. O. (2019). Appraisal on perceived multimedia technologies as modern pedagogical tools for strategic improvement on teaching and learning. *International Journal of Modern Education and Computer Science*, 11(8), 15. <https://doi.org/10.5815/ijmecs.2019.08.02>

- Adeyele, V. O. (2024). Relative effectiveness of simulation games, blended learning, and interactive multimedia in basic science achievement of varying ability pupils. *Education and Information Technologies*, 29(11), 14451–14470. <https://doi.org/10.1007/s10639-023-12414-z>
- Ahmed, A. A., Salau, R. O., & Alayande, O. K. (2026). Self-concept as a correlate of academic achievement of students of basic science in secondary school in Oyo State. *Iconic Research and Engineering Journals*, 9(6). <https://doi.org/10.64388/IREV9I6-1713107>
- Ajayi, O. A., Akintoye, O. H., Akindoju, O. G., & Onowugbeda, F. U. (2023). Impact of ethnobiology-based instruction and peer tutoring on the achievement of senior secondary school biology students in Ogun state southwest Nigeria. *World Journal of Advanced Research and Reviews*, 18(1), 1197–1207. <https://doi.org/10.30574/wjarr.2023.18.1.0737>
- Akata, C. E., Nkanu, N. O., & Effiong, A. I. (2025). The effect of self-concept on the academic performance of secondary school students in Ikom Local Government Area of Cross Rivers State. *Journal of Artificial Intelligence and Digital Economy*, 2(8), 530–546. <https://doi.org/10.61796/jaide.v2i8.1451>
- Anwo, A. O., Gana, C. S., Hassan, A. A., Moses, A. S., Bashir, A. U., & Muhammad, M. K. (2025). Enhancing secondary school students' self-concept through Vee-diagram and guided-inquiry strategies. *Physics Education*, 60(5), 55031. <https://doi.org/10.1088/1361-6552/adfac5>
- Babalola, E. O., & Omolafe, E. V. (2025). Enhancing biology learning through 3D models: A study of academic performance in Nigerian secondary schools. *International Journal of Essential Competencies in Education*, 4(1), 15. <https://doi.org/10.36312/ijece.v4i1.1862>
- Babalola, F., Fakoyede, S. J., Ojobola, F. B., Ayodeji, M. A., Ekundayo, S. K., & Alabi, D. O. (2025). Evaluating the effectiveness of multimedia integration in enhancing physics instruction in secondary schools. *Discover Education*, 5(1). <https://doi.org/10.1007/s44217-025-00871-2>
- Bello, S., Kamar, Y. M., Yusha'u, M. A., & Abubakar, H. S. (2022). Efficacy of computer assisted multimedia instruction on students' academic performance and retention of ecology in some northwestern states, Nigeria. *Journal of Educational Research in Developing Areas*, 3(2), 127–140. <https://doi.org/10.47434/JEREDA.3.2.2022.127>
- Cavanagh, T. M., & Kiersch, C. E. (2022). Using commonly-available technologies to create online multimedia lessons through the application of the Cognitive Theory of Multimedia Learning. *Educational Technology Research and Development*, 71(3), 1033–1053. <https://doi.org/10.1007/s11423-022-10181-1>
- Désiron, J. C., Schmitz, M.-L., & Petko, D. (2024). Teachers as creators of digital multimedia learning materials: Are they aligned with multimedia learning principles? *Technology, Knowledge and Learning*. <https://doi.org/10.1007/s10758-024-09770-1>
- ElSayad, G., Saad, N. H. M., & Ramayah, T. (2021). How higher education students in Egypt perceived online learning engagement and satisfaction during the COVID-19 pandemic. *Journal of Computers in Education*, 8(4), 527–550. <https://doi.org/10.1007/s40692-021-00191-y>
- Getenet, S., Cattle, R., Redmond, P., & Albion, P. (2024). Students' digital technology attitude, literacy and self-efficacy and their effect on online learning engagement. *International Journal of Educational Technology in Higher Education*, 21(1). <https://doi.org/10.1186/s41239-023-00437-y>
- Haruna, M. J., & Lawan, U. S. (2025). Effectiveness of media animation on academic achievement in ecology among secondary school students in Municipal Education Zone, Kano State, Nigeria. *UMYU Scientifica*, 4(1), 336–343. <https://doi.org/10.56919/usci.2541.033>
- John, J. (2025). *Mobile digital laboratories for inclusive science learning: Bridging the rural-urban divide in Ogbadibo LGA of Benue State*. <https://doi.org/10.5281/zenodo.17851700>
- Kiat, T. Y., Jumintono, J., Kriswanto, E. S., Sugiri, S., Handayani, E., Anggarini, Y., & Rofik, M. (2020). The effectiveness of multimedia learning on academic achievement in reproduction topic science subject. *Universal Journal of Educational Research*, 8(8), 3625–3629. <https://doi.org/10.13189/ujer.2020.080839>
- Kinta, M. J., & Philip, J. (2025). *Effects of inadequate laboratory resources on academic achievement and learning attitudes in biology among senior secondary school students in Kontagora*. <https://doi.org/10.5281/zenodo.18012421>

- Köseoğlu, P., & Efendioğlu, A. (2015). Can a multimedia tool help students' learning performance in complex biology subjects? *South African Journal of Education*, 35(4), 1–12. <https://doi.org/10.15700/saje.v35n4a1169>
- Liang, L., Zhong, Q., Zuo, M., Luo, H., & Wang, Z. (2021). What drives rural students' online learning continuance intention. *An SEM Approach*, 12, 112–116. <https://doi.org/10.1109/ISET52350.2021.00032>
- Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review*, 36(1). <https://doi.org/10.1007/s10648-023-09842-1>
- Mensah, C., Kugbonu, M. A., Appietu, M. E., Nti, G. A., & Forson, M. A. (2024). Social support, computer self-efficacy, online learning engagement and satisfaction among undergraduate hospitality students. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2335803>
- Miezah, W. S., & Whajah, G. (2023). A survey on the effects of using videos in biology lessons on student performance. *International Journal of Scientific Research in Science and Technology*, 118–132. <https://doi.org/10.32628/IJSRST5231047>
- Mishra, D. (2025). Mayer's cognitive theory of multimedia learning: An overview. In D. Mishra (Ed.), *Technology driven language learning: Innovations and applications*. Palgrave Macmillan. https://doi.org/10.1007/978-3-031-77232-0_2
- Moonasamy, D. A. R., & Naidoo, G. M. (2024). Digital learning: Challenges experienced by South African university students' during the COVID-19 pandemic. *The Independent Journal of Teaching and Learning*, 17(2), 76–90. <https://doi.org/10.17159/fwk81482>
- Musa, F. H., Mohammad, U., Mohammad, B., & Israel, K. (2025). Effect of multimedia-based instructional strategy on achievement in genetics concepts among secondary school biology students in Niger State, Nigeria. *Federal University Gusau Faculty of Education Journal*, 2(2), 59–65. <https://doi.org/10.64348/zije.2025120>
- Nkwocha, S. E. (2023). Utilization of multimedia facilities in the teaching of biology among secondary schools students in Obudu Local Government Area of Cross River State. *Journal of Digital Learning and Education*, 3(1), 11–24. <https://doi.org/10.52562/jdle.v3i1.397>
- Ntala, Y. W., & Mbaraka, S. R. (2023). Examining the impact of interactive multimedia instruction on the performance of secondary school students in biology in Dedza District, Malawi. *European Journal of Educational Research*. <https://doi.org/10.12973/eu-jer.12.4.1697>
- Nwuba, I. S., Egwu, S. O., Awosika, O. F., & Osuafor, A. M. (2023). Examining of crossover instructional strategy toward biology students' academic performance in secondary schools. *Inornatus Biology Education Journal*, 3(2), 50–59. <https://doi.org/10.30862/inornatus.v3i2.420>
- Offiong, A. E., Etim, E., Agbor, C. A., Oyamo, V. I., & Ogbor, C. O. (2026). *Self-efficacy, personal interest and senior secondary students in academic achievement in biology in Calabar Education Zone*. <https://doi.org/10.82340/injohkshe.vol1no1.7>
- Ogunyebi, T. H. (2025). Self-concepts and students' attitude as correlates of elementary school students performance in science learning. *SHILAP Revista de Lepidopterología*. <https://doi.org/10.51558/2744-1555.2025.8.2.504>
- Okela, A. H. (2024). The role of new media literacy in shaping online learning satisfaction: Evidence from Egyptian universities. *Journal of Media Literacy Education*, 16(2), 46–60. <https://doi.org/10.23860/JMLE-2024-16-2-4>
- Olanrewaju, G. S., Adebayo, S. B., Omotosho, A. Y., & Olajide, C. F. (2021). Left behind? The effects of digital gaps on e-learning in rural secondary schools and remote communities across Nigeria during the COVID-19 pandemic. *International Journal of Educational Research Open*, 2, 100092. <https://doi.org/10.1016/j.ijedro.2021.100092>
- Premalatha, M., & Rani, K. S. (2025). Cognition of secondary students in using multimedia to learn science (biology) and its impact. *International Journal of Environmental Sciences*, 717–726. <https://doi.org/10.64252/49xjwd54>
- Putri, A. D., Juandi, D., Jupri, A., Turmudi, & Muchsin, S. B. (2024). Mastering the TPACK framework: Innovative approaches by mathematics teachers. *Jurnal Elemen*, 10(3), 582–594. <https://doi.org/10.29408/jel.v10i3.26311>
- Rachel, A., Inaighe, F., Ewesor, S., Babatope, I. S., & Kachikwu, E. (2025). Effect of integrating animation videos into science instruction in under-resourced rural Nigerian schools. *Journal of Curriculum and Teaching*, 14(4), 87. <https://doi.org/10.5430/jct.v14n4p87>

- Samane-Cutipa, V. A., Quispe-Quispe, N. M., Talavera-Mendoza, F., & Limaymanta, C. H. (2022). Digital gaps influencing the online learning of rural students in secondary education: A systematic review. *International Journal of Information and Education Technology*, 12(7), 685–690. <https://doi.org/10.18178/ijiet.2022.12.7.1671>
- Sefinat, M. T., & Opeyemi, A. A. (2023). *Impact of multimedia technology on computer science students in achievement in secondary schools in Ilorin, Nigeria*. Zenodo. <https://doi.org/10.5281/zenodo.8400004>
- Toh, T. J., & Tasir, Z. (2024). The impact of a mobile learning application on students' cognitive load and learning performance in biology. *Journal of Information Technology Education Research*, 23, 26. <https://doi.org/10.28945/5380>
- Udo, A. E., & Inyang, P. E. (2022). *Psychological variables as correlates of biology students' academic achievement in Uyo Local Government Area, Akwa Ibom State*. <https://doi.org/10.5281/zenodo.6906691>
- Udu, D. A., & Nmadu, J. (2023). Students' interactive engagement, academic achievement and self-concept in chemistry: An evaluation of cooperative learning pedagogy. *Chemistry Education Research and Practice*, 24(2), 688–705. <https://doi.org/10.1039/D2RP00148A>
- Ugwuoke, C. U., Babajide, E. A., Ekenta, L. U., Eze, G. E., Nwankwo, C. U., Ifeanyieze, F. O., Nwachukwu, C. U., Odoh, V. O., & Isiwu, E. C. (2023). Effects of multimedia application on students' academic achievement in agricultural science. *Journal of Baltic Science Education*, 22(6), 1074. <https://doi.org/10.33225/jbse/23.22.1074>
- Usaini, J., & Basiru, M. (2025). Effects of computer-aided instruction on attitude and performance in family health concepts among upper basic students in Sabon Gari, Kaduna State, Nigeria. *Federal University Gusau Faculty of Education Journal*, 5(3), 338–343. <https://doi.org/10.64348/zije.202576>
- Wang, L. (2021). The role of students' self-regulated learning, grit, and resilience in second language learning. *Frontiers in Psychology*, 12, 800488. <https://doi.org/10.3389/fpsyg.2021.800488>
- Yang, X. (2023). A historical review of collaborative learning and cooperative learning. *TechTrends*, 67(4), 718–728. <https://doi.org/10.1007/s11528-022-00823-9>
- Yusuf, M. O., & Afolabi, A. O. (2010). Effects of computer-assisted instruction (CAI) on secondary school students' performance in biology. *The Turkish Online Journal of Educational Technology*, 9(1), 62.
- Zheng, K. (2024). Regional cultural integration and innovation in environmental design: Exploring strategies to maintain and inherit regional cultural values in the context of globalization. *Cultura: International Journal of Philosophy of Culture and Axiology*, 21(3). <https://doi.org/10.70082/cijpca.v21i3.542>