



Effect of Multimedia Instruction on Students' Motivation in the Respiratory System Concept in Biology: Evidence from Zaria Education Zone, Kaduna State, Nigeria

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ABSTRACT

This study investigated the effect of multimedia instruction on motivation in the respiratory system concept among SS II Biology students in Zaria Education Zone, Kaduna State, Nigeria. Two objectives, research questions, and hypotheses guided the study. A quasi-experimental research design involving a non-randomised pretest-posttest control group was adopted. The population comprised 3,709 SS II Biology students in public co-educational secondary schools in the study area, from which a sample of 138 students was selected using the intact class and assigned to experimental and control groups. The treatment lasted six weeks, during which the experimental group was taught using multimedia instruction, while the control group was taught using the conventional method. Data were collected using the Multimedia Motivation Questionnaire in Respiratory System (MMQRS), a 30-item four-point Likert scale instrument validated by experts Educational Psychology and Curriculum, with a reliability coefficient of 0.73. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) and Independent Samples t-test were used to test the hypotheses at 0.05 level of significance. Findings revealed no significant difference in the motivation scores between students taught using multimedia instruction and those taught using the conventional method. However, a significant difference was found between male and female students exposed to multimedia instruction, with female students recording higher motivation scores. The study concluded that multimedia instruction did not significantly improve students' motivation, although gender influenced motivational responses. It was recommended that Biology teachers adopt gender-responsive multimedia strategies to enhance students' motivation.

Keywords: Multimedia Instruction, Motivation, Respiratory System, and Biology Students

INTRODUCTION

Motivation is a fundamental psychological construct that drives individuals to initiate, sustain, and direct their behaviour toward the attainment of specific goals. In educational settings, motivation influences students' willingness to engage with academic tasks, persist through challenges, and invest effort in learning. Urhahne and Wijnia (2023) explained motivation as a construct that accounts for the direction, initiation, intensity, and persistence of learners' behaviour toward educational goals. Motivation is widely recognised as a critical determinant of students' academic engagement, persistence, and achievement across learning contexts (Nagy et al., 2022; Urhahne & Wijnia, 2023).

Educational motivation is broadly categorised into intrinsic and extrinsic forms. Intrinsic motivation refers to engaging in learning activities out of personal interest, curiosity, or enjoyment, while extrinsic motivation is driven by external factors such as grades, rewards, teacher approval, or future career goals (Ryan & Deci, 2020). Both forms shape students' learning behaviours, although intrinsic motivation is more closely associated



with deeper learning, creativity, and long-term retention. Self-Determination Theory (SDT) provides a comprehensive framework for understanding these motivational dynamics. According to Ryan and Deci (2020), motivation is enhanced when three basic psychological needs are met: autonomy, which refers to the learner's sense of control over their learning process; competence, which relates to the belief in one's ability to successfully complete tasks; and relatedness, which involves feeling connected to others within the learning environment. When these needs are fulfilled, students are more likely to develop intrinsic motivation, leading to deeper engagement and improved academic outcomes.

Complementing Self-Determination Theory, Expectancy-Value Theory posits that students' motivation is influenced by their expectations of success and the value they attach to a learning task. Students are more likely to engage in learning activities when they believe they can succeed and perceive the task as meaningful and useful to their lives (Eccles & Wigfield, 2020). Achievement Goal Theory further explains students' motivation in terms of their goal orientations, distinguishing between mastery goals, which focus on developing competence and understanding, and performance goals, which emphasize demonstrating competence relative to others (Chazan et al., 2022).

Biology is a fundamental science with wide-ranging applications in medicine, agriculture, environmental sustainability, and national development (Federal Republic of Nigeria, 2013). At the Senior Secondary School level in Nigeria, Biology is a core science subject that equips students with foundational knowledge necessary for careers in health sciences, agriculture, biotechnology, and environmental management. One of the most important and frequently examined concepts within the SS II Biology curriculum is the respiratory system. The respiratory system facilitates the exchange of gases between the body and the environment, supplying oxygen to cells for energy production and removing carbon dioxide as a metabolic waste product (Do & Musch, 2022). The system consists of structures such as the nose, pharynx, larynx, trachea, bronchi, bronchioles, and alveoli, which function together with the cardiovascular system to maintain physiological homeostasis (Tortora & Derrickson, 2020). In addition to gaseous exchange, the respiratory system helps filter, warm, and humidify inhaled air, thereby protecting the body from harmful particles and microorganisms (Widmaier et al., 2023).

Despite its significance, the respiratory system is frequently perceived as one of the most abstract and difficult topics in secondary school Biology. Many of its processes, including gas exchange, cellular respiration, and the regulation of blood pH, occur at microscopic and physiological levels that are not directly observable. When taught through conventional lecture methods, students often struggle to visualise and internalise these processes, which can result in low motivation and poor conceptual understanding. This challenge is particularly acute in public secondary schools in Zaria Education Zone, Kaduna State, where instructional resources are often limited and classroom instruction remains predominantly teacher-centred (Ugwuanyi et al., 2026; Yahaya & Sule, 2023).

Multimedia instruction refers to the deliberate integration of multiple forms of media including text, images, animations, audio, video, and interactive simulations into teaching to enhance learning experiences (Mayer, 2021). This approach is theoretically grounded in the Cognitive Theory of Multimedia Learning, which posits that learners process information through separate visual and verbal channels and achieve deeper understanding when both channels are simultaneously and coherently engaged (Mayer, 2021). In science education, multimedia and digital technologies have increasingly been incorporated into teaching and learning to support the representation of complex concepts through visual, auditory, and interactive resources (Riza et al., 2023; Ojetunde & Ramnarain, 2023). Evidence from multimedia-based educational interventions also suggests potential benefits for students' academic achievement and motivation (Öngör & Uslusoy, 2023). Animated models of the respiratory system, for instance, allow students to visualise the mechanics of inhalation, exhalation, and alveolar gas exchange in ways that static diagrams and verbal descriptions cannot achieve.

Beyond comprehension, multimedia instruction holds significant potential for enhancing student motivation. By incorporating interactive and visually stimulating elements, multimedia learning environments can capture learners' attention, sustain their interest, and encourage active participation in learning. Multimedia-supported learning also promotes learner autonomy through self-paced instruction, strengthens competence through clear

presentation of content, and encourages collaboration among learners (Alioon & Delialioğlu, 2019). These motivational benefits position multimedia instruction as a promising strategy for teaching complex Biology concepts such as the respiratory system, particularly in contexts where students exhibit low engagement with conventional instructional approaches.

Despite growing evidence of the effectiveness of multimedia instruction in science education globally, there is a paucity of empirical studies specifically examining its effect on motivation among Biology students in the Nigerian secondary school context, and particularly within Zaria Education Zone. Most available studies have focused on academic performance outcomes, with comparatively little attention given to the motivational dimension of learning. This study was therefore designed to fill this gap by investigating the effect of multimedia instruction on motivation in the respiratory system concept among SS II Biology students in Zaria Education Zone, Kaduna State, Nigeria.

Statement of the Problem

Biology is a core science subject in the Nigerian secondary school curriculum and provides foundational knowledge for careers in health sciences, agriculture, biotechnology, and environmental management. Despite its importance, many students experience difficulties in learning certain Biology concepts, particularly those involving abstract physiological processes. One such concept is the respiratory system, which encompasses complex processes such as pulmonary ventilation, gaseous exchange, and cellular respiration that are not directly observable in the classroom. Consequently, students often find the topic difficult to understand, resulting in reduced interest and engagement in learning.

Student motivation is a critical factor in science learning because it influences learners' engagement, persistence, and willingness to invest effort in academic tasks (Ryan & Deci, 2020; Urhahne & Wijnia, 2023). When students are insufficiently motivated, they are less likely to actively participate in learning activities, thereby limiting meaningful understanding of scientific concepts. This challenge may be more pronounced in contexts where instruction is predominantly teacher-centred and opportunities for active learning are limited.

Multimedia instruction has been identified as a promising instructional approach for teaching abstract and dynamic science concepts because it combines text, images, animations, audio, and video to support learning through multiple channels (Mayer, 2021). Through visualisation and interactive presentation of content, multimedia instruction may enhance students' interest, engagement, and motivation to learn. However, within the Nigerian secondary school context, existing studies have focused largely on students' academic achievement and retention, while comparatively little attention has been given to motivation as a learning outcome. Furthermore, limited empirical evidence exists on the use of multimedia instruction for teaching the respiratory system concept in Biology, particularly among students in Zaria Education Zone, Kaduna State.

The absence of context-specific evidence on how multimedia instruction influences students' motivation creates a gap in knowledge that may hinder informed decisions regarding instructional innovation in Biology classrooms. Therefore, this study investigated the effect of multimedia instruction on motivation in the respiratory system concept among Senior Secondary School II Biology students in Zaria Education Zone, Kaduna State, Nigeria.

Objectives of the Study

The main objective of this study was to determine the effect of multimedia instruction on students' motivation in the Respiratory System concept in Biology among Senior Secondary School students in Zaria Education Zone, Kaduna State, Nigeria. Specifically, the study sought to:

1. Examine the effect of multimedia instruction on motivation in Respiratory System concept of Biology among secondary school students in Zaria Education Zone.
2. Determine the effect of multimedia instruction on motivation in Respiratory System concept among male and female students in Zaria Education Zone.

Research Questions

The following research questions guided the study:

1. What is the mean difference between students' motivation taught the Respiratory System concept of Biology using multimedia instruction and conventional method?
2. What is the mean difference between motivation of male and female secondary school students taught Respiratory System concept of Biology using multimedia instruction?

Hypotheses

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

H₀₁: There is no significant difference between the mean motivation scores of students taught the Respiratory System concept of Biology using multimedia instruction and those taught using the conventional method.

H₀₂: There is no significant difference between the mean motivation scores of male and female students taught the Respiratory System concept of Biology using multimedia instruction.

METHODOLOGY

This study adopted a quasi-experimental research design, specifically the non-randomised pretest-posttest control group design. The design was considered appropriate because intact classes were used rather than randomly assigning individual students to treatment conditions, reflecting the practical realities of conducting research in secondary schools where class reorganisation is often impracticable. The design enabled the comparison of students' motivation levels before and after treatment in both the experimental and control groups. The study investigated the effect of multimedia instruction on students' motivation in the Respiratory System concept in Biology.

The population of the study comprised 3,709 Senior Secondary School II (SS II) Biology students in public co-educational secondary schools in Zaria Education Zone, Kaduna State, Nigeria (Ministry of Education, Zaria Education Zone, 2025). SS II students were selected because the Respiratory System concept is taught at that level of the Biology curriculum.

The sample consisted of 138 Senior Secondary School II (SS II) Biology students drawn from two public co-educational secondary schools in Zaria Education Zone, Kaduna State, Nigeria. Initially, seven public co-educational secondary schools constituted the accessible population. Purposive sampling was employed to select three schools because they possessed functional science laboratories, electricity supply, multimedia facilities suitable for instructional delivery, employed two Biology teachers each, implemented the same Biology curriculum, and shared comparable academic and environmental characteristics. Thereafter, a simple random sampling technique through balloting was used to select two of the three schools for participation in the study. Following the selection, another round of balloting was conducted to assign one school to the experimental group and the other to the control group. The participating schools are referred to as School A (experimental group) and School B (control group). Intact SS II Biology classes were retained in both schools because the quasi-experimental research design did not permit random assignment of individual students to treatment conditions. The experimental group comprised 76 students (34 males and 42 females), while the control group comprised 62 students (22 males and 40 females), giving a total sample of 138 students, consisting of 56 males and 82 females.

The instrument used for data collection was the Multimedia Motivation Questionnaire in Respiratory System (MMQRS), which was adapted from Nurhikmah et al. (2025) and modified to suit the objectives and content of the present study. The MMQRS consisted of 30 items structured on a four-point Likert scale with response options of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). Scores of 4, 3, 2, and 1 were assigned respectively for positively worded items, while negatively worded items were reverse scored. The instrument was designed to measure students' motivation toward learning the Respiratory System concept



in Biology. The MMQRS was administered twice: before the commencement of treatment to determine students' initial motivation levels and after the treatment period to assess post-intervention motivation levels.

The adapted MMQRS was subjected to face and content validation by two experts from Ahmadu Bello University, Zaria: one Educational Psychologist from the Department of Psychology and one specialist in Curriculum and Instruction from the Department of Educational Foundations and Curriculum. The validators examined the instrument for clarity of language, appropriateness of the items to the construct being measured, relevance to the objectives of the study, and adequacy of content coverage. Their observations and recommendations were incorporated into the final version of the instrument before administration.

To establish the reliability of the instrument, a pilot testing was conducted using an intact class of 58 SS II Biology students (28 males and 30 females) drawn from a public co-educational secondary school within the study area but outside the sampled schools. Data obtained from the pilot test were analysed using Cronbach's alpha reliability technique, which yielded a coefficient of 0.73. This value was considered acceptable for educational research instruments, as George and Mallery (2019) classified reliability coefficients between 0.70 and 0.80 as acceptable.

Ethical considerations were observed throughout the conduct of the study. Permission to conduct the study was obtained from the authorities of the participating schools. Informed consent was also obtained from the participating students and their parents or guardians. Participation was voluntary, and confidentiality as well as anonymity of participants were maintained throughout the study. Prior to the commencement of the study, the researcher trained two research assistants, one from each participating school, on the administration of the instrument and the procedures for implementing the treatment. The training focused on maintaining uniform conditions during pretest and posttest administration, coordinating classroom activities, and ensuring that students in the control group were not exposed to the multimedia treatment.

The treatment lasted six weeks, during which the researcher personally taught both the experimental and control groups to minimise teacher-related variation. Students in the experimental group received instruction through multimedia-based lessons using PowerPoint presentations, projected animations, and visual illustrations of the Respiratory System concept. The multimedia lessons incorporated animated demonstrations of breathing mechanisms, gaseous exchange, and respiratory processes to facilitate the visualisation of abstract biological concepts. During each lesson, the teacher presented the multimedia materials, paused at key stages to explain concepts, asked questions to stimulate discussion, encouraged students to participate in question-and-answer sessions, and guided learners through structured classroom activities. Students actively observed the multimedia presentations, responded to teacher questions, participated in guided discussions, completed classroom exercises and worksheets, and received feedback throughout the lesson. Detailed lesson plans were prepared to ensure uniform implementation of the instructional activities across the six-week intervention. Students in the control group were taught the same content using the conventional lecture-discussion method with equivalent lesson plans but without multimedia resources. Corresponding lesson plans were also prepared to ensure that both groups covered the same curriculum content within the same duration. Thus, the mode of instruction constituted the primary treatment variable between the groups. At the end of the six-week treatment period, the MMQRS was re-administered to both groups to obtain posttest data on students' motivation.

Data collected from the pretest and posttest administrations of the MMQRS were analysed using descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions by describing differences in students' motivation levels between the experimental and control groups and between male and female students exposed to multimedia instruction. Prior to hypothesis testing, the assumptions of normality and homogeneity of variance were examined and found satisfactory for parametric analysis. Analysis of Covariance (ANCOVA) was used to test the first null hypothesis, with pretest scores serving as a covariate to control for initial differences in motivation between groups, while the Independent Samples t-test was used to test the second null hypothesis. Both tests were conducted at the 0.05 level of significance. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS).

RESULTS

This section presents the results of the data analyses conducted to answer the research questions and test the null hypotheses formulated for the study. Mean and standard deviation were used to answer the research questions, while the Analysis of Covariance (ANCOVA) and Independent Samples t-test were employed to test the hypotheses at the 0.05 level of significance.

Research Question One: What is the mean difference between students' motivation taught the Respiratory System concept of Biology using multimedia instruction and conventional method?

Table 1:

Mean and Standard Deviation of Students' Motivation Scores in the Experimental and Control Groups

Groups	N	Pretest		Posttest		MD
		M	SD	M	SD	
Experimental	76	100.80	7.47	104.14	5.69	0.67
Control	62	99.94	8.59	103.47	5.78	

The data in Table 1 show that the experimental group recorded a pretest mean motivation score of 100.80 (SD = 7.47) and a posttest mean of 104.14 (SD = 5.69), while the control group recorded a pretest mean of 99.94 (SD = 8.59) and a posttest mean of 103.47 (SD = 5.78). The mean difference between the posttest scores of the experimental and control groups was 0.67, indicating that although both groups recorded improvement in motivation scores after intervention, the experimental group scored only marginally higher than the control group at posttest. This descriptive result suggests that multimedia instruction produced a negligibly higher motivation score relative to the conventional lecture method.

Hypothesis One: There is no significant difference between the mean motivation scores of students taught the Respiratory System concept of Biology using multimedia instruction and those taught using the conventional method.

Table 2:

Analysis of Covariance (ANCOVA) of Students' Motivation Scores in Experimental and Control Groups with Pretest as Covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2826.075 ^a	2	1413.037	115.164	.000	.630
Intercept	2819.701	1	2819.701	229.809	.000	.630
Pretest	2810.425	1	2810.425	229.053	.000	.629
Group	12.404	1	12.404	1.011	.316	.007
Error	1656.418	135	12.270			
Total	1492518.000	138				
Corrected Total	4482.493	137				

Not Significant $p \geq 0.05$

The results in Table 2 show that after controlling for students' pretest motivation scores, the effect of instructional method on posttest motivation was not statistically significant, $F(1, 135) = 1.011$, $p = .316$, partial $\eta^2 = .007$. The effect size indicates that instructional method accounted for less than 1% of the variance in

students' posttest motivation scores after adjusting for pretest differences, suggesting a negligible practical effect. Since the p-value of .316 is greater than the 0.05 level of significance, the difference observed between the two instructional groups was not statistically significant. Therefore, the null hypothesis which states that there is no significant difference between the mean motivation scores of students taught Respiratory System concepts in Biology using Multimedia Instruction and those taught using the conventional lecture method is not rejected.

Research Question Two: What is the mean difference between motivation of male and female secondary school students taught Respiratory System concept of Biology using multimedia instruction?

Table 3:

Mean and Standard Deviation of Motivation Scores of Male and Female Students Taught Respiratory System Using Multimedia Instruction

Gender	N	Mean	SD	MD
Male	34	101.00	7.71	
				4.74
Female	42	105.74	5.20	

The data in Table 3 reveal that female students in the experimental group recorded a higher mean motivation score of 105.74 (SD = 5.20) compared to male students who recorded a mean score of 101.00 (SD = 7.71), with a mean difference of 4.74 in favour of female students. This descriptive result suggests that female students demonstrated higher motivation toward learning the respiratory system concept through multimedia instruction than their male counterparts.

Hypothesis Two: There is no significant difference between the mean motivation scores of male and female students taught the Respiratory System concept of Biology using multimedia instruction.

Table 4:

Independent Samples t-test comparing the Motivation Levels of Male and Female Students taught Respiratory System concept of Biology using Multimedia Instruction

Groups	N	Mean	SD	df	t	P-value	Remark
Male	34	101.00	7.71				
				74	-3.189	0.002	Significant
Female	42	105.74	5.20				

Significant $p \leq 0.05$

The result in Table 4 shows that there was a statistically significant difference between the motivation scores of male and female students taught the Respiratory System concept using multimedia instruction, $t(74) = -3.189$, $p = .002$, 95% CI [-7.699, -1.777]. Since the p-value of .002 is less than the 0.05 level of significance, the null hypothesis is rejected. This indicates that female students were significantly more motivated than male students following exposure to multimedia instruction on the respiratory system concept, with female students recording a mean score that was 4.74 points higher than that of their male counterparts.

DISCUSSION OF FINDINGS

The first finding of the study, as revealed in Tables 1 and 2, was that there was no statistically significant difference in the motivation levels of students taught the respiratory system concept using multimedia instruction and those taught using the conventional lecture method ($F(1, 135) = 1.011$, $p = .316$, $\eta^2 = .007$). Although the experimental group recorded a marginally higher post-intervention mean motivation score of 104.14 compared to 103.47 for the control group, this difference was not significant at the 0.05 level,

indicating that both instructional approaches were comparably effective in influencing students' motivation toward learning the respiratory system concept.

The absence of a significant difference may be attributed to several factors. Both methods, when carefully and effectively implemented, are capable of providing meaningful learning experiences that sustain students' interest and engagement. Research has indicated that the motivational impact of multimedia instruction is not uniform and may be moderated by the quality of instructional design, learner characteristics, and implementation context (Abdullah, 2023). Furthermore, the six-week treatment period may not have been sufficient for the motivational advantages of multimedia instruction to manifest distinctly above those of conventional teaching, given that motivation as an affective construct often develops gradually over time. This aligns with findings by Alioon and Delialioğlu (2019), who reported that the motivational effectiveness of multimedia-supported learning depends substantially on the quality of learning activities and the extent of learner interaction with instructional content. It is also noteworthy that the baseline motivation scores of both groups were already high and closely comparable 100.80 for the experimental group and 99.94 for the control group suggesting that students in both schools entered the study with similarly elevated motivational dispositions. This proximity may have limited the observable range of motivational change and reduced the likelihood of detecting a statistically significant difference at post-intervention.

The second finding, as revealed in Tables 3 and 4, was that there was a statistically significant difference in the motivation scores of male and female students taught the respiratory system concept using multimedia instruction ($t(74) = -3.189, p = .002$), with female students recording a considerably higher mean motivation score of 105.74 compared to 101.00 for male students, leading to the rejection of the null hypothesis. This finding suggests that male and female students differ in the manner in which they engage with and respond to multimedia learning environments. Female students appeared to derive greater motivational benefit from the animated and visually structured nature of the multimedia lessons, which may align more closely with their preferred learning and cognitive engagement patterns. This finding is consistent with Dere (2024), who reported that gender differences can influence students' motivation and engagement in STEM-related learning environments, particularly when technology-supported instructional strategies are employed. The study further noted that female students often demonstrate strong motivational responses when appropriately supported in technology-enhanced learning contexts.

CONCLUSION

Based on the findings of this study, it was concluded that multimedia instruction did not produce a statistically significant difference in students' motivation when compared with the conventional lecture method. This suggests that the use of multimedia alone may not automatically result in higher student motivation when both instructional approaches are properly implemented.

The study also revealed a significant difference in the motivation of male and female students exposed to multimedia instruction, with female students recording higher motivation scores than their male counterparts. This indicates that students may respond differently to multimedia-based instruction depending on gender.

The findings therefore highlight the need for Biology teachers and curriculum planners to pay attention not only to the use of multimedia tools but also to the quality of instructional design and delivery, as well as the diverse learning characteristics of students. The study concludes that while multimedia instruction did not produce a significant overall motivational advantage over the conventional method under the conditions of this study, its motivational influence may vary across learner groups, as evidenced by the gender-differentiated responses observed.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:

1. Biology teachers should incorporate multimedia instructional strategies such as PowerPoint animations



and interactive visual materials into the teaching of the respiratory system and other abstract Biology concepts to enhance students' engagement and interest in learning.

2. Teachers and instructional designers should adopt gender-sensitive multimedia instructional approaches that consider the learning preferences and engagement patterns of both male and female students during Biology instruction.
3. School administrators and education policymakers in Kaduna State should provide functional multimedia facilities such as projectors, computers, and stable electricity supply in public secondary schools to support effective implementation of multimedia-based instruction.
4. Teacher education programmes and professional development workshops should include training in multimedia instructional design to equip Biology teachers with the skills required for effective integration of multimedia resources into classroom instruction.
5. Further studies should be conducted using longer treatment periods, larger samples, and additional Biology concepts to determine the long-term effect of multimedia instruction on students' motivation and other learning outcomes.

LIMITATIONS OF THE STUDY

The following limitations were encountered in the course of the study:

1. The study was limited to two public co-educational secondary schools in Zaria Education Zone, Kaduna State, which restricts the generalisation of the findings to other schools, education zones, or states in Nigeria.
2. The six-week treatment period may not have been sufficient to produce substantial changes in students' motivation, as affective outcomes often require longer periods of exposure before measurable differences become evident.
3. The study relied solely on a self-report questionnaire to measure students' motivation. Since self-report instruments may be affected by response bias and social desirability, the inclusion of additional methods such as classroom observation or interviews could have provided a more comprehensive assessment of students' motivation.

SUGGESTIONS FOR FURTHER STUDIES

Based on the findings and limitations of this study, the following suggestions are made for further research:

1. Similar studies should be replicated in other education zones and states in Nigeria, and extended to both public and private secondary schools, to enhance the generalisability of findings on the effect of multimedia instruction on student motivation in Biology education.
2. Further studies should investigate the long-term effects of multimedia instruction on students' motivation by adopting extended treatment periods beyond six weeks, to determine whether sustained exposure to multimedia-based teaching produces more pronounced and durable motivational outcomes than those observed in short-term quasi-experimental studies.
3. Research should be extended to other abstract and conceptually demanding topics within the Biology curriculum, as well as to other science subjects such as Chemistry and Physics, to establish whether the motivational patterns observed in this study are consistent across different content areas and disciplinary contexts.
4. Future research should examine the influence of other variables that may interact with or independently affect students' motivation in multimedia learning environments, including socio-economic background, learning environment, digital literacy levels, and prior exposure to technology-enhanced instruction, to provide a more comprehensive and nuanced understanding of the factors that shape motivational outcomes in science education.

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