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Effects of Multimedia Technology Instruction on Students' Retention of Mechanics Concepts in Physics in Kwali Area Council, Abuja

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Abstract

This study investigated the effects of Multimedia Technology (MMT) instruction on the retention of mechanics concepts among senior secondary school Physics students in the Kwali Area Council of Abuja, Nigeria. A quasi-experimental pre-test, post-test, non-equivalent control group design was adopted. The target population comprised 3,005 Senior Secondary Two (SS2) Physics students, from which a sample of 59 students (36 males and 23 females) was drawn using simple random sampling across two intact classes. The experimental group (n = 36) was taught using MMT, while the control group (n = 23) was taught using the conventional lecture method.

Data were collected using a 40-item Physics Retention Test (PRT) with a pilot-tested reliability coefficient of r = 0.90. Research questions were answered using mean and standard deviation, while the null hypotheses were tested using Analysis of Covariance (ANCOVA) at a 0.05 level of significance.

The results revealed that students taught with MMT demonstrated significantly higher retention mean scores than those in the conventional group. Regarding gender, while male students achieved higher descriptive mean scores within the experimental group, ANCOVA results indicated no statistically significant difference in the retention capacities of male and female students exposed to MMT. The study concludes that MMT is an effective, gender-equitable instructional tool for enhancing long-term conceptual retention in physics mechanics. It is recommended that the Federal and State Ministries of Education systematically integrate multimedia tools into the secondary school physics curriculum and provide corresponding ICT training for educators.

Keywords: Multimedia Technology, Retention, Mechanics. Physics.

1. Introduction

At the core of scientific advancement and industrial innovation lies physics, a discipline specifically des to foster critical thinking, scientific and technological technological literacy. While Physics is defined as the branch of science that examines the structural properties of matter, energy, and the fundamental interactions governing the observable universe (Britannica, 2026).

In Nigeria's senior secondary school curriculum, mechanics serves as the foundational cornerstone for advanced conceptual frameworks, including electromagnetism, thermal physics, and modern physics. Mechanics is a branch of physics that describes the motion of macroscopic objects—from projectiles to machinery and astronomical bodies—under the influence of a system of forces. It operates on the deterministic principle that if the present state of an object is known, its future behavior can be predicted using Newton's laws of motion Stehle, n.d.).

It is fundamental to the study of science to master the principles such as force, power, energy, and Newton's laws of motion is critical for subsequent academic success. Despite its pedagogical importance, numerous secondary students encounter profound challenges in physics owing to its perceived difficulty and inadequate classroom engagement (Kibona, n.d.). This frequently culminates in a superficial understanding of core mechanical principles, leading to poor cognitive retention and consistently depressed academic performance in standardized external examinations (Oyeniran & Oteyola, 2023).

This retention deficit stems largely from systemic pedagogical and infrastructural constraints within the contemporary Nigerian educational landscape. Traditional, lecture-based instructional methods remain stubbornly dominant across secondary institutions, reducing students to passive observers rather than active participants in the learning process (Ugwuanyi, n.d.). Such teacher-centered strategies fail to address students' intrinsic difficulties with highly abstract scientific concepts, forcing educators to present mechanics through rigid mathematical equations detached from real-world empirical contexts. This challenge is further exacerbated by acute logistical deficits, including overcrowded classrooms and a severe shortage of functional laboratory equipment. Consequently, student conceptual knowledge frequently fades shortly after formal instruction, obstructing the deep cognitive processing and mental model construction required to promote durable, long-term memory retention (Bada & Jita, 2023; Qanabita, n.d.).

Compounding these pedagogical barriers are the deep-seated sociocultural and gender dynamics prevalent within the Nigerian Science, Technology, Engineering, and Mathematics (STEM) ecosystem. Physics remains heavily stereotyped as a masculine, male-dominated discipline, a perception reinforced by societal expectations and traditional gender roles that prioritize domestic responsibilities for women over technical careers (Yusuf, n.d.). These systemic biases frequently infiltrate the classroom environment, where teachers' traditional perceptions of gender roles inadvertently influence their pedagogical expectations; male students are routinely called upon to execute complex problem-solving tasks, while female students are steered toward passive, collaborative, or marginal roles (Yusuf, n.d.). Such isolated treatment patterns induce STEM-related anxieties and lower self-efficacy among female learners, leading to visible disparities in academic achievement and participation across various educational zones (Ani et al., 2021; Yusuf, n.d.). Investigating the complex intersection of gender and active instructional strategy is therefore essential to engineering equitable, inclusive educational interventions.

To bridge these instructional and infrastructural gaps, educational researchers have increasingly turned to digital innovations and computer-assisted instructional packages. Multimedia Technology (MMT)—specifically the integration of computer-based simulations (CBS), localized video instructional packages (VIP), and digital animations—offers a transformative pathway to enhance students' cognitive retention capabilities (Oyeniran & Oteyola, 2023). Grounded in the Cognitive Theory of Multimedia Learning, this paradigm posits that effective learning occurs when complex, dynamic physical phenomena are presented simultaneously through multiple sensory channels combining visual imagery and verbal narration, thereby minimizing cognitive load (Qanabita, n.d.). By deploying interactive simulations and dynamic visualizations, abstract mechanical concepts—such as forces, motion vectors, and causal relationships—are rendered concrete, allowing students to build robust mental models (Qanabita, n.d.). Empirical evidence demonstrates that incorporating digital multimedia and animation courseware significantly enhances conceptual understanding, drives student interest, and maximizes long-term academic retention compared to traditional lecture-based methods (Oyeniran & Oteyola, 2023; Ugwuanyi, n.d These systemic inequities often manifest as disparities in academic achievement, digital literacy, and institutional support systems, which can ultimately influence how effectively male and female students process and retain scientific information. Investigating the intersection of gender and instructional strategy is therefore essential to developing equitable educational interventions.

To bridge these instructional and infrastructural gaps, educational researchers have increasingly turned to digital innovations. Multimedia Technology (MMT)—specifically the integration of localized audio-visual materials, digital projectors, and video animations—offers a promising pathway to enhance cognitive retentive ability.

Multimedia instructional packages for Mechanics in Physics typically combine interactive simulations, animations, videos, narrations, and text to improve conceptual understanding, visualization of abstract/dynamic phenomena (e.g., forces, motion, Newton's laws).

Key Software and Tools

1. PhET Interactive Simulations (University of Colorado Boulder): Free, HTML5-based tools widely used for Mechanics. Examples include Forces and Motion: Basics and Forces and Motion, which let students manipulate variables like applied force, friction, mass, and observe net force, acceleration, velocity, and Newton's laws in real-time. These support inquiry-based learning and are effective for topics like projectile motion and balanced/unbalanced forces.
2. Physclips (UNSW, Australia): Multimedia modules with animations, video film clips, and explanations for introductory Mechanics (e.g., Newton's laws, kinematics). Designed for different levels, with clear visuals of physical processes.
3. Other tools: PowerPoint with embedded animations/videos, Manim for custom animations, or commercial/educational software for 3D modeling. Mobile apps like Physics Toolbox Suite use device sensors.

Use of Videos and Animations

Short animated simulations and video demonstrations are common for dynamic concepts (e.g., motion graphs, collisions, energy transfer). Whiteboard animations and interactive videos enhance engagement and retention. YouTube playlists and educational channels offer series with 100s–1000s of visualized concept videos and problem solutions (e.g., for high school/AP Physics).

Interactive animations align with Mayer's Cognitive Theory of Multimedia Learning (dual channels: visual + auditory) and reduce cognitive load while building mental models. Consequently, this study is out to investigate if the integration of Multimedia Technology (MMT) instruction could address these persistent pedagogical failures and significantly improve students' retention in mechanics in mechanics concept of Physics.

Statement of the Problem

In Nigeria's senior secondary school Physics, Mechanics stands as a crucial foundation for almost all other advanced topics, from electromagnetism to thermal physics. Concepts like Force, Power, Energy, and Newton's Laws of Motion are the essential building blocks. Unfortunately, the statistics show a troubling trend. Between 2014 and 2025, the National credit pass rates (grades A1–C6) in the West African Senior School Certificate Examination (WASSCE) fluctuated between 41% and 60%. This means that in several academic cycles, more than half of the students who sat for the exam failed to attain a grade that would allow them gain admission into the university. In the Federal Capital Territory (FCT) and across the country, diagnostic reports point to the exact same hurdle: students are consistently tripping over the conceptual and mathematical demands of mechanics

This crisis stems from the classroom as any learners who are eager to learn but quickly lose heart when abstract ideas are not understood. The reasons are familiar to anyone in the system: overcrowded classrooms dominated by traditional "chalk-and-talk" lectures, a severe shortage of working laboratories, a lack of qualified teachers, and a heavy reliance on complex mathematical formulas that feel completely disconnected from real life. Without hands-on experiments or interactive visual tools, students turn into passive note-takers. They memorize just enough to pass a test, only for that knowledge to evaporate weeks later.

Purpose of the Study

The primary objective of this study was to evaluate the effects of Multimedia Technology (MMT) instruction on Physics students' retention in the Kwali Area Council of Abuja. The specific objectives sought to:

1. Determine the effect of MMT instruction on students' retention in mechanics concepts relative to the conventional lecture method.
2. Examine the influence of gender on the retention scores of students exposed to MMT instruction in mechanics concepts.

Research Questions

The study addressed the following research questions:

1. What is the difference in the mean retention scores on the Physics Retention Test (PRT) between students taught using MMT and those taught using the conventional lecture method?
2. What is the difference in the mean retention scores of male and female students taught mechanics concepts of physics using MMT?

Research Hypotheses

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

H01: There is no significant difference in the mean retention scores of students taught mechanics concepts using Multimedia Technology (MMT) and those taught using the conventional lecture method.

H02: There is no significant difference in the mean retention scores of male and female students taught mechanics concepts using Multimedia Technology (MMT) Instruction.

Methodology

Research Design

This study adopted a quasi-experimental pre-test, post-test, non-equivalent control group design. This design is appropriate for educational settings where random assignment of individual students into isolated groups would disrupt established school structures and schedules. Instead, intact, pre-existing classroom cohorts were assigned to treatment conditions. The operational design layout is illustrated below:

Experimental Group (Intact Class 1): O1 ---> X1 ---> O3

Control Group (Intact Class 2): O2 ---> X0 ---> O4

Where:

X1 = Experimental treatment using Multimedia Technology (MMT) instruction.

X0 = Control treatment using the conventional lecture method.

O1, O2 = Pre-test measures administered to both groups simultaneously.

O3, O4 = Post-test retention measures administered to both groups simultaneously following the instructional block.

Population and Sample

The target population comprised all Senior Secondary School Two (SS2) Physics students enrolled during the 2024/2025 academic session within the Kwali Educational Zone of FCT Abuja, Nigeria. According to data from the Secondary Education Board (SEB, 2025), the total population was 3,005 students (1,875 males, 1,130 females). A simple purposive sampling technique was utilized to select school, due to the availability of Multimedia facilities yielding an intact sample size of 59 students. The experimental group consisted of 36 students (20 males, 16 females) and the control group consisted of 23 students (16 males, 7 females).

Instrumentation

The data collection instrument was the Physics Retention Test (PRT), developed by the researcher. The instrument consisted of 40 multiple-choice items, each featuring four options (A, B, C, and D), spanning core secondary mechanics domains: Newton’s laws of motion, force, energy, and power.

Validity and Reliability

To establish psychometric validity, the PRT items were built around a two-way Table of Specifications mapped directly to the cognitive dimensions of Bloom’s Taxonomy. Content validity was established by a a Senior Lecturer (Ph.D.) from the Department of Science and Environmental Education and an experienced high school Physics teacher in Kwali. Face validity was verified a professor in the department of Science and Environmental Education to confirm alignment with regional testing guidelines.

To establish reliability, the PRT was pilot-tested at Government Day Senior Secondary School (GDSS), Gwagwalada—an institution matching population characteristics but excluded from the main study. The test was administered twice over a two-week interval using the test-retest method. The resulting paired scores were analyzed using the Pearson Product-Moment Correlation (PPMC) via SPSS, yielding a reliability coefficient of $r = 0.90$, confirming the instrument's stability over time.

Data Collection Procedure

The field work was executed over a six-week period during the 2025/2026 academic session. In the first week, the 40-item test was administered as a pre-test (O1, O2) to establish baseline cognitive parity. Over the subsequent four weeks, both groups covered identical mechanics curriculum outlines: Experimental Group (X1): Instructed via MMT. Students engaged with selected digital multimedia animations and video clips displaying physical demonstrations of forces, energy transfers, and algorithmic calculations.

Duration and Content Coverage

Modules/sessions: Often 40–80 minutes per lesson or topic cluster (e.g., 2-week interventions with multiple 80-minute sessions on force and motion). Individual simulations or video clips are shorter (1–10 minutes) for focused use, allowing pause/replay.

Content coverage: Core Mechanics topics include displacement, velocity, acceleration, dynamics Newton's laws, forces, friction, projectile motion, energy, momentum, and rotational aspects. Packages cover visualizations of invisible/abstract elements, real-world applications, and interactive experiments.

Control Group (X0): Instructed via the conventional lecture method. The teacher utilized conventional teaching method, verbal explanations, and textbook illustrations. Two weeks after the conclusion of the treatment (Week 6), the PRT was re-administered as a post-test/retention measure (O3, O4). To eliminate test-order memorization bias, the items were rearranged.

Method of Data Analysis

Descriptive statistics (means and standard deviations) were used to answer the two research questions. Main and interaction effects were tested using Analysis of Covariance (ANCOVA) at an alpha level of 0.05. The pre-test achievement scores served as the covariate to statistically control for initial baseline variations. All calculations were processed through SPSS software.

Presentation of Results

This section presents the result and interpretation of data collected from the study based on research questions and hypotheses

Answering Research Questions

Table 1: Mean Retention Scores and Standard Deviations by Group

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Mean Gain	(Mdf)
MMT	36	67.10	9.80	75.90	8.20	8.80	5.3
Control	23	66.00	8.88	69.50	7.80	3.50	
Total	59						

Table 1 indicates that the experimental group exposed to MMT achieved a post-test mean score of 75.90, whereas the control group finished with a post-test mean score of 69.50. While both instructional groups showed improvement from pre-test baselines, the experimental group achieved a higher mean gain (8.80) compared to the conventional lecture group (3.50). The final raw difference between the post-test mean achievement scores of the two groups was 5.04 in favour of the VBMT intervention.

Table 2: Descriptive Statistics for Retention Scores Based on Gender (Experimental Group Only)

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Mean Gain	(Mdf)
Male	20	63.61	9.45	68.93	4.87	5.32	0.62
Female	16	48.75	11.43	53.45	12.22	4.70	

Table 2 shows a clear performance difference between genders under the Multimedia technology-instruction. Male students exposed to MMT advanced from a pretest score of 63.61 to a post-test mean score of 68.93, yielding a mean gain of 5.32. Conversely, female counterparts within the same treatment with a pretest at 48.75 and completed the study at a post-test mean score of 53.45, demonstrating a mean gain of 4.70. The resulting post-test mean achievement gap between male and female students was 0.62, with a

Table 3: ANCOVA for Retention Scores of Students by Instructional Approach and Gender mean gain of 0.65 favoring the male participants.

Source	Type III SS	df	Mean Square	F	Sig. (p)	Decision
Corrected Model	908.820	4	227.205	4.271	.004	Significant
Intercept	6865.360	1	6865.360	129.050	.000	Significant
Pre-test (Covariate)	674.811	1	674.811	12.685	.001	Significant
Gender	190.079	1	190.079	3.573	.064	Not Sig.
Teaching Method	273.880	1	273.880	5.148	.027	Significant
Method * Gender	13.387 1	1	3.387	0.252	.618	Not Sig.
Error	2872.237	54	53.190 —	—	—	
Total	310407.000	59	— —	—	—	
Corrected Total	3781.057	58	— —	—	—	

Note: R Squared = .240 (Adjusted R Squared = .184). Significant at alpha = 0.05.

The ANCOVA output in Table 3 indicates that the main effect of the treatment (Teaching Method) was statistically significant: F(1, 54) =5.148 , p = 0.027. Because the calculated probability value (0.017) is less than the selected significance threshold (alpha = 0.05), the first null hypothesis (H01) is rejected. This indicates that the higher achievement gains observed in the MMT experimental group performed significantly than the control group.

Table 4: ANCOVA for Retention Scores by Gender within the Experimental Group (MMT)

Source	Type III SS	df	Mean Square	F	Sig.(p)	Decision
Corrected Model	672.286	2	336.143	6.916	.003	Significant
Intercept	3749.980	1	3749.980	77.157	.000	Significant
Pre-test (Covariate)	479.989	1	479.989	9.876	.004	Significant
Gender	187.166	1	187.166	3.851	.059	Retained
Error	1506.655	33	45.656	—	—	—
Total	172722.000	36	—	—	—	—
Corrected Total	2178.941	35	—	—	—	—

Note: R Squared = .309 (Adjusted R Squared = .264). Significant at alpha = 0.05.

The result presented in Table 4 shows that the main effect of Gender on retention within the experimental group is not statistically significant, $F(1, 33) = 3.851$, $p = 0.059$. Because the observed p-value (0.059) is greater than the significance level (0.05), the second null hypothesis (H02) is retained. This indicates that when exposed to MMT instruction, there is no statistically significant difference in the long-term retention performance of male and female students.

Discussion of Findings

The descriptive and inferential results from this study confirm that Multimedia Technology (MMT) instruction significantly improves senior secondary school students' retention of mechanics concepts relative to conventional lecture delivery. The visual and repeatable nature of digital multimedia assets provides an effective cognitive bridge for high schoolers grappling with complex physics principles.

This outcome aligns with some recent findings in multimedia learning design. For instance, Speirs et al. (2021) demonstrated that when multimedia technology resources are aligned with foundational physics concepts, students show substantial gains because they can review complex content at their own pace. Within developing educational landscapes, these interactive instructional interventions serve as an effective alternative for missing physical lab equipment, enabling experiential learning in resource-limited classrooms (Juita et al., 2023).

Additional studies reinforce the benefits of interactive multimedia and virtual simulations in physics education, particularly as alternatives to physical labs in resource-constrained settings. For example, research on interactive animation media has shown significant improvements in students' conceptual understanding of physics topics through dynamic visualizations that help bridge abstract concepts with real-world applications (Khualid & Rohmah, 2025).

Regarding gender, the descriptive data indicated that male students achieved a little higher in the mean retention scores than their female counterparts within the experimental group. However, when controlling for pre-test baseline scores by ANCOVA, this difference was found to be statistically non-significant ($p > 0.05$). This indicates that MMT is a gender-equitable educational intervention capable of helping both male and female students retain abstract physics principles uniformly.

Studies such as Gunawan et al. (2018) examined the effects of virtual labs on physics creativity (verbal, numerical, and figural) and found interactions with gender, the results on performance and retention often show no significant overall gender differences when using virtual labs—suggesting these tools can provide equitable opportunities by allowing self-paced review and repeated interaction

This finding contrasts with historical patterns of male dominance in traditional STEM tracks across Nigeria, which often stem from gendered digital literacy gaps or pedagogical biases (Okebukola et al., 2020). However, it directly supports the assertions of modern digital education researchers who argue that well-structured multimedia tools neutralize traditional classroom inequities. When abstract concepts like vector mechanics are contextualized through video animations, both male and female students process the information through dual cognitive channels (visual and auditory), mitigating differential entry-level anxieties (Docktor et al., 2015). Consequently, MMT acts as an equalizer, ensuring that long-term cognitive storage is dependent on instructional clarity rather than gender biases.

Limitations of The Study

1. **Lack of Random Assignment**
   Since intact classes rather than randomly selected individuals were assigned to groups, the treatment and control groups may differ in important characteristics before the intervention. This can introduce selection bias and affect internal validity.
2. **Limited Control of Extraneous Variables**
   Factors such as students' prior knowledge, motivation, socioeconomic background, teacher differences, and classroom environment may influence the outcomes and cannot be completely controlled.
3. **Factor of Generalizability**
   Findings obtained from specific schools, classes, or geographical locations may not be generalizable to all students or educational settings.
4. **Teacher Effect**
   Differences in teachers' competence, experience, enthusiasm, or instructional style may influence students' performance independently of the treatment.

Conclusion and Recommendations

Conclusion

This study establishes that Multimedia Technology (MMT) instruction is a highly effective tool for enhancing secondary school students' long-term retention of mechanics concepts. By integrating dynamic visual animations and audio-visual aids, MMT reduces cognitive load and closes the rank caused by the lack of physical laboratory infrastructure in Nigerian secondary schools. Furthermore, the study demonstrates that MMT acts as a gender-friendly intervention tool. While descriptive statistics initially favored male students, inferential analysis confirmed that MMT provides equal cognitive benefits to both male and female students. Ultimately, shifting from traditional 'chalk-and-talk' lectures to technology-mediated learning is critical for improving academic retention and fostering long-term conceptual mastery in physics.

Recommendations

Based on the empirical findings of this study, the following recommendations are put forward:

1. Curriculum Integration: The Federal Ministry of Education (FME), alongside the Nigerian Educational Research and Development Council (NERDC), should systematically integrate localized multimedia instructional packages into the national secondary school physics curriculum.

2. Teacher Capacity Building: Regular Information and Communication Technology (ICT) workshops and professional development training should be organized for science teachers in the Kwali Area Council and the wider FCT to equip them with the skills to design and implement interactive multimedia lessons.
3. Infrastructural Upgrades: The Secondary Education Board (SEB) and relevant educational stakeholders should prioritize equipping public secondary schools with functional digital infrastructure, such as steady power supplies, digital projectors, and interactive smartboards.
4. Gender-Inclusive STEM Policies: School administrators and educators should actively utilize multimedia technology as a strategic tool to bridge the gender gaps in science education, ensuring equal participation and motivation for female students in STEM subjects.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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