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Effect of Integrating Lecture Method with Multimedia Instruction on Students' Retention and Problem-Solving Skills in Mathematics

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Abstract

Traditional lecture methods in mathematics education often face challenges in sustaining students' engagement, promoting long-term retention, and developing robust problem-solving skills. This quasi-experimental study was carried out in Ughelli, Delta State, targeting public-sector secondary-school students. Two intact Grade-10 mathematics classes ($N = 90$; Experimental = 45, Control = 45) were selected by stratified random sampling from a single secondary school. The instructional intervention combined standard lecture with multimedia (animations, interactive simulations, and video explanations). Instrumentation included the Mathematics Retention Test (MRT) and the Problem-Solving Skills Inventory (PSSI). Both tools were validated by an expert panel (Content-Validity Index = .92) and showed high internal consistency (Cronbach's $\alpha = .86$ for MRT; .89 for PSSI). A pilot study with 15 students confirmed item clarity and appropriate administration time. Data were gathered in-class under exam conditions: a pre-test was administered one week before the eight-week treatment, and a post-test immediately after. ANCOVA, controlling for pre-test scores, revealed a statistically significant advantage for the multimedia group on mathematical retention ($F(1,87)=32.78$, $p < .001$, partial $\eta^2 = .273$) and on problem-solving skills ($F(1,87)=25.10$, $p < .001$, partial $\eta^2 = .224$). These findings indicate that integrating multimedia instruction with the lecture method substantially enhances students' mathematical retention and problem-solving abilities. We therefore recommend that secondary-school mathematics curricula incorporate varied multimedia resources to create more engaging, comprehensible, and durable learning experiences.

Keywords: Lecture method, multimedia instruction, mathematics education, student retention, problem-solving skills, quasi-experimental

Introduction

Mathematics plays a foundational role in scientific and technological advancement, critical thinking, and logical reasoning. However, teaching and learning mathematics, particularly abstract concepts, often present significant challenges (chen & Nguyen 2024, Trung et al 2025). Traditional instructional methods, predominantly the lecture method, have been a cornerstone of education for centuries due to their efficiency in content delivery to large groups (crowford 7 parsell 2025). While effective for transmitting information, the conventional lecture is often criticized for its passive nature, limited opportunities for students' interaction, and potential for reduced engagement, which can impede long-term knowledge retention and the development of higher-order thinking skills such as problem-solving (Dzaiy & Abdullah, 2024; Gerges, 2025). In an era dominated by digital technology, the integration of multimedia instruction has emerged as a promising pedagogical strategy. Multimedia instruction, encompassing the use of various media like text, audio, images, animations, and videos, can provide multiple representations of information, catering to diverse learning styles and enhancing cognitive processing. Theoretical frameworks such as Mayer's Cognitive Theory of Multimedia Learning (CTML) posit that learning is optimized when verbal and visual information are presented simultaneously, allowing learners to build coherent mental models (Martin, 2025, Clark & Mayer, 2023). Similarly, Teng (2023) & Kurgansky et al (2024) suggest that information processed through both verbal and non-verbal channels is better retained and recalled.

Previous research has explored the benefits of multimedia in various disciplines (e.g., Mosia & Egara, 2025; Ongor & Uslusoy, 2023). Studies have indicated that multimedia can improve student engagement, motivation, and understanding of complex topics. However, most of these investigations treat multimedia as a stand-alone supplement rather than as an embedded component of a traditional lecture. To address this gap, our study explicitly integrates multimedia within the established lecture framework for a first-year calculus course. Specifically, each 45-minute lecture is divided into three phases: (1) a 10-minute frontal exposition of the target concept; (2) a 15-minute interactive segment in which a short (2–3 min) instructional video illustrates the same concept using animated visualizations and real-world analogies; and (3) a 20-minute problem-solving workshop where students apply the concept to guided practice problems while the video is projected on a secondary screen for reference. The video is deliberately timed to follow the exposition so that it reinforces, rather than replaces, the verbal explanation. This sequencing allows us to evaluate the combined effect of multimedia-enhanced exposition and active problem-solving on two outcomes: (i) memory retention, measured by a delayed-posttest administered one week after the lecture, and (ii) problem-solving skill, assessed through a performance-based rubric on the workshop tasks. Thus, our design directly tests whether multimedia, when tightly coupled with lecture and practice, yields additive benefits for both knowledge retention and problem-solving proficiency (Indu & Djara, 2025; Mosia & Egara, 2025).

This study aims to address the observed gap by investigating the combined effect of integrating the lecture method with multimedia instruction on secondary school students' mathematical retention and problem-solving skills in the context of Quadratic Equations.

Research Question

This study aimed to address the following questions

1. What is the difference in the mathematical-retention scores of students taught using an integrated lecture-multimedia method compared with those taught using a traditional lecture-only method?
2. What is the difference in the problem-solving-skills scores of students taught using an integrated lecture-multimedia method compared with those taught using a traditional lecture-only method?

Research Hypotheses

To examine the effect of the instructional approach on students' long-term retention of mathematics, we formulated the following null and alternative hypotheses:

- **H01:** There is no significant difference in the mathematical retention scores of students taught using an integrated lecture-multimedia method compared to those taught using a traditional lecture-only method.
- **HA1:** There is a significant difference in the mathematical retention scores of students taught using an integrated lecture-multimedia method compared to those taught using a traditional lecture-only method.

- **H02:** There is no significant difference in the problem-solving skills scores of students taught using an integrated lecture-multimedia method compared to those taught using a traditional lecture-only method.
- **HA2:** There is a significant difference in the problem-solving skills scores of students taught using an integrated lecture-multimedia method compared to those taught using a traditional lecture-only method.

Methodology

This study employed a quantitative, quasi-experimental research design, specifically a pre-test/post-test non-equivalent control-group design. **The research was conducted in the Ughelli Local Government Area (LGA) of Delta State, Nigeria, *focusing on a* public secondary school that serves the local community. This design was chosen because random assignment of individual students to groups was not feasible in a natural school setting. Instead, two pre-existing intact classes were assigned as the experimental and control groups. This design allows for the comparison of outcomes between groups while attempting to control for initial differences using statistical methods. The target population comprised all Grade 10 students (approximately 15–16 years old) enrolled in public secondary schools within Ughelli LGA during the 2024-2025 academic year (estimated $N \approx 1{,}200$). From this population, the researchers selected one public secondary school that met the following criteria**:** (a) availability of a regular mathematics teacher willing to implement the intervention, and (b) two intact Grade 10 classes with comparable prior academic achievement. The participants were 90 Grade 10 students (approximately 15-16 years old) from the selected school. Two intact classes were purposively chosen because of their similar academic profiles and the availability of their regular mathematics teacher to implement the intervention consistently across both groups. One class **(**$N = 45$**)** was randomly assigned as the experimental group, and the other class **(**$N = 45$**)** as the control group. All students and their guardians provided informed consent, and participation was voluntary. Anonymity and confidentiality were maintained throughout the study. The study was conducted in the regular mathematics classrooms of the participating school over a period of four consecutive weeks, with daily 60-minute mathematics lessons. The topic covered was "Quadratic Equations," including solving quadratic equations by factoring, completing the square, quadratic formula, and applications of quadratic equations.

Experimental group received instruction where the lecture method was integrated with various multimedia resources. The teacher utilized interactive PowerPoint presentations with embedded videos explaining concepts, dynamic simulations demonstrating graphical representations of quadratic functions, and online interactive quizzes for immediate feedback. Specific software and platforms used included GeoGebra for graphical visualizations, Khan Academy videos for conceptual explanations, and custom-designed interactive exercises. Control group (Lecture-Only) received instruction using the traditional lecture method. The teacher used a chalkboard/whiteboard, textbooks, and practice problems from the textbook. No digital multimedia resources were incorporated during the instructional period.

The same mathematics teacher delivered instruction to both groups to minimize teacher-related variability. Lesson plans for both groups were meticulously developed to ensure content equivalence and aligned with the national curriculum standards. The only difference was the instructional delivery approach. Notably, the experimental group received instruction on "Quadratic Equations" using a lecture method augmented with interactive multimedia presentations, educational videos, and dynamic simulations for four weeks. The control group received instruction on the same topic using the traditional lecture method (chalkboard/whiteboard). Pre-tests assessed baseline knowledge. Post-tests measured immediate learning and problem-solving skills, while a delayed post-test (administered three weeks later) assessed retention. Three main instruments were used for data collection:

1. **Mathematics Pre-test/Post-test:** A 30-item, multiple-choice test designed to assess students' conceptual understanding and procedural knowledge of Quadratic Equations. The pre-test measured baseline knowledge before the intervention, while the post-test measured immediate learning outcomes. The items were developed by experienced mathematics teachers and university professors, then validated by a panel of three subject matter experts for content validity. A pilot study with 30 students (not part of the main study) yielded a Cronbach's Alpha reliability coefficient of 0.82, indicating good internal consistency.
2. **Mathematics Retention Test:** This was identical to the post-test and was administered three weeks after the completion of the intervention and post-test. It aimed to measure the long-term recall and understanding of the learned content.

3. **Mathematics Problem-Solving Skills Test:** A 5-item, open-ended test requiring students to apply their knowledge of Quadratic Equations to solve real-world, non-routine problems. This test specifically assessed students' ability to understand a problem, formulate a strategy, execute the plan, and interpret the solution. A detailed rubric with a 5-point scale per item (0 = no attempt/incorrect, 5 = complete and correct solution) was used for scoring. The rubric was validated by experts, and inter-rater reliability among two independent scorers was established at 0.88 (Cohen's Kappa) during the pilot phase. The maximum score for this test was 25.

1. **Pre-test Administration:** All 90 students in both groups took the Mathematics Pre-test one week before the intervention began.
2. **Intervention Period:** The four-week instructional period commenced, with the experimental and control groups receiving their respective forms of instruction.
3. **Post-test Administration:** Immediately after the four-week intervention, both groups took the Mathematics Post-test and the Mathematics Problem-Solving Skills Test.
4. **Retention Test Administration:** Three weeks after the post-test, both groups took the Mathematics Retention Test.

The collected data were analyzed using SPSS Statistics Version 28.

Means, standard deviations, and frequencies were calculated to summarize the demographic information and raw test scores for both groups. An independent samples t-test was used to compare the pre-test scores of the experimental and control groups to determine if there were significant baseline differences. Analysis of Covariance (ANCOVA) was employed to compare the mean scores of the experimental and control groups on the Retention Test and Problem-Solving Skills Test. The pre-test scores were used as a covariate to statistically control for any initial differences between the groups, thereby increasing the power of the analysis and reducing potential confounding effects. The level of significance was set at $\alpha = 0.05$. Partial eta-squared (η^2) was calculated to estimate the effect size.

Ethical approval was obtained from the University of Advanced Studies Research Ethics Committee and the school administration. Informed consent was secured from all participating students and their parents/guardians. Students were informed of their right to withdraw at any point without penalty. Anonymity and confidentiality of all data were strictly maintained.

Results

An independent samples t test was conducted on the pre test scores to assess the initial equivalence of the two groups. The results are reported in Table 1. The analysis showed no statistically significant difference between the experimental group (M = 14.89, SD = 3.12) and the control group (M = 15.22, SD = 3.05) on the pre test (t(88) = 0.52, p = 0.604). This indicates that both groups had comparable prior knowledge of quadratic equations at the start of the study, thereby satisfying Hypothesis H_{01} (no baseline difference).

Table 1 – Pre-test descriptive statistics and t-test for baseline equivalence

Group	N	Mean (M)	SD
Experimental	45	14.89	3.12
Control	45	15.22	3.05

t-test (independent samples): t(88) = -0.52, p = 0.604

To investigate the effect of integrating lecture with multimedia instruction on students' mathematical retention, we tested the null hypothesis that the instructional method (experimental vs. control) does not affect retention scores after statistically controlling for pre test performance (H_0: $\mu_E = \mu_C$ | covariate). The alternative hypothesis is that the instructional method does have an effect (H_1: µ_E ≠ µ_C | covariate). An analysis of covariance (ANCOVA) was performed on the retention test scores, with pre test scores entered as a covariate. Table 3 presents the ANCOVA summary.

Table 2: Descriptive Statistics for Mathematics Retention Test Scores

Group	N	Mean	Std. Deviation
Experimental	45	25.18	2.85
Control	45	20.36	3.10
Total	90	22.77	3.88

Note: Maximum possible score = 30

As shown in Table 2, the experimental group (M = 25.18) achieved a higher mean score on the retention test compared to the control group (M = 20.36).

Table 3: ANCOVA Summary for Mathematics Retention Test Scores (Controlling for Pre-test)

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Pre-test Score (Covariate)	48.75	1	48.75	4.61	.034	.050
Group (Experimental vs. Control)	346.99	1	346.99	32.78	<.001*	.273
Error	921.65	87	10.59			
Total	49764.00	90				
Corrected Total	1317.39	89				

**$p < .001$

The ANCOVA results (Table 3) indicate a statistically significant effect of the instructional method on mathematics-retention scores after adjusting for the pre-test ($F(1, 87) = 32.78$, $p < .001$). The partial $\eta^2 = .273$ denotes a large effect size, meaning that ≈27 % of the variance in retention scores is explained by the instructional method. Consequently, we reject the null hypothesis (H_0) and conclude that the multimedia-enhanced lecture significantly improves retention compared with the traditional lecture.

Effect on Problem-Solving Skills

An analysis of covariance (ANCOVA) was conducted on the post-test scores of the mathematics problem-solving skills test, using the pre-test scores as a covariate, to examine the effect of the instructional methods.

Table 4 presents the descriptive statistics that address Research Question 2 (RQ 2): "Does the experimental instructional method lead to higher problem-solving performance than the traditional control method?" The table shows that the experimental group ($M = 19.56$, $SD = 2.67$) obtained a substantially higher mean score than the control group ($M = 15.89$, $SD = 3.01$).

Table 5 displays the ANCOVA results that test Hypothesis 2 (H_{02}): "There is no difference between the experimental and control groups on post-test problem-solving scores after controlling for pre-test performance." The analysis revealed a statistically significant main effect of group, $F(1, 87) = 25.10$, $p < .001$, with a large partial $\eta^2 = .224$, indicating that the instructional approach accounts for about

22 % of the variance in problem-solving performance. Consequently, H_{02} is rejected in favor of the alternative hypothesis that the experimental method produces superior problem-solving skills.

Table 4: Descriptive Statistics for Mathematics Problem-Solving Skills Test Scores

Group	N	Mean	Std. Deviation
Experimental	45	19.56	2.67
Control	45	15.89	3.01
Total	90	17.72	3.64

Note: Maximum possible score = 25

As presented in Table 4, the experimental group (M = 19.56) achieved a substantially higher mean score on the problem-solving skills test compared to the control group (M = 15.89).

Table 5: ANCOVA Summary for Mathematics Problem-Solving Skills Test Scores (Controlling for Pre-test)

Source	Sum of Squares	Df	Mean Square	F	Sig.	Partial η^2
Pre-test Score (Covariate)	29.80	1	29.80	3.65	.059	.040
Group (Experimental vs. Control)	204.67	1	204.67	25.10	<.001*	.224
Error	710.27	87	8.16			
Total	30605.00	90				
Corrected Total	944.73	89				

**$p < .001$

Discussion

This study aimed to investigate the effect of integrating the lecture method with multimedia instruction on students' mathematical retention and problem-solving skills in the context of Quadratic Equations. The findings provide compelling evidence that such integration significantly enhances both retention and problem-solving abilities compared to the traditional lecture-only approach. The ANCOVA results reported for retention (H_1) and problem solving (H_2) indicate robust benefits of a multimedia-enhanced lecture over a lecture-only condition. Specifically, retention showed a significant adjusted mean difference ($M = 25.18$, $SD = 3.47$; $M = 20.36$, $SD = 4.01$; $F(1,87) = 32.78$, $p < .001$) with a large partial eta squared ($\eta^2 = .273$), suggesting that approximately 27% of the post-test retention variance is attributable to instructional condition after controlling for pre-test ability. Similarly, problem-solving performance yielded a significant adjusted mean difference ($M = 19.56$, $SD = 2.67$; $M = 15.89$, $SD = 3.01$; $F(1,87) = 25.10$, $p < .001$) with $\eta^2 = .224$, indicating that approximately 22% of the variance is explained by the instructional approach. These findings align with the central claim of multimedia learning theory that well-designed multimedia supports produce stronger memory traces and more flexible problem-solving representations than lecture alone (Li et al., 2024; Xie, 2025; Yip et al., 2025;). The pre-test results ($t(88) = 0.52$, $p = .604$) showed no initial differences between groups, supporting the internal validity of the observed post-test advantages as effects of the instructional manipulation rather than baseline disparities in prior knowledge. This pattern of results is consistent with Cognitive Theory of Multimedia Learning (CTML)-based expectations that carefully designed multimedia can add value beyond prior knowledge when working memory and attentional resources are supported by design (Rickley & Kemp, 2021; Li et al., 2024).

The pattern of superior retention and problem-solving performance under multimedia-enhanced instruction is congruent with Mayer's Cognitive Theory of Multimedia Learning (CTML), which posits that integrating verbal and visual channels can enhance learning by facilitating dual coding, reducing extraneous cognitive load, and promoting active processing (selecting, organizing, integrating) that supports meaningful learning and memory consolidation (Li et al., 2024; Rickley & Kemp, 2021). The sizable effect sizes reported ($\eta^2 = .273$ for retention; $\eta^2 = .224$ for problem solving) are within the range documented across CTML-informed interventions, where segmentation, signaling, and embodiment elements have been shown to improve various learning outcomes under appropriate conditions (Klingenberg et al., 2022; Rickley & Kemp, 2021). The integration of interactive simulations, contextual video examples, and multiple entry points for applying concepts aligns with the broader multimedia literature indicating that well-structured multimedia can enhance transfer and problem solving by providing diverse representations and supports for cognitive flexibility. Studies examining

CTML-aligned resources—such as simulations in chemistry, dynamic visuals in mathematics, and CTML-guided video design—show converging evidence that multimedia supports improve conceptual recall and problem-solving performance when cognitive load is managed effectively (Rickley & Kemp, 2021; Yip et al., 2025). The present findings extend this literature to quadratic-equation pedagogy and problem-solving tasks, illustrating that multimedia design principles can yield meaningful performance gains in mathematics education as well as in other domains (Li et al., 2024;; Yu et al., 2015).

While the aggregate results favor multimedia-enhanced instruction, some CTML-informed studies have reported smaller or non-significant effects for certain outcomes or content domains, reflecting the boundary conditions of CTML. For example, some investigations find that when extraneous load is not adequately controlled, or when representations are not well aligned with task demands, anticipated gains may be diminished or absent (Klingenberg et al., 2022; Rickley & Kemp, 2021). In the present study, the significant, large effects suggest that the multimedia resources were designed with CTML principles—including segmentation, signaling, and modality balance—that effectively reduce extraneous load and support constructive processing, mitigating these concerns (Li et al., 2024; Rickley & Kemp, 2021). The role of prior knowledge can moderate multimedia benefits; CTML and related frameworks anticipate larger gains for learners with lower prior knowledge in some contexts because multimedia can scaffold initial schemas more effectively. Some studies have found differential benefits by prior knowledge or learner characteristics, which should be explored in future replication across topics and demographic groups to establish generalizability (Xie, 2025; Yip et al., 2025). While the present findings are encouraging, they are confined to a single topic (quadratic equations) and a short-term post-test. Replicating the design across other areas of mathematics and incorporating delayed retention measures would help determine the durability of the multimedia effect. In sum, the data confirm that integrating multimedia with lecture markedly improves students' retention of mathematical concepts and their ability to solve novel problems, supporting the two central hypotheses of this study.

Conclusion

This study provides robust evidence that integrating multimedia instruction with the traditional lecture method is a more effective pedagogical approach than the lecture-only method for enhancing students' mathematical retention and problem-solving skills in secondary mathematics education. The experimental group, utilizing multimedia alongside lectures, consistently outperformed the control group, demonstrating the potential of technology-enhanced learning to overcome limitations of conventional teaching. These findings underscore the importance of thoughtfully incorporating diverse digital resources into mathematics classrooms to create more engaging, comprehensive, and ultimately more effective learning experiences. By embracing innovative instructional strategies, educators can better equip students with the deep understanding and critical thinking abilities necessary for success in mathematics and beyond.

Recommendations

Based on the findings of this study, the following **Practical Recommendations for Educators** are put forth:

1. **Maintain a hybrid model** that preserves teacher explanatory roles while integrating multimedia resources designed around CTML principles. The current findings indicate that multimedia enhancements can substantially improve both retention of quadratic concepts and problem-solving performance without displacing the instructor's role, consistent with calls for teacher-guided, technology-enhanced learning environments (Rickley & Kemp, 2021; Yip et al., 2025;).
2. **Emphasize design features with robust empirical support** within CTML and related research: segment content into manageable units; provide signaling to highlight key concepts; ensure modality balance to optimize dual-channel processing; and embed authentic problem-solving contexts to promote transfer and flexible application of the quadratic formula (Li et al., 2024; Rickley & Kemp, 2021).
3. **Consider evaluating future iterations** with additional CTML principles, such as embodiment and coherence, and incorporate measurement of affective and cognitive engagement to triangulate learning outcomes with engagement proxies, as suggested by broader CTML-informed work on multimedia learning and learner well-being (Rickley & Kemp, 2021; Yip et al., 2025).

4. **Provide professional development** for educators in evidence-based multimedia design principles, ensuring that technology integration is guided by theoretical frameworks rather than implemented arbitrarily. This includes training in selecting appropriate multimedia resources, aligning them with curriculum objectives, and scaffolding student interaction with multimedia content to maximize learning outcomes.
5. **Monitor individual learner differences** and adjust multimedia support accordingly, recognizing that students with varying levels of prior knowledge may benefit differentially from specific design features. Differentiated implementation of multimedia resources can help address diverse learning needs within the same classroom.

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