RESEARCH ARTICLE

Sustainable and Pedagogical Technologies
Volume 1 Issue 1, 2025, e41090
https://doi.org/10.33902/SPT.202541090

Video-based multimedia instructions and academic performance: An analysis of gender differences in learning linear equations at the basic school

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Submitted: 19 October 2025 Revised: 29 November 2025 Accepted: 2 December 2025

Abstract

This study investigated the effect of a video-based multimedia instructional package on the performance of male and female students in solving linear equations in four basic schools in the Ga West Municipality, Ghana. With 301 form two students, a quasi-experimental pre-test-post-test control group design was used which was guided by the constructivist learning theory. The experiment group received VBMI lessons while the control group was instructed using the conventional methods. Students' performance was evaluated using a test created by the researchers, and data were analysed with descriptive statistics, *t*-tests and ANCOVA at a .05 significant level. Results from the study shows that the experimental group did significantly better than the control group with large effect sizes, indicating an improved understanding of linear equations. Both male and female students benefited equally from the intervention and gender did not significantly moderate outcomes. Findings from the study suggests that VBMI promotes inclusive learning, increase students interests and accessible learning, helping students visualize abstract concepts while supporting constructivist learning. The study recommends providing teachers the needed training to integrate multimedia instructions, fostering gender inclusive and carrying out longitudinal research.

Keywords: Academic performance; Effect size; Gender; Video-based multimedia instruction

1. Introduction

The evolution of learning media has significantly transformed teaching methods; advances in digital technology now provide teachers with a wide range of instructional resources that support engaging, dynamic, and differentiated learning experiences tailored to diverse learner needs (Bond et al., 2021). Globally, the rapid use of technology in teaching and learning has necessitated curriculum adjustments and new pedagogical approaches that are reshaping traditional learning environments (Hodges et al., 2020). Learning environments have changed as a result. Computer-assisted teaching techniques are also incorporated into the learning environment that uses student-centered, active learning approaches (Tamim et al., 2021). One of the innovative techniques in this information era that has the potential to improve teaching and learning is multimedia technology (Nusir et al., 2013).

Multimedia resources that include videos, animation, pictures and interactive simulations are becoming more essential components of classroom instruction (Mayer, 2014, 2021). Video-Based Multimedia Instruction [VBMI], in particular has gained prominence due to its ability to make abstract concepts and facilitate deeper conceptual understanding. In the study of mathematics where majority of students often struggle to visualize and apply basic concepts, such innovations offer a considerable promise in mathematics education. This is particularly very important in the teaching and learning of mathematics as many students find it difficult to apply and visualize basic concepts such as linear equations in one variable.

Despite the growing popularity of video-based multimedia instructional resources, existing empirical evidence indicate an inconsistency regarding its effectiveness across various subject areas. Students who are exposed to multimedia instruction performed better in mathematics according to previous studies by Akinbadewa and Sofowora, (2020) and Alamina and Otuturu (2019) with their studies findings indicating that female students performed better than the male students. On the other hand, other research has documented instances where male students outperform their female counterparts (Egbunu et al., 2017; Safo et al., 2015). These conflicting findings suggest that students benefiting from the use of multimedia instructions may be moderated by gender. However, due to limitations such lack of Information and Communication Technology [ICT] resources, inadequate teacher preparation and over reliance on traditional method of teaching, the use of multimedia instruction in the basic school mathematics classroom in Ghana still remains relatively limited (Kissi et al., 2023). As a result, students may not benefit the transformative potential of multimedia instructional strategies in the classroom.

These challenges are further highlighted by recent studies by Arhin et al. (2024), that mathematics teachers in Ghana have favourable perception of the integration of ICT tools in the teaching and learning of the subject, but in order to incorporate them, they need more training, curriculum alignment and evaluation techniques. Similar findings were made by Susuroka et al. (2023), who indicated that the adoption of digital and audio-visual technology in the teaching and learning of mathematics was influenced by factors such age, gender and school location. Again, as noted by Padmore et al. (2025), meaningful ICT integration is further hindered in basic schools by the inadequate availability of mathematical learning resources. Furthermore, Asiamah and Fletcher (2023) showed how VBMI can improve students' academic performance in solid geometry, showing that the use of VBMI can improve the conceptual understanding and abstract thinking of students.

However, there is still a dearth of studies that explicitly examine how Video-Based Mathematics Instruction influences students' ability to solve linear equations in one variable, particularly within basic-school contexts. Investigating the effects of VBMI on students' learning is crucial given the consistently low performance of learners in algebra, limited access to ICT tools in many school environments, and the mixed empirical evidence regarding the gender-responsive benefits of multimedia instruction (Mayer, 2021). Thus, the purpose of this study, is to look into how male and female students' performance in mathematics is affected by VBMI at some selected basic schools in the Ga West Municipality of the Greater Accra region of Ghana.

1.1. Purpose of the Study

The purpose of this study is to examine the impact of a multimedia instructional package on the academic performance of male and female students in linear equations across four Basic Schools in the Greater Accra Region of Ghana. Specifically, the study seeks 1) to examine the impact of video-based multimedia instruction on the performance of students in solving linear equations in one variable, and 2) to determine how a multimedia teaching package affects male and female students' academic achievement in mathematics when it comes to linear equations in one variable.

1.2. Research Questions

The study seeks to provide answers to the question:

RQ 1) What are the impacts of video-based multimedia instruction on the performance of students in solving linear Equations in one variable?

RQ 2) What are the impacts of multimedia instructional package on the performance of male and female students regarding linear equations in one variable in mathematics, as assessed by their pre-test and post-test mean scores?

1.3. Research Hypotheses

The subsequent null hypotheses were established and evaluated at a significance level of .05:

H1: There is no significant difference in terms of their academic performance between student taught mathematics using video-based multimedia instruction and those taught using the conventional instructional method.

H2: There is no significant disparity in the academic performance of male and female students instructed on the concept of linear equations in one variable in mathematics using a multimedia educational program, as assessed by post-test mean scores.

2. Theoretical Framework

This study is grounded on the Constructivist Learning Theory, which posits that students should be actively be involved in a lesson to enable them construct their own knowledge by integrating new information with prior experiences (Schunk, 2020). This theory emphasizes meaningful learning through interaction, active engagement and provide opportunities for learners to revise, test and refine their understanding in the classroom (Eggen & Kauchak, 2003). Andam et al. (2015) also believe that students build conceptual understanding in the classroom through active participation, reflection and problem solving. In mathematics education, the constructivist theory transforms the conventional instruction which is dominated by abstract instruction into more encouraging, creativity and application of real-life mathematics ideas (Vintere, 2018). Within this theoretical framework, the use of video-based multimedia instruction operationalizes the core principles of constructivist. That is, first this method of instruction promotes active engagement by presenting problems, demonstrations and real-life situations that require students to work through step by step. Again, it also provides multimodal representations, that is made up of text, narration, animation, illustration and problem solving which in turn support deeper conceptual understanding (Mayer, 2021).

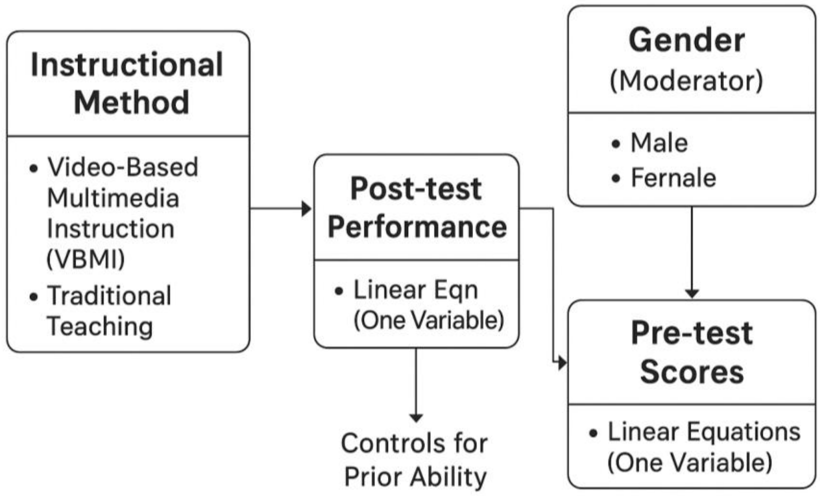
Lastly, the use of VBMI offers an implicit scaffolding, that is guiding students from easy task to complex tasks through a structured explanations and visual sequencing of learning materials that help students in integrating new concepts into an existing cognitive framework. These features in video-based multimedia makes the learning of mathematics more concrete and accessible which aligns with the constructivist theory. The constructivist theory also acknowledges that learners background and characteristics that includes gender also shape how students engage with and also benefits from the learning environments (Jonassen & Land, 2012). Prior studies shows that male and female students differ in motivational drivers, technology usage and cognitive preferences in the learning of mathematics (Poondej & Lerdpornkulrat, 2016). Guided by this theoretical framework, the current study examines whether the use of video-based multimedia instruction enhances students' performance in linear equation and if so can these improvements differ by gender. Thus, the constructivism provides a rational for anticipating the use of VBMI to assist students in actively creating mathematical knowledge while also recognizing the possible impact of gender on the use of multimedia learning experiences.

3. Conceptual Framework

This study posits that the methods of teaching (video-based multimedia versus traditional) influences students' academic performance in Mathematics. It is believed that students gender moderates this relationship by potentially affecting how students engage with and benefit from the teaching and learning of mathematics using any of the two methods of teaching approach. Additionally, student's pre-test scores account for early variations in students' proficiency and thereby guaranteeing that any differences in students' performance can be attributed to the teaching strategy used rather than to past knowledge or experiences.

The present study is structured around several key variables, summarized in Figure 1, that guide its analysis and interpretation. The independent variable is the instructional method, which comprises two distinct approaches: Video-Based Multimedia Instruction and Traditional Instruction. These methods represent the alternative pedagogical strategies whose effects on student learning are being compared. The dependent variable is the students' post-test performance in Linear Equations in One Variable, which serves as the primary measure of learning outcomes following the instructional intervention. In addition, the study includes a covariate, specifically the students' pre-test scores on Linear Equations in One Variable. This variable is used to control for initial differences in students' prior knowledge, ensuring a more accurate assessment of the instructional methods' impact. Finally, gender functions as the moderating variable, with male and female categories considered to determine whether gender influences or interacts with the effectiveness of the instructional approaches. Together, these variables form the analytical foundation for examining the relationships and effects central to the study.

Figure 1
Framework of the current study



3.1. Multimedia Instructions and Students' Performance in Mathematics by Gender

According to Akinbadewa and Sofowora, (2020), multimedia instructional packages are superior to traditional teaching approaches when it comes to improving student performance in biology classes in secondary schools. According to the authors, there was no discernible difference in the academic achievement of male and female biology students who received multimedia training. Alamina and Otuturu (2019) found that female students outperformed their male counterparts following the application of multimedia instructional package with female students showing a high level of achievement in Biology. Nevertheless, the study indicated that multimedia instruction did not produce any significance difference in the performance of male and female students. In their study Safo et al. (2015) examined how the use of computer-assisted instructional package influenced gender difference in their performance and retention in the concept Geometry. The study made use of test as the main instrument and pre-test-post-test quasi experimental design was adopted. The reliability coefficient was .78 using Pearson Product Moment Correlation and the data was subjected to a t-test analysis. The study's findings indicated that male students utilizing computer-assisted instruction surpassed their female peers in academic performance. These findings are in agreement with the current study as it facilitate a comparison between the use of technology integration in teaching and learning which is well established and a country in Ghana which is being faced with the challenge of adopting technology in schools. Similar research was done by Egbunu et al. (2017), who looked at how computer-aided education affected students' memory of mathematical concepts. A quasi-experimental methodology was used in the study, and achievement assessments were used to gather data. analysing the gathered data using the t-test, mean, and standard deviation. The study's conclusions show that male pupils who received computer-assisted arithmetic instruction retained the information better than their female peers. Although numerous studies have looked that effect of multimedia instruction in improving students' academic performance, most notable gaps in knowledge still remains. A key inconsistency has to do with gender differences in learning outcomes.

3.2. Importance of Video-Based Multimedia Instruction

According to research, VBM creates and fosters a learning environment where students take ownership of their education through problem-solving, peer instruction, and group discussions regarding the current task or concepts (Castro-Alonso et al., 2021). Additionally, VBM improves professional and technology abilities that are essential for a successful job in today's global setting, as well as proficiency in using Bloom's taxonomy levels (Akinoso, 2018). Video-based learning allows students to engage actively with content, often promoting interaction, motivation, and deeper engagement with learning materials, while teachers guide and facilitate rather than merely transmit information (Galatsopoulou et al., 2022). Accordingly, constructivism is the foundation of VBM (Tani et al., 2022). Similar to textbooks, educational multimedia promotes instructional practices in which the teacher's responsibility is to guide, support, and facilitate students in addition to providing information (Dipon & Dio, 2024).

Multimedia provides a range of media that are typically meaningfully mixed. This makes it possible to present concepts using the computer in a variety of ways, such as: (1) Images, such as scanned photos, drawings, maps, and slides; (2) Sounds, such as voice, noise, and music recordings; (3) Video, including intricate processes and "talking heads"; (4) Animation and simulations; and (5) Discussions among students (social networks, online discussions, and blogs). Adu et al. (2015) demonstrated that multimedia courseware plays a significant role in improving students' proficiency in solving linear equation word problems. Their findings showed that students taught with multimedia integrated into cooperative learning outperformed those who received cooperative learning alone or traditional instruction. The use of multimedia provided visual and animated representations of real-life algebraic situations, helping students better understand abstract concepts. It also heightened students' engagement, resulting in more active participation during lessons. Additionally, the multimedia-supported environment enhanced cooperative learning by promoting effective peer interaction and group problem-solving. Students further expressed positive perceptions of the technology-based approach, indicating that multimedia not only strengthens conceptual understanding but also improves motivation and attitudes toward learning mathematics.

3.3. Research Gaps

According to prior studies, multimedia instructional methods of teaching often improve the academic performance of students in a variety of areas. Several studies reports that multimedia instruction enhances the learning outcome of students, however the results regarding gender differences are still in a mixed. For example, after receiving instructions through the use of video-based multimedia in biology, Akinbadewa and Sofowora (2020) found no discernible differences between the male and female students' performance in the subject whereas a study by Alamina and Otuturu (2019) found that female students performed better than the male students. On the other hand, Egbunu et al. (2017) and Safo et al. (2015) in their studies reported that male students exposed to computer assisted instruction had better performance or retention as compared to female students. These conflicting reports demonstrate a lack of consensus on whether the use of video-based multimedia instruction do favour male or female students.

Furthermore, most of the existing empirical studies originated from Nigeria and other places where the use of technology in education is much more developed. The study by Adu et al. (2015) contributes valuable insights by demonstrating the effectiveness of multimedia courseware combined with cooperative learning. However, it did not isolate the impact of multimedia alone, nor did it investigate gender-based performance differences. Thus, it remains unclear whether multimedia independently enhances students' performance when teaching linear equations and whether its effects vary across gender. Additionally, although prior studies have explored multimedia in mathematics generally, there is insufficient focus on Linear Equations in One Variable, a foundational algebraic concept. The specific value of video-based multimedia instruction for this topic remains underexplored. Taken together, these gaps identified shows how empirical evidence is needed to: assess whether teaching and learning of linear equations through the use of video-based multimedia instruction results in a significantly different academic performance than the use of traditional method of teaching, and ascertain whether gender differences exist in students' performance in video-based multimedia instruction in the contexts of Ghana.

4. Methodology

4.1. Research Design

The study made use of quasi-experimental design, specifically the pre-test-post-test control group design. The choice of this design was due to its ability to determine cause-and-effect relationship in the educational settings where random assignment of participant is not always possible. In this study, four intact classes from Basic Schools in the GA West Municipality were assigned to an experimental group receiving video-based multimedia instruction on linear equations, or a control group taught using traditional methods. Pre-tests and post-tests measured baseline knowledge and learning outcomes, allowing comparisons between groups and gender subgroups. While the design supports evaluation of instructional effectiveness, teacher effects and class-based assignment pose risks to internal validity, as differences in teaching style or pre-existing class characteristics may influence results. Future studies should consider controlling teacher effects, randomizing participants when feasible, and using statistical controls to enhance validity.

4.2. Participants

The study's target demographic comprises all second-year students in Junior High Schools located in the Ga West Municipality of the Greater Accra Region of Ghana. The Accessible population included form two students from schools in one selected circuit within the municipality that met specific inclusion criteria. The accessible population has a total population of 1178. The study sampled 301 second-year students (147 males, 154 females) from four institutions. A multi-stage sampling procedure was used. First, simple random sampling selected one circuit from the eight in the municipality using a lottery method. Purposive sampling then identified four eligible schools within the chosen circuit based on three criteria: having at least one graduate Mathematics teacher, access to computers, and computer literacy among teachers and students. Only four schools met these requirements, so all were included. Form Two classes were deliberately selected because they had stable academic performance and no final examination pressures. Two schools were assigned to experimental group and the other two to a control group. The experimental group received multimedia-based instruction, while the control group used traditional teaching methods. To avoid disrupting normal school routines, intact classes were used. Opah M/A Basic School 1 and Sapeiman M/A Basic School 1 formed the Experimental Group, while Kuntuse M/A Basic School 1 and Anglican Basic School served as the Control Group. The experimental group consisted of 74 boys and 76 girls; the control group consisted of 73 boys and 78 girls. Table 1 shows the distribution of the sampled schools.

Table 1
Sample Students

Name of School	*Boys*	*Girls*	*Total*
Opah M/A Basic School 1	38	40	78
Kuntunse M/A Basic School 2	40	40	80
Anglican Basic School	33	38	71
Sapeiman M/A Basic School 1	36	36	72
Total	147	154	301

4.3. Data Collection Instrument

This study employed two tools: a STEM-produced educational video on linear equations and Students' Performance Test on Linear Equations [SPTLE] is a performance test created by the researcher that includes one variable. Ten (10) essay questions about the study's subject are included in the SPTLE. The ten questions were given to students to respond to. Students' performance on the pretest and posttest was evaluated using the linear equations performance test. Both content and face validation were applied to the two instruments. The test questions were thoughtfully crafted to make sure they aligned with the particular field chosen for the study as well as the Basic 8 mathematics curriculum. Experts in educational technology and mathematics education were asked to critique the questions and instructional video package, and their comments led to some changes being made to the tools. The instrument underwent a reliability test in a basic school not included in the study sample, yet possessing a comparable educational background. A Cronbach alpha reliability test yielded a result of 0.78 which falls within the commonly accepted threshold for educational research ($\alpha \geq 0.70$) indicating acceptable internal consistency and reliability of the instrument. Ethical considerations were strictly observed in the administration of the instruments that is permissions were obtained from the schools involved in the study and an informed consent was secured from parents of students who took part in the study. The researchers ensured that student's participation in the study was voluntary and anonymity was also ensured by assigning codes to students instead of using their names on the test scripts.

4.4. Intervention

The researcher designed an intervention in the form of lesson delivery and class discussion in the classroom. One of the classrooms was used as the ICT laboratory where the experimental group was taught linear equation by the use of computers and projector with the mathematics teacher of the school being the facilitator. The content of the lesson was delivered in a sequence manner:

- Introduction (10 min): Review of prior knowledge and objectives for the lesson
- Video Presentation (30 min): Step-by-step explanation of linear equations in one variable using animations, worked examples, and interactive prompts.
- Class Discussion and Practice (30 min): Students solved practice questions individually and collaboratively while the teacher provided feedback.
- Summary and Reflection (10 min): Recap of key concepts, clarification of misconceptions, and assignment of additional practice exercises.

The control group was also taught linear equation traditionally by another mathematics teacher. Time used was one hour and twenty minutes each day. The lesson was taught for two weeks. Both groups received instruction for 80 minutes per day over two weeks. The two-week duration was justified as sufficient to cover the selected topic comprehensively while remaining feasible within the school timetable and minimizing disruption to other lessons. Randomization was conducted at the class-level within the selected schools, ensuring that each school had one experimental and one control class. This design minimized contamination between groups while maintaining comparability in school environment and student demographics.

4.5. Data Analysis

Data collected from the study were analysed using both descriptive and inferential statistics. The descriptive statistics includes mean, range and standard deviation which were employed to summarize students' performance in the pre-test and the post-test. The inferential statistics was used to test the research hypotheses. That is, the t-test was used for initial comparisons between the control group and the experimental group while Analysis of Covariance [ANCOVA] was employed to determine the effects of the multimedia instructional package on students' performance from the experimental group as compared to those from the control group. Before the intervention, a pre-test was administered to the two group to establish baseline performance. After the two weeks intervention, a post-test was conducted using the same instrument that was developed in an alternate but similar format to the pre-test. All hypotheses were tested at the 0.05 level of significance. The decision rule was based on the comparison of the calculated p-value with the significance threshold: if $p < .05$, the null hypothesis was rejected; if $p > .05$, the null hypothesis was retained.

5. Results

The study formulated two research questions and established two null hypotheses, which were then analysed to answer the enquiries. The examination of pre-test and post-test data, collected using traditional demonstration methods and technology-enhanced video instruction, was utilised to answer the research questions, informed by the two hypotheses. The pre-test and post-test data were analysed using mean, range, standard deviation, independent *t*-test, and ANCOVA.

5.1. Research Question One: What are the effects of video-based multimedia instruction on the academic performance of students on the topic linear Equations in one variable?

The purpose of the first research question is to determine whether students who get instruction utilising video-based multimedia perform differently from those who did not, and to answer this research question Descriptive and inferential statistics were used to compare the scores of students in the experimental group, which received multimedia instruction based on videos, with the control group, which was taught using a conventional method. To ascertain the extent of the observed differences, the results also contain effect size. To determine the baseline comprehension of the control group in comparison to the experimental group, the two groups were pre-tested before to the intervention. Table 2 demonstrates that the experimental group's mean score was 3.05 with a standard deviation of 2.04, which was almost the same as the control group's mean score of 3.03 with a standard deviation of 1.94.

Table 2
Descriptive Statistics for Pre-Test Scores by Group

Group	*N*	*Mean*	*SD*	*SE*
Control	151	3.03	1.94	0.16
Experimental	150	3.05	2.04	0.17

The pre-test mean scores for the control group was (M = 3.03, SD = 1.94) whiles that on the experimental group had a mean rate of (M = 3.05, SD = 2.04) and these mean rate ware nearly identical. The descriptive statistics of the pre-test for the experimental and control groups show that, before the intervention, the two groups were almost identical, suggesting that both the experimental and control group had a balanced starting position meaning the two groups were homogenous.

An independent sample *t*-test was used to ascertain whether the difference between the two groups in the pre-test was statistically significant. The independent sample t-test confirmed that there was no statistically significant difference between the two groups ($t(299) = -0.09$, $p = .93$), indicating that there is no statistically significant difference between the pre-test scores of the control group and the experimental group. This confirms that both groups were equivalent in their knowledge before the intervention. To assess the magnitude of the difference, effect size measures were calculated and the result is displayed in Table 3.

Table 3
Effect Size of the Pre-Test

Effect Size Type	*Value*	*95% CI Lower*	*95% CI Upper*
Cohen's *d*	−0.01	−0.24	0.22
Hedges' *g*	−0.01	−0.23	0.21
Glass's delta	−0.01	0.24	0.22

The effect size measures (Cohen's d = −0.01, Hedges' g = −0.01, Glass's Δ = −0.01) showing that all of the effect sizes are close to zero, and their confidence intervals encompass zero. This means that there was almost no difference in how well the two groups did on the pre-test. After the intervention, a post-test was given to see how well the students did. Table 4 shows the descriptive statistics for the scores on the post-test.

The experimental group, which received instruction through video-based multimedia, had a significant mean score of 8.65 with a standard deviation of 1.32, while the control group, which did not receive the multimedia intervention, had 151 students and a mean score of 5.90 (SD=1.78), according to the Table 4 that shows the descriptive statistics of the post-test for both the experimental and control groups. These findings point to a discernible performance gap between the two groups. With a mean score difference of 2.75, the experimental group outperformed the control group in terms of mean gain.

Table 4
Descriptive Statistics of the Post-Test

Group	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Control	151	5.90	1.78	0.15
Experimental	150	8.65	1.32	0.11

In order to further address research question one, a hypothesis of First Hypothesis: Students who are taught mathematics utilising video-based multimedia instruction and those who are taught using the traditional instructional approach do not significantly differ in their academic performance. The difference in post-test means was then examined using an independent *t*-test to see if it was statistically significant, as shown in Table 5.

Table 5
Independent t-test in the Post-Test

Assumption	*t*	*df*	*p (2-tailed*	*Mean difference*	*Std. Error diff.*	*95% CI Lower*	*95% CI Upper*
Equal variance assumed	−15.25	299	< .001	−2.75	0.18	−3.11	−2.39
Equal variance not assumed	−15.26	276.23	< .001	−2.75	0.18	−3.11	−2.39

With a mean difference of −2.75, statistically significant mean difference shown in Table 5 ($t(299) = -15.25$, $p < .001$) indicates that the experimental group did much better than the control group. This shows that the results were statistically significantly different, which contradicts the null hypothesis that students taught mathematics using video-based multimedia instruction and those taught using the traditional instructional method did not significantly differ in their academic performance. According to this high degree of statistical significance, VBMI considerably raised students' post-test maths performance. Additionally, as indicated in Table 6, effect sizes were calculated to evaluate the difference's practical relevance.

Table 6
Effects Size of the Post-Test

Effect Size Type	*Value*	*95% CI Lower*	*95% CI Upper*
Cohen's *d*	1.56	−2.02	−1.49
Hedges' *g*	1.57	−2.01	−1.48
Glass's delta	1.32	−2.42	−1.76

Table 6 shows that (Cohen's $d = 1.56$, Hedges' $g = 1.57$, Glass's $\Delta = 1.32$). An impact size greater than 0.8 is considered large, according to Cohen's (1988) recommendations. The study's conclusions show that multimedia training affects students' academic performance in a way that is both statistically significant and educationally useful. Additionally, the effect size estimates demonstrate that students in the experimental group benefited more from the multimedia education than those in the control group, who received instruction using the traditional teaching methodology.

This demonstrates how well multimedia integration can improve pupils' mathematical ability. Once more, the observed difference between the two groups highlights the practical usefulness of video-based multimedia technology as a tool for enhancing learning outcomes in educational settings, in addition to its statistical significance in terms of their performance. In contexts, the large effect size shows that the intervention did not only produce a statistically significant differences but also let to a substantial improvement of students understanding of linear equation in one variable. The intervention therefore helped students to visualize abstract concepts of algebra and their conceptual understanding. This shows that multimedia instruction does enhance the performance of students in mathematics.

5.2. Research Question Two: What are the impacts of multimedia instructional package on the academic performance of male and female students regarding Linear Equations in One Variable in Mathematics, as assessed by their pre-test and post-test mean scores?

Before conducting the two-way mixed ANCOVA to evaluate the effect of the multimedia instruction package on the male and female students' performance in solving linear equation in one variable, it was essential to examine whether the data satisfied the statistical assumptions required for ANCOVA. Two major assumptions were assessed that is normality and homogeneity of regression slopes. Ensuring these two assumptions has to be met to provide confidence that the ANCOVA results would be valid and interpretable.

To begin, the assumption of normality was evaluated using the Shapiro–Wilk test applied to the standardized residuals of the adjusted post-test scores. The results showed no significant deviations from normality for either male students (W = 0.97, p = 0.12) or female students (W = 0.98, p = 0.19). In addition, visual checks using Q–Q plots and histograms indicated that the residuals closely approximated a normal distribution. These findings collectively confirm that the normality assumption was satisfied. The homogeneity of regression slopes assumption was assessed by examining the interaction between the covariate (pre-test scores) and gender. The interaction effect was nonsignificant, $F(1,146) = 0.89$, $p = 0.35$, demonstrating that the relationship between the covariate and the dependent variable remained consistent across male and female groups. This confirms that the assumption of homogeneity of regression slopes was met (see Table 7).

Table 7

Summary of ANCOVA Assumption Tests

Assumption	*Test*	*Statistic*	*Result / Conclusion*
Normality	Shapiro–Wilk test	Males: W = 0.97, p = 0.12 Females: W = 0.98, p = .19	Residuals approximately normal; assumption met
Homogeneity of regression slopes	Interaction of Pre-test × Gender	$F(1,146) = 0.89$, p = .35	Slopes consistent across groups; assumption met

As shown in Table 7, the two assumptions necessary for conducting a valid ANCOVA normality, and homogeneity of regression slopes were met. This confirms that the subsequent ANCOVA results can be interpreted with confidence, ensuring the robustness and credibility of the analysis. To provide answers to the study question two, a descriptive and a two-way mixed ANCOVA was conducted. The experimental group's male and female students' pre-test and post-test descriptive statistics are shown in Table 8. Males had a higher mean pre-test score (M = 4.03, SD = 1.92) than females (M = 2.07, SD = 1.31). Male students outscored female students (M = 8.81, SD = 1.28) by a small margin in the post-test (M = 8.66, SD = 1.32).

Table 8

Pre-test and Post-test Descriptive Statistics

Gender	*Pre-Test Mean*	*SD*	*Post-Test Mean*	*SD*	*N*
Male	4.03	1.92	8.82	1.24	76
Female	2.07	1.31	8.49	1.38	74

Prior to the intervention, there was a noticeable difference in the baseline in terms of performance of male and female students. From the pre-test the male students recorded a higher mean score of 4.03 with an SD of 1.92 as compared to the female students who recorded a mean score of 2.07 and an SD of 1.31. This finding shows that male students demonstrated relatively stronger initial understanding of linear equations than their female counterparts before the initial introduction of the video-based multimedia instructional package. The high score of standard deviation for the male students suggests a greater variability in their pre-test scores, whiles the female students showed a more clustered performance pattern around the mean score. After the two-week intervention, both the male and female students showed a substantial improvement in their performance.

From Table 8, the male students recorded a post-test mean score of 8.82 (SD = 1.24), while the female students had a mean score of 8.49 (SD = 1.38). even though the male students still had a slightly higher mean score with a relatively small mean difference. The increase is the scores for the two groups shows the positive effects of the video-based instructional package on students conceptual understanding in linear equations. Across the two genders, there was improvement from the pre-test scores to the post-test scores is evident, showing that the intervention was effective irrespective of students' gender. The difference in the mean scores of the pre-test (1.96) which was reduced significantly in the post-test scores (0.33), suggesting that the video-based multimedia instructional package may have helped bridge the initial performance disparities between the male and female students.

The impact of gender (male vs. female) and time (pre-test vs. post-test) on mathematical achievement in the experimental group was evaluated using a two-way mixed-design ANOVA. Table 9 shows the multivariate tests (within subjects).

Table 9
Multivariate Tests

Effect	*Test Stats*	*F*	*df (Error)*	*Sig.*	*Partial Eta Squared*
Time (Factor 1)	Wilks Lambda	813.78	148	<0.001	0.856
Time * Gender	Wilks Lambda	0.89	148	0.35	0.006

The AVOVA results summarized in Table 9 shows a highly significant main effect of Time (F = 813.78, p < .001, η^2 = 0.856), indicating that student's performance significantly improved from the pre-test to post-test. This finding shows that the instructional intervention, that is the video-based multimedia instruction, had a big and good effect on learning outcomes for everyone in the sample. The Time × Gender interaction was not statistically significant $F(1,148) = 0.89$, $p = 0.35$, $\eta^2 = 0.006$, which means that the intervention had the same effect on both male and female students. In other words, even though all of the students made significant academic progress after the intervention, the amount of progress was about the same for both male and female. This means that the way the lesson was taught worked just as well for boys and girls, which is good for all students. The fact that there was no significant interaction supports the idea that the gain in performance was due to the way the lessons were taught and not because of variations in how male and female students learn.

Gender was the between-subjects factor, and time was the within-subjects' component. Students showed considerable improvement from the pre-test to the post-test after the multimedia intervention, as evidenced by the significant main impact of time ($F(1, 148) = 813.77$, p <.001, $\eta^2 = 0.85$). Time and gender also had a statistically significant interaction impact ($F(1, 148) = 2.57$, $p = 0.347$, $\eta^2 = 0.006$). This implies that male and female students' scores improved in slightly different ways (see Table 10).

Table 10
Tests of Within Subjects Effects

Source	*SS*	*df*	*MS*	*F*	*p*	*Partial η^2*
Time	2355.11	1	2355.11	813.77	< 0.001	0.85
Time × Gender	2.57	1	2.57	0.89	0.347	0.006
Error (Time)	428.32	148	2.89			

The results reveal a clear increase in mean scores from the pre-test to the post-test. This suggests that the educational method used, which was video-based multimedia instruction, helped students understand the material better. Also, the interaction effect between Time and Gender is still not significant, which supports the idea that both male and female students benefited equally from the intervention. The fact that this is true across all tables makes the conclusion that gender did not change the effect of the teaching method more likely to be true. In real life, this means that the teaching method works for both boys and girls and may be used in coed situations without needing to make any changes for boys or girls.

The large partial eta-squared value ($\eta^2 = 0.85$) reflects a very strong practical effect of the intervention on students' academic performance. In other words, the improvement was not only statistically meaningful but also educationally significant. The lack of a significant interaction indicates that gender did not moderate the effect of the video-based multimedia instruction, making it equally effective for both boys and girls. This supports the potential of video-based multimedia instruction as an inclusive instructional strategy in co-educational settings. Practically, this shows that the intervention can be applied in mixed-gender classrooms without much modification.

6. Discussion

The findings provide a meaningful insight into how technology use, specifically Video-Base Multimedia Instruction in the classroom can shape students learning outcomes in mathematics. This finding is consistent with the constructivist learning theory, which emphasizes the active construction of knowledge by students through interaction with learning materials (Piaget, 1970; Vygotsky, 1978). The results from the study shows that students who received video-based multimedia instruction significantly outperformed those taught through the conventional methods. Analysis of the pre-test scores indicate that the control group and the experimental group possessed almost the same level of prior knowledge. An indication that the improvement recorded in the post-test can be confidently linked to the intervention that is the video-based multimedia and not to any pre-existing differences. This outcome aligns with Mayer's (2021) Cognitive Theory of Multimedia Learning, which posits that learning is enhanced when the information is presented through many channels that include visual and auditory facilitation cognitive processing and retention. By combining visuals, audio and interactive components, VBMI allows learners to construct meaningful connections between abstract concepts in mathematics and concrete representations. The intervention promotion of active participation reflects

These results highlight the potential benefits of multimedia instruction in the teaching and learning of mathematics which are consistent with similar studies (Asiamah & Fletcher, 2023; Dipon & Dio, 2024) who reported that the use of video-based multimedia instruction strategies help to improve the conceptual understanding and retention in mathematics and other STEM subjects. However, these results are in contrast with earlier finding where the effectiveness of video-based multimedia instruction was limited. Ferman and Milagros (2017) and Gambari et al. (2016) reported a minimal improvement in mathematics achievement following the use of video-based multimedia instructions. The discrepancies may be attributed to contextual and implementation differences that includes curriculum alignment, level of teacher facilitation and availability of technological resources. From those studies the use of multimedia instruction was used passively without structured guidance from the facilitators, which may reduce its effectiveness in the classroom. Whereas, the current study employed an intervention that combines a well-designed multimedia content with active facilitation and opportunities for students' engagement which reflect the constructivist and multimedia learning strategies (Mayer, 2021). According to these comparisons, video-based multimedia instruction can be highly effective, even though its effects is context-dependent. In addition to having access to high-quality digital content, successful implementation needs curricular integration, teacher facilitation and opportunities for students to engage with and reflect on the content. The preset study reinforces that, VBMI can meaningfully improve learning outcomes when used appropriately, even in contexts where conventional method of teaching has struggled to foster conceptual understanding.

The study again investigated how gender as a moderating factor affects the learning outcome of male and female students, the study revealed no statistically significant difference in learning outcomes between the two genders. From the findings of the study both genders showed a significant improvement after the intervention, even though the male students initially did better on the pre-tests. These findings contrast studies that showed continuing gender differences in mathematics achievement (Safo et al., 2015) but support previous studies by Adeoye and

Abimbola (2016) who reported equitable benefits of technology-mediated learning. According to this study, VBMI can ensure that both male and female students gain equal understanding of the concepts which offers inclusive and accessible learning opportunities. Practically the findings underscore how VBMI can be used to establish a fair learning environments in mathematics classes. Students with a variety of learning styles and skill levels can interact effectively with concepts that are abstract through the integration of audio, visual and interactive modalities. While the position of teachers as facilitators supports scaffolding and problem solving which is a key component of constructivist pedagogy. The self-paced and revisit able nature of video contents enables students to solidify their understanding. This result is in keeping with that of Akinoso (2018) which found that, there was no significant difference on mathematics proficiency using gender-based multimedia resources. Additionally, the research conducted by Anyamene et al. (2012) on how CAI packages affect the senior secondary students' performance in physics, history, and mathematics, respectively showed that there was no discernible difference between male and female test performance scores

In a Ghanaian basic school classroom, where the conventional methods of teaching often limit students' engagement and conceptual understanding, VBMI provides a scalable way to improve learning results and lessen gender gaps and encourage active involvement. The findings are in contrast with previous studies that suggest that video-based instruction produced a minimal academic enhancement (Gambari et al., 2016; Ferman & Milagros, 2017), yet it agrees with other studies that highlighted the benefits of multimedia instruction on the performance of genders (Asiamah & Fletcher, 2023; Egbunu et al., 2017). These differences could be attributed to differences in the subject areas, the curriculum alignment, the implementation of the instructional video and the availability of ICT tools. The current study reveals that it is possible to decrease initial gender differences and considerably increase students' understanding of linear equations when conditions are controlled and the right teacher is present and students have access to multimedia materials. The study concludes by showing that multimedia instruction based on videos is an effective teaching method for teaching mathematics. In addition to improving students' academic performance and conceptual understanding, it also promotes gender-neutral learning outcomes. The results highlight how multimedia-based instructions may help basic school students gain essential STEM competencies by converting conventional classrooms into welcoming, dynamic, and stimulating learning spaces.

7. Conclusion

This study examines the effects of Video-Based Multimedia Instruction on students understanding of linear equation in the basic school of the Ga West Municipality, Ghana. The findings shows that VBMI significantly enhanced students' academic performance in mathematics. Most importantly the intervention was equally effective for both male and female students who were involved in the study. This intervention demonstrates inclusivity and potential to provide equitable learning opportunities for students. Through the use of interactive, visual and auditory modalities, VBMI helps students to overcome the abstract nature of mathematics, making learning more interesting or engaging, accessible and meaningful. The study therefore concludes by emphasizing how important it is to use video-based multimedia instruction as a viable alternative or a complement to conventional teaching methods in mathematics education.

8. Recommendations

Based on the findings of this study, several recommendations were made. Educational stakeholders and school administrators should integrate video-based multimedia instructional tools into the teaching and learning of mathematics to enhance student engagement and overall performance. Mathematics teachers should also be provided with professional development opportunities to design and effectively implement multimedia tools that align with best pedagogical practices. Since VBMI was found to be equally effective for both male and female students, teachers are encouraged to adopt multimedia instruction as a strategy to promote inclusive and equitable learning environments. Finally, the study recommends conducting further research to investigate the long-term impact of multimedia instruction on various mathematical concepts and to examine its effectiveness across different demographic groups, particularly in rural and urban educational settings.

Author Contributions: Every author contributed to the article's conception, design, data gathering, interpretation, writing, and critical revision. The article's final draft has been approved by all writers.

Data availability: Upon reasonable request, the corresponding author will provide the datasets created and/or analysed during the current work.

Declaration of Conflicts of Interest: Regarding the authoring of this study and the publication of this paper, the authors affirm that they have no potential conflicts of interest.

Ethics statement: This study was approved for publication by the ethics committee since it was overseen by faculty supervisors. The names of the participants were not stated. Every participant in the study gave their informed consent. The goal, methods, and freedom to discontinue participation at any moment without consequence were explained to the participants. The subjects' anonymity and confidentiality were maintained for the entire study.

Funding: The research and/or writing of this article were not supported financially by the authors.

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