Pedagogical Research
2024, 9(3), em0213
e-ISSN: 2468-4929
https://www.pedagogicalresearch.com

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Research Article **OPEN ACCESS**

Performance of mathematics students using video learning in flipped and flipped collaborative learning settings

Ibrahim Abba Mohammed [1]*, Ahmed Bello [1]

[1] Department of Science Education, Federal University of Kashere, Kashere, Gombe State, NIGERIA
***Corresponding Author:** muhammadia@fukashere.edu.ng**

Citation: Mohammed, I. A., & Bello, A. (2024). Performance of mathematics students using video learning in flipped and flipped collaborative learning settings. *Pedagogical Research, 9*(3), em0213. https://doi.org/10.29333/pr/14699

ARTICLE INFO

Received: 14 Nov. 2023

Accepted: 24 May 2024

ABSTRACT

Due to rapid technological advancement that continues to permeate almost all facets of the education sector, video learning has been explored to enhance performance, but most researchers do not incorporate flipped classroom in mathematical videos, which affects the teaching and learning of the subject in Nigeria. This study checked the effectiveness of video learning in flipped and flipped collaborative classroom on mathematics students' achievement and retention. Using a randomized controlled trial with repeated measures approach, 70 senior secondary school students were purposively sampled from two private secondary schools in Gombe State, Nigeria, out of which they were randomly assigned into two experimental groups: video learning flipped classroom and video learning flipped collaborative classroom (VLFCC). Data was obtained using a 30-item mathematics achievement test, which was validated and pilot-tested (r=0.93). Results were computed using descriptive statistics and two-way mixed design repeated measures analysis of variance. Findings revealed that while the students' within subject performance improved tremendously in the post-test after the four-week treatment, the students in VLFCC performed better in both achievement ($F_{[1, 69]}$=1,576.362, p=0.000, effect size of (η_p^2) of 0.954) and retention ($F_{[1, 69]}$=114. 119, p=0.000, with an effect size (η_p^2) of 0.785. The finding has some implications for it exposes mathematics teachers, researchers, and policy makers to the credence of deploying video learning in flipped collaborative classroom to improve students' performance by engaging students in collaborative learning in addition to watching pre-class videos, where students discuss in small groups in order to learn through observation, imitation, repetition and behavior modeling, thus making them to learn at their pace in order to construct their own knowledge.

Keywords: achievement, retention, collaborative learning, flipped classroom, video learning, mathematics, technology

INTRODUCTION

Mathematics is a compulsory discipline taught from elementary up to secondary schools. At the tertiary levels in Nigeria, it is offered as a course of study due to its importance in the field of science and technology, which is driving home unprecedented development in various facets. Mathematical knowledge helps to inculcate in students the abilities of problem-solving and critical thinking in order to perfect the cognitive capabilities of students to think rationally. In the areas of science, technology and industrial development, mathematics is seen as a vital tool (Ogbu et al., 2023). For any nation to achieve a great height in the prism of social, economic and technological development, such nation must prioritize and expend resources that are capable of improving the quality of teaching and learning of mathematics (Dauda & Umar, 2014). Due to the importance of mathematics to every nation's drive towards technological advancement given that it has a strong correlation with other fields of science and technology (Suleiman & Hammed, 2019), it becomes necessary to incorporate modern day technological advancement in order to improve students' performance in the subject.

The education ecosystem has continuously been impacted by advancement in technology almost in all facets. Due to technological advancement in teaching and learning, innovative strategies that are learner-centered have continued to evolve. In view of this development, therefore, it is absolutely important for educators to carefully select the right technological tools and plan learner-centered classroom environment to improve learning. The pervasive growth and integration of learning technologies brings the need to recognize their added value for quality instruction, thus educators are required to expand their digital competencies and strategies to accommodate these peculiarities (Blau et al., 2020; Mohammed et al., 2023, 2024b). Advancement in technology has made it possible to eliminate the constraints of space and location by making teaching and learning more flexible instead of restricting it to the classroom alone (Falode & Mohammed, 2023a; Ibragimov et al., 2023). One area currently being explored is the video learning strategy due to its ability to appeal to many senses.

Video learning is a kind of multimedia that conveys verbal and non-verbal information incorporated with audio and visual materials. It develops the smooth continuity of thought and offers an actual experience that arouses serious interest on the part of the students. Video provides interactional features designed to facilitate learning that can be delivered through various forms of both auditory and visual media (Lange & Costley, 2020). Video serves as an audiovisual learning medium that offers real world examples with rich contextual detail (Khoo et al., 2020). Using video as an educational tool is a productive way of engaging students in collaborative learning. It also has the prospects to nurture a way of thinking about the world through numerous discussions carried out (Higgins et al., 2018). Many studies have shown the usefulness of video based learning in education. For example, the study of Ghahfarokhi et al. (2022) and Tani et al. (2022) revealed that video learning improved students' achievement. Students' achievement and retention improved in environmental education when exposed to video learning using YouTube (Mohammed & Ogar, 2023). Students' achievement improved in biology using video-based multimedia learning but the students in the conventional group retained the information better (Gambari et al., 2014). The performance of students improved when three courseware formats of video, Moodle and learning management system were used (Falode & Mohammed, 2023a). Students' chemistry achievement and retention improved significantly using video-based learning (Gabriel & Akinboboye, 2019). Video-based learning is now used to plan an effective collaborative learning atmosphere in order to improve learning outcome. When incorporated in collaborative learning environment, video learning has the potential to increase performance and enable students to discuss in groups.

Collaborative learning is a term used to refer to instructional circumstances, where two or more learners work together on a shared learning goal. Collaborative learning enables students to cooperatively participate, negotiate, and work together within a group in order to explain problems during the process of learning (Alharbi et al., 2022). Collaborative learning encompasses a group of students holding a common duty in which they are allocated to work together to find a solution. Collaborative learning has enormous benefits for learning outcomes such that when students present ideas and opinions and consider other ideas put forward by others, it activates individuals' cognitive development by strengthening their existing mental capabilities, thus revamping and filling the gaps in disjointed and incomplete knowledge (Haataja et al., 2022). Collaborative learning is a method in which students work in small groups of two or more people, where each community is responsible for finishing particular tasks in order to achieve learning objectives. In this approach, group members receive adequate reinforcement based on their group's results (Abd Algani, 2021). In other words, collaborative learning could be characterized as one form of social interaction during learning processes that provides an additional platform for coordination within formal and informal learning environments. Learning through collaboration is based on the notion that learning is a natural social act in which students converse with one another and learn together through observation, imitation, repetition and behavior modeling (Mohammed, 2023).

Several studies show the usefulness of collaborative learning. Putri et al. (2019) found that students' exposed to collaborative learning technique achieved better in their comprehension. Students' achievement and retention improved using computer-supported collaborative learning (Gambari & Yusuf, 2017). Chemistry students' achievement and retention improved when computer-based collaborative strategy was used (Suleiman et al., 2017). Students' achievement improved using e-collaborative learning more than those exposed to e-individualized method (Alharbi et al., 2022). Students' mathematics achievement improved after exposure to collaborative learning (Abd Algani, 2021). The learning outcomes of students with special needs improved when exposed to collaborative learning strategy (Sharma et al., 2021). Students' physics achievement and retention improved when computer-based collaborative learning was used as against individualized computer-based learning (Gambari & Yusuf, 2016). Students' chemistry achievement improved when exposed to mobile-based collaborative learning (Fakomogbon & Bolaji, 2017). In view of the foregoing, there is need to incorporate flipped learning strategy with collaborative learning in order to give students ample opportunities to learn from different perspectives.

Flipped classroom is an instructional method, where students preview learning materials before class usually through videos carefully planned and designed by the teacher or other learning resources provided through the internet while the in-class lecturing is made of student-centered learning activities (Falode & Mohammed, 2023b). The flipped classroom combines the asynchronous video-assisted learning with real-world learning activities like assignment, collaborations, and conversation based on constructivist theories and behaviorist principles (Yu & Gao, 2022). As a student-centered learning technique, flipped classroom is a technique, where students conduct pre-class work to achieve basic information before engaging in classroom activities (Ugwuanyi, 2022). Fung (2020) stated that the interaction of teachers with students in a flipped classroom can be more personalized, less stressful, and students are enthusiastically involved in knowledge attainment and production as they take part in the process to evaluate their learning. Flipped classroom is an active, student-centered method designed to intensify the quality of classroom period (Nolan et al., 2021), offers prospects for organized, active learning (Strelan et al., 2020), and boosts students to inquire and to cooperate with teachers, peers, employers and learning resources (Divjak et al., 2022).

As a result, these pre-class exercises in a flipped classroom comprise of textbook, web-based, or literature readings, as well as watching recordings of classroom lessons at their own freedom (Lichvar et al., 2016). In flipped classroom, video learning could encourage students' expectations, improve comfort. An introductory video could be used to mediate students' conceptualization. When students pause and restart a video in the process of learning, it meaningfully influences their perception of learning contents. Students tend to be more active in learning when assisted with embedded prompts in videos, which could enhance instructional efficiency and improve learning outcomes (Moos & Bonde, 2016). In the flipped classroom, students could accelerate the speed of watching videos and maintain the same comprehension level as the normal speed.

Studies on the effectiveness of flipped classroom have been very promising. Falode and Mohammed (2023b) found that students' geography achievement and retention improved when exposed to computer animation and simulation instructional strategy in flipped classroom settings. Flipped classroom strategy improved students' achievement in basic science (Ugwuanyi, 2022). Students' achievement and retention improved in a statistics course using flipped classroom (Förster et al., 2022). Students' achievement and retention improved in biology after exposure to flipped classroom strategy (Adonu et al., 2021). Using three

Table 1. Research design layout

Groups	Pre-test	Treatment	Post-test	Retention
Experimental group I	O_1	X_1	O_2	O_3
Experimental group II	O_1	X_2	O_2	O_3

formats of flipped learning (audio, video, and text), Oladimeji et al. (2021) revealed that students' achievement and retention improved in electrical installation and maintenance. Students' English achievement improved significantly when short videos were used in flipped classroom settings. In a review of several papers, Divjak et al. (2022) revealed that flipped classroom improved the achievement of students' more than conventional approach. Using a mixed-method approach, Ng et al. (2021) found that students are motivated about flipped classroom, which improved their achievement. Gambari et al. (2016) found that students' achievement and retention improved in biology when flipped classroom was used. Seeing that most of these studies were not carried out in mathematics, it therefore calls for the need to conduct a study about the possibilities of using video learning to improve students learning outcomes in flipped and flipped collaborative learning settings.

In spite of the role being played by technology to improve learning, the performance of students in mathematics in Nigeria continues to deteriorate due to high failure. Several reasons have been attributed to have caused these lingering failures in mathematics like teacher influence towards the subject (Adegoke, 2011), poor motivation (Ajayi et al., 2012), lack of qualified teachers and poor facilities (Popoola & Olanrewaju, 2010), inadequate instructional facilities and poor instructional methods (Gambari et al., 2016), students' attitude and lack of qualified teachers (Suleiman & Hammed, 2019). Most of these problems boil down to teacher-related factors. Yet, several technology-based methodologies were used in Nigeria to improve students' performance using flipped learning strategy (Falode & Mohammed, 2023b; Gambari et al., 2016; Oladimeji et al., 2021; Ugwuanyi, 2022) but these studies were not carried out in mathematics and most of them concentrated on flipped classroom alone without extending it to incorporate collaborative learning. It therefore becomes necessary to try a different approach to accommodate mathematics. Thus, we intend two fill these two gaps: to conduct our study using a video-based mathematics lesson in flipped classroom settings and also to incorporate collaborative learning in our flipped classroom strategy. Therefore, in this present study, we attempted to incorporate collaborative learning into video-based learning in flipped classroom.

In view of the literature gaps noticed in the aforementioned review, we formulated these questions to guide the study:

1. What is the difference in the achievement scores of mathematics students before and after exposure to video learning in flipped and flipped collaborative learning settings?
2. What is the difference in the retention scores of mathematics students exposed to video learning in flipped and flipped collaborative learning settings?

Hypotheses

1. There is no significant difference in the achievement of mathematics students exposed to video learning in flipped and flipped collaborative learning settings.
2. There is no significant difference in the retention of mathematics students exposed to video learning in flipped and flipped collaborative learning settings.

METHODOLOGY

The study adopted a randomized controlled trial with repeated measures design, where the periodic performance of students was checked over time in order to determine the within subject effects as a function of time or treatment (Edmonds & Kennedy, 2017). In this study, participants were exposed to various test occasions in order to determine their performance at the end of the treatment. This design has been used in some studies (e.g., Mohammed et al., 2024a). **Table 1** shows research design layout, where X_1 is treatment for experimental group I using video learning flipped classroom (VLFC), X_2 is treatment for experimental group II using video learning flipped collaborative classroom (VLFCC), O_1 is pre-test for experimental group I and group II, O_2 is post-test for experimental group I and group II, and O_3 is retention for experimental group I and group II.

Participants

The population of the study comprised of 6,435 senior secondary school students in Gombe Metropolis. The target population comprised of 734 senior secondary school two students in private schools in Gombe Metropolis during the 2022/2023 session. Purposive sampling technique was used to select two private secondary schools in Gombe Metropolis, out of which a sample of 70 senior secondary two students randomly drawn from two intact classes were selected. The schools were Matrix International Academy and Yahaya Ahmed Model School. The schools were purposively selected based on their equivalence in terms of information and communications technology (ICT) facilities, school type (boarding) and well-equipped facilities. The two schools were then randomly assigned into experimental group I (VLFC) and experimental group II (VLFCC).

Instrument

A mathematics achievement test (MAT) drafted by the researchers was used to obtain data. The instrument consists of 30-item multiple-choice questions drawn along Benjamin Bloom's table of specification that covers the cognitive domain of educational objectives. The instrument has options A-D, consisting of one correct answer and three distracters drawn from SSII syllabus that covers logarithm, approximation, bearing, quadratic equation and algebraic fraction.

The instrument was administered as a pre-test, post-test and retention test to both groups with the questions reshuffled at different intervals. In order to score the students, one mark was given for each correct answer and zero for any incorrect answer. This means the minimum score is zero, while the maximum score is 30. The results were then converted to percentage. The item difficulty index was computed and a value of 0.41 was obtained and this falls within the acceptable range of 0.30 and 0.49 given by Hasancebi et al. (2020).

Development of Video Package

Using ADDIE model instructional design model, the video package was developed by the researchers with the help of a script-writer, video-editor and language editor. The videos contain a brief 10-15-minute clip, where the researchers explained the various mathematical concepts in different unit lessons. The video editors edited the voice and sound and also to eliminate any form of unnecessary sound. The videos were made to be brief in order to eliminate boredom and also to help capture students' attention because medium videos are more effective for flipped classroom learning than long ones (Yu & Gao, 2022). In order to ensure effective formative evaluation and to accommodate various styles, the videos were made to contain learning objectives, self-assessment exercises at regular intervals as well as end of unit assignments so that students could measure their understanding by pausing and rewinding throughout. The students were allowed to study the contents after school hours in their ICT centers in order to discuss with the teacher during classroom engagement.

Validity & Reliability of Instrument

MAT was validated by four experts in the field of mathematics in Federal University Kashere, Gombe State University and Federal College of Education in Gombe State, Nigeria. They checked the contents, chronological arrangement as well as clarity and spread in terms of covering the curriculum content. All their suggestions were incorporated in the final draft of the instrument. In order to check the internal consistency of the questions, the instrument was later pilot-tested over a period of two weeks in a different school that was within the population but outside the sample using a test re-test method and a reliability figure of 0.93 was obtained by correlating the two tests for any positive linear relationship using PPMC formula. The video learning package was validated by two experts in the field of computer science and educational technology in Federal University Kashere, where they determined the speed of the voicing, self-assessment pane, transition from various stages to another and the graphics used and with the help of the video editor, their suggestion were used to modify the package.

Experimental Procedure

The researchers visited the schools a week to the experiment in order to seek for their cooperation and permission to proceed. The participants were assured of their privacy and safe-usage of data with respect the study. The researchers administered the pre-test in the first week in order to determine their entry behavior. Thereafter, the video learning package was installed in the various desktop computers at the ICT centers in order to enable the students to study the learning materials during night classes so as to prepare for classroom engagement with the teacher the following day. The treatment took four weeks for a minimum of 40 minutes per lesson every day. The students in experimental group I, VLFC, watched the mathematics videos after school hours in order to get themselves familiarized with the contents and in preparation for engagement with the teacher during classroom engagements. Those in experimental group II, VLFCC, were assigned into a think-pair-share collaborative learning settings that required them to watch the video contents after school hours in order to discuss among themselves in groups and share what they have learnt with each other during engagement, with the teacher serving as a mere facilitator. At the end of each study unit of the video lesson, the students answered some self-assessment exercises so as to ensure continuous formative evaluation. At end of the overall video lesson, every student took an end-of-module evaluation. After the treatment was administered within four weeks, a post-test was administered to check the students' understanding of the whole lesson. In order to determine whether they have retained the information, a retention test was administered after a two-week interval. Altogether, the students were exposed to three test measures of pre-test, posttest and retention during the experiment.

Analysis

Descriptive statistics of mean and standard deviation was used to answer the research questions while a mixed design two-way repeated measures ANOVA was used to test the null hypothesis at 0.05 level of significance using. A normality test was conducted using Kolmogorov-Smirnov goodness of fit test and the result revealed that the data set was normally distributed ($p>0.050$) hence the adoption of parametric statistics.

RESULTS

Research question 1. *What is the difference in the achievement scores of mathematics students exposed to video learning in flipped and flipped collaborative learning settings?*

Table 2 revealed the mean and standard deviation of the pre- and post-test scores of students exposed to video learning in flipped and flipped collaborative learning. **Table 2** revealed that the students exposed to video learning in flipped classroom had mean (M)=38.623, standard deviation (SD)=9.223 at pre-test and M=68.363, SD=4.776 at post-test. It also revealed that the students exposed to video learning in flipped collaborative learning had M=39.663, SD=6.978 at pre-test and M=79.233, SD=5.951 at post-test. This revealed that the students exposed to video learning in flipped collaborative learning performed better.

Research question 2. *What is the difference in the retention scores of mathematics students exposed to video learning in flipped and flipped collaborative learning settings?*

Table 2. Pre- & post-test scores of students exposed to video learning in flipped & flipped collaborative learning

Groups	n	Pre-test		Post-test	
		Mean	Standard deviation	Mean	Standard deviation
VLFC	35	38.623	9.223	68.363	4.776
VLFCC	35	39.663	6.978	79.233	5.951

Table 3. Post-test & retention scores of students exposed to video learning in flipped & flipped collaborative learning

Groups	n	Post-test		Retention	
		Mean	Standard deviation	Mean	Standard deviation
VLFC	35	68.363	4.776	66.753	5.934
VLFCC	35	79.233	5.951	69.090	6.308

Table 4. Two-way repeated measures ANOVA of students' performance using video learning in flipped & flipped collaborative learning

Source		Type III sum of squares	df	MS	F	Sig.	Partial eta squared
VLFC	Sphericity assumed	2,730.159	1.000	2,730.159	67.464	.000	.470
	Greenhouse-Geisser	2,730.159	1.000	2,730.159	67.464	.000	.470
	Huynh-Feldt	2,730.159	1.000	2,730.159	67.464	.000	.470
	Lower-bound	2,730.159	1.000	2,730.159	67.464	.000	.470
Error (VLFC)	Sphericity assumed	3,075.591	69.000	40.468			
	Greenhouse-Geisser	3,075.591	69.000	40.468			
	Huynh-Feldt	3,075.591	69.000	40.468			
	Lower-bound	3,075.591	69.000	40.468			
VLFCC	Sphericity assumed	92,479.120	1.000	92,479.120	1576.362	.000	.954
	Greenhouse-Geisser	92,479.120	1.000	92,479.120	1576.362	.000	.954
	Huynh-Feldt	92,479.120	1.000	92,479.120	1576.362	.000	.954
	Lower-bound	92,479.120	1.000	92,479.120	1576.362	.000	.954
Error (VLFCC)	Sphericity assumed	4,458.630	69.000	58.666			
	Greenhouse-Geisser	4,458.630	69.000	58.666			
	Huynh-Feldt	4,458.630	69.000	58.666			
	Lower-bound	4,458.630	69.000	58.666			
VLFC*VLFCC	Sphericity assumed	1,860.549	1.000	1,860.549	35.535	.000	.319
	Greenhouse-Geisser	1,860.549	1.000	1,860.549	35.535	.000	.319
	Huynh-Feldt	1,860.549	1.000	1,860.549	35.535	.000	.319
	Lower-bound	1,860.549	1.000	1,860.549	35.535	.000	.319
Error (VLFL*VLFCL)	Sphericity assumed	3,979.201	69.000	52.358			
	Greenhouse-Geisser	3,979.201	69.000	52.358			
	Huynh-Feldt	3,979.201	69.000	52.358			
	Lower-bound	3,979.201	69.000	52.358			

Note. Significant p<0.050 & MS: mean square

Table 3 revealed the mean and standard deviation of the retention scores of students exposed to video learning in flipped and flipped collaborative learning. **Table 3** revealed that the students exposed to video learning in flipped classroom had M=66.753, SD=5.934 during the retention test while those exposed to video learning in flipped collaborative learning had M=69.090, SD=6.308. This revealed that both students exposed to video learning in flipped collaborative learning and those exposed to video learning in flipped classroom retained the information quite well.

Testing of Null Hypotheses

Hypothesis 1. *There is no significant difference in the achievement of mathematics students before and after exposure to video learning in flipped and flipped collaborative learning settings*.

Table 4 revealed the two-way repeated measures analysis of variance for within subject effects of students' performance in flipped and flipped collaborative learning settings. **Table 4** revealed a significant difference in the performance of both students exposed to VLFC ($F_{[1, 69]}$=67.464, p=0.000, η_p^2=0.470) and VLFCC ($F_{[1, 69]}$=1576.362, p=0.000, η_p^2=0.954). However, while the two groups performed better in the posttest after the treatment, the students in VLFCC performed better with an effect size of 0.954 as against those in VLFC with an effect size of 0.470. Thus, it can be deduced that 95.4% and 47.0% of the variance in students' performance in VLFCC and VLFC is attributable to the treatment administered. What this means is that VLFCC improved the performance of students by 95.4% while VLFC improved the performance of students by 47.0%. Judging by the standards of Cohen (1988), VLFCC improved students' performance by a large extent while VLFC improved their performance by a medium extent. Additionally, the result revealed a significant interaction effect of VLFCC and VCFC ($F_{[1, 69]}$=35.535, p=0.000 with an effect size of 0.319), which means that 31.9% of the overall variance in students' performance can be linked to the interaction effect of both VLFCC and VLFC.

Hypothesis 2. *There is no significant difference in the retention of mathematics students after exposure to video-based learning in flipped and flipped collaborative learning settings*.

Table 5 shows the two-way repeated measures analysis of variance for within subject effects of students' retention after exposure to VLFC and VLFCC.

Table 5. Two-way repeated measures ANOVA of students' retention scores after exposed to video learning in flipped & flipped collaborative learning settings

Source		Type III sum of squares	df	MS	F	Sig.	Partial eta squared
VLFC	Sphericity assumed	2,659.172	1.000	2,659.172	79.532	.000	.411
	Greenhouse-Geisser	2,659.172	1.000	2,659.172	79.532	.000	.411
	Huynh-Feldt	2,659.172	1.000	2,659.172	79.532	.000	.411
	Lower-bound	2,659.172	1.000	2,659.172	79.532	.000	.411
Error (VLFC)	Sphericity assumed	2,541.078	69.000	33.435			
	Greenhouse-Geisser	2,541.078	69.000	33.435			
	Huynh-Feldt	2,541.078	69.000	33.435			
	Lower-bound	2,541.078	69.000	33.435			
VLFCC	Sphericity assumed	3,358.081	1.000	3,358.081	104.119	.000	.785
	Greenhouse-Geisser	3,358.081	1.000	3,358.081	104.119	.000	.785
	Huynh-Feldt	3,358.081	1.000	3,358.081	104.119	.000	.785
	Lower-bound	3,358.081	1.000	3,358.081	104.119	.000	.785
Error (VLFCC)	Sphericity assumed	2,451.169	69.000	32.252			
	Greenhouse-Geisser	2,451.169	69.000	32.252			
	Huynh-Feldt	2,451.169	69.000	32.252			
	Lower-bound	2,451.169	69.000	32.252			
VLFC*VLFCC	Sphericity assumed	1,401.458	1.000	1,401.458	66.123	.000	.265
	Greenhouse-Geisser	1,401.458	1.000	1,401.458	66.123	.000	.265
	Huynh-Feldt	1,401.458	1.000	1,401.458	66.123	.000	.265
	Lower-bound	1,401.458	1.000	1,401.458	66.123	.000	.265
Error (VLFL*VLFCL)	Sphericity assumed	1,610.792	69.000	21.195			
	Greenhouse-Geisser	1,610.792	69.000	21.195			
	Huynh-Feldt	1,610.792	69.000	21.195			
	Lower-bound	1,610.792	69.000	21.195			

Note. Significant p<0.050 & MS: mean square

Table 5 revealed a value of $F_{[1, 69]}$=79.532, p=0.000, η_p^2=0.41 for VLFC and $F_{[1, 69]}$=114. 119, p=0.000, η_p^2=0.785 for VLFCC. While the two groups retained the information, the students in VLFCC retained the information more. The partial eta squared effect size of 0.41 and 0.785 means that 41.0% and 78.5% of the total variance in students' retention for VLFC and VLFCC, respectively is linked to the treatment. This means that the treatment improved students' retention by 41.0% and 78.5% for VLFC and VLFCC, respectively. Furthermore, the result revealed a significant interaction effect of VLFC and VLFCC ($F_{[1, 69]}$=66.123, p=0.000, η_p^2=0.265. This means that 26.5% of the total variance in students' retention is attributable to the duo of VLFC and VLFCC.

DISCUSSION

The main focus of this study is to determine the effectiveness of video learning in flipped and flipped collaborative learning settings. As a result of exposure to video learning in flipped and flipped collaborative learning, the students' performance improved significantly especially those exposed to VLFCC. The result of hypothesis one revealed that a significant difference exists in the achievement scores of students exposed to video learning in flipped and flipped collaborative learning. The result revealed that the use of video learning in flipped collaborative learning improved students' performance by 95.4% as against the 47.0% recorded for VLFC due to the effect sizes witnessed. Going by the standards of Cohen (1988), video learning flipped collaborative learning improved students' performance to a large extent while VLFC improved students' performance with a medium extent. Thus, while the two groups performed better in the within subject test, the students exposed to video learning in flipped collaborative classroom performed better. With a VLFC, the students are presented with opportunities to learn at their pace, pause and rewind learning contents as they so wish, which translates into forming a lasting cognitive experience in their understanding. It also gives them an avenue to see and equally hear what is being said, which could improve their understanding as well as critical thinking skills to solve problems. This finding has further revealed and validated the usefulness of incorporating flipped classroom in many ways. It confirms the findings of Falode and Mohammed (2023b) who found that students' geography achievement and retention improved when exposed to computer animation and simulation instructional strategy in flipped classroom settings. Flipped classroom strategy improved students' achievement in basic science (Ugwuanyi, 2022). Students' achievement and retention improved in a statistics course using flipped classroom (Förster et al., 2022). Students' achievement and retention improved in biology after exposure to flipped classroom strategy (Adonu et al., 2021). Using three formats of flipped learning (audio, video and text), Oladimeji et al. (2021) revealed that students' achievement and retention improved in electrical installation and maintenance. Students' English achievement improved significantly when short videos were used in flipped classroom settings. Divjak et al. (2022), in a review of several papers, revealed that flipped classroom improved the achievement of students more than conventional approach. Using a mixed-method approach, Ng et al. (2021) found that students are motivated about flipped classroom, which improved their achievement. Gambari et al. (2016) found that students' achievement and retention improved in biology when flipped classroom was used.

Furthermore, it was discovered that incorporating collaborative learning into video flipped learning improved students' performance more than ordinary video without flipped classroom. This finding is possible because while the students watch the mathematics video at their own pace after school hours, which enabled them to pause, rewind and practice endlessly, they were

equally grouped in a think-pair-share collaborative environment in order to discuss with their peers and share what they have learnt with their teacher who was a facilitator in the experiment. This is because students' learn better when they discuss in pairs and groups rather than mere individualized learning. This finding shows that incorporating video collaborative learning in a flipped classroom environment is more effective than only video in flipped classroom. This finding confirms the study of Putri et al. (2019) who found that students' exposed to collaborative learning technique achieved better in their comprehension. Students' achievement and retention improved using computer-supported collaborative learning (Gambari & Yusuf, 2017). Chemistry students' achievement and retention improved when computer-based collaborative strategy was used (Suleiman et al., 2017). Students' achievement improved using e-collaborative learning more than those exposed to e-individualized method (Alharbi et al., 2022). Students' mathematics achievement improved after exposure to collaborative learning (Abd Algani, 2021). The learning outcomes of students with special needs improved when exposed to collaborative learning strategy (Sharma et al., 2021). Students' physics achievement and retention improved when computer-based collaborative learning was used as against individualized computer-based learning (Gambari & Yusuf, 2016). Students' chemistry achievement improved when exposed to mobile-based collaborative learning (Fakomogbon & Bolaji, 2017). Students' microteaching performance improved after exposure to collaborative learning using Telegram and WhatsApp (Mohammed, 2023).

The result of hypothesis two was rejected and this means there was a significant difference in the retention scores of both students exposed to video learning in flipped and flipped collaborative learning. While the two group performed better in the retention test, the students in video learning flipped collaborative learning retained the information better with 78.5% given the effect size recorded, which, according to Cohen (1988), represents a high extent. This result is possible because in addition to exposing the students to video learning that enables them to see, hear, pause and rewind content at their own pace, the students were equally grouped into small groups of peers, where they discussed and learn from each other, which enables them to retain the content better. He various discussions enable students to construct their own knowledge to suit their learning preferences. This finding agrees with Adonu et al. (2021), Förster et al. (2022), Gambari et al. (2016), and Oladimeji et al. (2021), whose study revealed that students' retention improved after exposure to flipped classroom strategy. The finding also agrees with Mohammed and Ogar (2023) who discovered that students' retention improved after exposure to video learning using YouTube. It also agrees with Falode and Mohammed (2023a) whose study using three formats of courseware to improve students' performance revealed that students' retention score was improved using video. Conversely, the finding disagrees with Falode and Mohammed (2023b) whose study revealed no significance differences in students' retention using computer simulation and animation in flipped classroom.

CONCLUSIONS

The use of video learning in flipped classroom generally improved students' performance but the students in VLFCC performed and retained the information better than those exposed to only VLFC. The study revealed that the students found VLFCC very useful because they had the ample opportunity to discuss in pairs and small groups after watching the pre-class videos, which enabled them to construct their own knowledge through sharing of ideas in addition to what they have watched. This particular study is the first, in the researchers' understanding, to have incorporated video learning in flipped collaborative environment in Nigeria, which has yielded serious impact in terms of performance.

Implication for Practice & Theory

The implication of this finding is that mathematics teachers, researchers, and education policy-makers will find this study very useful given that most of the studies concentrated only on flipped classroom but this particular one incorporated video learning in flipped collaborative learning, where the students demonstrated high level of performance in terms of achievement. This study has added more credence to the fact that video learning in flipped classroom is important towards enhancing learning outcomes but when video learning is incorporated with collaborative learning in flipped classroom settings, students tend to perform way better because they are afforded with the opportunities to learn together through discussion, observation, imitation, repetition and behavior modeling, which makes them to build their own knowledge and understanding based on what they watched and the collaborative discussion carried out. Additionally, on a theoretical basis, this study has provided more credence to collaborative learning theory and the constructivist theory, whereby students learn through group discussions and collaboration by constructing meaning out of what they learn.

Limitations & Future Research Directions

This study has some limitations. First, it was limited to a few mathematics concepts; as a result, more studies should be conducted on other concepts to provide more credence to the effectiveness of video learning in flipped and flipped collaborative learning. Secondly, the study was conducted on private senior secondary schools with access to internet facilities, thus, similar studies should be conducted on public schools in order to advance the frontiers of knowledge in the field of flipped classroom. Lastly, the study was limited to senior secondary students; similar studies should be conducted at the lower levels like primary schools.

Recommendations

In line with the findings of this study, it is hereby recommended that:

1. Mathematics teachers should consider the deployment of video learning in flipped collaborative classroom in order to improve students' learning outcome. This is because when students are grouped in video collaborative learning strategy

in flipped classroom settings, they tend to watch and hear in practical terms the learning contents after school hours and then come back to the classroom to discuss and share ideas about the lesson during normal classroom settings. This will enable them to construct meaning and also to meet their learning preferences.

2. Mathematics teachers should be trained through workshops, trainings, seminars etc. on how to carefully design a technology-enhanced, student-centered, flipped classroom environment in order to give students different varieties to earn from.

Author contributions: IAM: wrote the first draft & **AB:** reviewed the draft & made corrections Both authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgment: The authors would like to thank the students for their participation.

Ethical statement: The authors stated that ethical approval has been waived as per national regulations in Nigeria (referred to as Federal Ministry of Health, National Code of Research Ethics at: https://portal.abuad.edu.ng/lecturer/documents/1588255709NCHRE_Aug_07.pdf). All respondents were assured of their confidentiality during this study.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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