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Research Article

Impact of Demonstration and Animation Videos in Flipped Classroom on Chemistry Students' Performance

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Abstract
The persistent underperformance of chemistry students in Nigeria remains a growing concern among educators and policymakers. This challenge is largely driven by the subject's conceptually demanding nature and educators' limited adoption of technology-driven instructional approaches, even as chemistry continues to underpin critical sectors such as medicine, engineering, and national development. Against this background, this study examined how the use of demonstration and animation videos within flipped classroom environments affects students' academic outcomes in Niger State, Nigeria. Specifically, the study assessed the impact of these instructional approaches on students' achievement scores, retention, and attitude toward chemistry. We used a pre-test post-test quasi-experimental design and purposively sampled 144 students from three intact classes in three schools. Descriptive statistics were employed to address the research questions, while Analysis of Covariance, Sidak post-hoc comparisons, and independent samples *t*-test were used to test the stated hypotheses at a 0.05 significance level. The findings showed statistically significant improvements in both achievement ($F(2,140) = 49.945$, $p = 0.000$, $\eta^2 = 0.927$) and retention ($F(2,140) = 70.083$, $p = 0.000$, $\eta^2 = 0.859$) among students in the flipped classroom groups relative to those taught conventionally. Attitude scores, however, did not differ significantly between the demonstration and animation groups, implying both approaches were equally effective in enhancing positive dispositions toward chemistry. These outcomes point to a compelling need for pedagogical transformation in Nigerian chemistry classrooms, with a shift toward more technology-integrated and learner-centered instructional methods in Nigerian schools.

Keywords: Animation Videos, Demonstration Videos, Chemistry Education, Flipped Classroom

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1. INTRODUCTION

Chemistry occupies a central position in Nigeria's secondary school curriculum and is offered as a discipline at the tertiary level. Over the years, the underperformance of chemistry students in the subject has remained consistently poor, over the years a trend that has been a concern to educators, curriculum designers, and policymakers, which could be due to the abstract and theoretically intensive nature of the subject, compounded by teachers' inability to make learning engaging and stimulating through innovative technology. This trend persists despite the essential role of chemistry in all aspects of life. Fields such as medicine, engineering, and related disciplines rely on chemistry knowledge for effective practice (Sunday et al., 2019). Given the role of chemistry in national development, it should be taught using modern technology to engage students' interests and contribute to national progress. Thus, technology plays a vital role in making chemistry more relevant, accessible, and meaningful to students. Advances in technology have made education increasingly student-centered, aiming to engage students by employing various learning approaches tailored to their capabilities (Mohammed & Ogar, 2023). The infiltration of technology in present educational practices has become a trend in this era and has provided means for educators to easily provide lessons in different instructional formats (Sobowale et al., 2024). Considering this paradigm shift driven by technological advancements, it is crucial to make teaching and learning student-centered by incorporating suitable technology into 21st-century pedagogy (Falode & Mohammed, 2023b). With technology's integration into modern education, numerous techniques have emerged, significantly enhancing instructional delivery (Eke et al., 2025; Exposito et al., 2020; Mohammed et al., 2024). Among the many technological approaches that have shown measurable positive effects on teaching and learning quality across various disciplines is the use of demonstration videos.

Demonstration videos are increasingly used in video-based learning, offering learners practical opportunities to see what is expected of them and engage multiple senses. Padmavathi et al. (2019) highlighted that video-based strategies are advantageous for teaching large groups uniformly and authentically. Vrbik and Vrbik (2017) found video demonstrations to be highly engaging as a means of instructional delivery. Students can learn by observing others, enabling them to construct their own understanding of the material. Numerous studies on video demonstrations have shown promising results. For instance, research by Padmavathi et al. (2019), Ghahfarokhi (2022), and Maleki et al. (2010) confirmed the potential of demonstration videos in improving students' academic achievement across different educational contexts. Similarly, animation videos are used to boost student performance.

Animation videos combine motion graphics, audio-visual components, and structured content delivery to support deeper assimilation. They provide additional information and intellectual stimulation, allowing for greater cognitive processing (Gambari et al., 2016). Animation videos, resembling movies with engaging images, capture children's attention and interest, improving learning and development (Aye et al., 2022). These videos facilitate smooth teaching and learning and enhance concept retention, as long-term recall is crucial for improved performance (Faruk et al., 2022). In educational settings, students can repeatedly watch animation videos at their convenience, reinforcing their learning (Foster et al., 2022). The benefits of animation videos in enhancing learner achievement and retention have been documented in several empirical research studies (Aye, 2022; Lailatul & Efendi, 2022; Faruk et al., 2022; Gambari et al., 2014; Olatunde-Aiyedun, 2021; Ridha et al., 2022). While these studies generally agree on their findings, most were not conducted in the context of chemistry. Also, demonstration and animation videos can be effectively integrated into flipped classroom settings.

The flipped classroom is an instructional method where lectures are assigned outside of class, reserving class time for diverse learning activities (DeLozier & Rhodes, 2017). In a flipped classroom, tasks typically done outside, like homework and assignments, are shifted into the classroom, while traditional classroom activities are completed beforehand (Falode & Mohammed, 2023a; Lag & Sæle, 2019). This approach allows students to initially use learning materials outside class, either by reading learning content, listening to learning content, or watching instructional videos, and use class time for deeper knowledge assimilation through problem solving, discussion, or debates for enhanced learning outcomes (Leo & Puzio, 2016). The flipped classroom technique accommodates individual student differences, improving achievement by replacing boredom with exciting, fun-filled, and pleasurable learning approaches. Students enter the classroom confidently after reviewing content at home and are prepared to discuss it (Nja et al., 2022). Ozyurt (2022) observed that in flipped classrooms, activities traditionally done in class are moved to the home, and vice versa. Fung (2020) noted that the flipped classroom facilitates teacher-student interactions through participation and evaluation. In a flipped learning environment, technological advancements allow students to study pre-assigned content. This method requires students to use learning materials outside of class so that during class time, they can interact more with their peers and instructors instead of just listening to lectures (Mustapha & Abdullah, 2024).

Research on flipped classrooms has shown promising results in enhancing achievement, retention, and attitudes. For instance, Falode and Mohammed's (2023a) study revealed that computer simulations and animations in flipped classrooms were equally effective in enhancing students' learning. Mohammed and Bello (2024) reported that students' achievement and retention improved with video learning in both a flipped and a flipped collaborative classroom. Studies by Leo and Puzio (2016), Balaban et al. (2016), Zhonggen and Guifang (2016), Ichinose and Clinkenbeard (2016), Aziz et al. (2019), and Salas-Rueda (2022) all indicated increased student performance after exposure to flipped classroom environments. These studies generally agree on the effectiveness of the flipped classroom, but most were not conducted in the context of chemistry. Therefore, it is necessary to explore the effect of the flipped classroom in chemistry to expand the literature in this field.

Achievement is the result that indicates how well a student has mastered a concept. Retention refers to the ability to recall facts and previously learned concepts after a series of instructions, essentially the capacity to remember stored knowledge (Falode & Mohammed, 2023a). Attitude is an individual's tendency to respond with a certain level of favorableness to an object, behavior, person, institution, event, or any other discernible aspect of their environment (Ajzen, 2014). A positive attitude leads to positive outcomes, while a negative attitude results in poor performance (Marcela & Mala, 2016). Similarly, several studies (Falode & Mohammed, 2023a; Mohammed & Bello, 2024; Foster et al., 2022; Oladimeji et al., 2021; Gambari et al., 2016; Adonu et al., 2021) showed that students' achievement and retention significantly improved after exposure to the flipped classroom instructional method. Although there are generalized conclusions about the flipped classroom's effectiveness, further exploration in various circumstances is needed to advance knowledge and test the strategy's effectiveness across different disciplines, given that the studies were not conducted in chemistry. Furthermore, studies (Singay, 2020; Turra et al., 2019; Romero & Angeles, 2023; Aburayash, 2021) revealed that students have a positive attitude towards the flipped classroom instructional approach, thereby finding it beneficial for their learning. Similarly, some studies (Yang & Chen, 2020; Nja et al., 2022; Bin-Hady & Hazaea, 2020) also indicated that students' achievement and attitudes improved after exposure to the flipped classroom strategy.

In senior secondary schools in Niger State, students' performance in chemistry has drastically declined, with many struggling to achieve a credit pass in the SSS III examination. This poor performance is attributed to various issues, including rote learning, overcrowded classrooms, a shortage of qualified teachers, poor attitudes, and the use of traditional teaching methods considered outdated, as they promote one-way communication. To address this issue, researchers have explored several teaching approaches, but the problem persists. The conventional teaching method has proven ineffective and teacher-centered, failing to enhance learning outcomes (Gambari et al., 2016; Mohammed & Ogar, 2023; Falode & Mohammed, 2023a; Mohammed et al., 2023; Mohammed et al., 2024; Adonu et al., 2021; Oladimeji et al., 2021). While various studies have employed innovative, technology-supported methods in teaching chemistry, the potential of these technological innovations in flipped classroom settings has not been thoroughly explored, especially in chemistry. Therefore, this study aimed to determine whether using demonstration and animation videos in flipped classroom settings can enhance students' learning outcomes in chemistry.

1.1. Hypotheses

HO_1: There is no significant difference in the mean achievement scores of students taught chemistry using demonstration and animation-based videos in flipped classroom settings and the conventional method

HO_2: There is no significant difference in the mean retention scores of students taught chemistry using demonstration and animation-based videos in flipped classroom settings and the conventional method

HO_3: There is no significant difference in the mean attitude scores of students taught chemistry using demonstration and animation-based videos in flipped classroom settings

2. METHODOLOGY

2.1. Design

The study employed a quasi-experimental design featuring a pretest, posttest, control group research design. Quasi-experimental design, as described by Armstrong and Patnaik (2009), is suitable for evaluating the causal effect of an instructional intervention on a defined population without requiring random participant assignment. This research design allowed for meaningful causal comparisons between the independent and dependent variables across the three instructional groups.

Table 1. Research Design Layout

Group	Pretest	Treatment	Posttest	Retention
Experimental Group I	O_1	X_1	O_1	O_1
Experimental Group II	O_2	X_2	O_2	O_2
Control Group	O_3	X_0	O_3	O_3

Key:
X_1 = Treatment for demonstration-based video in a flipped classroom (Experimental Group I)
X_2= Treatment for animation-based video in the flipped classroom (Experimental Group II)
$O_{1:}$ Pretest, posttest, and retention of Experimental Group I
$O_{2:}$ Pretest, posttest, and retention of Experimental Group II
O_3 = Pretest, posttest, and retention of the control group
X_0 = Conventional lecture method without any treatment

2.2. Participants

The study population consisted of all 7,432 Senior Secondary School chemistry students from the 2023/2024 academic session in private schools located in Minna, Niger State, Nigeria. The targeted population specifically included 2,352 Senior Science II students in Minna Metropolis. A sample of 144 comprising SS II students was selected from intact classes across three private schools for the study. The sample size was made up of 89 males, 55 females, with an age range of 72 students within 14 to 15 years, 43 aged 16 to 17 years, and 29 aged 18 years and above. Initially, a purposive sampling technique was employed to select three comparable secondary schools in Minna Metropolis based on criteria such as equivalence in laboratory and staffing resources, school type (private boarding schools), availability and accessibility of ICT facilities for learners, and gender composition (co-educational schools). The selected schools were Himma International College, MYPA School, Minna, and Saint Clement Secondary School, Minna. Subsequently, these three schools were randomly assigned to experimental Group I (demonstration-based video), experimental Group II (animation-based video), and a control group (traditional lecture method), respectively.

2.3. Research Instruments

Two research instruments were utilized to collect data for this study: the Chemistry Achievement Test (CAT) and the Chemistry Attitude Questionnaire (CAQ). The CAT consisted of two sections: Section A, containing demographic data of the participants, and Section B, containing 20 multiple-choice questions with four options (A-D), where only one option was correct, and three were distractors. The test covered concepts such as the periodic table, chemical equilibrium, rate of reaction, and acids and bases (pH scale). The CAT had 20 items and was scored 0–20. The minimum possible score that students could obtain was zero, and the maximum possible score that students could obtain was 20. The students were given 40 minutes to answer the CAT. The Chemistry Attitude Questionnaire (CAQ) consisted of two parts, A and B. Part A collected personal data from respondents, while Part B assessed students' attitudes towards chemistry. The CAQ consists of 16 positively worded items and four negatively worded items; the negatively worded items were reverse-coded. The CAQ was based on a 5-point Likert scale ranging from Strongly Agree to Strongly Disagree. In the positively worded items, Strongly Agree was awarded 5 points, Agree was awarded 4 points, Undecided was awarded 3 points, Disagree was awarded 2 points, and Strongly Disagree was awarded 1 point. The CAQ ranged from 20 to 100 using a 5-point Likert scale. The minimum possible points that students could obtain for the CAQ was 20, and the maximum possible points that students could obtain were 100. The students were given 25 minutes to complete the CAQ.

The demonstration and animation-based videos were created with the assistance of a chemistry laboratory for filming and a studio for developing animated segments to engage and capture students' attention. The process involved selecting content, outlining instructional objectives, and designing activities based on specific learning outcomes and student needs. Each video unit included lesson objectives, main content, and various activities conducted by researchers. These video applications were designed for both classroom and remote learning environments, accessible online and offline via computers, phones, and laptops provided by the sampled schools. The flipped classroom model was structured around pre-class, in-class, and post-class activities. During the pre-class phase, teachers provided lecture materials to students along with guidelines for self-study. Students engaged with the video and animation packages at their own pace after school hours to digest the content. Students were encouraged to watch, rewind, pause, and take notes from the pre-class videos at their convenience. Following the instructional period, during the post-class phase, teachers administered an achievement test to assess students' learning outcomes. Additionally, a retention test was conducted after two weeks to evaluate whether students retained the information.

Content validity of the CAT was done by three educational technologists, one psychometrist, two chemistry lecturers from the Federal University of Technology (FUT), Minna, and a chemistry teacher from Maryam Babangida Government Science College, Minna. The CAQ was validated by two experts in counseling and educational psychology from Ibrahim Badamasi Babangida University, Lapai, and a measurement and evaluation specialist from FUT Minna. The video instructional packages were further validated by two educational technology experts and one instructional designer, all from FUT Minna. A pilot test conducted at Bahago Secondary School and Zarumai Model School, in Minna, yielded a Cronbach's alpha reliability coefficient of 0.87 for the CAQ and a Pearson Product-Moment Correlation (PPMC) reliability coefficient of 0.88 for the CAT using the test-retest method. Formal permission was obtained from school management in the first week of the study, and cooperation from subject and computer teachers was actively sought. The CAT pretest was also administered one week before the intervention to establish baseline knowledge equivalence across the groups. Over three weeks of instruction (one session per week), Experimental Groups I and II engaged with three content units via the flipped classroom model while the Control Group received conventional teacher-led lectures. Students in the experimental groups were required to watch their respective videos (approximately 15 minutes each) before attending class, where in-class activities consisted of problem-solving exercises and group discussions. Post-tests using the CAT and CAQ were administered after the three-week teaching phase.

2.4. Data Analysis

Data collection spanned five weeks in total, encompassing both instruction and assessment. Normality assumptions were confirmed via the Kolmogorov-Smirnov and Shapiro-Wilk tests (p >0.05), supporting the use of parametric statistics. ANCOVA was employed to test Hypotheses 1 and 2, and Sidak post-hoc comparisons were used to identify significant differences, while an independent samples t-test was used for Hypothesis 3. Normality tests using Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that the dataset met the assumption of normal distribution ($p > 0.05$), supporting the use of parametric inferential statistics. Statistical Package for the Social Sciences (SPSS) version 25 was used for data analysis.

3. RESULTS

The demographic data of the respondents show the gender and age distribution of the respondents, as shown in Table 2.

Table 2. Demographic Distribution of the Respondents

Demographic Data	Frequency	Percent
Male	89	61.81
Female	55	38.19
14-15 years	72	43.06
16-17 years	43	36.80
18 years and above	29	20.14

From Table 2, 89 of the respondents were male, accounting for 61.81%, while female respondents constituted 55 participants (38.19%). This indicates that males were more represented than females. Based on age, the majority of the respondents were within the 14–15 year age bracket, with 72 participants representing 43.06% of the sample. This was followed by those aged 16–17 years, who comprised 43 respondents (36.8%). The least represented group was respondents aged 18 years and above, with 29 participants (20.14%).

HO_1: There is no significant difference in the mean achievement scores of students taught chemistry using demonstration and animation-based videos in flipped classroom settings and the conventional lecture method.

ANCOVA was used to test the hypothesis, as shown in Table 3.

Table 3. ANCOVA Result of Achievement Scores of Students in Chemistry

Source	Type III Sum of Squares	df	MS	F	Sig.	Partial Eta Squared
Corrected Model	28368.301a	3	9456.100	35.704	.000	.324
Intercept	83214.636	1	83214.636	314.198	.000	.561
Pretest (Covariate)	1691.343	1	1691.343	6.386	.013	.082
Treatment (Achievement)	26455.490	2	13227.745	49.945	.000*	.927
Error	37078.692	140	264.848			
Total	733617.000	144				
Corrected Total	65446.993	143				

*Significant at 0.05 level

From Table 3, the analysis yielded a significant F statistic ($F_{(2,140)} = 49.945$, $p = 0.000$) with an effect size of 0.927 (partial eta squared). Since the p-value is less than 0.05, hypothesis one is rejected, indicating a substantial difference in mean achievement scores among the groups.

The large effect size of 0.927 suggests that 92.7% of the variance in students' overall achievement can be attributed to the use of demonstration and animation videos. According to Cohen (1988), this represents a large effect size, indicating that the implementation of demonstration and animation videos in flipped classroom settings significantly enhanced students' performance.

Table 4. Sidak Post-Hoc Analysis of Students' Achievement Scores

Treatment	Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Demonstration	Animation	-.8643	3.57130	.993	-9.4941	7.7655
	Conventional	28.1241*	3.68700	.000	19.2147	37.0335
Animation	Demonstration	.8643	3.57130	.993	-7.7655	9.4941
	Conventional	28.9884*	2.55114	.000	22.8237	35.1530
Conventional	Demonstration	-28.1241*	3.68700	.000	-37.0335	-19.2147
	Animation	-28.9884*	2.55114	.000	-35.1530	-22.8237

*Significant at the 0.05 level

The analysis revealed no significant difference between achievement scores for demonstration-based versus animation-based videos within the flipped classroom setting. However, significant differences were found between achievement scores for demonstration-based videos versus the conventional lecture method, as well as between animation-based videos in flipped classroom settings versus the conventional lecture method. These results indicate that both demonstration- and animation-based videos in flipped classrooms significantly outperformed the conventional lecture method in teaching chemistry.

HO_2: There is no significant difference in the mean retention scores of students taught chemistry using demonstration- and animation-based videos in flipped classroom settings and the conventional lecture method.

ANCOVA was used to test hypothesis two, as shown in Table 5. The analysis table revealed a significant difference with $F(2,140) = 70.083$, $p = 0.000$. This indicates that there is a substantial difference in the mean retention scores among the groups. The effect size, as measured by partial eta squared (0.859), suggests that 85.9% of the total variance in students' retention scores can be attributed to the use of demonstration and animation videos. This large effect size underscores the impact of these instructional methods on student retention in chemistry.

Table 5. ANCOVA Result of Retention Scores of Students in Chemistry

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	28085.002[a]	3	9361.667	46.998	.000	.281
Intercept	49383.018	1	49383.018	247.914	.000	.495
Achievement (Covariate)	86.982	1	86.982	.437	.510	.682
Treatment (Retention)	27920.268	2	13960.134	70.083	.000*	.859
Error	27887.158	140	199.194			
Total	555939.000	144				
Corrected Total	55972.160	143				

*Significant at the 0.05 level

To further explore the specific differences among the treatment groups, Sidak post-hoc analysis was conducted as detailed in Table 6.

Table 6. Sidak Post-Hoc Analysis of Students' Retention Scores

Treatment	Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Demonstration	Animation	-.6643	3.57130	.993	-9.4941	7.7655
	Conventional	23.1641*	3.68700	.000	19.2147	37.0335
Animation	Demonstration	.6643	3.57130	.993	-7.7655	9.4941
	Conventional	23.1641*	2.55114	.000	22.8237	35.1530
Conventional	Demonstration	-23.1641*	3.68700	.000	-37.0335	-19.2147
	Animation	-23.1641*	2.55114	.000	-35.1530	-22.8237

*Significant at the 0.05 level

Table 6 shows that neither the demonstration nor animation group differed significantly from each other in retention performance (p = .993). However, both groups significantly outperformed the conventional instruction group (p = .000), with the demonstration group recording a slightly higher mean retention score.

HO$_3$: There is no significant difference in the mean attitude of students towards chemistry when taught using demonstration and animation-based videos in flipped classroom settings

An independent samples t-test was used to test the hypothesis. The results are presented in Table 7.

Table 7. Independent Samples T-Test on the Mean Attitude of Students Towards Chemistry

Groups	N	df	Mean	SD	t-value	p-value
Demonstration	70	88	53.203	0.505	0.017	0.986 [ns]
Animation	20		53.205	0.436		

Not Significant: p>0.05

The analysis yielded a t-value of 0.017 and a corresponding p-value of 0.986. The p-value exceeds the significance level of 0.05; hypothesis three is accepted. This implies that there is no statistically significant difference in the mean attitude of students towards chemistry when demonstration and animation-based videos are employed in a flipped classroom environment. These results suggest that students maintain a positive attitude towards chemistry irrespective of whether they are taught using demonstration or animation-based videos in a flipped classroom setting.

4. DISCUSSION

The primary aim of this study was to evaluate how demonstration and animation videos embedded within a flipped classroom model influence chemistry students' academic outcomes. Across all three indicators of achievement, retention, and attitude, the results offer valuable insights for chemistry education in Nigeria. The rejection of hypothesis 1 confirms a statistically significant difference in achievement between the flipped classroom groups and the conventional method. The large effect size (η^2 = 0.927) indicates that the type of instructional method used accounts for a substantial proportion of variance in students' performance. Post-hoc comparisons further revealed that while neither the demonstration nor animation group differed significantly from each other, confirming the comparative effectiveness of both groups, they clearly outperformed their counterparts in the conventional lecture group. The slight advantage of the demonstration video group may be attributed to the nature of the format itself: demonstration videos allow students to observe and replicate procedures, techniques, and physical movements in their own time and at their own pace. This observational-replication model is especially useful in chemistry, where experimental procedures are central to learning. Students can pause, rewind, and replay the videos multiple times, which promotes mastery before class interaction. The sensory stimulation offered by demonstration formats also aids in the deeper processing of content. These findings align with those reported by Falode and Mohammed (2023a), Mohammed and Bello (2024), Leo and Puzio (2016), Balaban et al. (2016), Salas-Rueda (2022), Zhonggen and Guifang (2016), Ichinose and Clinkenbeard (2016), Nja et al. (2022), Aziz et al. (2019), Foster et al. (2022), Oladimeji et al. (2021), Gambari et al. (2016), and Adonu et al. (2021), all of whom documented notable performance gains following flipped classroom instruction.

The rejection of hypothesis 2 similarly confirms that both video-based flipped classroom approaches significantly enhanced students' ability to retain chemistry content compared to conventional teaching. The large effect size ($\eta^2 = 0.859$) underscores the durable impact of these approaches on long-term knowledge recall. Post-hoc analysis again showed no significant difference between the demonstration and animation groups in terms of retention, although the demonstration group showed a higher mean gain. This could be due to the advantage that is linked to the repetitive engagement that demonstration-based flipped learning enables, where students who study at home by repeatedly viewing demonstrations before attending class develop a familiarity and mastery with the material that could support retention. Also, in using demonstration videos in flipped classroom settings, students get to construct their own meaning through mere observation and replication of techniques, procedures, and body movements at their own leisure time at home, and this is vital towards enhancing performance, especially during chemistry experiments. Also, demonstration videos used in flipped classroom settings promote observational and individualized learning, which enables students to pause, replicate, replay, and repeat a given task countless times at home before coming to discuss in class with the teacher to attain mastery. Demonstration videos also have what it takes to stimulate various senses, which facilitates learning easily. The flexibility, self-pacing, and student-centred nature of this approach enhance motivation and make learning more meaningful, which together support long-term retention. Thus, this finding agrees with the studies of Gambari et al. (2016), Adonu et al. (2021), Oladimeji et al. (2021), Foster et al. (2022), Falode and Mohammed (2023a), and Mohammed and Bello (2024), all of whom reported improved retention outcomes after the use of flipped classroom-based instruction.

The acceptance of hypothesis 3 indicates that no significant difference in attitude existed between the demonstration and animation groups. This is because both groups displayed improved attitudes toward chemistry after instruction. This is because when learning is made interesting, flexible, and student-centered in order to arouse the interests of learners using a given technology tool, students tend to develop a positive attitude toward learning due to the fact that they derive satisfaction through good performance in what they do. The more students develop a positive attitude, the better their performance, and the less students develop a poor attitude, the poorer their performance. These results are consistent with findings reported by Turra et al. (2019), Singay (2020), Aburayash (2021), and Romero and Angeles (2023), whose results revealed that the use of the flipped classroom instructional strategy increased students' attitude by making learning interesting and also meeting the individual expectations of students. The finding also agrees with Bin-Hady and Hazaea (2020), Yang and Chan (2020), and Nja et al. (2022), who observed gains in both performance and attitude after the flipped classroom.

Finally, these findings provide strong empirical support for constructivist learning theory, which states that students learn best when they construct their own knowledge. When students learn through watching video elements and in flipped classroom settings, they will be able to construct their own understanding and plan their learning in accordance with their own pace, as proven in this study.

5. CONCLUSION

The implementation of demonstration and animation-based videos within flipped classroom settings has shown significant promise in addressing students' underperformance in chemistry by enhancing both achievement and retention compared to conventional methods. While the demonstration video group achieved slightly higher means in both retention and achievement, both approaches markedly outperformed traditional teaching methods. Furthermore, the use of demonstration and animation-based videos has been instrumental in fostering positive attitudes toward learning among students, which plays a crucial role in enhancing overall educational outcomes. The study fosters a significant shift towards more innovative and student-centered instructional methods in Nigerian schools.

The immediate implication of our findings is the pedagogical shift from teacher-centred to learner-centred instruction. Students' gains in achievement and retention show that integrating demonstration and animation videos within a flipped classroom is a high-impact instructional intervention. The result can inform classroom practice by structuring effective flipped classrooms, as teachers should operationalise the flipped model using a three-phase structure: Pre-class phase, where students engage with short-duration (10–15 minutes) demonstration or animation videos. The ability to pause, rewind, and replay supports self-paced cognitive processing, especially for abstract chemistry concepts like equilibrium or reaction rates. The in-class phase could entail activities such as guided problem-solving, laboratory simulations, real experiments, discussion, peer instruction, and collaborative learning. The post-class phase could comprise continuous assessment, such as quizzes and reflective tasks, which reinforce retention. No significant learning outcome difference was observed between the demonstration and animation in our study. So, animation and demonstration should not be used as alternatives but should be complementary. Researchers should examine hybrid multimedia environments, such as integrating videos, simulations, and gamification in a flipped model, and explore other multimedia-supported learning environments. Based on the findings, curriculum developers could restructure the chemistry curriculum so that the flipped classroom could be effectively embedded into the chemistry curriculum. They could also support the development of standardised multimedia instructional packages for students that align with the chemistry curriculum and encourage teachers and students to use them.

The respondents were drawn from only three intact classes, which portrays limited representativeness as the sample did not adequately capture the diversity of the broader population of secondary school students in Nigeria. Also, since intact classes were used, students within each group might share similar characteristics as a result of teacher influence, which may potentially inflate treatment effects. The study was conducted exclusively in private boarding schools within Minna, Niger State, selected based on the availability of ICT facilities and comparable infrastructure. Students in private schools may have higher socio-economic backgrounds, greater parental support, and better exposure to technology, which could restrict the generalisation of the study's findings to public schools. The study was conducted in Minna, Niger State; its findings may not be generalized to other regions of Nigeria. The study's intervention lasted for three weeks of instruction, with an additional retention test conducted after two weeks. The study's duration was sufficient to detect immediate and short-term retention effects, but it could not detect long-term learning, retention, and stability of learning outcomes. The study was limited to some chemistry topics such as the periodic table, equilibrium, acids, and bases. The effectiveness of the intervention might vary in other chemistry concepts. The study was also conducted in private boarding schools, and students in boarding schools have more structured study time and supervision, which supports compliance with pre-class video viewing, which might not be feasible in day school settings. Based on the aforementioned limitations, future studies should focus on a larger, more diverse, and broader population of secondary school students. Also, similar studies could be conducted on students in public schools. Similar studies can also be done in other regions of Nigeria. Future studies could adopt a longitudinal design to ascertain the study's intervention for long-term learning, retention, and stability of learning outcomes. Future research could also be conducted on other chemistry topics aside from the periodic table, equilibrium, acids, and bases.

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Research Ethics. The study was conducted in accordance with the standards of the Nigerian national code of research ethics. All the participants provided informed consent to participate in the study and were assured of their confidentiality during the research study. Informed consent to publish the results of the article was also obtained from all individual participants, and the identities of respondents were not disclosed in the study. This study was also conducted in accordance with the ethical guidelines and regulations of the Federal University of Technology (FUT)

Minna, and approved by the FUT Minna review board on 11th of November, 2021, with reference number SSTE/EDU/026, and all procedures were carried out in compliance with applicable ethical standards and the institutional regulations.

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