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Effect of Computer Animation Instruction on Senior School Students' Learning Outcomes in Atomic and Nuclear Physics, Kwara State, Nigeria

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Abstract
This study investigates the impact of computer animation instructional strategy on senior school students' performance and retention in atomic and nuclear physics in Kwara State, Nigeria. The researchers used a pre-test, and post-test design with a non-randomized, non-equivalent control group. The target population comprised all SS3 physics students in Kwara State. Two co-educational public senior secondary schools were selected from two out of the sixteen Local Government Areas in Kwara State, employing a sampling technique that involves multiple stages. Two intact classes, comprising 177 students were involved in the study. The instruments used for data collection were the Atomic and Nuclear Physics Performance Pre-Test (ANPPT I), Atomic and Nuclear Physics Performance Post-Test (ANPPT II), and Atomic and Nuclear Physics Retention Test (ANPRT). The instruments' reliability, carried out by experts, was 0.87. The research questions were answered using mean and standard deviation, and the null hypotheses were tested using the t-test and ANCOVA. The study's findings indicated a significant difference in mean scores between the experimental and control groups, which favoured the experimental group. Additionally, there was a significant difference in mean retention scores between the experimental and control groups, with the experimental group exhibiting higher scores. Notably, neither score level nor gender had a significant impact on either performance or retention. Based on the results, it was suggested that educational authorities at both the Federal and State Ministries of Education should organize workshops and seminars for teachers, focusing on utilizing computer animation as an instructional strategy to enhance students' performance in physics.

Keywords: Atomic and Nuclear Physics, Computer Animation, Score Level, Gender.

Introduction

Physics is a science that utilizes experimental observation and quantitative measurement to comprehend natural events (Mamuda et al., 2023). This branch of science has contributed immensely to solving problems that are faced in the contemporary world. The study of physics has contributed to the economic growth of Nigeria in the areas of Agriculture, healthcare, security, and energy. Adeola et al. (2022) stated that the knowledge of exploration geophysics led to the discovery, extraction, and refining of crude oil which has been the major economic backbone of the Nation. Despite the enormous benefits of physics to the nation, there has not been satisfactory academic performance of students in physics (Onah et al., 2020; Ugwuanyi et al., 2020; Offordile et al., 2021). Students' poor academic outcomes could be due to inadequate retention. Wieman (2023) attributes poor retention to teachers' use of teaching approaches which could not concretize the abstractness of physics concepts. When students cannot remember what they have been taught or have studied, their performance in an examination may be hindered. As asserted by Adonu et al., (2021), if there is no intact storage mechanism developed in the learners, information retrieval may be hindered, and this could consequently result in poor performance. By analyzing specific themes, a deeper understanding can be gained regarding the unsatisfactory performance of students in physics and their poor retention. As reported in the WAEC Chief Examiners' report (2018 & 2019), candidates exhibited poor understanding of atomic and nuclear physics, as a significant portion of candidates either avoided such questions or attempted them poorly. Atomic and nuclear physics is a sub-theme of physics that includes the post-Newtonian

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concept in physics. It is based on relativity and quantum theory, which are breakthroughs of the twentieth century (Wieman, 2023).

Macuácua et al. (2021), and Wieman (2023) noted some difficulties and lack of motivation among students during lessons on this topic as teachers mainly use conventional teaching methods which merely make students sit silently in the classrooms as the teacher narrates the lesson. The main physical activity performed by the students is either note-taking or waiting to respond to any question posed by the teacher (Noreen & Rana, 2019). Due to the abstract nature of atomic and nuclear physics, students tend to have misconceptions. Makiyah (2019) highlighted the presence of misconceptions in atomic physics, which can be reduced by using a suitable instructional approach. López-Segovia et al. (2023) suggested that employing diverse instructional styles is crucial, as a purely conventional approach hampers students' understanding of the underlying physical foundations of atomic and nuclear physics. Teachers need to liken concepts to what can be easily understood by students while teaching atomic physics to ensure that students have a proper understanding (Mustu & Sen, 2019). Teaching embodies an artistic aspect, as it necessitates the utilization of individual talent and creativity. That is why it entails a variety of techniques and procedures. To arrest the shortcomings that could emanate as a result of using the conventional method of teaching alone, many ICT-related teaching strategies such as computer animation. Computer animation, defined as the rapid succession of still images to create the illusion of movement, has been found to captivate students' attention and enhance their motivation to learn (Nwoye & Okeke, 2019). This method entails teachers presenting instructions through graphics, text, audio, and visual files, followed by animations related to the concepts taught.

Computer animation appears to capture learners' interest and boost their motivation to engage in learning. Nwoye and Okeke, 2019) ascertained that our lesson ought to incorporate computer animation because many pupils are stimulated by it daily. The instructional strategy of computer animation entails the teacher presenting lessons through the use of graphics, text, audio, and visual materials (Nwoye & Okeke, 2022). Following the completion of each instructional topic, the corresponding animation illustrating explained ideas will be presented to facilitate understanding, thereby resulting in more effective learning. Studies have shown that integrating animation and multimedia elements into instruction can lead to significant improvements in student performance and retention. For instance, Eguabor and Adeleke (2017) found that using animation alongside textual information in physics classes for secondary school students in Nigeria resulted in substantial performance gains. Similarly, Ameen et al. (2023) demonstrated that multimedia courseware improved students' ability to solve word-problem mathematics questions in contrast to traditional methods. The researchers also observed that females exhibited better retention. Understanding students' proficiency levels through score categorization is crucial, especially when considering the multifaceted influences on academic performance. Score level serves as a means for categorizing students according to their proficiency in particular subjects, dividing them into high, medium, or low achievement groups (Akanmu et al., 2014). The speed of learning and adaptability to new material influenced this categorization. Students' progress in the educational system is measured through a variety of evaluations, including tests and exams. Additionally, Abdulwahab (2014) asserted that educators utilize score levels to evaluate the effectiveness of different teaching methods and interventions in enhancing students' academic performance.

Gender is another variable that has been identified by researchers as a possible influencer of the effect of the use of innovative instructional strategies on the academic performance of students. Gender, according to Acar (2019), refers to an individual's inherent characteristics which enables categorization into male and female whereas gender roles refer to the duties allocated to genders by culture. Gender has been a major discourse due to gender bias in social responsibilities, education, career, income, and healthcare. Science education researchers who have tested the impact of gender as a moderating variable ended up having divergent conclusions.

Statement of the Problem

The inability of students to solve questions on atomic and nuclear physics, and consequent unsatisfactory poor performance in external examinations as reported in the Chief WASSCE Examiners' reports of 2018 and 2019, was pinned on a lack of adoption of modern methodologies such as computer animation instructional strategy among other computer-aided instructional strategies. This unsatisfactory performance was attributed to several factors, such as ineffective teaching methods (Macuácua et al., 2021; Wieman, 2023), unqualified and inexperienced teachers handling the subject (Assem et al., 2023), inadequate utilization of appropriate and effective media resources

(WAEC, 2016; Hanaysha et al., 2023), learners' retention ability (Nwoye & Okeke, 2019), among others. Measures taken through several types of research to address the unsatisfactory performance of students in physics have proved abortive. The problem remains unresolved as reflected in physics students' performance recently. To address the poor performance, alternative teaching strategies like the computer animation instructional strategy, if utilized, could potentially enhance the academic achievement of secondary school students in physics. As a result, the focus of this study is to look into the effects of the use of computer animation instructional strategy on senior school students' performance and retention in atomic and nuclear physics in Kwara State, Nigeria.

Aim and Objectives of the Study

The study aimed to investigate the effects of computer animation instructional strategy on senior school students' performance and retention in atomic and nuclear physics in Kwara State, Nigeria. Specifically, the study sought to determine the:

1. difference in the performance of senior school physics students taught atomic and nuclear physics using computer animation instructional strategy (CAIS) and those taught using conventional teaching method (CTM);
2. difference in the retention of senior school physics students taught atomic and nuclear physics using CAIS and those taught using CTM;
3. influence of gender on the performance of senior school students taught atomic and nuclear physics using CAIS;
4. influence of gender on the retention of senior school students taught atomic and nuclear physics using CAIS.
5. influence of score level on the performance of senior school students taught atomic and nuclear physics using CAIS;
6. influence of score level on the retention of senior school students taught atomic and nuclear physics using CAIS.

Research Questions

The following research questions were raised and addressed.

1. Is there any difference in the performance of senior school physics students taught atomic and nuclear physics using CAIS and those taught atomic and nuclear physics using CTM?
2. Will differences emerge in the retention of secondary school physics students taught atomic and nuclear physics using CAIS and those taught atomic and nuclear physics using CTM?
3. Will differences exist in the performance of male and female students taught atomic and nuclear physics using CAIS?
4. Is there any difference in the retention of male and female students taught atomic and nuclear physics using CAIS?
5. Will there be any difference in the performance of students taught atomic and nuclear physics using CAIS based on score level?
6. Will there be any difference in the retention of students taught atomic and nuclear physics using CAIS based on score level?

Hypotheses

The following hypotheses were tested:

H_{01}: There is no significant difference in the performance of senior school physics students taught atomic and nuclear physics using CAIS and those taught atomic and nuclear physics using CTM;
H_{02}: There is no significant difference in the retention of senior school physics students taught atomic and nuclear physics using CAIS and those taught atomic and nuclear physics using CTM;
H_{03}: There is no significant difference in the performance of male and female students taught atomic and nuclear physics using CAIS;
H_{04}: There is no significant difference in the retention of male and female students taught atomic and nuclear physics using CAIS;
H_{05}: There is no significant difference in the performance of students taught atomic and nuclear physics using CAIS based on score level;

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H_{06}: There is no significant difference in the retention of students taught atomic and nuclear physics using CAIS based on score level.

Materials and Methods

The researchers used a pre-test, and post-test design with a non-randomized, non-equivalent control group. A 2x3x2 factorial research design was employed. The groups received different instructional strategies: one group used computer animation, while the other employed a conventional teaching method. Motivation was a moderating variable at three levels (high, moderate and low motivation) while gender was another moderating variable which is of two categories (male and female). The dependent variables are senior school students' performance and retention in atomic and nuclear physics. The research design outline is shown below.

Research Design Outline

Group	Pre-test	Treatment	Post-test	Retention
Control	O_1	X_1	O_2	O_3
Experimental	O_1	X_2	O_2	O_3

(O_1: pre-test, O_2: post-test, O_3: retention test, X_1: treatment for the Control Group, X_2: treatment for Experimental Group)

The population includes senior secondary school students in Kwara State, Nigeria, with the target being SSIII physics students. The choice of the SSIII students was considered appropriate for the study because the content to be taught (atomic and nuclear physics) is in the SSIII syllabus. Two co-educational schools were selected using multi-stage sampling techniques, with consideration for computer facilities and gender balance. Seven (7) research instruments, namely: Atomic and Nuclear Physics Performance Pre-Test (ANPPT I), Atomic and Nuclear Physics Performance Post-test (ANPPT II), Atomic and Nuclear Physics Retention Test (ANPRT), Animation Videos on Atomic and Nuclear Physics (AVANP), Atomic and Nuclear Physics Lesson Plan for Control Group (ANPLP I), Atomic and Nuclear Physics Lesson Plan for Experimental Group (ANPLP II), and Training Manual for Research Assistance on Computer Animation (TMRACA) were adapted for this study. ANPPT I, ANPPT, II and ANPRT are researcher-developed sets of multiple-choice questions on Atomic and Nuclear Physics. These were used for the pretest, post-test as well as retention test respectively. The instruments consisted of two sections (A and B). Section A collected bio-data of the respondents while B consisted of 40 multiple-choice questions. Each question has four options (A-D) one of which is the correct option. ANPPT I, ANPPT II and ANPRT contained the same questions but printed in different fonts and reordered for each of the pretest, post-test and retention tests. This is to obtain valid data, devoid of the influence of memory and familiarity, and accurately reflect the participants' actual learning or change in knowledge. AVANP are videos on atomic and nuclear physics topics. The videos were downloaded for the students to watch. The permissions to use the animation videos were obtained from the respective authors. ANPLP I and ANPLP II are lesson plans, for control and experimental groups respectively, on the contents of atomic and nuclear physics to be taught and how they were to be taught. These two instruments described the procedure followed in lesson execution in both the control and experimental classes. The two instruments were consciously designed to reflect computer animation for the experimental group and conventional teaching methods for the control group. Finally, the training manual (TMRACA) gave a detailed guide to teachers on how to effectively handle the computer animation class.

The face and content validity of the instruments were done by two physics lecturers from Physics Department, a lecturer from Education Technology Department, both of University of Ilorin, and three experienced secondary school physics teachers and the validity indices were ANPPT I (0.84), ANPPT II (0.84), ANPRT (0.84), AVANP (0.78), ANPLP I (0.76), and TMRACA (0.80) respectively. The reliability of ANPPT I was tested through test-retest methods by administering the instruments to 20 randomly selected senior school three (SSII) students outside the sample of the study but within the population scope within two weeks. The two scores were correlated using Pearson's Product-Moment Correlation (PPMC), and the instrument's reliability index was 0.78. Permission was obtained from school authorities and informed consent from students and teachers. Research assistants were trained to administer tests and implement instructional strategies. The study lasted for ten weeks. Training of the research assistants, week I; administration of pretest, week II, treatments to the two groups simultaneously, weeks III-VI;

administration of post-test, week VII; administration of retention test, week X. Mean, standard deviation, t-tests, and ANCOVA were used to analyze data at a significance level of 0.05 using IBM SPSS software version 29.02.

Results

Research Question 1: Is there any difference in the performance of senior school physics students taught atomic and nuclear physics using computer animation instructional strategy and those taught atomic and nuclear physics using conventional teaching methods? The data obtained on the performance of S.S. Three students taught atomic and nuclear physics using computer animation instructional strategy and those taught atomic and nuclear physics using the conventional teaching method is presented in Table 1.

Table 1: Pre-test and Post-test mean scores for Experimental and Control Groups

Group	N	Pre- Test		Post- Test		Mean Gain	MD
		Mean	SD	Mean	SD		
Experimental	68	8.48	2.73	28.39	1.17	19.91	9.00
Control	109	7.35	2.41	18.26	1.58	10.91	

Table 1 suggests that there was a difference in the performance of senior school physics students taught atomic and nuclear physics using computer animation instructional strategy compared to those taught using conventional teaching methods. Students in the experimental group obtained a mean gain score of 19.91, while those in the control group had 10.91. Notably, there was a difference of 9.00 in the mean gain score, with the experimental group achieving a higher gain.

Hypothesis 1: There is no significant difference in the performance of senior school physics students taught atomic and nuclear physics using computer animation instructional strategy and those taught atomic and nuclear physics using conventional teaching methods.

Table 2: Summary of Analysis of Covariance of Significant Difference in the Performance of Experimental and Control Group

Source	SS	Df	MS	F	p-value
Corrected Model	4553.225[a]	2	2276.613	1097.358	.000
Intercept	8999.579	1	8999.579	4337.920	.000
COVARIATES	1159.172	1	1159.172	558.737	.000
GROUPS	4112.487	1	4112.487	1982.275	.000
Error	360.986	174	2.075		
Total	41434.162	177			
Corrected Total	4914.211	176			

a. R Squared = .927 (Adjusted R Squared = .926)

Table 2 shows that the main effects of the group (computer animation instructional strategy vs conventional teaching method) are significant ($F_{(1,174)} = 1982.275$, $p < 0.05$, suggesting that there is indeed a significant difference in the performance of students in the experimental and control groups in the favour of the experimental group.

Research Question 2: Will differences emerge in the retention of secondary school physics students taught atomic and nuclear physics using computer animation instructional strategy and those taught atomic and nuclear physics using conventional teaching methods?

Table 3: Pre-test and Retention mean scores for Experimental and Control Groups

Group	N	Pre- Test	Retention Test	Mean Gain	Mean

							Difference
		Mean	SD	Mean	SD		
Experimental	68	8.48	2.78	22.09	1.83	13.61	5.79
Control	109	7.35	2.41	15.17	2.11	7.82	

It is indicated in Table 3 that there is a difference in the performance of senior school physics students who were taught atomic and nuclear physics using computer animation instructional strategy compared to those taught using conventional teaching methods. The mean gain score for students in the computer animation instructional strategy group was 13.61, whereas for those in the conventional teaching method group, it was 7.82. The mean difference between the groups is 5.79.

Hypothesis 2: There is no significant difference in the retention of senior school physics students taught atomic and nuclear physics using computer animation instructional strategy and those taught atomic and nuclear physics using conventional teaching methods.

Table 4: Summary of Analysis of Covariance of Significant Difference in the Retention of Experimental and Control Group

Source	SS	Df	MS	F	Sig.
Corrected Model	2635.765[a]	2	1317.883	323.527	.000
Intercept	5900.920	1	5900.920	1448.619	.000
COVARIATES	1231.701	1	1231.701	302.371	.000
SCORE LEVELS	1938.627	1	1938.627	475.914	.000
Error	708.786	174	4.073		
Total	21201.591	177			
Corrected Total	3344.551	176			

a. R Squared = .788 (Adjusted R Squared = .786)

Table 4 shows that the main effect of the group (computer animation instructional strategy vs conventional teaching method) is significant ($F_{(1,174)} = 475.914$, $p < 0.05$), suggesting that there is a significant difference in the retention of students in the experimental group and those in the control group. Therefore, the null hypothesis is rejected. This suggests that there is a significant difference in retention between students taught atomic and nuclear physics using computer animation instructional strategy and those taught with conventional teaching methods.

Research Question 3: Will differences exist in the performance of male and female students taught atomic and nuclear physics using computer animation instructional strategy?

Table 5: Pre-test and Post-test mean scores for Male and Female Students in the Experimental Group

Group	N	Pre- Test		Post test		Mean Gain Score	Mean Difference
		Mean	SD	Mean	SD		
Male	32	8.96	2.19	28.30	0.95	19.34	0.43
Female	36	8.70	3.23	28.47	1.34	19.77	

From Table 5, it can be seen that there is a difference in the performance of male students and female students taught atomic and nuclear physics using computer animation instructional strategy. The mean gain score of male students in the computer animation instructional strategy group is 19.34 while that of female students is 19.77, resulting in a mean difference of 0.43.

Hypothesis 3: There is no significant difference in the performance of male and female students taught atomic and nuclear physics using computer animation instructional strategy.

Table 6: The t-test Analysis of the Performance of Male and Female Students in the Experimental Group.

Group	No	Mean	S D	t-value	df	p-value
Male	32	19.34	2.19	0.634	66	0.528
Female	36	19.77	3.23			

p>0.05

The results of the t-test in Table 6 revealed that there is no significant difference in the performance of male and female students when both were taught using the CALS, $t_{(66)}$ =0.634, $p > 0.05$. Therefore, the null hypothesis was rejected.

Research Question 4: Is there any difference in the retention of male and female students taught atomic and nuclear physics using computer animation instructional strategy?

Table 7: Pre-test and Retention mean scores of Male and Female Students in the Experimental Group

Group	N	Pre-Test Mean	Test SD	Retention Mean	Test SD	Mean Gain	Mean Difference
Male	32	8.24	2.19	22.13	2.05	13.89	0.53
Female	36	8.70	3.23	22.06	1.64	13.36	

Table 7 shows that there was a difference in the retention of male and female students taught atomic and nuclear physics using computer animation instructional strategy. The mean gain score for males was 13.89, while that of female students was 13.36 which resulted in a mean difference of 0.53.

Hypothesis 4: There is no significant difference in the retention of male and female students taught atomic and nuclear physics using computer animation instructional strategy.

Table 8: The t-test Analysis of the Retention of Male and Female Students in the Experimental Group.

Group	No	Mean	S D	t-value	df	p-value
Male	32	13.89	2.19	0.78	66	0.437
Female	36	13.36	3.23			

p < 0.05

The results of the t-test in Table 8 revealed that there is no significant difference in the performance of male and female students when both were taught using the CALS, $t_{(66)}$ =0.78, $p > 0.05$. The null hypothesis is rejected.

Research Question 5: Will there be any difference in the performance of students taught atomic and nuclear physics using computer animation instructional strategy based on score level?

Table 9: Pre-test and Post-test mean scores of High, Medium and Low Scorers in the Experimental Group

Group	N	Pre-Test Mean	Test SD	Post Mean	Test SD	Mean Gain Score
High Scorer	20	9.18	3.03	28.11	0.88	18.93
Medium Scorer	30	8.67	2.50	28.51	1.06	19.84
Low Scorer	18	7.39	2.77	28.51	1.57	21.12

Table 9 showed that there were differences in the performance of high, medium and low scorers among the students taught atomic and nuclear physics using computer animation instructional strategy. The mean gain scores of high, medium and low were 18.93, 19.84 and 21.12 respectively.

Hypothesis 5: There is no significant difference in the performance of students taught atomic and nuclear physics using computer animation instructional strategy based on score level.

Table 10: Summary of Analysis of Covariance of Significant Difference in the Performance of Low, Medium and High Scorers in the Experimental Group

Source	SS	Df	MS	F	p-value
Corrected Model	516.657[a]	3	172.219	123.839	.000
Intercept	4944.925	1	4944.925	3555.780	.000
COVARIATES	471.122	1	471.122	338.773	.000
SCORE LEVELS	2.405	2	1.202	.865	.426
Error	89.003	64	1.391		
Total	27556.556	68			
Corrected Total	605.660	67			

a. R Squared = .853 (Adjusted R Squared = .846)

Table 10 indicates that the p-value exceeds 0.05. Therefore, the null hypothesis is not rejected. This means there is no significant difference in the performance of students taught atomic and nuclear physics using computer animation instructional strategy based on score level.

Research Question 6: Will there be any difference in the retention of students taught atomic and nuclear physics using computer animation instructional strategy based on score level?

Table 11: Pre-test and Retention mean scores of High, Medium and Low Scorers in the Experimental Group

Group	N	Pre-Test Mean	Pre-Test SD	Retention Test Mean	Retention Test SD	Mean Gain Score
High Scorer	20	9.18	3.03	22.50	2.15	13.32
Medium Scorer	30	8.67	2.50	21.98	1.87	13.31
Low Scorer	18	7.39	2.77	21.82	1.36	14.43

Table 11 showed that there was a difference in the performance of high, medium and low scorers among the students taught atomic and nuclear physics using computer animation instructional strategy. The mean gain scores of high, medium and low were 13.32, 13.31 and 14.43 respectively.

Hypothesis 6: There is no significant difference in the retention of students taught atomic and nuclear physics using computer animation instructional strategy based on score level.

Table 12: Summary of Analysis of Covariance of Significant Difference in the Performance of Low, Medium and High Scorers in the Experimental Group

Source	SS	Df	MS	F	Sig.
Corrected Model	561.673[a]	3	187.224	54.821	.000
Intercept	3166.738	1	3166.738	927.244	.000
Covariates	545.329	1	545.329	159.676	.000
SCORE LEVELS	6.068	2	3.034	.888	.416
Error	218.574	64	3.415		
Total	13376.280	68			
Corrected Total	780.247	67			

a. R Squared = .720 (Adjusted R Squared = .707)

As revealed in Table 12, the effect of score level on performance was not statistically significant ($F_{(2, 64)} = 0.89$, $p > 0.05$). This suggests that there is no significant difference in the retention of students taught atomic and nuclear physics using computer animation instructional strategy based on their score level (low, medium, or high).

Discussion

This study revealed a significant difference in the performance of students taught atomic and nuclear physics using Computer Animation Instructional Strategy (CAIS) compared to those taught using the Conventional Teaching Method (CTM). The mean gain scores indicated that students in the CAIS group outperformed those in the CTM group, suggesting that CAIS may offer a more effective approach to teaching complex physics concepts. This echoes findings from Eguabor and Adeleke, who also reported substantial improvements in student performance with the use of animation-based teaching strategies. The results showed a significant difference in retention, with students in the CAIS group demonstrating higher mean gain scores compared to the CTM group. This indicates that CAIS not only facilitates initial learning but also contributes to longer-term retention of physics concepts. The findings of this study align with Ameen et al. (2023), who submitted that students exposed to multimedia courseware outperformed and had better retention than those taught using traditional methods.

Similarly, the results indicated a significant difference, with female students achieving slightly higher mean gain scores in performance, while males retained better than female students in the retention. However, it's important to note that both male and female students benefited from CAIS, indicating its effectiveness regardless of gender. Lastly, on the impact of score level on performance and retention among students taught with CAIS, the results indicated no significant difference in performance or retention based on score level, suggesting that CAIS is equally beneficial for students across different levels of academic proficiency.

Conclusion

In conclusion, the findings of this study provide strong evidence supporting the effectiveness of Computer Animation Instructional Strategy (CAIS) in improving the performance and retention of senior school students in atomic and nuclear physics. The results demonstrated that students taught with CAIS outperformed those taught with the Conventional Teaching Method (CTM) and exhibited higher levels of retention. Furthermore, this study found that females tended to improve a bit more right away with the CAIS, while males seemed to remember the material better over time. However, both male and female students benefited from using the CAIS, showing that it's effective irrespective of gender. Additionally, students at different levels of academic proficiency showed comparable improvements when taught with CAIS, indicating its versatility and effectiveness across diverse student populations. These findings underscore the potential of computer animation as a valuable instructional tool in physics education, particularly in regions such as Kwara State, Nigeria. Implementing CAIS in physics classrooms can enhance student engagement, comprehension, and long-term retention of complex scientific concepts, ultimately contributing to improved academic achievement and scientific literacy among senior school students.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Educational policymakers and curriculum developers ought to explore the integration of Computer Animation Instructional Strategy (CAIS) into senior secondary school physics curricula. By infusing CAIS into lesson plans and educational materials, educators stand to enrich the learning environment and enhance student proficiency in atomic and nuclear physics.
2. Educators must receive comprehensive training and professional development opportunities to adeptly implement CAIS in their classrooms. Through a diverse range of learning platforms such as workshops, seminars, and online courses, teachers can acquire the requisite skills and knowledge to effectively utilize computer animation tools, thereby fostering a dynamic and captivating learning atmosphere for students.
3. Steps must be taken to ensure equitable access to technology and digital resources within school communities. Providing schools with adequate computer systems and infrastructure can facilitate the seamless integration of CAIS, thereby affording all students, regardless of socioeconomic status, the opportunity to benefit from enhanced learning experiences.
4. It is crucial to maintain ongoing assessment and evaluation of the efficacy of CAIS implementation. School administrators and educational authorities should conduct regular evaluations to assess student performance

and retention in physics. Utilizing a blend of quantitative and qualitative assessment methods will enable a comprehensive understanding of the impact of CAIS on learning outcomes.

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