IMPACT OF VIRTUAL LABORATORY INSTRUCTIONAL STRATEGY ON SENIOR SCHOOL STUDENTS' PERFORMANCE IN MODERN PHYSICS IN NORTH CENTRAL, NIGERIA

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Abstract
This research examined the efficacy of virtual laboratory on senior school students' performance in modern physics in North Central, Nigeria. The target population is all senior secondary school students. Employing a multi-stage sampling technique, two out of the six states in the North Central Region were randomly selected, and then two co-educational senior schools were selected from the capital cities of the selected state by purposive sampling technique, with a total of 158 students from two intact classes participating. Participants underwent the Modern Physics Performance Pre-test (MPPT I), comprising 40 multiple-choice questions. Subsequently, for four weeks, the experimental group received instruction utilizing virtual laboratory instructional strategy (VLIS), while the control group received instruction through traditional teaching methods (TTM). Modern Physics Performance Post-test (MPPT II) was conducted a week later. The instruments had a reliability coefficient of 0.87. Research questions were answered using mean and standard deviation, and t-tests and ANCOVA assessed the null hypotheses. Results showed a significant difference in mean scores favoring the experimental group. Academic motivation and gender did not significantly influence performance. Based on these findings, it is recommended that educational authorities organize workshops and seminars for educators to promote VLIS, thereby enhancing students' physics performance.

Keywords: Modern physics, virtual laboratory, academic motivation, gender.

Introduction

In Nigeria, students are introduced to basic science at the upper basic level, covering elementary concepts in biology, chemistry, and physics. At the senior secondary school level, physics becomes a distinct subject within the Nigerian Senior Secondary School curriculum. The importance of physics is underscored by the admission requirements of Nigerian tertiary institutions. These institutions, as stated by Shehu, et al. (2024), mandate that students aiming to study engineering, computer science, aeronautics, and similar fields must secure a good grade in physics in exams like the West African Senior School Certificate Examination (WASSCE), Senior School Certificate Examination (SSCE), or their equivalents, and must achieve the necessary cut-off score in the Unified Tertiary Matriculation Examinations (UTME). Nwoye et al. (2019) describe physics as a scientific discipline dedicated to explaining the cause-and-effect relationships between matter and energy, as well as their application to natural phenomena. This field has greatly aided problem-solving in the modern world. Adeola et al. (2022) emphasized that knowledge in exploration geophysics has facilitated the discovery, extraction, and refining of crude oil, which plays a critical role in driving Nigeria's economy. Despite the significant contributions of physics and interdisciplinary courses to national development, recent secondary school student performance has been disappointing, as observed by Onah et al. (2020), Ugwuanyi et al. (2020), and Offordile et al. (2021).

Modern physics, broadly encompassing topics in atomic and nuclear physics, is often a challenging area for students due to its abstract nature. According to WAEC Chief Examiners' reports (2018, 2019), candidates demonstrated poor understanding of atomic physics, with many either avoiding related questions or answering them poorly. The abstractness of the modern physics topics resulted to misconceptions. Makiyah (2019) noted the prevalence of misconceptions in modern physics, which can be reduced through the use of appropriate instructional methods. López-Segovia et al. (2023) argued that employing diverse instructional styles is essential, as relying solely on conventional methods hinders students' grasp of the fundamental principles of modern physics. Mustu and Sen (2019) emphasized that teachers should relate concepts to easily understandable contexts when teaching modern physics to ensure students have a proper understanding. The objectives of an educational process determine the content, materials, and instructional methods required to achieve those goals. Many science teachers frequently utilize the traditional teaching method (TTM), which is characterized by teacher-centered instruction. In this approach, the teacher directs the teaching-learning process while students generally remain passive recipients of knowledge. Bo et al. (2022) highlighted that in traditional teaching environments, the teacher mainly delivers information and knowledge to students, who primarily engage by listening. Noreen and Rana (2019) observed that in traditional classrooms, students sit silently while the teacher delivers the lesson, speaking only when prompted by the teacher. This setup limits learners to merely replicating what the teacher says or writes on the board, thus impeding their ability to process information through thinking, evaluating, and investigating. The primary physical activities students engage in are either taking notes or waiting to answer questions posed by the teacher (Noreen & Rana, 2019). A virtual laboratory is a computer program that allows students to conduct simulated experiments using the web, software, or smartphone applications. Ojo and Owolabi (2020) described a virtual laboratory as a computer-based instructional strategy comprising simulated experiments that enable students to perform experiments in a virtual environment using computer programs. The use of virtual laboratory could address misconceptions encountered by students. As reported by Famuwagun and Mohammed (2020), students exposed to a virtual laboratory instructional package in science subjects performed better than those taught by conventional methods. Similarly, Falode et al. (2020) discovered that virtual laboratories were considered innovative and user-friendly for physics education in Nigerian secondary schools, although their interactivity was rated lower.

Mochama et al. (2020) reported significantly higher post-test scores for students trained with the Virtual Physics Laboratory (VPL) compared to those without, with no significant gender-based score differences. Also, Lasisi et al. (2021) showed that computer-simulated instruction improved understanding of abstract science concepts compared to traditional lectures, with no significant gender-based performance differences. Babalola and Alabi (2021) revealed that students using a virtual physics laboratory outperformed their peers taught traditionally, with female students performing particularly well. As reorted by Samosa (2021), virtual laboratories act as a catalyst for authentic experimentation, transforming the educational landscape. These digital labs, accessible via mobile phones, not only optimize instructional time but also reduce the need for hazardous and expensive equipment. Additionally, they enable students to undertake advanced investigations that were previously beyond the reach of secondary school classrooms. The effectiveness of any instructional intervention largely depends on the inherent characteristics of individual learners, such as intrinsic and extrinsic motivation. Naz et al. (2021) defined academic motivation as the internal processes that drive and sustain learners' engagement in activities aimed at achieving specific academic goals. It reflects students' willingness to engage in the learning process. Highly motivated students are typically more attentive, persistent, and successful in classroom activities and assignments compared to their less motivated peers (Yustina et al., 2020). Thus, motivation involves encouraging the desire to learn, and feeling motivated means that students align themselves with the learning objectives.

Gender is another variable identified by researchers as a potential influencer on the effectiveness of innovative instructional strategies on students' academic performance. Science education researchers who have examined gender as a moderating variable have reached differing conclusions. Nwankwo and Madu (2014) studied the impact of the analogy instructional technique on students' conceptual understanding of light refraction in physics. Their findings showed that female students outperformed male students in the Physics Concept Test (PCT).

Statement of the Problem

Amidst the educational challenges faced by senior secondary students in North Central, Nigeria, a pressing concern arises regarding their performance in physics. Despite the urgency of addressing this issue, there exists a significant gap in understanding how instructional strategies, notably those involving computer animations, can effectively support students in mastering physics concepts. This alarming situation is compounded by existing reports highlighting the widespread difficulty students' encounter in comprehending abstract concepts in physics, especially, modern physics, ultimately impacting their academic performance and future opportunities. Existing studies have underscored the challenge students' face in grasping atomic physics concepts, as evidenced by the WAEC Chief Examiner's Reports and academic literature. Many students struggle with abstract concepts, resulting in poor performance and avoidance of atomic physics questions. Consequently, there is a growing recognition of the importance of adopting modern instructional methodologies with adequate demonstration to improve students' comprehension and engagement with modern physics concepts.

However, a comprehensive analysis of the effectiveness of computer animation instructional strategy, specifically in the context of modern physics in North Central, is currently lacking. This study aims to fill this gap by examining whether the integration of this innovative instructional approach leads to significant improvements in students' academic outcomes. Through these efforts, we aim to enhance science education practices and improve learning outcomes for senior school students in North Central, while also shedding light on the potential moderating influence of students' academic motivation and gender on the outcomes of computer animation instructional strategy in the context of modern physics.

Objectives of the Study

The objectives of the study are to determine the:

1. difference in the performance of students taught modern physics using virtual laboratory instructional strategy (VLIS) and those taught using traditional teaching method (TTM);
2. Influence of academic motivation on the performance of students taught modern physics using VLIS;
3. Influence of gender on the performance of students taught modern physics using VLIS.

Research Questions

The following research questions were posed and answered:

1. What is the difference in the performance of students taught modern physics using VLIS and those taught modern physics using TTM?
2. What is the difference in the performance of students taught modern physics using VLIS based on academic motivation?
3. What is the difference in the performance of male and female students taught modern physics using VLIS?

Research Hypothesis

The following hypotheses were formulated and tested:

H_{01}: There is no significant difference in the performance of students taught modern physics using VLIS and those taught modern physics using TTM;

H_{02}: There is no significant difference in the performance of students taught modern physics using VLIS based on academic motivation;

H_{03}: There is no significant difference in the performance of male and female students taught modern physics using VLIS.

Methodology

This study utilized a quasi-experimental research design, specifically employing a pre-test, post-test, non-randomized, non-equivalent control group design. A 2x3x2 factorial research design was employed, with groups receiving different instructional strategies: one group utilized virtual laboratory instruction, while the other employed traditional teaching methods. Moderating variables included motivation, categorized into three levels, and gender, categorized into two levels. The dependent variable assessed was the performance of senior school students in modern physics. The population under consideration comprises senior secondary school students located in North Central, Nigeria, while the target population is SSIII physics students. The selection of SSIII students was deemed suitable for the study due to the inclusion of modern physics content within the SSIII syllabus. Two co-educational schools were chosen using multi-stage sampling techniques, with careful attention given to factors such as computer facility availability and gender balance. Six research instruments were employed, including the Modern Physics Performance Pre-test (MPPT I), Modern Physics Performance Post-test (MPPT II), Virtual Laboratories of Modern Physics (VLMP), Modern Physics Lesson Plan for

the Control Group (MPLP I), Modern Physics Lesson Plan for the Experimental Group (MPLP II), and Training Manual for Research Assistance in Virtual Laboratory (TMRAVL). The face and content validity of the instruments were assessed by two physics lecturers from the Physics Department, a lecturer from the Education Technology Department, all from the University of Ilorin, along with three experienced secondary school physics teachers. The validity indices obtained for the six instruments were 0.84, 0.84, 0.84, 0.78, 0.76, and 0.80, respectively. To evaluate the reliability of MPPT I, a test-retest method was employed, involving the administration of the instrument to 20 randomly selected senior school three (SSIII) students outside the study sample but within the population scope, with an interval of two weeks between administrations. The scores obtained were then correlated using Pearson's product-moment correlation (PPMC), resulting in a reliability index of the instrument, r = 0.78.
Permission is obtained from school authorities and informed consent forms were given to students and teachers. Research assistants were trained to administer tests and implement instructional strategies. The study lasted for seven weeks. Training of the research assistants, week I; administration of pretest, week II; treatments to the two groups simultaneously, weeks III- VI; and administration of post-test, week VII. Mean, standard deviation, t-tests, and ANCOVA are used to analyze data, with a significance level of 0.05, employing IBM SPSS software version 23.

Results

Research Question 1: What is the difference in the performance of senior school physics students taught modern physics using VLIS and those taught modern physics using TTM?

Table 1

Pre-test and Post-test mean scores for Experimental and Control Groups

Group	*N*	Pre- Test		Post- Test		Mean Gain Score	Mean Difference
		Mean	*SD*	Mean	*SD*		
Experimental	49	10.30	3.60	30.66	1.50	20.36	9.55
Control	109	7.26	2.42	18.07	1.66	10.81	

It is indicated in table 1 that the mean gain score of students in the VLIS group stood at 20.36, whereas for those in the TTM group, it was 10.81. The mean difference between the groups is 9.55 indicating a superior performance of the VLIS group.

Hypothesis 1: There is no significant difference in the performance of senior school physics students taught modern physics using VLIS and those taught modern physics using TTM.

Table 2

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

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	4346.01[a]	2	2173.00	831.73	.00
Intercept	8645.79	1	8645.79	3309.21	.00
Pretest	1264.60	1	1264.60	484.03	.00
Groups	4296.52	1	4296.52	1644.51	.00
Error	404.96	155	2.61		
Total	34731.05	158			
Corrected Total	4750.97	157			

a. R Squared = .915 (Adjusted R Squared = .914)

Table 2 shows that the F-value ($F_{(1,155)} = 1644.51$, $p < .05$) was significant, as the *p*-value of .00 is less than .05 alpha level, as shown in Table 2. This means that there is statistically significant difference in the performance of students taught modern physics using VLIS and those taught using TTM.

Research Question 2: What is the difference in the performance of students taught modern physics using VLIS based on academic motivation?

Table 3

Pre-test and Post-test mean scores of High, Moderate and Low Motivation Students in the Experimental Group

Group	*N*	Pre-Test Mean	Pre-Test *SD*	Post-Test Mean	Post-Test *SD*	Mean Gain Score
High Motivation	18	10.26	3.60	30.66	1.50	20.40
Moderate Motivation	24	10.36	3.85	30.56	1.76	20.20
Low Motivation	7	10.18	3.18	31.52	1.08	21.34

Table 3 showed that there were differences in the performance of high, moderate and low motivation among the students taught modern physics using VLIS. The mean gain scores of high, moderate, and low motivation students are 20.40, 20.20, and 21.34 respectively, with low motivation group achieving best. The low motivation group had the highest mean gain score.

Hypothesis 2: There is no significant difference in the performance of students taught modern physics using VLIS based on academic motivation.

Table 4

Summary of Analysis of Covariance of Significant Differences in the Performance of Low, Moderate, and High Motivation Students in the Experimental Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	579.22[a]	3	193.07	85.74	.000
Intercept	4712.29	1	4712.29	2092.75	.000
Pretest	571.35	1	571.35	253.74	.00
Motivation	6.29	2	3.15	1.40	.26
Error	101.33	45	2.25		
Total	20995.45	49			
Corrected Total	680.54	48			

a. R Squared = .851 (Adjusted R Squared = .841)

It can be seen in Table 4 that the *p-value* associated with motivation (0.26) is greater than .05. Hence, hypothesis 2 was not rejected. This means that there is no statistically significant difference in performance attributable to motivation levels.

Research Question 3: **What is the difference in the performance of male and female students taught modern physics using VLIS?**

Table 5

Pre-test and Pre-test mean scores of Male and Female Students in the Experimental Group

Group	*N*	Pre- Test		Retention Test		Mean Gain Score	Mean Difference
		Mean	*SD*	Mean	*SD*		
Male	23	9.58	3.77	30.29	1.49	20.71	0.67
Female	26	10.94	3.38	30.98	1.47	20.04	

From table 5, it can be seen that there is a difference in the performance of male students and female students taught modern physics using VLIS. The mean gain score of male students in the VILS group is 20.71 while that of female students is 20.04, resulting to a mean difference of 0.67.

Hypothesis 3: There is no significant difference in the performance of male and female students taught modern physics using VLIS.

Table 6

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

Group	*N*	Mean	*S D*	t-value	*df*	*p-value*
Male	23	20.71	3.77	0.66	47	0.515
Female	26	20.04	3.38			

P < 0.05

The results of the t-test in table 6 revealed that there is no statistically significant difference in the performance of male and female students when both were taught using the VLIS, $t_{(47)} = .66$, $p > .05$.

Discussions

The findings of this research demonstrate a significant difference in the performance of students instructed in modern physics utilizing Virtual Laboratory Instructional Strategy (VLIS) compared to those taught through Traditional Teaching Method (TTM). The mean gain scores unequivocally illustrate that students exposed to VLIS surpassed their counterparts in the TTM group, implying that VLIS could present a superior method for imparting intricate physics concepts. This is in line with the findings of Ojo and Owolabi (2020) and Babalola and Alabi(2020), who found that the virtual laboratory strategy enhanced students' performance in physics, but it is not consistent with the findings of Hamed and Aljanazrah (2020), who submitted that the virtual laboratory produced no better result than the traditional method when used to teach students. It is obvious from the findings that academic motivation does not determine the performance of students exposed to VLIS, as the result shows that there is no statistically significant difference in the performance of students taught modern physics using VLIS based on academic motivation levels. Similarly, there was no significant difference in the performance of male and female students taught using modern physics through VLIS. This implies that students' gender is not an influencing factor in the performance of students taught modern physics using VLIS. This aligns with the findings reported by Lasisi et al. (2020) and Mochama et al. (2020), who found that gender-based differences do not play a significant role in physics students' performance, but it is contrary to Babalola and Alabi (2021), who declared that female students exhibited better performance compared to male students.

Conclusion

In conclusion, this study provides valuable insights into the effectiveness of Virtual Laboratory Instructional Strategy (VLIS) in improving students' performance in modern physics education. The findings not only highlight the considerable potential of VLIS as an instructional strategy but also underscore its role in fostering a deeper understanding of complex scientific concepts and enhancing students' practical skills in physics. Moreover, our results suggest that VLIS may transcend barriers related to academic motivation levels, as it appears to be equally beneficial for students with varying levels of motivation. Additionally, our study reveals that VLIS shows promise in promoting equitable learning outcomes across different gender groups, suggesting that it can serve as an inclusive educational tool that caters to the diverse needs of students. These findings offer valuable insights for educators and policymakers seeking to leverage innovative instructional approaches to enhance the quality and inclusivity of physics education.

Recommendation

Based on the findings of this research, the following recommendations are proposed:

1. Students should actively engage with Virtual Laboratory Instructional Strategy (VLIS) by utilizing all available resources, collaborating with peers, and seeking feedback from teachers. Regular practice with virtual labs and maintaining a positive, open-minded attitude towards this innovative learning approach will help deepen their understanding of complex physics concepts and improve their overall performance.
2. Teachers should be provided with comprehensive training and ongoing professional development to effectively implement and utilize VLIS. This will ensure that educators are well equipped to maximize the potential benefits of this instructional strategy.
3. Educational institutions should consider incorporating VLIS into their physics curricula. Given the significant improvement in student performance demonstrated by this study, VLIS presents a promising alternative to traditional teaching methods for teaching abstract physics concepts.
4. Policymakers and educational authorities should support the adoption of VLIS by allocating necessary resources and infrastructure. This includes providing schools with the technological tools and internet connectivity required to successfully implement virtual laboratories.
5. The study's findings indicate that VLIS can promote equitable learning outcomes irrespective of students' gender or academic motivation levels. Therefore, educational programs should emphasize the inclusive nature of VLIS to ensure that all students have equal opportunities to benefit from this innovative teaching approach.

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