VIRTUAL LEARNING ENVIRONMENT: A PATHWAY TO ENHANCING PHYSICS AND INTEGRATED SCIENCE UNDERSTANDING IN SOUTH-WESTERN NIGERIAN UNIVERSITIES

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Abstract

The integration of Virtual Learning Environments (VLEs) into higher education has significantly transformed instructional delivery, particularly in science education, which requires conceptual depth and abstract reasoning. This study investigates the role of the virtual classroom as a pathway to enhancing students' understanding of Physics and Integrated Science in South-western Nigerian universities. Anchored in constructivist and multimedia learning theory, the research adopted a quantitative survey design involving undergraduate science education students across six South-western Nigerian States. Using descriptive statistics, Pearson correlation, independent samples t-test, and regression analyses, it provided answers to four research questions and tested two hypotheses. A twenty-item questionnaire of four points Likert scale was engaged via online Google form, to elicit information from respondents. To examine how participation in virtual classroom settings influences conceptual understanding and academic engagement while exploring the moderating effect of school type (federal vs state universities) a total number of 206 science education students constituted the sample. The research instrument was face-validated by experts in tests and measurement and an empirical reliability of 0.83 Cronbach's Alpha was obtained through a pilot study in a university different from the population. Findings revealed that structured and interactive virtual classroom environments significantly enhanced students' comprehension of complex Physics and Integrated Science concepts, with no variations observed between federal and state universities in spite of their differences in infrastructure, instructional support, and digital readiness. The study provides empirical insight which shows that the benefits of virtual classroom engagement are consistent across institutional types. Following this, the study recommended among others that university administrators institutionalize structured virtual classroom engagement strategies in science courses.

Keywords: Virtual Learning, Physics, Integrated Science, Understanding

Introduction

The rapid expansion of digital technologies has redefined pedagogical practices in higher education, globally. Virtual Learning Environments (VLEs) have become central to instructional delivery, specifically following the disruptions caused by the COVID-19 pandemic (Aleedy, Atwell, & Meshoul, 2022). Among the various forms of VLEs, the virtual classroom, a synchronous, technology-mediated instructional space where teachers and students interact in real time, has emerged as a prominent model for teaching and learning (Bawan, Kamgba, & Obi, 2024). Unlike static e-learning platforms, virtual classrooms integrate live video conferencing, screen sharing, digital whiteboards, breakout rooms, and instant feedback mechanisms, thereby approximating face-to-face instruction while leveraging digital convenience. Science education, particularly in subjects such as Physics and Integrated Science, presents unique instructional challenges due to the abstract, mathematical, and experimental nature of the content. Adejuyigbe, Ukoh, and Okeke (2025) submitted that students often struggle with conceptual understanding, problem-solving, and application of principles when instruction is predominantly lecture-based. Virtual classrooms, when effectively designed, can enhance visualization through simulations, encourage collaborative problem-solving, and provide immediate clarification of misconceptions. Research indicates that interactive online environments promote deeper cognitive processing and improved conceptual understanding in STEM disciplines (Babajide, Adeyemo, & Omosule, 2024).

Virtual classroom engagement as used in this study is conceptualized in terms of interactivity, instructor presence, collaborative learning opportunities, and real-time feedback. These features are linked to active learning principles and social constructivist theory, which posit that knowledge is constructed through interaction and dialogue. Studies show that when students actively participate in virtual classrooms, their cognitive engagement and academic performance significantly improve (Jing, 2023). There is no gainsaying the fact that understanding of Physics and Integrated Science concepts, goes beyond rote memorization to include conceptual clarity, application of scientific principles, and problem-solving competence. Contemporary science education emphasizes conceptual change and meaningful learning, rather than procedural recall (Lee & Lee, 2021). Virtual classrooms can support this through multimedia explanations, live demonstrations, and guided inquiry activities aligned with Mayer's Multimedia Learning principles (Zhang, 2023). However, the effectiveness of virtual classrooms may not be uniform across institutional contexts. In Nigeria, disparities exist between federal and state universities in terms of funding, digital infrastructure, internet bandwidth, and staff training (Onyema et al., 2021; Okeke & Ibrahim, 2024). Federal universities, funded by the national government, often have relatively better access to educational technologies and structured ICT support systems. In contrast, state universities may experience infrastructural and financial constraints that limit optimal implementation of virtual classroom systems. This institutional disparity introduces school type (federal vs state universities) as a moderating variable in the relationship between virtual classroom engagement and students' conceptual understanding. A moderator variable influences the strength or direction of a relationship between independent and dependent variables. Adejumo & Akanbi, (2022) opined that it is plausible that the impact of virtual classroom engagement on science understanding may be stronger in federal universities where technological support systems are more stable, compared to state universities where connectivity challenges and limited digital resources may constrain learning effectiveness.

In South-western Nigeria, home to a high concentration of both federal and state universities, the need to enhance science education is particularly urgent due to national demands for STEM-driven innovation and development. While virtual classrooms offer promising pedagogical benefits, empirical evidence is required to determine whether they truly enhance Physics and Integrated Science understanding across different institutional settings. Addressing this gap is critical for ensuring equitable and effective digital transformation in Nigerian higher education.

Succinctly put, virtual classrooms represent a strategic pathway for strengthening science education, but their success depends on both pedagogical design and institutional context. Examining their role in enhancing Physics and Integrated Science understanding, while accounting for school type as a moderating factor, provides valuable insight for policy formulation, instructional improvement, and digital equity in South-western Nigerian universities.

The theoretical framework for this study is anchored primarily on Constructivism and the Cognitive Theory of Multimedia Learning developed by Richard E. Mayer. Constructivism posits that learners actively construct knowledge through interaction, collaboration, and engagement with learning tasks rather than passively receiving information. Within the context of a virtual classroom, this theory explains how synchronous discussions, breakout sessions, shared digital whiteboards, and real-time questioning foster active meaning-making in Physics and Integrated Science. The theory assumes that conceptual understanding in science emerges when learners interact socially, test ideas, confront misconceptions, and refine their thinking through guided facilitation (Adejumo &

Akanbi, 2022). Thus, virtual classroom engagement (interactivity, instructor presence, collaborative learning, and feedback) becomes a mechanism for deeper cognitive processing and conceptual change.

Complementing this perspective, the Cognitive Theory of Multimedia Learning explains how students process information presented through words, images, animations, and simulations within virtual classrooms. The theory is based on three key assumptions: dual-channel processing (visual and auditory), limited cognitive capacity, and active processing. In Physics and Integrated Science, subjects characterized by abstract concepts and symbolic representations, well-designed multimedia instruction in virtual classrooms can reduce cognitive overload and enhance both thematic and schematic constructions.

Research Objectives

The objectives of the study are to:

1. Examine the level of students' engagement in virtual classroom environments for physics and integrated science in South-western Nigerian universities
2. Explore the extent to which participation in virtual classrooms enhances students' understanding of physics and integrated science
3. Determine the relationship between virtual classroom engagement (interactivity, instructor presence, collaborative activities, and real-time feedback) and students' understanding of physics and integrated science concepts
4. Explore how virtual classroom participation influences students' problem-solving ability and application of scientific principles in physics and integrated science

Research Questions

1. What is the level of students' engagement in virtual classroom environments for physics and integrated science in South-western Nigerian universities?
2. To what extent does participation in virtual classrooms enhance students' understanding of physics and integrated science?
3. What is the relationship between virtual classroom engagement (interactivity, instructor presence, collaborative activities, and real-time feedback) and students' understanding of physics and integrated science concepts?
4. How does virtual classroom participation influence students' problem-solving ability and application of scientific principles in physics and

integrated science?

Research Hypotheses

1. There is no significant difference in the effectiveness of virtual classrooms on students' understanding of physics and integrated science between federal and state universities
2. School type (federal vs state universities) does not moderate the relationship between virtual classroom engagement and students' understanding of physics and integrated science

Method

The study adopted a descriptive survey design with a correlational approach. The population comprises all university physics education and integrated science students across six south-western Nigerian states (Lagos, Oyo, Ogun, Osun, Ondo, and Ekiti), while a sample size of 206 was engaged in the study. A multistage sampling procedure was employed thus: stage one was stratified sampling, where universities were stratified into categories: federal and state**.** Stage two was random assignment of institutions, where a proportional number of universities offering physics education and integrated science were randomly selected from each stratum, while stage three was student selection, where within selected institutions, students enrolled in physics and integrated science courses were selected using simple random sampling.

Data were collected using a structured questionnaire titled "Virtual Classroom and Science Understanding Questionnaire (VCSUQ)" via online google form. A pilot study was conducted outside the sampled institutions, and a Cronbach's Alpha of 0.83 reliability coefficient was obtained for internal consistency. A Cronbach's Alpha above 0.7 and a benchmark of average scores are considered acceptable for internal consistency and mean rating (Adejumo & Akanbi, 2022).

Results

Research Question One: What is the level of students' engagement in virtual classroom environments for physics and integrated science in South-western Nigerian universities?

Table 4.1: Students' Engagement in Virtual Classroom by Discipline (n = 206)

S/N	Engagement Items	Physics (n = 77) Mean ± SD	Int. Science (n = 129) Mean ± SD	Decision
1.	I use chat features or reaction tools to interact during virtual classes	12.48 ± 0.81	13.00 ± 0.75	High

2.	I remain attentive throughout most virtual classroom sessions	12.92 ± 0.89	12.82 ± 0.83	High
3.	I contribute ideas during virtual classroom activities	16.73 ± 0.77	15.91 ± 0.89	V. High
4.	I ask questions when I do not understand concepts during virtual sessions	12.74 ± 0.91	12.88 ± 0.76	High
5.	I rarely participate in discussions during virtual classroom sessions	9.81 ± 0.70	9.99 ± 0.86	Low
	Grand Mean	**12.94± 0.82**	**12.92 ± 0.77**	**High**

The results in Table 4.1 show that Physics students recorded a grand mean of 12.94 (SD = 0.82), while Integrated Science students recorded 12.92 (SD = 0.77). Both values are slightly above the benchmark mean of 12.5, indicating that students in both cohorts demonstrate a high level of engagement in virtual classroom environments. The closeness of the grand mean scores further suggests that there is no substantial difference in engagement levels between Physics and Integrated Science students. Overall, the findings imply that virtual classroom participation is positively embraced by students across both disciplines in South-western Nigerian universities.

Research Question Two: To what extent does participation in virtual classrooms enhance students' understanding of physics and integrated science?

Table 4.2: Extent to Which Virtual Classroom Enhances Students' Understanding (n = 206)

S/N	Items	Physics (n = 77) Mean ± SD	Int. Science (n = 129) Mean ± SD	Decision
1.	Virtual classroom recordings help me revisit complex topics for further understanding	13.10 ± 0.81	13.25 ± 0.75	High
2.	Interactive features during VCP enhances my understanding	13.45 ± 0.79	13.60 ± 0.72	High
3.	Virtual presentation and screen sharing help me clarify abstract ideas	13.30 ± 0.80	13.40 ± 0.77	High
4.	VCP helps me understand difficult concepts	13.55 ± 0.74	13.65 ± 0.70	High

5.	Live online explanations improve my comprehension of physics and integrated science	13.20 ± 0.82	13.35 ± 0.76	High
	Grand Mean	**13.32± 0.79**	**13.45± 0.75**	**High**

The findings in Table 4.2 show that Physics students (M = 13.32, SD = 0.79) and Integrated Science students (M = 13.45, SD = 0.75) recorded grand mean scores above the benchmark mean of 12.5. This indicates that virtual classroom participation enhances students' understanding of Physics and Integrated Science to a large extent in South-western Nigerian universities. The high mean values across all items further suggest that features such as recordings, interactive tools, and live explanations play significant roles in improving conceptual understanding.

Research Question Three: What is the relationship between virtual classroom engagement (interactivity, instructor presence, collaborative activities, and real-time feedback) and students' understanding of physics and integrated science concepts?

Table 4.3: Pearson Correlation for Integrated Physics (n=77) and Science Students (n=129)

Variables	Physics VCE	Physics Understanding	Int. Sc. VCE	Int. Sc. Understanding	VCE Both Cohorts	Understanding Both Cohorts
Virtual Classroom Engagement	1		1		1	
Students' Understanding	.903	1	.861	1	.882	1
Sig. (2-tailed)	.000		.000		.000	
N	77	77	129	129	206	206

Key: VCE- Virtual Classroom Engagement

The overall result ($r = .882$, $p < .05$) indicates a very strong positive relationship between virtual classroom engagement and students' understanding of Physics and Integrated Science concepts. Though physics students showed a slightly stronger relationship ($r = .903$, $p < .05$), integrated science students also demonstrated a very strong positive relationship ($r = .861$, $p < .05$). This suggests that virtual classroom engagement enhances students' conceptual understanding across both disciplines, with a marginally higher association among Physics students.

Research Question Four: How does virtual classroom participation influence students' problem-solving ability and application of scientific principles in physics and integrated science?

Table 4.4[a]: Model Summary for Influence of Virtual Classroom Participation on Students' Problem-Solving Ability and Application of Scientific Principles

Model	R	R Square	Adjusted R Square	Std. Error
1	.846[a]	.716	.714	3.972

a. Predictors: (Constant), Virtual Classroom Participation

Table 4.4[b]: Regression Coefficients

Model	Unstandardized B	Std. Error	Standardized Beta (β)	t	Sig.
(Constant)	11.284	1.167		9.667	.000
Virtual Classroom Participation	.792	.044	.846	18.123	.000

Table 4.4[b] shows that virtual classroom participation predicts students' problem-solving ability and application of scientific principles, $\beta = .846$, $t(204) = 18.123$, $p < .05$. The model explains 71.6% (R square of 0.716) (*See Table 4.4[a]*) of the variance in students' performance. Therefore, virtual classroom participation has a strong positive influence on students' scientific problem-solving and application skills.

Hypothesis One: There is no significant difference in the effectiveness of virtual classrooms on students' understanding of physics and integrated science between federal and state universities

Table 4.5: Independent Samples t-Test Showing Differences in Students' Understanding by University Type (n = 206)

Group	N	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Federal Universities	125	13.02	0.80	0.48	204	0.632
State Universities	81	12.98	0.78			
Mean Difference		**0.04**				

The independent samples t-test revealed no significant difference in students' understanding of Physics and Integrated Science between federal universities (M = 13.02, SD = 0.80) and state universities (M = 12.98, SD = 0.78), t(204) = 0.48, p = 0.632. Since the p-value (0.632) is greater than 0.05, the null hypothesis is accepted. This implies that the effectiveness of virtual classrooms on students' understanding is statistically similar in both federal and state universities, hence the null hypothesis is hereby retained.

Hypothesis Two: School type (federal vs state universities) does not moderate the relationship between virtual classroom engagement and students' understanding of physics and integrated science

Table 4.6: Model Summary for Moderating Effect of School Type on the Relationship between Virtual Classroom Engagement and Students' Understanding (n = 206)

S/N	Model	R	R^2	Adj. R^2	ΔR^2	F change	Sig. F Change
1.	Understanding	.882	.778	.776	.778	356.924	.000
2.	2.School Type *Engagement* Understanding	.883	.780	.776	.002	1.214	.272

Following the introduction of interaction term in Model 2, the change in R^2 was very small ($\Delta R^2 = .002$) and not statistically significant ($p = .272 > .05$).This indicates that adding school type as a moderator did not significantly improve the model. The absence of a moderating effect of school type may be attributed to the increasing accessibility of digital learning tools across both federal and state universities.

Although federal universities traditionally possess relatively stronger institutional infrastructure, many state university students now have personal access to laptops, personal computers, and internet-enabled mobile devices. Furthermore, the growing availability of affordable data services, off-campus internet subscriptions, and private ICT facilities may have minimized infrastructural disparities between the two university categories. As a result, students' engagement in virtual classrooms appears to function similarly across institutional types, thereby reducing the likelihood of school type significantly altering the strength of the relationship between engagement and understanding, hence the null hypothesis is retained.

Discussion

The findings of the study revealed that virtual classroom practices significantly enhanced students' learning outcomes in Physics and Integrated Science. Descriptive results indicated that virtual classroom instruction improved students' conceptual understanding to a large extent. Correlation analysis further showed a very strong positive relationship between virtual classroom engagement and students' understanding, suggesting that increased participation in online learning activities substantially strengthens knowledge retention and conceptual clarity. In the same manner, regression analysis demonstrated that virtual classroom participation significantly predicted students' problem-solving ability and application of scientific principles, accounting for a substantial proportion of the variance in performance. This confirms the findings of Bawan, (2024) that active engagement in virtual learning environments plays a critical role in fostering higher-order thinking and scientific reasoning skills. The study further established that there was no significant difference in the effectiveness of virtual classrooms on students' understanding between federal and state universities. Similarly, school type did not significantly moderate the relationship between virtual classroom engagement and students' understanding. The non-significant moderating effect suggests that the benefits of virtual classroom engagement are consistent across institutional types. This may be attributed to the increasing accessibility to digital devices, internet connectivity, and personal learning technologies among students in both federal and state universities, which appear to have minimized infrastructural disparities. Overall, the findings affirm that virtual classroom engagement is a strong and reliable predictor of students' academic success in science-related disciplines, irrespective of university type.

Recommendations

1. University administrators should institutionalize structured virtual classroom engagement strategies in science courses, particularly in Physics and Integrated Science
2. Lecturers should incorporate interactive elements such as live discussions, collaborative tasks, simulations, and formative virtual assessments to sustain high levels of student participation
3. Curriculum planners should formally integrate blended and virtual learning frameworks into science education programs, ensuring that virtual classroom methodologies are not treated as supplementary but as core instructional approaches.
4. Universities should invest in sustainable digital infrastructure, including stable learning management systems and technical support services, to maintain the effectiveness of virtual learning environments.
5. Both federal and state universities should continue expanding access to personal digital devices and affordable internet connectivity, as equal access appears to have minimized institutional disparities in learning outcomes.

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