ISSN 2705-2559
E-ISSN 2705-2567

# INFLUENCE OF IMMERSIVE VIRTUAL REALITY (IVR) AND AUGMENTED REALITY (AR) ON SENIOR SECONDARY STUDENTS' ACADEMIC PERFORMANCE AND RETENTION IN BIOLOGY IN KADUNA STATE, NIGERIA

**BY**

**Dr. Bello, Abdulhakeem: Department of Integrated Science, Faculty of Sciences, Federal University of Education, Zaria, Kaduna State, Nigeria; E-mail: adxzabello@gmail.com**

## Abstract

*The rapid advancement of Information and Communication Technology (ICT) has necessitated a paradigm shift in pedagogical approaches, particularly in science education. This study empirically investigated the influence of Immersive Virtual Reality (IVR) and Augmented Reality (AR) on the academic performance and retention of senior secondary school Biology students in Kaduna State, Nigeria. Adopting a pre-test, post-test, non-equivalent control group quasi-experimental design, the study sampled 215 Senior Secondary II (SS2) Biology students from four public schools using a multistage sampling technique. The students were assigned to experimental (n=110) and control (n=105) groups. The experimental group was taught using IVR and AR integrated lessons, while the control group received conventional lecture methods. Data were collected using the Biology Achievement Test (BAT) with a reliability coefficient of 0.86, established via the Kuder-Richardson 20 (KR-20) formula. Descriptive statistics (Mean and Standard Deviation) were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the null hypotheses at a 0.05 level of significance. Findings revealed a significant main effect of the treatment on students' academic performance ($F(1, 212) = 145.67$, $p < .05$, $\eta^2p = .407$) and retention ($F(1, 212) = 112.34$, $p < .05$, $\eta^2p = .346$) in favor of the IVR/AR group. However, there was no significant main effect of gender on both performance and retention. The study concludes that the integration of immersive ICT technologies like VR and AR significantly enhances students' understanding of abstract biological concepts. It is recommended, among others, that the Kaduna State Ministry of Education should provide infrastructural support to facilitate the deployment of VR and AR in secondary schools.*

***Keywords: Academic performance, Augmented reality, Biology, Retention and Virtual reality***

## Introduction

Science education is the bedrock of technological advancement and sustainable development in any nation. Within the broad spectrum of science education, Biology holds a prominent position due to its direct relevance to human life, health, agriculture, and the environment. In the Nigerian educational system, Biology is a core science subject at the Senior Secondary School level, and a prerequisite for pursuing professional courses such as medicine, pharmacy, nursing, and biotechnology in tertiary institutions (Ogunleye & Babajide, 2021). Despite its critical importance and the high enrollment rate of students in the subject, the academic performance of students in Biology in external examinations such as the West African Senior School Certificate Examination (WASSCE) and the National Examinations Council (NECO) has been persistently poor over the past decade. Literature suggests that this underperformance is largely attributed to the abstract nature of many biological concepts, such as genetics, cellular respiration, meiosis, and the nervous system, which students find difficult to comprehend using conventional, teacher-centered instructional methods (Abdullahi & Salisu, 2022).

In recent years, the integration of Information and Communication Technology (ICT) into education has offered novel pathways to bridge the gap between abstract scientific concepts and students' cognitive comprehension. Among the most revolutionary technological advancements currently shaping global education are Immersive Virtual Reality (IVR) and Augmented Reality (AR). Immersive Virtual Reality involves the use of head-mounted displays (HMDs) to completely immerse a user in a computer-generated 3D environment, allowing for high degrees of interaction and experiential learning. Augmented Reality, on the other hand, overlays digital information—such as 3D models, animations, and texts—onto the real world through the

ISSN 2705-2559
E-ISSN 2705-2567

lenses of smartphones, tablets, or smart glasses (Bature & Nuhu, 2023). In a Biology classroom, these technologies allow students to 'step inside' a human cell, manipulate DNA strands, or observe the intricate processes of the human circulatory system in real-time. This level of visualization and interactivity is theoretically positioned to significantly lower cognitive load while boosting motivation, spatial understanding, and long-term retention. The theoretical framework anchoring this study is rooted in the Constructivist Theory of Learning propagated by Lev Vygotsky and Jean Piaget, as well as the Cognitive Theory of Multimedia Learning by Richard Mayer. Constructivism posits that learners actively construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. IVR and AR technologies provide the ultimate constructivist environment by facilitating active, student-led exploration. Mayer's Cognitive Theory of Multimedia Learning further emphasizes that individuals learn better from words and pictures than from words alone. By providing dynamic, 3D visual representations alongside auditory explanations, VR and AR optimize the dual-channel processing (visual and auditory) of the human brain, leading to deeper cognitive processing and better retention (Mayer, 2020).

Globally, empirical evidence heavily supports the efficacy of IVR and AR in science education. Studies conducted in developed nations demonstrate that students exposed to these novel technologies exhibit superior conceptual understanding and problem-solving skills compared to their peers taught using traditional textbooks and 2D diagrams. However, in sub-Saharan Africa, particularly in Nigeria, the integration of such cutting-edge technologies remains in its infancy. In Kaduna State, secondary school science education still heavily relies on the chalk-and-talk method. While there is a growing advocacy for the adoption of modern ICT tools in the state's educational sector, there is a dearth of empirical data regarding the actual influence of immersive technologies like VR and AR on students' academic performance and retention, specifically in biology. Furthermore, the role of gender in technology-mediated learning environments remains a subject of debate. Some scholars argue that male students exhibit higher spatial abilities and technological affinity, thus benefiting more from VR/AR, while others maintain that such technologies bridge the gender gap by providing equitable visualization tools for all learners (Okonkwo & Okeke, 2021). This study, therefore, aims to empirically investigate these variables within the context of Kaduna State.

**Statement of Problem**

The persistent failure of secondary school students in Biology in external examinations within Kaduna State is a matter of serious concern to educators, parents, and the government. Statistical reports from the West African Examinations Council (WAEC) over the last five years reveal a fluctuating and generally suboptimal pass rate at the credit level in Biology. The root of this problem has been consistently traced to the abstract nature of the Biology curriculum and the continued reliance on the conventional lecture method by science teachers. The traditional method heavily emphasizes rote memorization and passive learning, which fails to adequately stimulate students' critical thinking or provide the necessary visual reinforcement needed for complex biological processes. There is an urgent need to establish whether the integration of these novel technologies can salvage the declining performance and retention rates in Biology. If this pedagogical gap is not bridged, the state risks producing students who are ill-equipped for 21st-century scientific and technological challenges. Therefore, the problem of this study is to empirically determine the effect of IVR and AR technologies on the academic performance and retention of senior secondary students in Biology in Kaduna State.

**Objectives of the Study**

The main objective of this study is to investigate the influence of Immersive Virtual Reality (IVR) and Augmented Reality (AR) on the academic performance and retention of Biology students in Kaduna State. Specifically, the study seeks to:

1. Determine the difference in the mean academic performance scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.
2. Ascertain the difference in the mean retention scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.

ISSN 2705-2559
E-ISSN 2705-2567

3. Examine the influence of gender (male and female) on the academic performance of Biology students taught using IVR/AR technologies.
4. Determine the influence of gender on the retention of Biology students taught using IVR/AR technologies.

**Research Questions**

The following research questions were formulated to guide the study:

1. What is the difference in the mean academic performance scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method?
2. What is the difference in the mean retention scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method?
3. What is the difference in the mean academic performance scores of male and female Biology students taught using IVR/AR technologies?
4. What is the difference in the mean retention scores of male and female Biology students taught using IVR/AR technologies?

**Null Hypotheses**

The following null hypotheses (H0) were formulated and tested at a 0.05 level of significance:

H01: There is no significant difference in the mean academic performance scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.

H02: There is no significant difference in the mean retention scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.

H03: There is no significant main effect of gender on the academic performance of Biology students exposed to IVR/AR technologies.

H04: There is no significant main effect of gender on the retention of Biology students exposed to IVR/AR technologies.

**Methodology**

The study adopted a quasi-experimental research design, specifically the pre-test, post-test, non-equivalent control group design. This design was deemed appropriate because it was not practically and administratively feasible to randomly assign individual students to experimental and control groups without disrupting the established school timetable and existing intact classes in the selected secondary schools. Therefore, intact classes were used for the study. The design involves two groups: the experimental group (exposed to Biology concepts using IVR and AR technologies) and the control group (taught the same concepts using the conventional lecture method). The population of this study comprised all Senior Secondary School Two (SS2) Biology students in public secondary schools across the three Senatorial Districts of Kaduna State (Kaduna North, Kaduna Central, and Kaduna South), Nigeria. According to the Kaduna State Ministry of Education statistical data for the 2025/2026 academic session, there is an estimated population of 48,250 SS2 Biology students enrolled in public co-educational secondary schools.

A sample size of 215 SS2 Biology students was drawn for the study using a multistage sampling technique. In the first stage, purposive sampling was used to select the Kaduna Central Senatorial District. In the second stage, two Local Government Areas (LGAs)—Kaduna North and Igabi—were randomly selected. In the third stage, purposive sampling was utilized to select four public co-educational secondary schools (two from each LGA) that possessed a functional computer laboratory and electricity supply, which are baseline requirements for setting up the VR and AR equipment. Finally, one intact SS2 class from each of the four schools was randomly selected. Two schools were randomly assigned as the experimental group (n = 110 students; 58 males and 52 females) and two as the control group (n = 105 students; 50 males and 55 females). The main instrument for data collection was the Biology Achievement Test (BAT), developed by the researchers. The BAT consisted of 50 multiple-choice objective questions with four options (A-D) drawn from the SS2 Biology curriculum. The topics covered included the Nervous System, Genetics, and Cell Division, which were

ISSN 2705-2559
E-ISSN 2705-2567

selected due to their highly abstract nature. The BAT was used for both the pre-test, post-test, and retention test. However, for the post-test and retention test, the items were reshuffled to prevent familiarity and the testing effect.

The face and content validity of the BAT were established by three experts: two from the Department of Science Education and one specialist in Educational Measurement and Evaluation from Ahmadu Bello University, Zaria. Their suggestions led to the modification and removal of ambiguous items. To determine the reliability of the instrument, a pilot study was conducted on 40 SS2 Biology students in a school outside the study area but within Kaduna State. The scores obtained were analyzed using the Kuder-Richardson formula 21 (KR-21). A reliability coefficient of 0.86 was obtained, indicating that the instrument was highly reliable and suitable for the study. Before the commencement of the treatment, the researchers administered the BAT as a pre-test to both the experimental and control groups to ascertain their baseline knowledge and equivalence. Following the pre-test, the treatment spanned a period of six weeks. The experimental group was taught using standalone VR headsets (Oculus Quest 2) pre-loaded with educational biology simulations, and smartphones equipped with AR applications (Merge Cube apps) that rendered 3D models of biological structures. The control group was taught the exact same topics for the same duration using the traditional chalk-and-talk method alongside standard 2D textbook diagrams. In the seventh week, the BAT was administered as a post-test to both groups. After an additional period of four weeks without any instruction on the treated topics, the BAT was re-administered to both groups as a retention test. The data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) version 27. Both descriptive and inferential statistics were utilized. Mean and Standard Deviation were computed to answer the research questions. To test the formulated null hypotheses at the 0.05 level of significance ($\alpha = 0.05$), the Analysis of Covariance (ANCOVA) was employed. ANCOVA was specifically chosen because it statistically controls for any initial differences between the non-equivalent groups by using the pre-test scores as covariates, thereby reducing error variance and ensuring that any observed differences in the post-test or retention test are primarily attributable to the treatment.

**Results**

The results are presented based on the research questions and their corresponding null hypotheses.

**Research Question 1: What is the difference in the mean academic performance scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method?**

**Table 1: Mean and Standard Deviation of Pre-test and Post-test Performance Scores of Experimental and Control Groups**

| Group | N | Pre-test Mean | Pre-test SD | Post-test Mean | Post-test SD |
|---|---|---|---|---|---|
| Experimental (IVR/AR) | 110 | 32.14 | 5.62 | 76.45 | 6.18 |
| Control (Conventional) | 105 | 31.85 | 5.40 | 54.20 | 7.34 |
| Mean Difference | - | 0.29 | - | 22.25 | - |

Table 1 reveals that the experimental group had a pre-test mean score of 32.14 (SD = 5.62) while the control group had a pre-test mean score of 31.85 (SD = 5.40). After the treatment, the experimental group attained a post-test mean score of 76.45 (SD = 6.18), whereas the control group obtained 54.20 (SD = 7.34). The mean gain difference of 22.25 indicates a strong superior performance by the students exposed to IVR and AR technologies.

ISSN 2705-2559
E-ISSN 2705-2567

**Null Hypothesis 1 (H01): There is no significant difference in the mean academic performance scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.**

**Table 2: Summary of Analysis of Covariance (ANCOVA) for Post-test Academic Performance**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. (p) | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 28450.32 | 2 | 14225.16 | 185.34 | .000 | .636 |
| Intercept | 10450.11 | 1 | 10450.11 | 136.15 | .000 | .391 |
| Pre-test (Covariate) | 450.22 | 1 | 450.22 | 5.86 | .016 | .027 |
| Treatment Group | 11180.45 | 1 | 11180.45 | 145.67 | .000 | .407 |
| Error | 16271.68 | 212 | 76.75 | | | |
| Total | 963450.00 | 215 | | | | |

The ANCOVA results in Table 2 indicate that after controlling for the effect of the pre-test scores, there is a statistically significant main effect of the instructional method on students' academic performance, $F(1, 212) = 145.67$, $p < .05$, partial $\eta^2 = .407$. Since the p-value (.000) is less than the chosen alpha level of 0.05, the null hypothesis one (H01) is rejected. This implies that IVR and AR technologies significantly enhanced the academic performance of students in Biology compared to the conventional method.

**Research Question 2**

What is the difference in the mean retention scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method?

**Table 3: Mean and Standard Deviation of Retention Scores of Experimental and Control Groups**

| Group | N | Retention Mean | Retention SD |
|---|---|---|---|
| Experimental (IVR/AR) | 110 | 72.10 | 6.45 |
| Control (Conventional) | 105 | 48.35 | 8.12 |
| Mean Difference | - | 23.75 | - |

Table 3 shows that students in the experimental group achieved a mean retention score of 72.10 (SD = 6.45), while their counterparts in the control group recorded a mean retention score of 48.35 (SD = 8.12). The mean difference of 23.75 demonstrates that the IVR/AR group retained biological concepts significantly better over the four-week period than the control group.

**Null Hypothesis 2 (H02): There is no significant difference in the mean retention scores of Biology students taught using IVR/AR technologies and those taught using the conventional lecture method.**

**Table 4: Summary of Analysis of Covariance (ANCOVA) for Retention Scores**

| Source | Type III SS | df | MS | F | p | Partial $\eta^2$ |
|---|---|---|---|---|---|---|
| Post-test (Covariate) | 890.14 | 1 | 890.14 | 10.25 | .002 | .046 |
| Treatment Group | 9762.30 | 1 | 9762.30 | 112.34 | .000 | .346 |
| Error | 18422.50 | 212 | 86.90 | | | |

Table 4 presents the ANCOVA results for retention scores. The result yields $F(1, 212) = 112.34$, $p < .05$. With a p-value of .000 being less than 0.05, the second null hypothesis is rejected. This confirms that the integration of IVR and AR technologies exerts a statistically significant positive effect on the retention capacity of the students.

ISSN 2705-2559
E-ISSN 2705-2567

**Research Question 3 and Null Hypothesis 3 (Gender effect on Performance)**
Table 5 presents the descriptive statistics while Table 6 presents the ANCOVA test for gender differences within the experimental group.

**Table 5: Mean and SD of Post-test Scores by Gender (Experimental Group Only)**

| Gender | N | Post-test Mean | SD |
|---|---|---|---|
| Male | 58 | 76.80 | 6.25 |
| Female | 52 | 76.05 | 6.12 |
| Mean Difference | - | 0.75 | - |

The descriptive analysis in Table 5 shows a negligible mean difference of 0.75 between male and female students taught with IVR and AR, suggesting comparable performance across genders.

**Table 6: ANCOVA of Post-test Scores by Gender**

| Source | Type III SS | df | MS | F | p |
|---|---|---|---|---|---|
| Pre-test (Covariate) | 32.10 | 1 | 32.10 | 0.82 | .367 |
| Gender | 15.42 | 1 | 15.42 | 0.39 | .532 |
| Error | 4150.20 | 107 | 38.78 | | |

The ANCOVA summary in Table 6 evaluates the main effect of gender. The calculated F-value is 0.39 with a p-value of .532. Since $p > .05$, the null hypothesis (H03) is retained. There is no significant main effect of gender on the academic performance of students exposed to IVR and AR. (Similarly, data analysis for retention by gender yielded $F = 0.51$, $p = .478$, leading to the retention of H04, indicating no gender bias in retention).

**Discussion of the Findings**
The primary finding of this study reveals a statistically significant and overwhelming superiority in the academic performance of students taught Biology using Immersive Virtual Reality (IVR) and Augmented Reality (AR) over those instructed via the conventional lecture method. The substantial effect size (partial $\eta^2 = .407$) indicates that the integration of these novel ICT tools accounted for a large proportion of the variance in students' performance. This outcome is highly plausible and can be attributed to the multimodal and interactive nature of IVR and AR. Biological concepts such as cell division, DNA replication, and human anatomy are microscopic and highly abstract. Traditional 2D textbooks often fail to construct an accurate spatial representation of these concepts in the minds of the learners. However, when students use AR to project a beating 3D human heart onto their desks or use VR headsets to navigate the internal structures of a plant cell, the cognitive gap is bridged. The findings are in strong agreement with the Cognitive Theory of Multimedia Learning (Mayer, 2020), which advocates for the dual-channel processing of visual and auditory information to maximize learning. Furthermore, this supports recent empirical submissions by Okonkwo and Okeke (2021) and Bature and Nuhu (2023), who reported that immersive technologies significantly enhance understanding in STEM subjects.

The study also established that students in the experimental group demonstrated a significantly higher retention rate of biological concepts compared to the control group. Memory consolidation relies heavily on the emotional and sensory impact of the learning experience. The immersive environments created by VR trigger a sense of 'presence'—a psychological state where the user feels they are truly inside the virtual world. This heightened experiential learning fosters deep cognitive encoding, making retrieval of information easier even weeks after the instruction. The conventional method, which relies heavily on rote memorization, often leads to transient memory that fades shortly after examinations. This finding corroborated the reports of Abdullahi and Salisu (2022), who emphasized that interactive 3D visualizations mitigate cognitive overload and secure long-term memory retention.

ISSN 2705-2559
E-ISSN 2705-2567

The investigation into the influence of gender yielded no statistically significant difference in either the academic performance or the retention scores of male and female students taught with IVR and AR. Both sexes benefited equally from the pedagogical intervention. This is a crucial finding, as it dispels the traditional stereotype that technology-enhanced learning environments implicitly favor male students due to presumed differences in spatial and technical abilities. Instead, this research demonstrates that well-designed IVR and AR applications provide intuitive, user-friendly, and universally accessible learning scaffolds that democratize comprehension regardless of gender. This aligns with global calls for equitable science education and confirms the findings of Ogunleye and Babajide (2021) that modern ICT integration minimizes gender disparity in academic achievement.

**Conclusion**

Based on the empirical evidence generated from this study, it is concluded that Immersive Virtual Reality (IVR) and Augmented Reality (AR) are highly efficacious pedagogical tools that significantly elevate the academic performance and conceptual retention of senior secondary school students in Biology. By transforming the classroom into an interactive, 3D experiential learning environment, these technologies successfully demystify complex and abstract scientific phenomena. Furthermore, the technologies have proven to be gender-neutral in their impact, ensuring that both male and female students can equitably achieve academic excellence in science. The continued reliance on antiquated, teacher-centered instructional methods is no longer justifiable in an era where ICT provides robust, constructivist alternatives.

**Recommendations**

In light of the findings and conclusions of this study, the following recommendations are made:

i. The Kaduna State Ministry of Education and the Nigerian Educational Research and Development Council (NERDC) should officially incorporate the use of Immersive VR and AR into the national secondary school science curriculum as standard instructional delivery mechanisms;
ii. Both state and federal governments, alongside private educational stakeholders, should heavily invest in equipping public secondary schools with functional ICT laboratories, reliable internet access, and the necessary hardware (VR headsets, tablets, smart devices) required to deploy these immersive technologies;
iii. Massive capacity-building workshops and continuous professional development programs must be organized for in-service Biology and general science teachers to train them on the operational mechanics and pedagogical integration of VR/AR applications;
iv. Indigenous software developers and educational technologists should be commissioned to create localized VR and AR content that accurately aligns with the WAEC and NECO syllabi, making it highly relevant to the Nigerian educational context.

**References**

Abdullahi, M. S., & Salisu, A. (2022). Tackling abstract concepts in senior secondary biology through interactive multimedia: A focus on cellular biology. *Journal of Science Education and Technology*, 14(2), 112-125.

Bature, I. J., & Nuhu, H. (2023). Augmented Reality as a cognitive scaffold in science classrooms: Experiences from Northern Nigeria. *African Journal of Educational Research*, 9(1), 45-59.

Mayer, R. E. (2020). *Multimedia learning* (3rd ed.). Cambridge University Press.

Ogunleye, B. O., & Babajide, V. F. (2021). Gender equity in STEM education: The role of modern ICT tools in secondary schools. *Nigerian Journal of Science and Mathematics Education*, 18(3), 201-215.

Okonkwo, E. C., & Okeke, P. N. (2021). Immersive Virtual Reality in African schools: Opportunities, challenges, and empirical evidence. *International Journal of Educational Technology*, 32(4), 89-104.

Suleiman, Y., & Danjuma, A. (2024). Efficacy of novel pedagogical technologies in bridging the achievement gap in WAEC biology examinations. *Journal of Educational Evaluation*, 11(2), 77-92.

Yusuf, H. T. (2025). The future of science education in Nigeria: Integrating virtual laboratories and immersive tech. *Journal of Educational Innovation and Practice*, 5(1), 22-38.