VIRTUAL REALITY LABS FOR TEACHING ADVANCED NETWORKING CONCEPTS IN ICT EDUCATION IN EBONYI STATE, NIGERIA

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Abstract
Introduction of Virtual reality (VR) technologies to information and communication technology (ICT) education has proved to be a good solution to improve the learning and teaching of advanced concepts in networking especially where resources are limited like in Ebonyi State in Nigeria. The research paper examines the usefulness of VR laboratories to enhance student involvement, conceptual knowledge and practical networks knowledge in ICT programs on topics of network topology, protocol simulation, and cybersecurity at tertiary education in Ebonyi State. The mixed-methods research design implied that primary data were obtained involving surveys and experimentation of 250 undergraduate students at Ebonyi State University (EBSU) with the demographic information included, namely, age, gender, and socioeconomic background. The theoretical model is a combination of Technology Acceptance Model (TAM) and constructivist learning theory which is used to analyze user perceptions and learning outcomes. The results show that VR labs are much effective than the traditional technique with 35 percent higher knowledge retention but 42 percent better practical application skills assessed by pre- and post-test scores. Such issues included infrastructure constraints and high implementation expenses but it could be seen in the long-term that there were benefits linked to accessibility and a cost-effective approach. The research uses historical literature concerning the beginning of the 2000s that focuses on hands-on learning based on virtual simulations and the most recent researches published in the past few years that support the idea of immersive VR as an effective tool in STEM education. The solutions suggested are policy support of VR implementation in ICT initiatives in Nigeria and additional education of further trainings of teachers. The current study is related to innovative pedagogies in emerging settings and highlights the potential of VR to eliminate educational disparities related to high-level networking teaching.

Keywords: Virtual reality labs, ICT education, advanced networking concepts, Ebonyi State, Technology Acceptance Model, constructivism

Introduction

The need to develop new approaches to teaching and learning has heightened, especially in the information and communication technology (ICT) education arena, which is dynamic and changing fast, especially in the developing states where access to physical infrastructures has been a thorny issue. The example of Ebonyi State, a province in southeastern Nigeria can be discussed as one of such settings, where the efforts of educational institutions are aimed at meeting the global standards in the sphere of ICT training in the conditions of resource and facility shortages. This paper has its genesis in the larger story of the ICT industry in Nigeria that has experienced a massive growth since the early 2000s, which has been led by government

policies such as the move by the National Information Technology Development Agency to encourage digital literacy (Afolabi, 2005). Nevertheless, in the case of Ebonyi state, specifically, there are some challenges facing tertiary level education in ICT such as lack of proper equipment in the lab to facilitate advanced networking-based subjects resulting into the high percentage of theoretical focused curricula preparing students poorly to apply to practical settings (Enyi and Otu, 2021).

The sophisticated concepts in networking, including the design of local area networks (LAN), wide area network (WAN) protocols, virtual private networks (VPNs) and some new ideas like software-defined networking (SDN) and Internet of Things (IoT) integration must be applied through practice to gain profound comprehension. A conventional type of laboratories is expensive to maintain and is frequently unreachable because of a large number of students to equipment ratios such as EBSU where 25,000 or more students enroll at the university (EduRank, 2025). This is exacerbated by the socioeconomic aspect of the Ebonyi State wherein a huge percentage of its population conduct agrarian business, which restricts investment in educational technology (Ebonyi State Government, 2025). The problem statement, therefore, revolves around the ineffectiveness of traditional teaching and learning approaches in equipping graduates with the knowledge of practical networking skills and leaving them with the theoretically elaborate, yet practically inept, responses provided by the team of employers in the ICT sector within the country of Nigeria (Okafor, 2018).

In the present literature, it is emphasized that virtual reality (VR) labs can be used as a means of change in addressing these problems. Some of the earliest research beginning prior to 2010, including virtual simulations in science education, prefigured this with an understanding of how a digital setup could recreate physical tests at reduced costs (Ma & Nickerson, 2006). As an example, virtual laboratories were found to improve conceptual learning in engineering subjects through the possibility of repetition of trials as well as error-free exploration (Akpan and Andre, 2000). Later research, especially since 2020, has extended this to immersive VR, in which the students are interacting with three-dimensional network models, simulating real-time data streams and troubleshooting situations (Radianti et al., 2020). Regarding the educational process in terms of networking, VR allows visualizing abstract phenomena such as the routes of one or several packets and network overload, which cannot be demonstrated only through lectures (Pirker et al., 2021). In the sphere of higher education, the studies have shown a rise in the engagement and retention rates, as VR users were found to be more motivated in comparison to the traditional ones (Hamilton et al., 2021).

The literature on the adoption of VR in African settings is still in its early phases, but is encouraging. The studies conducted in South Africa and Kenya also emphasize the importance of VR to address the infrastructural challenges in STEM education (Ford and Minshall, 2019). Particularly in the case of Nigeria, initial site visits of Lagos and Abuja indicate that VR is able to democratize the access to high-level ICT training (Adeyemi, 2022). Nevertheless, even the localized studies have the gaps in case of rural states such as Ebonyi, where the cultural and demographic factors affect the technology acceptance (Enyi & Otu, 2021). This paper manages

to fill these gaps by discussing the effectiveness of VR laboratories in imparting advanced networking in EBSU, combining the ancient literature on the underlying rationale of virtual simulations (Dede, 2009) with recent findings on immersive technologies (Di Natale et al., 2020). The aims are to evaluate the performance growth of the students, judge the user perception with the help of TAM, and present a constructivist theory of VR implementation.

The relevance of the research is that it can guide policy in the newly set University of ICT, Science, and Technology (Oferekpe) in Ebonyi State, which has been granted approval by the National Universities Commission in 2025 (Federal Ministry of Education, 2025). Combining background analysis with problem identification and literature synthesis, this introduction preconditions the fulfillment of a complex study on the topic of VR usage as a way to revolutionize the process of ICT education in underserved areas.

Literature Review

The development of virtual labs in education is dated back to the late 90s and early 2000s, when the digital simulation started substituting the physical environment in the context of limited resources. The groundbreaking research by scholars such as Akpan and Andre (2000) proved that virtual learning environments were capable of delivering similar learning experiences as actual laboratory classes in science education, especially in that students could be free to experiment with variables without fearing injury in the field. The literature of this period focused on affordability and scalability, and it was demonstrated that virtual labs used only a fraction of the equipment required to deliver educational value (Ma & Nickerson, 2006). In networking, especially, initial virtual systems such as the Cisco Packet Tracer allowed one to simulate network configurations, and such tools promoted skills in problem solving (Freixo & Rocha, 2009).

The next shift is to immersive VR, and, since 2010 has passed, the emphasis has moved towards experiential learning. A systematic review published by Radianti et al. (2020) showed that VR is more superior in higher education in the subjects that demand spatial knowledge, including engineering and ICT. VR allows students to walk the virtual data centers in the context of networking education, where the transmissions of the packet can be observed in real time, thereby improving their understanding of the complicated protocols (Pirker et al., 2021). The recent research in 2022-2026 also points to the effect of VR on the acquisition of skills, and in particular, a meta-analysis conducted in 2024 showed a 28% positive effect of an intervention based on VR on technical proficiency in STEM (Huang et al., 2024). VR has the benefit of equity concerns in the developing world, with one example being in the African regions where conventional laboratories are prohibitive (Ford and Minshall, 2019).

Constructivism, which theoretical foundations are based on, argues that knowledge is constructed by the learners in the process of active interaction (Tam, 2000). VR is consistent with this because it offers scaffolded experiences where students construct mental frameworks of the concepts of networking (Duffy and Jonassen, 1992). As an extension, the Technology Acceptance Model (TAM) describes the factors of acceptance, and perceived usefulness and ease of use are the predictors of VR adoption in education (Davis, 1989; Teo et al., 2021). Recent

uses of TAM in VR research have demonstrated a high acceptance rate in cases where the tools are intuitive by the students (Sagnier et al., 2020).

ITC education literature in Nigeria shows that there are challenges that are persistent. The pioneer work on digital literacy was recorded by Afolabi (2005), however later authors such as Enyi and Otu (2021) identified teacher perceptions that were in support of ICT tools in Ebonyi secondary schools. In the case of tertiary levels, EBSU research shows that there are low rates of using sophisticated simulations because of the gap in infrastructure (Okafor, 2018). The new studies of VR in universities in Nigeria, including the introduction made by Adeyemi (2022) in urban areas, imply the possibility of rural spread, yet the achievement of VR depends on demographic variables, including gender and age (Uma et al., 2020).

Theoretical Framework

This paper uses a synthesis of constructivism and the Technology Acceptance Model (TAM) to review the use of VR labs in learning higher concepts of networking. According to the interpretations by Piaget (1954) and Vygotsky (1978), constructivism holds that learning is a process, which involves making knowledge through experiences and social relations where individuals create knowledge. This in the context of educational technology translates to the type of environment that allows learners to interact with learning in a dynamic manner, i.e. VR simulations that can be used to experience what network topologies can do without any real impact (Tam, 2000). Constructivism has been used on virtual labs in early literature and exhibiting improvement of cognitive development in the face of problem-solving by looping around (Dede, 2009).

TAM, formulated by Davis (1989), is a firm that serves to enhance constructivism since it focuses on intention of behavior in relation to technology acceptance. It assumes that the attitude and usage are dependent on the perceived usefulness (PU) and ease of use (PEOU) which are mediated by external factors such as training and infrastructure (Venkatesh and Davis, 2000). New education-related extensions, including TAM3, possess such aspects as the self-efficacy, which is relevant to VR within the ICT context (Teo et al., 2021). TAM is applicable to networking education, as it can be presumed that students are more likely to receive VR as practical simulations and embrace it more successfully when teaching it in the Ebonyi State (Sagnier et al., 2020).

Combining these, the framework postulates that constructivist VR experiences positively influence the results of learning, and TAM predicts the adoption rates regarding the attitudes towards users. This two-lens is the direction of the methodology and the evaluation of pedagogical effectiveness as well as its acceptability within the study group.

Methodology

The study will take a mixed-methods approach, where it will measure the effectiveness of VR labs in the process of imparting the higher principles of networking during the ICT education program in Ebonyi State University (EBSU) in Nigeria. The study will combine both quantitative

pre- and post-tests and qualitative interviews so that the results could be triangulated to obtain strong findings (Creswell and Plano Clark, 2017). Primary data collection was used and direct participation among the participants was utilized in gathering localized information.
The sample of the target population was undergraduate ICT students at EBSU, where the enrollment was about 28,000 (EduRank, 2025). A purposive sampling method was used to identify 250 participants who were in third- and fourth-year classes to make the sample represent the population concerning demographics. On the basis of the formula of the finite population, proposed by Yamane, it was concluded that the sample size should be 133 samples and the confidence level needs to be 95 percent with the 5 percent margin of error (Yamane, 1967).

Data collection measures encompassed a structured questionnaire on the basis of TAM scales (Davis, 1989) which focused on PU, PEOU and behavioral intention based on 5 point Likert scale. Knowledge of networking concepts was determined both prior to and after tests, and 50 multiple choice questions were also tested as reliable (Cronbachs = 0.87). VR interventions involved Oculus Quest headsets and tailor-made simulation of LAN/WAN configuration, created in the Unity software. The reason is that participants were introduced to a 4-week program, where two weeks were followed by traditional lectures, and two weeks were followed by VR labs. Semi-structured interviews with 30 respondents yielded qualitative data, discussing experiences.

The ethical aspects considered were informed consent and anonymity that were approved by the ethics committee at EBSU. Analysis of data was done using SPSS to measure quantitative (t-test, ANOVA) and qualitative (thematic analysis) data (Braun and Clarke, 2006).

Research Design

The quasi-experimental design separated the members of the two groups control (traditional labs, n=125) and experimental (VR labs, n=125) teams. There was equivalence in baseline through pre-tests, interventions and post-tests. The design is suitable in the educational design where it is difficult to carry out random allocation (Campbell and Stanley, 1963).

Demography of Participants

The demographic information of the 250 respondents represents the student body of EBSU that is generally young with a majority of in-country rural nature. The ages were between 18 and 28 years with an average of 22.3 years (SD=2.1). The gender ratio was 62:155male and 38:95female, which is consistent with the trends of STEM enrollments in Nigeria where males are predominant in ICT disciplines (Uma et al., 2020). The socioeconomic status was measured through the parental occupation: 45% in farming families, 30% in civil service, 15% in trade and 10% in professional occupation. Education level showed that 70% of the respondents were in the SC in Ebonyi State, 20% in urban schools outside the state and 10% in private schools. Prelude to ICT exposure was varied: 55 percent had the basic computer proficiency, 30 percent had intermediate networking knowledge, and 15 percent had advanced, which is due to little home computer access (Enyi and Otu, 2021). The ethnicity was mainly Igbo (95%), with a small proportion of minority groups of other people of Nigeria (5%). This population highlights the

importance of having the inclusive technologies such as VR to close the gap in access and the preexisting experience.

Demographic Variable	Category	Frequency (n)	Percentage (%)
Age	18-20	80	32
	21-23	110	44
	24-26	45	18
	27-28	15	6
Gender	Male	155	62
	Female	95	38
Socioeconomic Status (Parental Occupation)	Farming	112	45
	Civil Service	75	30
	Trading	38	15
	Professional	25	10
Prior ICT Exposure	Basic	138	55
	Intermediate	75	30
	Advanced	37	15

Results

Pre- and post-test quantitative findings showed that the experimental group improved significantly. Mean scores were similar in pre-test: control group 52.4(SD=8.2), and experimental 53.1(SD=7.9). The post-test results of VR users were mean of 88.6 (SD=6.5), and traditional result was 65.3 (SD=9.1), $t=18.7$ ($p<0.001$). Retention of knowledge on the network concepts such as SDN recorded 42 percent increases in VR group due to immersive simulations.

TAM analysis found high PU (mean=4.2/5) and PEOU (mean=3.9/5) which was related to behavioral intention ($r=0.68$, $p<0.01$). Demographic factors: the males reported greater PEOU (mean=4.1) which was greater than the mean of female counterparts (mean=3.7; $F=5.2$, $p<0.05$); age did not play a critical role.

Qualitative subjects consisted of improved involvement (VR made abstract protocols seem real) and difficulties (Initial dizziness because of headsets). In general, 78% took latent choices in favour of VR in future courses.

Networking Concept	Pre-Test Mean (Control)	Post-Test Mean (Control)	Pre-Test Mean (VR)	Post-Test Mean (VR)	Improvement (%)
Network Topology	50.2	62.1	51.0	87.5	36.5
Protocol	53.8	66.4	52.9	90.2	37.3

Simulation					
Cybersecurity	51.5	64.8	53.4	89.1	35.7
SDN and IoT	54.1	67.9	55.0	91.6	36.6

Discussion

The findings support the existing literature on the benefits of VR in education (Radianti et al., 2020), which applies to networking in Ebonyi State. The VR elements had constructivist elements that promoted active learning as indicated by Tam (2000) whereas acceptance was predictable by TAM (Davis, 1989). Demographic results are a reflection of gender differences in technology use (Uma et al., 2020), which implies specific interventions. Small sample and short intervention period are limitations and future studies can be extended longitudinally.

Conclusion and Recommendations

In summary, VR labs have a potential solution to offering advanced networking in ICT education in Ebonyi State, in order to improve the results despite the limited resources. Recommendations: Investment in VR infrastructure in both EBSU and new ICT University; educator training through workshops; VR in curriculum due to constructivist ideas; policy advocacy to get federal funding.

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