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Evaluating the efficacy of virtual reality-based pedagogical interventions on skill acquisition and cognitive engagement in technical education: A case study of Kogi state, Nigeria

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Abstract
Technical education is important in ensuring practical skills acquisition that are key for industrial and economic improvement, though traditional teaching methods often associated with deficit in promoting deep cognitive involvement and tangible skill acquisition in fields of technical context. This research work evaluates virtual reality (VR)-based pedagogical interventions and their effects on acquisition of skill and cognitive engagement within technical education students in Kogi State, Nigeria being an area under low exploration in such research methods. By implementing immersive VR simulations directed to local technical trades (e.g., automobile repair, electrical installation), this research determines the impacts of VR environments on the development psychomotor skill acquisition, knowledge retention, and learner encouragement compared to conventional instructional approaches. A mix mode design method was used, involving 120 students from four technical colleges in Kogi State, data gathered through pre- and post-intervention assessments, psychomotor skill evaluations, cognitive engagement surveys, and semi-structured interviews. Results indicate that VR-based interventions significantly enhance skill acquisition speed ($p < 0.01$), thereby improving knowledge retention by 32%, and improve cognitive engagement scores by 45% compare to the control sets. Qualitative results underscore students' views of VR as a motivating and contextually relevant instrument, despite constraints such as inadequate technological infrastructure and the necessity for enhanced instructor training. This study examines VR's application in technical education within a Nigerian context, providing insights for curriculum innovation, policy formulation, and possible technology adoption under resource-insufficient settings. Future research should dwell on long-term skill transferability and the cost-minimization of VR interventions across different technical education frameworks.

Keywords: Virtual Reality, Technical Education, Skill Acquisition, Cognitive Engagement, Psychomotor Skills, Kogi State

Introduction
The role of technical education in economics and industries cannot be over emphasis, as it ascertains that students are acquainted with needed practical knowledge and psychomotor skills (Vats, 2023) necessary for specialized trades like repair of automotive, installation of electrical gadgets, and welding. VR has helped in converting technical education by immersing learners in actual, computer-generated environments that stimulate real world scenarios. Unemployment rate is 33.3% in Nigeria and it has been a serious issue (Bwanbale Akello 2024, NBS 2021). Technical and vocational education and training (TVET) is given priority in order to address unemployment and industrial demands. The poor effectiveness of traditional teaching method that relies on lectures, demonstrations, and little hands-on practice has resulted in failure to elevate deeper cognitive engagement or efficient skill acquisition. This is noticeable in complicated technical fields requiring deeper understanding and practical mastery, the problem worsen where resource problems and obsolete curricula play key roles.

The onset of full technologies engagement, specifically virtual reality (VR), presents a great change opportunity. It also enables students to learn in a more collaborative, exploratory and independent way, where they can practice continuously until they have full understanding of what each step entails. (Rafiq et al 2022). VR's enablement encourages real-world outline in taking hold of the interactive environments and has shown hope in enhancing the development of skill and has hold attention in developed contexts (Radianti et al., 2020). Although, it application in sub-Saharan Africa, particularly Nigeria, remains under investigation as a result of poor infrastructures cost and lack of precise-environment research. Kogi State is in the North-Central Nigerian state with a mixture of urban and rural technical colleges, serves as a case study in investigating VR's potential under a resource-limited setting.

Problem statement
There is a serious problem between the traditional teaching methods and the zeal's for modern technical education,

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where students find it difficult to interpret theoretical knowledge into practical skills. In Nigeria, less than 25% of TVET graduates are suitable for industries, as a result of deficiency in facilities training and low involvement (UNESCO, 2023). Traditional teaching method such as Bloom's taxonomy (1956), stress cognitive and psychomotor domains, despite the fact that traditional methods places priority on lower-order recall than higher-order application. Makransky et al. (2019), worked on motivational and cognitive benefits of training in immersive VR, their findings revealed immersive simulations could close this space, but their work centers on Western world, not considering the peculiarity of Africa such as their value on culture and deficiency in infrastructure.

The effectiveness of VR in Kogi State, with not less than 10,000 students going through technical colleges annually (NBS, 2023), is yet to be ascertained. Recent world studies (2023–2025) list VR's advantages in medicine and engineering education, but little address TVET in developing economies (Jensen & Konradsen, 2024). This study addresses these loopholes by determining VR-based interventions geared to local trades, determining their role on acquisition of skills, knowledge retention, and cognitive involvement.

The study is based on the following aims to:

Determine VR's effect on acquisition of psychomotor skill in technical trades.

Asses VR's impact on knowledge retention and cognitive engagement.

Identify challenges and suggest possible solutions in using VR.

Theories

Bloom's Taxonomy and Psychomotor Learning

Bloom's taxonomy (1956) classified learning into the cognitive, affective, and psychomotor domains, with technical education stressing the affective and the psychomotor. Dave's (1970) psychomotor taxonomy further depicts skill acquisition from copying to mastery. VR in cognizance with these emphasizing repetition practices in simulated environments, bringing improvement from observation to mastering.

Constructivism and Immersive Learning

Constructivist theory (Piaget, 1970) postulate that learners gain insight through action experiences. VR's immersive simulations ensure learning by experience, gives room for cognitive engagement by contextualizing abstract concepts (Fowler, 2015). In technical education, VR can simulate workplace scene, bringing a closing between theory and practice.

Self-Determination Theory (SDT)

Deci & Ryan, (1985) reiterates three basic instincts in human psychological needs which are independence, efficiency, and relatedness as gear of motivation. VR's interactive nature supports independence and efficiency, potentially increasing engagement in TVET learners.

VR in Education: Global and African Perspectives

Worldwide, VR has brought tremendous improvement in education, countries like Canada, Austrialia, UK and China have made significant improvement in integrating VR into virtually every part of their educational sector, many Africa countries like Nigeria are still struggling with assessment and implementation challenges (Chasokela, 2025) (Merchant, 2014) showed VR improves spatial understanding in science education, by increase in retention. Wu et al., (2023) reported that VR allows skill acquisition in technical fields like engineering while (Pottle, 2024) VR simulations improve accuracy in procedure in medical training.

Cognitive Engagement and Acquisition of skills

Fredricks et al., 2004 defined Cognitive engagement as sustained mental effort and interest, which TVET really needs. Problem solving skill and critical thinking is found by (Sun et al. (2021) to have significantly increase in the academic performance, (Jensen & Konradsen, 2024) observed that continuous practice using VR, reduced errors by over 20% in technical skills accomplished exercises.

While worldwide studies authenticate VR's potency, African TVET research is constrained. Nigeria in particular, (Oke & Adeyemi, 2023) studies focus on ICT widely, not VR. Kogi's special blend of urban-rural colleges and trade-specific needs (e.g., automotive repair) remains unstudied. This research prioritized VR's application in this context, dealing with infrastructure and cultural barriers.

Contextual Analysis: Kogi State's Technical Education Landscape

Kogi State, sitting on 29,833 km² with a population of 5.2 million in 2023, with different ethnic groups namely (Okun, Igala, Ebira) and various economic activities (NBS, 2023). National Board for Technical Education (NBTE) is saddled with the responsibility of monitoring TVET system in the state that serves at least 10,000 students across 12 technical colleges paying special attention on trades like automotive repair, electrical installation, and welding. However, less than 30% of graduates get industry jobs due to skill deficiency (NBTE, 2024).

Infrastructure and Challenges

Jersen and Korandson (2018) stated that barriers in technology such as limited internet, inadequate training for instructors, insufficient hard ware's etc can obstruct effective usage of VR in educational environment. Similarly, Kogi technical colleges face shortage of resources e.g. lack modern workshops, and over 75 % depend on tools that are no longer in vogue (local survey, 2024). Exposure to Internet is below average, with erratic power supplies in most rural areas (NCC, 2023). These have reduced ICT integration, including VR. The instructors are not properly trained, hence

have low morale in the use of instruments that are technologically advance

Cultural and Educational Context

Kogi's has a unique cultural heritage that duels on practical, relevant community- skills. Trades like automotive repair is in line with local demands (e.g., transport sector growth). VR's potential to simulate these trades could bring relevance, but cultural resistance to technology and cost barriers pose challenges.

Methodology

A mixed mode design method according to (Cressswell, 2008) was used, by combining quantitative pre/post assessments with qualitative interviews to evaluate VR's effectiveness. It was conducted Febuary–September 2025 from four technical colleges in Kogi (Mopa, Okene, Idah, Ankpa), the study allocated experimental to (VR) and (traditional) group approach to the control.

The population comprised 3,000 students in accredited NBTE colleges. A stratified random sampling technique was used to select 120 students (30 per college; 60 experimental, 60 control) ensured gender representation (50% male, 45% female) and trade in (automotive, electrical, welding).

Local stakeholders developed VR simulations, using a replicated Oculus Quest 2 headset. Scenarios included installation of circuit and engine diagnostics. The experimental set received 12 weeks of VR training (2 hours/week), while controls used traditional methods (demonstrations, manuals).

Psychomotor Skills: Were determined using standardized NBTE rubrics (e.g., speed and task accuracy,). Pre/posttests scored 0–100.

Knowledge Retention: Alternative choice tests comparing 30 items (α=0.88) in order to measured specific trade understanding.

Cognitive Engagement: Survey (Fredricks et al., 2004; α=0.90) assessed effort, interest, and motivation.

Qualitative Data: 20 semi-structured interviews questions-based perceptions and challenges.

Data Analysis

Quantitative: Paired t-tests compared pre/post scores; MACOVA was used to compare mean across the group to determine differences. Qualitative: Thematic analysis via NVivo (inter-coder reliability 90%). Allows agreement, without revealing identity and willing participation were guaranteed. VR equipment was donated for post-study, approved by Kogi State University IRB.

Limitations: Short duration time; potential Hawthorne effect; infrastructure flexibility.

Quantitative Results

Skill Acquisition

Experimental set: Pre-test mean = 45.2/100, post-test = 78.6/100 (t=12.3, p<0.01).

Control set: Pre-test = 44.8, post-test = 58.4 (t=6.1, p<0.05).

VR set enhanced 33.4 points against 13.6 for controls set (F=18.6, p<0.01).

Knowledge Retention

VR group: Pre-test = 50.1%, post-test = 82.3% (+32.2%).

Control group: Pre-test = 49.8%, post-test = 65.4% (+15.6%).

MACOVA: VR effect significant (F=22.4, p<0.01).

Cognitive Engagement

VR set: Pre-test = 2.8/5, post-test = 4.1/5 (+45%).

Control set: Pre-test = 2.7, post-test = 3.2 (+18%).

t-test: VR group was significantly higher (t=9.8, p<0.01).

Metric	VR set (Pre/Post)	Control set (Pre/Post)	Effect Size (Cohen's d)
Skills	45.2/78.6	44.8/58.4	1.2
Retention	50.1%/82.3%	49.8%/65.4%	0.9
Engagement	2.8/4.1	2.7/3.2	1.1

Qualitative Insights

Motivation and Relevance: Students found VR "exciting" and "realistic," e.g., "Fixing an engine in VR feels like a real garage" (Lokoja students). Engagement stemmed from independence to game and fun feedback.

Challenges: Power outages affected 30% of sessions. Instructors are in dire need of training (60% reported low VR confidence). Rural students had discomfort with the use of headset.

Cultural Fit: VR scenarios incorporating local vehicles (e.g., Toyota Corolla) enhanced relevance.

Discussion and Proposed Framework

VR has significantly better performance to the conventional methods, this agrees with studies globally (Wu et al., 2023). The 33.4 skill point gained shows that VR's iterative practice is beneficial, per Dave's taxonomy. Improvements in Retention (32%) echo constructivist principles, as VR contextualizes understanding (Piaget, 1970). Engagement accrues (45%) support SDT, driven by self-sufficiency and capability (Deci & Ryan, 1985).

Kogi's context is cultural tailoring enhanced, but various adoption challenges have been itemized which

includes: infrastructure deficiency as shown in African trends (ITU, 2023). Rural-urban differences (urban 70% vs. rural 25% connectivity) calls for urgent solution.

Implication

Nigeria's TVET could improve VR and employment opportunity by 25–30% if findings can be implemented. Innovative solutions to address the costs of headset and power issues can be attained e.g. establishment solar-powered laboratories.

Policy Recommendations

Infrastructure Improvement: Establishment solar-powered VR labs in technical colleges will go a long way

Training of instructors: TVET instructors should be mandated by NBTE to be VR certified by allocating 5% percent of their Budget for such purpose.

Development of content: localized module should be developed through Partnering with technological firms such as Meta Nigeria.

Cost Minimization: By subsidizing headsets through exploring mobile-based VR.

Proper monitoring: to ensure quality education through yearly supervision to ascertain the effect of VR and also integrate into SDG 4

Conclusion

This study showcases VR's application in Kogi's technical education, showing VR pedagogical effectiveness in promoting significant acquisition of skill (33.4 points), retention (32%), and engagement (45%). By addressing limitation in infrastructure and training obstacles, VR can bring to limelight TVET, improve Nigeria's preparedness for industries. Future research should look in-depth for long-term skill transfer and cost-minimization.

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