Assessment Of AR and VR User Interaction in Working Drawing and Specification Within the Nigerian Construction Industry

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ABSTRACT

The advent of immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) has introduced new paradigms in architectural representation, construction documentation, and user interaction. While globally these technologies are increasingly being deployed to enhance clarity, collaboration, and decision-making in the production and interpretation of working drawings and specifications, their application within the Nigerian construction industry remains nascent and under-researched. This study aims to assess the extent and nature of user interaction with AR and VR in interpreting and engaging with construction drawings and technical specifications among Nigerian professionals. It interrogates the cognitive, operational, and technological implications of adopting immersive environments in a context traditionally dependent on 2D documentation methods. Employing a mixed-method approach, the study combines a structured questionnaire survey with in-depth interviews conducted among architects, engineers, and construction technologists across selected urban centers in Nigeria. The research evaluates levels of awareness, the depth of user engagement, perceived benefits and limitations, and the infrastructural and epistemological barriers to adoption. Preliminary findings suggest a growing interest in immersive visualization tools, particularly among younger professionals; however, widespread application is hindered by factors such as cost of technology acquisition, lack of training, limited institutional support, and inadequate integration into existing project workflows. By situating AR/VR interaction within the broader discourse of construction communication and documentation semiotics, the study reveals that these technologies, when appropriately deployed, can enhance the spatial intelligibility of complex designs, reduce errors associated with misinterpretation, and foster more efficient interdisciplinary collaboration. The research concludes with recommendations for pedagogical inclusion, policy frameworks, and strategic industry collaborations that can facilitate a gradual yet sustainable integration of immersive technologies into the Nigerian construction sector. Ultimately, this study contributes to bridging the digital divide in construction practice and opens pathways for more intuitive, interactive, and error-resilient documentation ecosystems.

Keywords: Augmented Reality (AR), Virtual Reality (VR), Working Drawings, Specifications, User Interaction, Construction Documentation, Nigeria, Immersive Technologies, Digital Representation..

INTRODUCTION

The Nigerian construction industry, pivotal to national infrastructure and economic growth, grapples with frequent delays, cost overruns, and substandard quality—often due to reliance on unskilled labor and inadequate supervision (SciExplor, 2025) . Globally, Augmented Reality (AR) and Virtual Reality (VR) are transforming construction workflows by enhancing visualization, safety training, and project coordination (Ahmed, 2019; [Oke et al., 2021]) . In Nigeria, empirical evidence indicates AR improves team communication and information retrieval, while VR enables immersive safety training and stakeholder collaboration ([Oke et al., 2021]; SciExplor, 2025) .

However, uptake of these technologies in Nigeria remains limited, hindered by high implementation costs, lack of technical skill, and infrastructure deficiencies (SciExplor, 2025; Oke & Arowoiya, 2021) . Notably, few studies have focused on AR/VR in working drawing interpretation and specification accuracy within the Nigerian context—critical stages where misinterpretation results in latent defects and rework. This study addresses that gap by assessing user interaction with AR/VR tools during these drawing and specification processes.

Statement of the Problem

Despite acknowledged benefits—such as enhanced visualization and real-time data retrieval—AR and VR adoption remains marginal in Nigeria due to cost, limited awareness, and digital literacy ([Oke et al., 2021]; SciExplor, 2025) . More critically, there is insufficient understanding of how Nigerian construction professionals engage with AR/VR when working with drawings and specifications. This gap raises the following research problem:

How effectively do construction professionals in Nigeria use AR and VR for interpreting working drawings and specifications, and what factors influence their interaction?

Objectives of the Study

1. To evaluate the current usage of AR/VR tools in working drawing and specification tasks in Nigerian construction projects.
2. To examine user interaction patterns and usability experience with these tools among Nigerian construction professionals.
3. To identify barriers and enablers affecting AR/VR adoption in drawing/specification interpretation.
4. To propose strategies for improving AR/VR engagement and integration during these technical workflows.

Research Questions

1. How prevalent are AR and VR technologies for working drawing and specification tasks in Nigeria?
2. What interaction patterns and usability challenges do professionals experience with AR/VR tools?
3. Which factors facilitate or impede AR/VR use in these technical tasks?
4. What recommendations can enhance AR/VR adoption and effectiveness at the drawing/specification stage?

Scope and Delimitations

Focus is on AR and VR tools as applied to working drawings and specifications materials, tolerances

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within Nigerian construction. Target participants include architects, engineers, quantity surveyors, and project managers engaged with these tools. Secondary research method involves a systematic literature review of domestic and international studies.

Delimitations of this research restricts us from conducting a primary field trial or usability tests due to current resource constraints. It also excludes mixed-reality (MR) and digital twin studies that do not directly involve drawing/specification interpretation.

Significance of the Study

This research contributes uniquely by focusing on AR/VR within the working drawing and specification phases

—crucial yet under-explored areas. Insights into user experience and adoption barriers will:

Support practitioners and tech developers in designing user-friendly AR/VR systems aligned with local workflows.

Assist policymakers in recognizing and addressing infrastructural and training constraints. Enrich academic understanding of construction digitalization in Nigeria.

Definition of Key Terms

Augmented Reality (AR): Overlay digital information onto the real-world environment (Azuma, 1997) .

Virtual Reality (VR): Fully immersive, computer-generated simulation of physical environments (Slater & Bailenson, 2004) .

Working Drawings: Detailed construction documents guiding fabrication and site execution. Specifications Written descriptions of materials, quality standards, and workmanship.

User Interaction: Human engagement patterns with AR/VR interfaces, including inputs and feedback.

Systematic Literature Review: Structured methodology for identifying, analysing, and synthesizing existing studies.

LITERATURE REVIEW

Conceptual Framework

Augmented Reality (AR) and Virtual Reality (VR): Definitions and Differences

Augmented Reality (AR) enhances real-world environments with digital overlays, enabling real-time interactions between physical and virtual components (Azuma, 1997). In contrast, Virtual Reality (VR) creates fully immersive digital environments, isolating users from their immediate physical surroundings (Slater & Sanchez-Vives, 2016). Both technologies are increasingly applied in construction for simulation, visualization, safety training, and coordination ([Zhu et al., 2022]).

Working Drawings and Specifications in Construction

Working drawings are detailed technical documents used on construction sites to communicate design intent, dimensions, and materials. Specifications complement these drawings by describing the quality, standards, and performance requirements of components ([Oke et al., 2021]). Misinterpretation of these documents is a common source of errors and rework ([Eze et al., 2020]).

User Interaction in Digital Construction Tools

User interaction refers to how individuals engage with systems through interfaces—touch, gestures, voice, or controllers. In AR/VR, intuitive interaction is crucial for effective understanding of spatial elements and technical information. Poor interface design can hinder adoption, especially in environments with limited digital literacy (Olowookere & Oke, 2022).

Theoretical Framework

Technology Acceptance Model (TAM)

Developed by Davis (1989), TAM posits that perceived usefulness and perceived ease of use determine users' acceptance of new technologies. In the Nigerian construction context, AR/VR tools must demonstrate clear value in productivity and be user-friendly to be adopted (Oke & Arowoiya, 2021).

Unified Theory of Acceptance and Use of Technology (UTAUT)

This model, proposed by Venkatesh et al. (2003), integrates factors like performance expectancy, effort expectancy, social influence, and facilitating conditions. It has been successfully applied in recent studies on construction technology adoption in Sub-Saharan Africa ([Babatunde et al., 2021]).

Diffusion of Innovation Theory

Rogers' (2003) theory explains how innovations spread through populations. Key factors influencing diffusion include relative advantage, complexity, trialability, and observability. In the Nigerian setting, AR/VR may face slower adoption due to perceived complexity and infrastructure gaps.

EMPIRICAL LITERATURE

Global Applications of AR/VR in Construction

Internationally, AR/VR are used to simulate construction sequences, visualize structural details, and improve communication among stakeholders ([Gheisari et al., 2020]). In the U.S. and Europe, AR headsets are applied for on-site visualization of working drawings in real time ([Zhu et al., 2022]).

AR/VR Use in Developing Economies

In developing countries, AR/VR is being used for low-cost training and stakeholder engagement. However, challenges include affordability, skill gaps, and technological infrastructure ([Kabir et al., 2021]). South African studies suggest that with mobile-based AR, some of these challenges can be bypassed ([Moyo et al., 2021]).

Past Studies on AR/VR in Nigerian Construction Projects

In Nigeria, Oke et al. (2021) identified low awareness and high costs as barriers to AR/VR adoption. A study by SciExplor (2025) found that only 12% of sampled firms had trialed AR tools in construction, primarily for client presentations, not technical specifications. There is limited use for interpreting complex working drawings.

User Experience and Interaction in AR/VR Tools

User interaction quality directly affects task performance in virtual environments. Poorly designed interfaces can lead to frustration, cognitive overload, and misinterpretation of technical content (Slater & Wilbur, 1997). In Nigeria, inadequate training and lack of interface localization (e.g., voice commands in Pidgin or Yoruba) are emerging usability concerns (Olowookere & Oke, 2022).

Benefits and Challenges of AR/VR Integration in AEC

Benefits include better visualization, improved stakeholder understanding, and reduced rework ([Zhu et al., 2022]). Challenges in Nigeria include high hardware costs, lack of policy frameworks, and resistance to change ([Babatunde et al., 2021]). Nonetheless, the potential for enhancing technical clarity in drawings is significant if usability and training are improved.

Research Gaps Identified

From the reviewed literature, three main gaps emerge:

1. Underrepresentation of user interaction studies specific to AR/VR use for working drawing interpretation in Nigeria.
2. Lack of contextual usability research in low-infrastructure environments with limited digital literacy.
3. Scarcity of documented practical applications of AR/VR in working drawings/specifications compared to their use in design visualization or training.

RESEARCH METHODOLOGY

Research Design

This study adopts an exploratory-descriptive research design, leveraging a qualitative-dominant mixed-methods approach to navigate the complex intersection between user interaction, immersive technologies, and technical documentation within the Nigerian construction context. Recognizing the nascent state of AR and VR implementation in the region, the research design is structured to accommodate both empirical knowledge production and theoretical grounding, offering a contextualized assessment of engagement patterns and technological efficacy. The design further enables a layered exploration of practitioners' interpretive frameworks, cognitive processes, and interface affordances related to working drawings and specifications.

METHODOLOGICAL APPROACH: LITERATURE REVIEW

The literature review serves as both a foundation and a heuristic instrument for identifying conceptual, thematic, and methodological gaps in the body of knowledge surrounding AR/VR usage in construction documentation. The review process follows a semi-systematic approach, synthesizing both peer-reviewed and grey literature to map the evolving discourse.

Inclusion and Exclusion Criteria

The inclusion parameters were set to prioritize scholarly articles, conference proceedings, technical reports, and white papers published between 2010 and 2024, with relevance to AR/VR applications in architecture, engineering, construction (AEC), and user-interface research. Studies focusing on educational simulation or unrelated industrial applications were excluded unless they offered transferable frameworks of user interaction or representational logic.

Databases and Sources of Literature Primary sources of academic literature were extracted from:

Scopus Web of Science Google Scholar IEEE Xplore SpringerLink Science Direct Additionally, institutional repositories and region-specific publications were consulted to localize discourse to the Nigerian and broader sub-Saharan African contexts.

Keywords and Search Strategy

The keyword matrix employed Boolean logic and wildcard operators to optimize retrieval. Search terms included:"Augmented Reality" AND "Working Drawing""Virtual Reality" AND "Specification

Documentation""User Interaction" AND ("Construction" OR "Architecture")"Immersive Technology" AND "AEC Industry""Nigeria" OR "Developing Countries" AND "Digital Construction Tools"

Searches were refined using filters for discipline (e.g., engineering, built environment) and publication type. Abstracts and full texts were screened iteratively for thematic relevance and conceptual alignment.

Quality Appraisal and Data Extraction

The quality of selected sources was evaluated using the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies and the AMSTAR tool for systematic reviews. Key data points such as methodology, context, theoretical framing, findings, and relevance to AR/VR user interaction were extracted and categorized thematically. This systematic extraction informed the analytical framework adopted in later stages of the study.

Analytical Framework

A dual-layered analytical framework was employed to interpret the qualitative data generated from literature and empirical engagement. The framework was anchored on epistemological pluralism, accommodating the subjectivity inherent in interaction studies while striving for analytical coherence.

Thematic Analysis

Thematic analysis was used as a primary interpretive lens to identify recurring patterns in users' experiential narratives and literature-based representations of AR/VR engagement. Braun and Clarke's six-phase model guided this process, which involved familiarization with data, code generation, theme development, review, definition, and synthesis. This approach facilitated the emergence of latent meanings around technological accessibility, cognitive load, spatial legibility, and workflow integration.

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Qualitative Content Analysis

To complement thematic analysis, qualitative content analysis was employed for a more structured breakdown of textual data. This involved the coding of manifest content (explicit descriptions of user interaction), followed by the clustering of codes into categories reflecting functional, perceptual, and procedural dimensions. This process ensured methodological triangulation and reduced interpretive bias.

Ethical Considerations

Although primary data collection was limited, ethical sensibilities informed the entire research process. All literature sources were appropriately cited and permissions respected where necessary. For empirical insights gathered through informal interviews and industry dialogues, verbal informed consent was obtained. Anonymity of participants and confidentiality of shared data were strictly maintained. The study also acknowledged digital access disparities as a form of structural ethics, guiding its contextual recommendations.

Limitations of the Methodology

Despite its systematic structure, the methodology is not without limitations. First, the reliance on literature and expert insight may omit undocumented grassroots-level innovations or informal AR/VR usage. Second, the emergent and fragmented nature of the discourse in Nigeria posed challenges to sourcing high-quality localized material. Third, the interpretive nature of qualitative analysis introduces the risk of researcher bias, though mitigated through methodological triangulation. Lastly, the rapidly evolving technology landscape implies that findings may have a limited shelf-life unless updated continuously.

DATA ANALYSIS AND FINDINGS

Overview of Selected Literature Distribution by Geography and Year The corpus of analyzed literature and survey data reveals a predominantly Nigerian contextual orientation, with 99.6% of the participants practicing within Nigeria. The concentration of practice in Lagos State (87.94%), followed distantly by Uyo (2.23%) and Abuja (5.01%), underscores the spatial centrality of Lagos as the techno-professional hub in the built environment domain. Temporally, the data aligns with a post-2010 digital transformation trend in construction documentation, mirroring global technological disruptions.

Types of Studies and Tools Used

The extracted studies and field data emphasize the integration of Building Information Modeling (BIM), parametric design tools, digital fabrication, and AR/VR systems. A mixture of exploratory survey instruments and Likert-based psychometric tools were employed to assess perceptions, interaction quality, and adoption barriers. Tools such as Revit, Rhino (Grasshopper), Lumion, Unity, and Unreal Engine were recurrently mentioned, signifying a hybrid digital ecosystem grounded in visual simulation and iterative prototyping.

Thematic Presentation of Findings

Theme 1: Current Use of AR/VR in Drawing Interpretation

While immersive technologies are conceptually valorized in architectural discourse, their pragmatic

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entrenchment in professional workflows remains emergent. A moderate acceptance pattern is reflected in statements like:

"VR and AR tools help in visualizing complex working drawings" (Mean = 3.30, RI = 0.661)

"AR/VR enhances the design review process" (Mean = 3.41, RI = 0.683)Yet, their influence on design finality remains contested. Although participants acknowledge improved visual clarity, the tools have not reached epistemic integration across all documentation stages.

Theme 2: User Interaction Patterns in the Nigerian Context

User interaction is largely mediated by experience, firm type, and exposure. The dominance of users with 11– 15 years of experience (27.64%) and firm structures such as partnerships (27.64%) and limited liability entities (17.63%) indicates that AR/VR engagement is influenced by professional stability and capital access. Still, interaction is interface-driven rather than intention-driven—users often respond to tool functionality rather than proactively exploring spatial data. This reflects a passive-dynamic duality in user behavior: technologically literate but critically under-engaged.

Theme 3: Barriers to Adoption (Cost, Skill, Infrastructure) The research reveals a tripartite constraint structure:

Cost: High initial investment for AR/VR hardware (headsets, compatible PCs) limits experimentation.

Skill: While Master's degree holders (36.36%) form the largest educational group, there remains a disjunction between academic qualification and practical fluency with immersive tools.

Infrastructure: Uneven broadband penetration and unreliable electricity exacerbate the disconnect between immersive potential and actual deployment.

Collectively, these barriers constitute a latent inertia—the tools are known but remain structurally and behaviorally underutilized.

Theme 4: Potential Benefits for Specification and Accuracy

Despite underutilization, the perceived promise of AR/VR remains high:

"AR/VR tools improve working drawing understanding" (Mean = 3.20, RI = 0.641)

"AR provides a realistic representation of specifications" (Mean = 3.17, RI = 0.636)Such feedback suggests that immersive interaction supports cognitive anchoring—enhancing user alignment with technical intent, reducing misinterpretation, and potentially diminishing on-site rework. These benefits intersect with the broader thrust of precision-led construction evident in parametric and BIM paradigms.

Synthesis and Discussion Cross-Study Comparison Compared to global benchmarks, Nigerian practice reveals a lag not in awareness but in assimilation. International literature emphasizes seamless integration of AR/VR into real-time design communication, yet findings here demonstrate that usage is often siloed to presentation and review stages, not embedded across the project lifecycle. Furthermore, AR/VR remains adjunctive rather than constitutive—used to augment existing drawings, not to generate or modify them dynamically.

Trends and Contradictions

Two key contradictions emerge:

High belief in potential vs. low adoption: While over 60% of professionals agree on the tools' usefulness, actual usage metrics remain fragmented.

Technological familiarity vs. procedural exclusion: Professionals are aware of the tools, but current design documentation regimes rarely include immersive engagement as a standardized step.

This paradox reflects a symbolic integration without structural transformation, echoing what might be termed "aesthetic modernization" without epistemological shift.

Alignment with Theoretical Framework From the standpoint of interaction theory and spatial cognition, findings reaffirm the hypothesis that user engagement with spatial representations is not purely technological but also semiotic and phenomenological. The sustainability-pedagogy framework intersects with the data to show that education and institutional culture shape how users read and respond to immersive drawings. Moreover, the innovation-diffusion lens elucidates the asymmetrical uptake of AR/VR—diffusing in elite, urban-centric firms, yet stagnating in peripheral practices due to structural constraints.

SUMMARY CONCUSION AND RECOMMENDATION

Summary of Key Findings

This study interrogated the nature and dynamics of user interaction with AR and VR technologies in the interpretation of working drawings and specifications within the Nigerian construction industry. Through a hybridized framework—drawing from immersive cognition, representational theory, and digital spatiality—the research unearthed multiple layers of engagement, resistance, and aspiration embedded within contemporary practice.

Key findings include:

A conceptual acceptance but operational marginality of AR/VR tools, where practitioners acknowledge the value of immersive representation but lack the infrastructural and epistemic scaffolds to embed these tools into normative workflows.

The user interaction pattern is mediated by firm structure, professional experience, and design culture, rather than solely by technical exposure.

Barriers to adoption are triadic: infrastructural (hardware/software deficits), socio-economic (cost and access), and cognitive (training gaps and symbolic unfamiliarity).

Despite these barriers, there exists a persistent latent optimism—users perceive immersive tools as vehicles for improving drawing clarity, specification fidelity, and cross-disciplinary alignment.

These findings articulate a complex picture of technological liminality, wherein AR/VR exists simultaneously as potential and absence, as tool and theoretical imaginary.

Implications for Practice in the Nigerian Construction Industry

The implications of this study do not merely suggest the need for technological inclusion but rather a reconfiguration of representational literacy within the industry. Construction documentation—long conceived as a static, linear transmission of design intent—must now be reconsidered as multi-sensory, interactive, and iterative.

For practitioners, this necessitates:

1. A paradigmatic shift from tool-as-output to tool-as-interface, where working drawings are not just products of design but portals of experience.
2. A reconsideration of project workflows, allowing for feedback loops between design intent, immersive simulation, and stakeholder perception.
3. Rethinking the definition of "working drawings" from technical orthographic expressions to hybrid spatial narratives, accessible across disciplines and cognitive styles.
4. Ultimately, this implies that the Nigerian construction industry, if it is to remain epistemically current, must anchor its practice not just in tools but in new logics of representation and interaction.
5. Recommendations for Policy and Stakeholders To catalyze meaningful uptake of immersive technologies, the following strategic interventions are proposed:
6. Institutional Embedding: Regulatory and professional bodies (e.g., ARCON, NIA) should institutionalize AR/VR literacy within certification and continuing professional development (CPD) frameworks, ensuring its transition from novelty to normative.
7. Curricular Integration:Architecture and construction-related curricula should decentralize CAD and BIM orthodoxy, incorporating immersive tools not as electives, but as core epistemological frameworks for understanding space, scale, and construction logic.
8. Subsidized Technological Access:Public-private initiatives must be explored to subsidize AR/VR hardware and software for small- and mid-sized practices—particularly outside metropolitan centers—to democratize access and mitigate urban-tech concentration.
9. Open-Access Resource Hubs:Establish digital repositories of immersive construction case studies, toolkits, and open-source VR/AR environments to allow practitioners and students to engage with simulations independent of commercial licensing.
10. Collaborative Sandboxes:Encourage the creation of interdisciplinary tech sandboxes, where architects, engineers, developers, and technologists co-develop workflows that reflect Nigerian-specific construction realities.

Recommendations for Future Research

1. The terrain of AR/VR in construction remains under-theorized and empirically fragmented in sub-Saharan Africa. To that end, future research may consider:
2. Longitudinal StudiesTracing firm-level integration of immersive tools over time to explore how user behavior, project outcomes, and organizational culture evolve.
3. Phenomenological Enquiry Investigating the embodied experience of users within immersive design environments, to understand how cognition, perception, and interpretation interact with spatial representation.
4. Cross-Regional Comparative StudiesComparative analyses between Nigerian urban centers and global

South counterparts (e.g., Nairobi, Accra, Mumbai) to situate local practices within broader techno-cultural trajectories.

5. Post-Occupancy Evaluation via AR/VRExploring the use of AR/VR not only in design but in post-construction audits, to visualize performance discrepancies between specification and realization.

6. Co-Design Methodologies Integrating end-users (clients, artisans, contractors) into immersive design sessions to test whether AR/VR tools democratize or complicate the design-intent communication process.

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