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# Evaluating the impact of virtual reality on student learning outcomes in higher education: A mixed-methods study from Zambia

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**Abstract*:*** Virtual and Augmented Reality (VR and AR) technologies are increasingly recognized as transformative tools in education, offering immersive learning experiences that enhance engagement and understanding. This study explored the impact of VR and AR on higher education at Zambia University College of Technology (ZUT), guided by Constructivist Learning Theory, which emphasizes active, experiential learning. An embedded mixed-methods design was used. Quantitative data were collected through surveys (N = 286), determined using the Yamane formula with a 5% margin of error and simple random sampling, while qualitative insights were obtained via semi-structured interviews and institutional document analysis. Selected students also engaged directly with Meta Quest VR headsets to assess usability and learning outcomes. Quantitative analysis using descriptive statistics, t-tests, and ANOVA showed that while awareness of immersive technologies is relatively high, implementation remains limited. VR-based instruction in graph theory led to significantly higher post-test scores (average = 78.7%) compared to traditional methods (average = 56.2%), reflecting enhanced engagement and conceptual understanding. Thematic analysis of qualitative data identified key barriers, including high infrastructural costs, limited technical expertise, and absence of formal institutional policies. These findings provide practical insights for strategic planning and evidence-based policy development to support the integration of immersive technologies in higher education in Zambia and the broader region.

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## Introduction

Augmented reality (AR) and virtual reality (VR) are not recent innovations; their use in education dates back many years. The earliest documented application of a digital VR system was in 1966, with the flight simulator created by the United States Air Force for training. These initial uses provided the groundwork for the development of VR technology. The term "virtual reality" gained popularity in the United States during the 1980s, thanks to Jaron Lanier, while the phrase "augmented reality" was introduced in 1990 by researchers Thomas Caudell and David Mizell to describe head-mounted displays (HMDs) used by electricians working on complex wiring harnesses (Elmqaddem, 2019).

From the 1990s onward, major companies began employing AR and VR for visualization and training purposes. More recently, improvements in computing power and the widespread adoption of mobile devices have made it more feasible to integrate AR and VR technologies into everyday educational environments. This technological advancement has not only facilitated the inclusion of immersive tools in classrooms but also expanded opportunities for interactive learning experiences (Diegmann et al., 2015).

Learning through VR and AR technologies enables learners to explore environments and scenarios that may be difficult or impossible to experience in reality, such as abstract concepts like non-Euclidean geometry or extreme conditions like the surface of Venus. These technologies also enhance immersive and experiential learning by encouraging self-directed learning through hands-on and immersive construction tasks, which are not typically supported by existing Learning Management Systems (LMSs) (Kavanagh et al., 2017; Scavarelli et al., 2020). Additionally, VR and AR allow learners to incorporate various creative technologies, thereby expanding both their real-world and virtual environments. The adoption of VR and AR shows great potential for learning and training across different educational settings, Higher Education (Samosorn et al., 2020), Vocational Education (Babu et al., 2018), and Industrial Training (Delgado et al., 2020). The integration of VR and AR as educational tools has attracted considerable interest from researchers (Babalola et al., 2023).

The transformative potential of immersive technologies, particularly Virtual Reality (VR) and Augmented Reality (AR), is reshaping higher education globally, offering new opportunities to create highly interactive, student-centered learning environments. These technologies facilitate experiential and situated learning, which aligns with Constructivist Learning Theory, a pedagogical approach emphasizing active, hands-on knowledge construction through exploration and engagement (D'Elia, et al., 2012). When thoughtfully integrated into curricula, VR and AR can enhance conceptual understanding, boost student motivation, and enable the visualization of complex content, especially in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Hunaepi et al., 2023; Sümer & Vaněček, 2024).

Despite their growing global adoption, the implementation of VR and AR in many developing countries remains limited, hindered by infrastructural challenges, high costs, and insufficient technical expertise (Alalwan et al., 2020). In the African context, particularly in Zambia, there is a significant gap in empirical research exploring how these immersive technologies are being use, or could be used, in higher education. Most existing literature focuses on global case studies or contexts from countries with more advanced technological infrastructures, leaving a knowledge void regarding the practical realities in institutions like the Zambia University College of Technology (ZUT).

ZUT presents a unique and relevant case for examining both the potential and the challenges of integrating immersive technologies in a resource-constrained environment. As a key technical institution, ZUT seeks to innovate its pedagogical approaches to better prepare students for the demands of an increasingly digital workforce. However, meaningful integration of VR and AR requires an evidence-based understanding of local institutional readiness, faculty capacity, student access, and the existence (or absence) of strategic policies supporting digital transformation.

This study, therefore, seeks to assess the awareness, relevance, accessibility, and effectiveness of VR and AR in the ZUT context. Grounded in Constructivist Learning Theory, the research employed an embedded mixed-methods approach, combining survey data (N=286) with qualitative insights from interviews and institutional documents. Findings revealed that while awareness of immersive technologies is relatively high, actual use remains minimal and largely experimental, primarily within the Computer Science Department. The study also uncovered significant barriers to broader adoption, including high infrastructural costs, lack of institutional policies, and insufficient staff training.

By focusing on ZUT, this investigation contributes to filling the research gap on immersive learning technologies in Zambia's higher education setting. The findings offer actionable insights that can inform institutional strategy, capacity building, and policy formulation aimed at advancing the integration of VR and AR in higher education. Ultimately, this research supports the broader goal of leveraging technology to foster more inclusive, engaging, and effective learning experiences within the Zambian educational landscape.

## Research Questions

The following are the research questions for this study:

1. What is the current level of awareness and use of VR and AR technologies among students and faculty at Zambia University College of Technology (ZUT)?
2. How effective are VR and AR technologies in enhancing student engagement and conceptual understanding in higher education at ZUT?
3. What barriers affect the adoption and implementation of VR and AR technologies within ZUT?
4. How can institutional policies and infrastructure support the integration of immersive technologies in higher education in Zambia?

## Literature Review

A growing body of research explores the application of Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR) in higher education, particularly within STEM, health sciences, and engineering disciplines. These technologies offer immersive, interactive learning experiences that enhance conceptual understanding, spatial visualization, and student engagement. A recent meta-analysis reviewing AR-based instruction in higher education from 2000 to 2023 reported a large overall effect size ($g \approx 0.896$), highlighting significant improvements in learning outcomes. The analysis found AR particularly effective when used to support content delivery and knowledge acquisition, rather than for engagement alone (Hunaepi et al., 2023). Similarly, a narrative review of 53 studies concluded that both AR and VR typically result in positive educational outcomes, though they also identified persistent implementation challenges (Sümer & Vaněček, 2024).

Discipline-specific studies further underscore the value of immersive technologies in laboratory-based instruction. For instance, one study comparing the use of VR, desktop applications, and traditional slides for food microbiology instruction found that VR significantly enhanced visual attention, presence, and long-term retention (Xue et al., 2023). Another comparative study in computing and engineering education found that both VR-based and computer-based pedagogical agents were effective, with no clear superiority of VR across all learning metrics, suggesting that effectiveness is highly context-dependent and shaped by factors such as instructional design and learner familiarity with the technology (Hadjiliasi, et al., 2024).

Most applications of immersive technology remain concentrated in STEM, medicine, and engineering, with relatively limited use in the humanities or business disciplines (Hunaepi et al., 2023). Effective instructional designs typically incorporate interactive simulations, spatial reasoning tasks, and multisensory content, often in blended learning environments. The degree to which VR or AR is embedded pedagogically, through guided exploration, real-time feedback, or instructor mediation, has been shown to significantly affect outcomes. For AR in particular, the instructional function (e.g., content delivery vs. engagement) moderates its impact on learning (Hunaepi et al., 2023). While many studies report improved engagement, comprehension, and motivation, others find no advantage over traditional methods for simpler tasks or short-term retention (Xue et al., 2023).

Despite promising benefits, numerous barriers continue to hinder the integration of immersive technologies, especially in resource-constrained settings. These include the high costs of hardware and software, ongoing maintenance needs, and dependence on stable internet and power infrastructure (Alalwan et al., 2020). A major obstacle is the shortage of digital literacy and technical expertise among faculty, which contributes to resistance or ineffective adoption. Institutional challenges such as the absence of formal policies, strategic plans, and curriculum alignment also slow progress (RSIS International, 2023). Addressing these gaps requires not only investment in infrastructure, but also systemic strategies including mobile integration, public-private partnerships, and capacity building at institutional and policy levels.

Equity and ethical concerns also emerge in the literature. Socioeconomic disparities restrict student access to devices and reliable internet, particularly in underserved regions. Furthermore, issues of inclusivity, privacy, and accessibility remain under-addressed, with few studies examining how VR/AR can be adapted for learners with disabilities or those from marginalized groups (Aini, 2025). Some research also flags potential negative side effects of prolonged VR use, such as motion sickness, visual fatigue, and mental overload, raising concerns about learner well-being and long-term sustainability (Msweli & Phahlane, 2025).

In the African context, while the research base remains limited, emerging studies offer valuable parallels. In Zimbabwe, for example, recent frameworks for VR in higher education identify key challenges such as lack of educator awareness, infrastructure constraints, and outdated pedagogical practices (RSIS International, 2023). South African institutions are piloting AR/VR technologies with support from government and industry, yet still face challenges around cost, infrastructure, and digital literacy. These examples illustrate both the enthusiasm for immersive learning and the structural barriers that limit its widespread adoption.

Significantly, there remains a lack of empirical research focused specifically on Zambia, and even fewer studies targeting institutional settings like the Zambia University College of Technology (ZUT). Most available studies are either global in scope or based in more technologically advanced African countries. Furthermore, few have adopted a mixed-methods approach that combines quantitative breadth with qualitative depth, including document analysis and policy review. Studies tend to focus narrowly on STEM, with limited attention to cross-disciplinary perspectives or how constructivist instructional design operates in under-resourced educational systems. Additionally, the influence of institutional readiness, policies, staff training, infrastructure, on implementation success remains underexplored.

This study seeks to address these gaps by employing an embedded mixed-methods design, using a quantitative sample (N=286), qualitative interviews, and document analysis to examine the integration of immersive technologies at ZUT. By grounding the research in Constructivist Learning Theory, the study evaluates not only learning outcomes but also the interactive, student-centered dynamics enabled by VR and AR. This contributes new empirical evidence from a Zambian context and offers practical insights into the systemic, pedagogical, and infrastructural factors that affect technology integration. The findings aim to support evidence-based planning and policy formulation for the broader and more equitable implementation of immersive technologies across Zambia's higher education landscape.

## Theoretical Underpinning: Constructivist Learning Theory

This study is grounded in Constructivist Learning Theory, which asserts that learners actively construct knowledge through experience, exploration, and reflection rather than passively receiving information. Rooted in the works of educational theorists such as Jean Piaget and Lev Vygotsky, constructivism emphasizes the importance of context, interaction, and engagement in the learning process (Piaget, 1970; Vygotsky, 1978).

Constructivist theory supports the idea that meaningful learning occurs when students are actively involved in a task, encouraged to explore environments, and provided with opportunities for collaborative problem-solving (Fosnot, 2013). In the context of immersive technologies, Virtual Reality (VR) and Augmented Reality (AR) align well with constructivist principles because they create experiential, hands-on learning environments where learners can interact with content in ways that are often impossible in traditional classroom settings (Kavanagh et al., 2017; D'Elia, et al., 2012).

By allowing students to manipulate virtual objects, navigate complex simulations, and receive real-time feedback, VR and AR technologies promote the kind of deep, conceptual understanding and situated learning that constructivism advocates (Scavarelli et al., 2020). These technologies also foster learner autonomy and motivation, as students are able to engage in self-directed exploration that is both relevant and personally meaningful.

In this study, Constructivist Learning Theory serves as a guiding framework for analyzing how immersive tools like the Meta Quest VR headset contribute to engagement, knowledge construction, and skill acquisition among students at Zambia University College of Technology (ZUT). The theory also underpins the qualitative exploration of student and faculty experiences, highlighting the interactive, student-centered dynamics that VR and AR can bring to higher education (D'Elia, et al., 2012; Hunaepi et al., 2023).

By applying this theoretical lens, the study not only evaluates the effectiveness of immersive technologies but also interrogates the broader pedagogical shifts required for their meaningful integration, particularly in resource-constrained environments such as Zambia. Constructivism thus provides a robust foundation for understanding both the opportunities and the limitations of VR/AR-based learning within the institutional context of ZUT.

## Methods

This study employed an embedded mixed-methods design to explore the potential of Virtual Reality (VR) and Augmented Reality (AR) in enhancing teaching and learning at Zambia University College of Technology (ZUT). This design was chosen to provide both broad, generalizable insights via quantitative analysis and in-depth contextual understanding through qualitative inquiry, thereby capturing the multifaceted nature of immersive technology integration in higher education.

Grounded in Constructivist Learning Theory, which asserts that learners actively construct knowledge through experience, exploration, and social interaction (D'Elia, et al., 2012), this study aligns well with VR and AR technologies that facilitate interactive, experiential learning.

The study adopts a pragmatic research paradigm, emphasizing practical, solution-oriented approaches and embracing mixed methods to examine complex educational phenomena. This paradigm is especially appropriate for educational technology research, where integrating diverse data sources enables actionable insights into both adoption processes and learning outcomes.

An embedded mixed-methods design was employed, featuring a quantitative core complemented by qualitative components. The quantitative strand involved administering structured surveys to assess participants' awareness, experiences, access to immersive technologies, perceived benefits, and implementation challenges. A pre-test and a posttest were designed on graph theory in discrete mathematics with two groups. The experimental Group had 30 students learning graph theory in Discrete Mathematics using the Meta Quest 3 VR headset.

The Control Group also had 30 students receiving traditional instructions on the same topic.

The qualitative strand consisted of semi-structured interviews and institutional document analysis, providing deeper insight into strategic, pedagogical, and infrastructural aspects.

This approach facilitated data triangulation, enhancing the validity and reliability of findings by cross-verifying information from multiple sources and methods. It also enabled a detailed understanding of both observable patterns and contextual dynamics within ZUT.

The quantitative sample included 286 participants, including 250 students and 36 faculty members, selected using simple random sampling.

The sample size was determined using Yamane's (1967) formula for finite populations, applying a 5% margin of error:

$$n = \frac{N}{1 + N(e^2)}$$

Where:

$n$ = sample size

$N$ = population size

$e$ = level of precision (0.05)

Prior to the main survey, a pilot test was conducted with 20 participants to validate the questionnaire's reliability and clarity. This approach ensured that the quantitative data were statistically representative of the broader ZUT population.

For the qualitative strand, purposive sampling selected 15 participants, which included faculty, department heads, and administrators directly involved in ICT policy formulation and technology-enhanced teaching. These individuals were chosen to provide rich, context-specific insights into institutional dynamics affecting immersive technology adoption.

Quantitative data was collected through a structured questionnaire featuring closed-ended and Likert-scale items. The instrument captured information on participant demographics, access to immersive technologies, training and usage patterns, instructional integration, and perceived learning outcomes.

As part of the qualitative exploration, participants were introduced to immersive experiences using the Meta Quest VR headset. This device features a Qualcomm Snapdragon XR2 Gen 2 processor, 8 GB RAM, and storage capacities of 512 GB. The headset is equipped with dual LCD panels offering a resolution of 2064 × 2208 pixels per eye (branded as "4K+ Infinite Display") and supports refresh rates of up to 120 Hz. It has an adjustable interpupillary distance (IPD) range of 53–75 mm and a field of view of approximately 110° horizontal and 96° vertical. These features made it ideal for demonstrating immersive simulations relevant to STEM and technical education.

Qualitative data were gathered via semi-structured interviews that explored themes such as implementation barriers, pedagogical integration, infrastructural capacity, and institutional readiness. Furthermore, institutional documents, including ICT strategy plans, course outlines, and relevant policy briefs, were reviewed to assess institutional alignment with immersive technology integration.

Quantitative data were analyzed using descriptive and inferential statistics. Descriptive statistics (frequencies, means, percentages) summarized usage patterns, awareness, access, and participant perceptions. Inferential tests including t-tests and ANOVA examined statistically significant differences across demographic groups (e.g., faculty vs. students, STEM vs. non-STEM) and variables linked to engagement, comprehension, and perceived learning outcomes.

Qualitative data were analyzed using thematic analysis, guided by (Braun & Clarke, 2006) six-phase framework, which are: familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report.

Both inductive and deductive coding approaches were used to identify themes relating to infrastructure, pedagogy, institutional readiness, and policy. The qualitative findings were then triangulated with the quantitative results to build a comprehensive understanding of the challenges and opportunities associated with immersive technology adoption at ZUT.

Ethical clearance was granted by the ZUT Research Ethics Committee. Participants were fully informed about the study's aims, procedures, and their rights, including the right to withdraw at any time without penalty. Informed consent was obtained before data collection. Confidentiality was strictly maintained by anonymizing survey and interview responses and securely storing all data in line with ZUT's data protection policies.

## Results

This section presents the findings from the quantitative surveys and qualitative interviews conducted to explore the awareness, usage, perceived benefits, and barriers related to Virtual Reality (VR) and Augmented Reality (AR) technologies at Zambia University College of Technology (ZUT).

### Quantitative Results

Quantitative results are categorized under demographics, awareness and usage, barriers to adoption and specific statistics analysis.

### Participant Demographics

A total of 286 participants completed the survey, comprising 250 students (87.4%) out of a population of 667 and 36 faculty members (12.6%) out of a population of 40 from various departments. Most participants (86%) were from STEM-related disciplines. Gender distribution was 53.1% male and 46.9% female.

Table 1. Frequency table for demographic variables

| Demographic Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| **Role** | | |
| Students | 250 | 87.4 |
| Faculty | 36 | 12.6 |
| **Discipline** | | |
| STEM | 246 | 86.0 |
| Non-STEM | 40 | 14.0 |
| **Gender** | | |
| Male | 152 | 53.1 |
| Female | 134 | 46.9 |

## Awareness and Usage of VR/AR Technologies

Survey results revealed that 78% (n = 223) of participants were aware of Virtual Reality (VR) and Augmented Reality (AR) technologies, while only 22% (n = 63) reported having used or interacted with such technologies in an educational context.

As part of the study, a group of students and faculty members were given access to Meta Quest VR headsets to experience immersive learning firsthand. These devices, equipped with Qualcomm Snapdragon XR2 Gen 2 processors, 8 GB RAM, and high-resolution 2064 × 2208 pixels per eye displays, were used in pilot learning sessions across selected STEM courses. The 120 Hz refresh rate and 110° field of view provided an immersive and realistic simulation experience, particularly in virtual laboratories and 3D model visualizations.

Out of the 63 participants who had prior VR/AR experience, 28 reported direct usage of the Meta Quest headsets during these sessions. These individuals engaged in practical simulations, spatial design tasks, and virtual explorations that supported course content delivery. Notably, their responses indicated a higher perceived benefit of VR/AR compared to those who had not used the headsets.

Table 2: Comparison of perceptions between VR Headset users and non-users

| **Perceived Benefit** | **Headset Users (n = 28)** | **Non-Users (n = 35)** | **t-value** | **p-value** |
|---|---|---|---|---|
| Enhanced conceptual understanding | 4.6 (SD = 0.5) | 3.9 (SD = 0.7) | 2.45 | $p < 0.05$ |
| Increased engagement (1–5) | 4.7 (SD = 0.4) | 4.0 (SD = 0.6) | 2.81 | $p < 0.01$ |

In addition, several students described the experience as "transformative", particularly in engineering subjects that traditionally rely on abstract or spatially complex content. However, despite the positive outcomes reported by headset users, broader access to such technologies remains limited due to cost and logistical constraints.

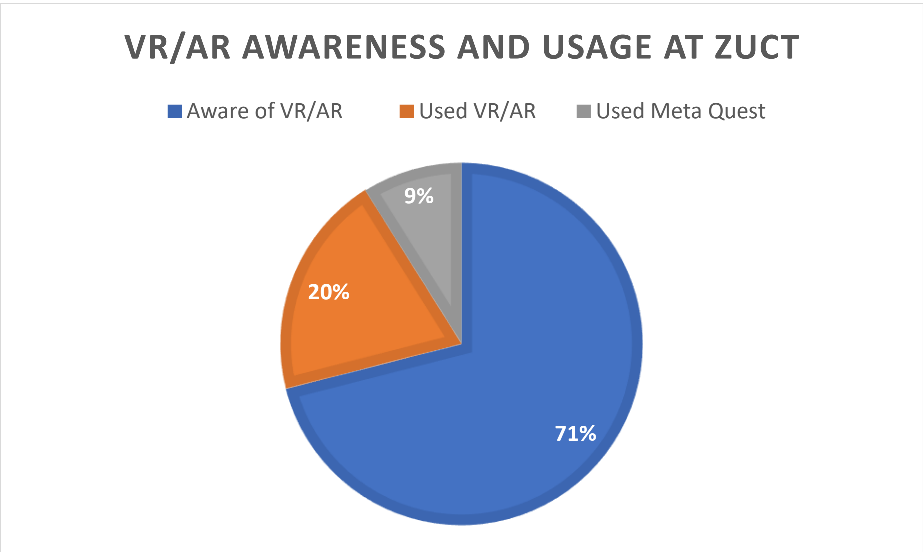


Figure 1. Survey results showing awareness, general usage, and Meta Quest headset usage

Table 3: Stacked bar chart showing perceived benefits of VR/AR in teaching and learning

| **Perceived Benefits** | **Likert Agreement Levels** | | | | |
|---|---|---|---|---|---|
| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| Engagement | 9 | 21 | 30 | 125 | 101 |
| Understanding | 10 | 19 | 32 | 126 | 99 |
| Simulation Safety | 14 | 21 | 35 | 120 | 96 |

## Barriers to Adoption

Table 4: Reported Barriers to VR/AR Adoption

| Barrier | Frequency (n) | Percentage (%) |
|---|---|---|
| High infrastructural costs | 234 | 82 |
| Lack of technical expertise | 217 | 76 |
| Absence of formal policies | 194 | 68 |
| Limited availability of equipment | 172 | 60 |

## Pre-test and Post test Results

Table 5: Reported Barriers to VR/AR Adoption

| | Experimental Group(VR group) | Control Group(Non-VR group) |
|---|---|---|
| Pre-Test Mean Score (%) | 12.3 | 12.7 |
| Post Test Mean Score(%) | 78.7 | 56.2 |

The results clearly show that the use of VR enhanced engagement & conceptual understanding

## Statistical Analysis

1. **T-Test:** Faculty reported significantly lower access to VR/AR technologies ($M = 2.1$, $SD = 1.3$) compared to students ($M = 3.4$, $SD = 1.2$), $t(284) = 5.32$, $p < 0.01$.
2. **ANOVA:** Significant difference in VR/AR usage across disciplines, $F(1, 284) = 4.57$, $p = 0.033$, with STEM students reporting higher usage.
3. No significant gender differences in perceptions of VR/AR benefits ($p > 0.05$).

## Qualitative Results

### Thematic Analysis Summary

Four main themes emerged from interviews with 15 participants (faculty, department heads, and ICT staff): Table 6 below shows the main thematic areas and the respective comments across interviews.

Table 6: Theme mentions across interviews

| Theme | Description | Supporting Quote |
|---|---|---|
| Institutional Readiness & Policy | Lack of formal VR/AR policies limits institutional support. | "Without policies, resource allocation is challenging." |
| Technical & Infrastructure | Inadequate ICT infrastructure hampers VR/AR implementation. | "Our labs lack necessary hardware and internet bandwidth." |

| Theme | Description | Supporting Quote |
|---|---|---|
| Pedagogical Integration & Training | Need for professional development and instructional design. | "We need training to use VR/AR effectively in teaching." |
| Learning Potential | VR/AR enhances engagement and understanding. | "VR helps students visualize complex concepts much better." |

Figure 2 shows the frequency of theme mentions across interviews.

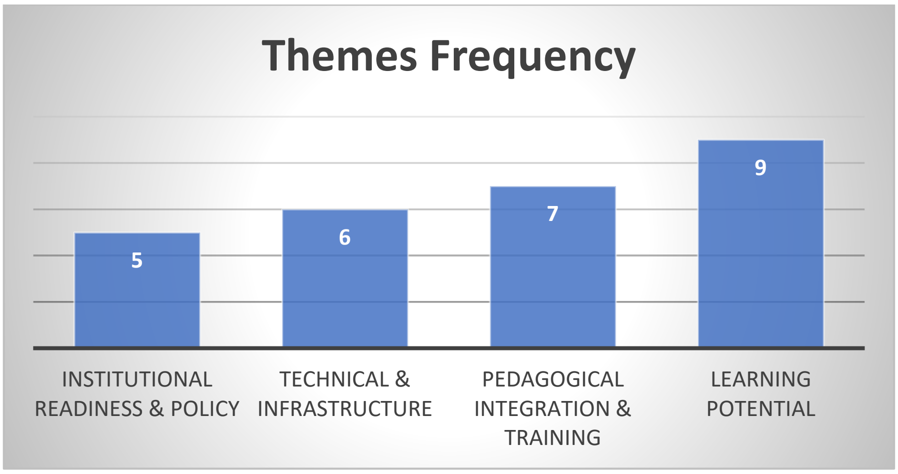


Figure 2: Bar graph representing frequency of theme mentions across interviews.

**Document Analysis**

The following were the results from document analysis:

ICT strategic plans focused on broad digital literacy but did not mention immersive technologies explicitly. Curriculum documents showed limited integration of VR/AR, mostly confined to the Computer Science department.

**Integration of Quantitative and Qualitative Findings**

Both quantitative and qualitative data confirm that while awareness and enthusiasm for VR/AR are high, practical usage remains limited and largely experimental. Key barriers such as infrastructure, policy gaps, and lack of training emerged consistently across methods. Conversely, participants strongly acknowledged VR/AR's potential to enhance student engagement and understanding, highlighting opportunities for future institutional investment.

## DISCUSSIONS

This study's findings reveal that while awareness of Virtual Reality (VR) and Augmented Reality (AR) technologies among students and faculty at Zambia University College of Technology (ZUT) is relatively high, their actual implementation remains limited and experimental. This aligns with prior research demonstrating that immersive technologies are predominantly adopted in STEM disciplines due to their practical applications in visualizing complex concepts and conducting simulations (Babu et al., 2018; Samosorn et al., 2020).

Quantitative results showed that STEM students and faculty reported higher engagement and perceived learning benefits from VR/AR use compared to their non-STEM counterparts, supporting earlier findings that immersive technologies yield greater impact in STEM education (Hunaepi et al., 2023). However, the underutilization in non-STEM fields highlights an area for potential expansion, as immersive learning can support constructivist pedagogies across disciplines.

Qualitative data highlighted several significant barriers to adoption, including infrastructural costs, lack of institutional policies, and insufficient technical expertise. These challenges mirror those reported in other resource-constrained African settings (RSIS International, 2023). One faculty member noted, "We have the interest, but the hardware and training are just not available. Without support, it's hard to move beyond pilot projects."

Faculty capacity building emerged as a critical need; without targeted professional development, educators find it difficult to design constructivist learning experiences utilizing VR and AR effectively (D'Elia, et al., 2012). As another participant remarked, "Training is essential and technology alone won't improve learning unless we know how to use it pedagogically." While participants widely acknowledged the pedagogical value of VR and AR in enhancing conceptual understanding and student engagement, practical implementation at ZUT remains minimal. Notably, a limited number of Meta Quest VR headsets, equipped with high-resolution 4K+ displays, Snapdragon XR2 Gen 2 processors, and immersive field-of-view capabilities, were utilized during this research to allow selected respondents (students and faculty) to experience immersive learning environments firsthand. These headsets were not yet integrated into formal teaching but served as tools for demonstrating the potential of VR-based instruction. The controlled exposure enabled the collection of direct feedback on usability, content engagement, and perceptual learning benefits, thereby offering insight into how full-scale adoption could unfold if supported by institutional policy, training, and infrastructure investment.

The study also confirmed that VR and AR align well with Constructivist Learning Theory, promoting experiential, active learning. Students reported deeper conceptual understanding and increased motivation when using immersive tools, consistent with previous studies (Hunaepi et al., 2023). However, effectiveness depends heavily on curricular integration and instructor facilitation.

Equity issues were raised, with concerns about unequal access to devices and stable internet, reflecting broader digital divides in Zambia (Aini, 2025). One student commented, "Not everyone has a smartphone or good internet. This limits who can benefit from VR/AR." This underscores the importance of inclusive policies to ensure broad access.

By focusing on ZUT, this study fills a critical gap in the literature by providing context-specific empirical insights from Zambia, an underrepresented region in VR/AR educational research. The mixed-methods approach allowed for a comprehensive understanding of both quantitative trends and qualitative contextual factors, supporting informed institutional planning.

In summary, the results of this research reveal that VR and AR have clear transformative potential for higher education at ZUT. However, sustainable integration requires strategic investments in infrastructure, faculty training, policy development, and equity-focused initiatives. Future research should explore longitudinal impacts and broaden disciplinary applications to maximize the benefits of immersive learning technologies.

## Conclusion

This study examined the role of Virtual Reality (VR) and Augmented Reality (AR) in enhancing teaching and learning at Zambia University College of Technology (ZUT) using an embedded mixed-methods approach. The findings reveal that while awareness of immersive technologies among students and faculty is relatively high, their actual use remains limited and largely experimental. The experimental component demonstrated that students exposed to VR-based instruction achieved significantly higher post-test scores and reported greater engagement and conceptual understanding compared to those taught using traditional methods. Additionally, both quantitative and qualitative results consistently identified key barriers to adoption, including high infrastructural costs, limited technical expertise, lack of institutional policies, and restricted access to equipment.

These findings have important practical and theoretical implications. From a practical perspective, they highlight the need for higher education institutions, particularly in resource-constrained settings, to move beyond awareness toward structured implementation supported by infrastructure investment, staff training, and policy development. The results also reinforce the relevance of Constructivist Learning Theory, demonstrating that immersive technologies can effectively support experiential, student-centered learning by enabling interaction, visualization, and active knowledge construction. At an institutional level, the study underscores the importance of aligning technological innovation with pedagogical design and strategic planning to ensure meaningful and sustainable integration of VR and AR in teaching and learning.

Based on these findings, several recommendations are proposed. Institutions should adopt a phased approach to VR/AR integration, beginning with pilot programs in high-impact disciplines such as STEM, alongside targeted professional development for faculty. Investment in shared VR laboratories, development of institutional policies, and exploration of public–private partnerships can further support sustainable implementation. To address equity concerns, strategies for improving access to devices and connectivity should also be prioritized. Future research should expand on this study by employing larger and more diverse samples across multiple institutions, conducting longitudinal and experimental studies across different disciplines, and exploring the pedagogical potential in greater depth, particularly in non-STEM fields. Such efforts will contribute to a more comprehensive understanding of how immersive technologies can be effectively and equitably integrated into higher education.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research. All findings and conclusions presented are unbiased and solely the result of the study conducted.

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