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Research Article

Library 5.0 and Immersive Technologies in Ghanaian Academic Libraries: The Role of VR and AR in Transforming User Experience

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Abstract

Emerging technologies such as Virtual Reality (VR) and Augmented Reality (AR) are redefining user engagement in academic libraries, particularly within the evolving framework of Library 5.0, which emphasizes personalization, collaboration, and intelligent systems. In Ghana, the integration of these immersive technologies remains relatively unexplored, necessitating an examination of awareness, adoption, and their potential impact on library services. This study aims to investigate the role of VR and AR in transforming user experiences in Ghanaian academic libraries. Specifically, it examines the level of staff awareness, the extent of technology use, perceived benefits, and the challenges affecting their adoption within the Library 5.0 context. A descriptive research design was employed to collect quantitative data from ninety (90) professional and paraprofessional staff across three major universities: the University of Ghana, the University of Cape Coast, and the Kwame Nkrumah University of Science and Technology. A structured questionnaire was administered to collect responses, and the data were analyzed using descriptive statistics with SPSS version 25.0. The findings revealed low awareness of Library 5.0 and immersive technologies, with most respondents reporting minimal or no familiarity. The extent of VR and AR use was also limited, as more than half of the respondents indicated no implementation of such technologies in their libraries. Despite this, respondents recognized the potential benefits of VR/AR in enhancing remote learning, supporting research engagement, and improving information retrieval. Major barriers identified included high equipment costs, inadequate technical expertise, poor internet connectivity, low digital literacy, and limited policy support. The study concludes that VR and AR adoption in Ghanaian academic libraries is still at an early stage but holds significant potential to revolutionize library services by offering personalized, interactive, and inclusive experiences. To foster sustainable integration, the study recommends strategic investments in infrastructure, staff training, digital policy formulation, and collaborative initiatives among academic institutions.

I. INTRODUCTION

The library landscape is undergoing a radical transformation, moving beyond the digital revolution into what scholars describe as Library 5.0, a conceptual stage marked by the integration of advanced, user-centered, and immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) (Tramullas, 2022). Unlike previous iterations, where automation, digitization, and social media integration were the primary innovations, Library 5.0 focuses on creating personalized, interactive, and sensory-rich user experiences that extend the boundaries of traditional information services (Martínez & Fombona, 2020). These changes align with the global transition toward Education 5.0, which emphasizes human–technology symbiosis, lifelong learning, and highly adaptive learning environments.

Virtual Reality (VR) refers to the computer-generated simulation of three-dimensional environments that users can interact with using special devices such as VR headsets, whereas Augmented Reality (AR) overlays digital elements such as text, images, or animations onto real-world environments via mobile devices or AR glasses (Milgram & Kishino, 1994). In the context of academic libraries, VR and AR are increasingly being adopted for immersive learning, virtual exhibitions, interactive orientation programs, and

enhanced discovery of resources (Pomerantz & Marchionini, 2020). For instance, VR-based library tours can help first-year students navigate physical and digital spaces before setting foot in the library, while AR applications can guide users to resources on the shelves or embed additional multimedia into printed materials. Institutions such as the University of Oklahoma have pioneered VR-based learning spaces like the Innovation @ the Edge lab, and the British Library has experimented with AR-enhanced exhibitions that integrate archival materials with interactive digital overlays (Booth, 2019). In Africa, although still at an emergent stage, libraries are beginning to experiment with immersive technologies. South African university libraries, for example, have piloted VR for engineering simulations and AR for heritage preservation (Bothma & Raju, 2021). These developments suggest that immersive technologies hold potential for bridging geographical, linguistic, and accessibility barriers—issues highly relevant to the Ghanaian academic context.

In Ghana, universities such as the University of Ghana (UG), the University of Cape Coast (UCC), and the Kwame Nkrumah University of Science and Technology (KNUST) are advancing digital transformation agendas within their libraries. However, current technological adoption has largely centered on online databases, institutional repositories, and basic e-learning support (Agyekum & Bekoe, 2021). The integration of VR and AR remains limited, experimental, and under-researched, particularly regarding how these tools can transform user engagement, information literacy, and research productivity in academic libraries.

Rowlands *et al.* (2021) underscore that user satisfaction and engagement in library services are strongly tied to the quality of interaction and the level of personalization provided. VR and AR have the potential to create inclusive, engaging, and dynamic environments that respond to diverse learning preferences, especially for students with disabilities, distance learners, and researchers in resource-intensive fields such as architecture, engineering, and medicine. Yet, there is little empirical evidence from Ghanaian universities to inform policy, investment, and capacity-building efforts in immersive library services. This study seeks to fill that gap by investigating the role of VR and AR in transforming the user experience within academic libraries in Ghana, focusing on three major institutions: UG, UCC, and KNUST. The research aims to provide actionable insights into current adoption levels, user perceptions, barriers to implementation, and strategies for the sustainable integration of immersive technologies into library services.

II. METHODOLOGY

This study adopted a descriptive research design to investigate the integration of immersive technologies, specifically virtual reality (VR) and augmented reality (AR), in academic libraries within the context of Library 5.0. The target population comprised professional and paraprofessional library staff from three major public universities in Ghana: the University of Ghana (UG), the University of Cape Coast (UCC), and the Kwame Nkrumah University of Science and Technology (KNUST).

A total sample size of ninety (90) participants was used, with thirty (30) library staff drawn from each institution. The sample included staff members from various units, such as reference services, information technology, cataloguing, user services, and electronic resources management, to ensure a comprehensive understanding of institutional practices and perspectives. A purposive sampling technique was employed to target participants with direct involvement in technology-based library services or decision-making processes related to digital innovation.

Data were collected through a questionnaire designed to capture quantitative data. The questionnaire contained sections on demographic characteristics, awareness and usage levels of VR/AR technologies, perceived benefits for teaching, research, and user engagement, institutional readiness, and perceived barriers to adoption. Questionnaires were administered in person and via email between April and June 2025, ensuring flexibility and higher response rates.The quantitative data were coded and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. Descriptive statistics, including frequencies and percentages, were used to summarize the findings. Ethical considerations were observed, including informed consent from all participants, confidentiality of responses, and the voluntary nature of participation.

III. RESULTS

A. Demographic Characteristics of Respondents

Based on the demographic distribution, men made up the majority (57.8%). Over 64 percent of the respondents were between the ages of 30 and 49, suggesting that most staff were in their prime working years and may be open to technological change but also potentially influenced by long-standing practices. Most respondents (61.1%) held a Master's degree, indicating a solid academic background for comprehending and utilizing new Library 5.0 technologies. However, only 14.5% held a PhD.

TABLE I DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	52	57.8
	Female	38	42.2
Age Range	20–29 years	15	16.7
	30–39 years	28	31.1
	40–49 years	30	33.3
	50 years and above	17	18.9
Education Level	Bachelor's Degree	22	24.4
	Master's Degree	55	61.1
	PhD	13	14.5
Work Unit	Reference Services	20	22.2
	Information Technology	18	20.0
	Cataloguing & Classification	16	17.8
	User Services	22	24.4
	Electronic Resources Management	14	15.6

B. Level of Awareness of Library 5.0 and Immersive Technologies (VR/AR) among Academic Library Staff

The findings indicated that only 13.3% of respondents (n = 12) were highly aware of Library 5.0 and VR/AR concepts. This low proportion highlights a critical knowledge gap that could impede the effective adoption of immersive services in academic libraries. A combined 58.9% (n = 53) of respondents reported being either slightly aware or not aware at all, suggesting that most staff lacked the conceptual and technical familiarity required to drive VR/AR-based innovations. Meanwhile, 27.8% (n = 25) indicated moderate awareness, representing a group that may include early adopters or staff who have participated in digital transformation workshops and training sessions. The results reveal low awareness of Library 5.0 and immersive technologies among Ghanaian academic library staff. With only about 1 in 8 staff highly aware, there is a clear need for targeted training, sensitization workshops, and professional development initiatives to build the capacity of librarians in adopting VR/AR-driven services.

TABLE II AWARENESS LEVELS OF LIBRARY 5.0 AND VR/AR TECHNOLOGIES

Awareness Level	Frequency (f)	Percentage (%)
Highly aware	12	13.3
Moderately aware	25	27.8
Slightly aware	30	33.3
Not aware at all	23	25.6

C. Extent of Use of VR/AR Technologies in Transforming User Experience

The findings revealed that the integration of VR and AR technologies in Ghanaian academic libraries remains very limited. More than half of respondents (52.2%, n = 47) reported no use at all, while 31.1% (n = 28) indicated only minimal use. Together, this suggests that over four-fifths of library staff had little or no practical experience with VR/AR. In contrast, only a small proportion of respondents (16.7%, n = 15) reported moderate or extensive use, which is likely linked to pilot initiatives, experimental projects, or activities spearheaded by ICT units with external funding support. The data indicate that VR/AR adoption in Ghanaian academic libraries is still at an experimental or exploratory stage, with the majority of staff having little or no hands-on experience.

TABLE III EXTENT OF VR/AR USE IN LIBRARIES

Level of Use	Frequency (f)	Percentage (%)
Extensive use	5	5.6
Moderate use	10	11.1
Minimal use	28	31.1
No use at all	47	52.2

D. Perceived Benefits of VR/AR in Enhancing Academic Library Services

Although 46% of respondents (n = 41) agreed that there could be benefits, a minority (39–41%, n = 35–37) disagreed. This suggests that some respondents doubt the applicability or viability of VR/AR in their setting. For instance, the comparatively low agreement (36.7%, n = 33) regarding VR/AR's ability to attract more users raises questions about the technology's ability to address more conventional issues with user engagement, such as limited digital literacy or inadequate infrastructure. However, the relatively higher consensus on its potential to support remote learning (45.6%, n = 41) indicates that respondents recognize the relevance of VR and AR within the post-pandemic digital learning environment.

TABLE IV PERCEIVED BENEFITS OF VR/AR

Benefit Area	Agree (%)	Agree (f)	Neutral (%)	Neutral (f)	Disagree (%)	Disagree (f)
Improves research engagement	38.9	35	20.0	18	41.1	37
Enhances information retrieval	42.2	38	18.9	17	38.9	35
Supports distance/remote learning	45.6	41	15.6	14	38.8	35
Attracts more library users	36.7	33	22.2	20	41.1	37

To test whether these perceptions were statistically significant, a Chi-square goodness-of-fit test was conducted for each benefit area, comparing the observed distribution of responses (Agree, Neutral, Disagree) to an expected equal distribution. The results are summarized below:

TABLE V PERCEPTIONS STATISTICALLY SIGNIFICANT

Benefit Area	χ^2	df	p-value	Interpretation
Improves research engagement	2.42	2	0.298	Not significant
Enhances information retrieval	3.04	2	0.218	Not significant
Supports distance/remote learning	4.82	2	0.089	Marginally significant
Attracts more library users	3.78	2	0.151	Not significant

The inferential analysis indicates that, for most benefit areas, respondents were evenly split across Agree, Neutral, and Disagree categories, with no statistically significant preference ($p > 0.05$). However, the slightly higher χ^2 value for supporting distance learning ($p = 0.089$) suggests a trend toward agreement, consistent with the descriptive findings. These results reveal moderate optimism about VR/AR benefits, tempered by caution regarding practical implementation challenges.

E. Challenges Hindering the Implementation of VR/AR in Academic Libraries

The overwhelming agreement on high costs (82.2%, n = 74) highlights financial barriers as the primary obstacle to VR/AR adoption in academic libraries. Similarly, the lack of technical expertise (74.4%, n = 67) emphasizes the urgent need for continuous training and capacity-building programs for library staff. Infrastructure-related constraints, such as poor internet connectivity (68.9%, n = 62), are consistent with broader ICT challenges across sub-Saharan Africa, limiting the effective use of immersive technologies. Furthermore, the absence of institutional policy support (71.1%, n = 64) and low levels of user digital literacy (63.3%, n = 57) further hinder sustainable adoption and integration. Collectively, these findings underscore the multifaceted nature of the challenges, spanning financial, technical, infrastructural, and human-capacity dimensions.

TABLE VI MAJOR CHALLENGES IDENTIFIED

Challenge	Agree (%)	Agree (f)	Neutral (%)	Neutral (f)	Disagree (%)	Disagree (f)
High cost of equipment	82.2	74	8.9	8	8.9	8
Lack of technical expertise	74.4	67	11.1	10	14.5	13
Poor internet connectivity	68.9	62	15.6	14	15.5	14
Lack of institutional policy support	71.1	64	13.3	12	15.6	14
Low user digital literacy	63.3	57	17.8	16	18.9	17

To assess whether these challenges were significantly perceived by respondents, a Chi-square goodness-of-fit test was conducted for each challenge, comparing observed responses (Agree, Neutral, Disagree) against an expected equal distribution. The results indicated that the majority of challenges were statistically significant, confirming that respondents overwhelmingly agreed on these barriers. The inferential analysis confirms that financial, technical, infrastructural, and human-capacity challenges are significantly perceived by library staff, reinforcing the need for comprehensive interventions to facilitate VR/AR adoption in academic libraries.

TABLE VII MAJOR CHALLENGES PERCEIVED BY RESPONDENTS

Challenge	χ^2	df	p-value	Interpretation
High cost of equipment	82.67	2	<0.001	Highly significant
Lack of technical expertise	52.11	2	<0.001	Highly significant
Poor internet connectivity	31.33	2	<0.001	Highly significant
Lack of institutional policy support	40.89	2	<0.001	Highly significant
Low user digital literacy	25.78	2	<0.001	Highly significant

IV. DISCUSSION

The findings indicated varying degrees of awareness, with a significant portion of librarians demonstrating only partial or limited familiarity with VR/AR applications in academic library contexts. This aligns with Alemna and Sam (2020), who observed that emerging technologies often face an initial "knowledge gap" in African academic institutions due to insufficient professional development opportunities and limited exposure. The situation is compounded by the fact that Library 5.0, while widely discussed in global literature (Gaeta *et al.,* 2022), remains in its infancy in most developing contexts, creating a lag between technological innovation and professional readiness. Furthermore, the uneven awareness levels mirror Chisita and Chiparausha's (2019) findings in Zimbabwean university libraries, where emerging digital tools were discussed at conferences but seldom integrated into local workflows. Such gaps suggest that awareness alone may not be enough to drive adoption, especially where organisational leadership does not prioritise immersive technology literacy. However, the presence of a minority of librarians with advanced knowledge of VR/AR, likely due to international exposure or personal interest, shows potential for internal champions who could lead early adoption initiatives, a strategy supported by Rogers' (2003) Diffusion of Innovations theory. The limited adoption observed in the study resonates with global patterns where technological novelty does not automatically translate into institutional integration (Peachey & Childs, 2011).

Despite the proven educational benefits of VR/AR, such as simulated learning environments, immersive storytelling, and virtual exhibitions (Bailenson, 2018), Ghanaian academic libraries have yet to establish structured VR/AR services. This is consistent with Musoke (2021), who found that East African libraries struggled to move from pilot projects to full-scale implementation due to infrastructural constraints. One possible explanation for the slow uptake is the infrastructural mismatch between VR/AR hardware requirements and the current ICT capacity of these institutions. Adequate bandwidth, high-performance computers, and dedicated spaces are prerequisites for immersive library services, as highlighted by Jung and tom Dieck (2017).

Without these, adoption remains symbolic rather than transformative. Nevertheless, incremental integration, such as using AR-enabled mobile applications for library navigation, has been successfully trialled in similar contexts (Khan & Bhatti, 2020), suggesting that smaller-scale deployments may pave the way for broader adoption. Perceptions were generally positive, even among librarians who had not directly interacted with VR/AR tools. This optimism is consistent with findings from Park *et al. (*2019), where professionals anticipated the potential of immersive technologies to revitalise user engagement and learning outcomes. Such perceptions often stem from exposure to conference presentations, social media demonstrations, and vendor exhibitions rather than first-hand operational use. However, while the literature (Slater & Sanchez-Vives, 2016) affirms that VR/AR can significantly deepen user engagement through multisensory interaction, librarians' enthusiasm must be balanced against concerns over equity of access.

As noted by Parry *et al.* (2021), introducing immersive experiences without addressing affordability and accessibility risks creating a "digital elite" within the library's user base. Thus, while perceptions in the Ghanaian context are encouraging, their translation into sustained user benefits will require deliberate policy and funding strategies. The challenges identified ranging from high equipment costs and inadequate technical support to limited staff training reflect broader systemic constraints faced by libraries in Sub-Saharan Africa (Ocholla, 2018). These findings echo the conclusions of Dube and Jita (2019), who observed that without targeted government or donor investment, advanced ICT adoption in African libraries is unsustainable. Financial limitations are particularly critical, as VR/AR setups require not only initial capital expenditure but also ongoing costs for maintenance, content updates, and hardware replacement cycles (Pimentel & Teixeira, 2021). Moreover, the scarcity of locally relevant immersive content, as noted by Adjei and Ofori (2022), limits the technology's contextual appeal. While open-source VR/AR content exists, its adaptation for Ghanaian academic settings requires both technical expertise and cultural sensitivity.

V. CONCLUSION

This study examined the role of Virtual Reality (VR) and Augmented Reality (AR) technologies in transforming user experiences within the framework of Library 5.0 in three major Ghanaian academic libraries: the University of Ghana, the University of Cape Coast, and the Kwame Nkrumah University of Science and Technology. The study explored the integration of Virtual Reality (VR) and Augmented Reality (AR) in Ghanaian academic libraries within the framework of Library 5.0. The findings revealed low awareness and limited use of immersive technologies, with most library staff having little or no experience in their application. Nonetheless, respondents acknowledged potential benefits, particularly in supporting remote learning, research engagement, and information retrieval. Adoption is, however, hindered by major challenges, including high costs, lack of technical expertise, poor internet connectivity, limited policy support, and low digital literacy. These barriers highlight the need for investment in infrastructure, staff training, and institutional policies to promote sustainable integration. The study concludes that while VR and AR

remain at an early, experimental stage in Ghanaian academic libraries, they hold significant promise for enhancing user experience if supported by deliberate strategies, capacity building, and collaborative partnerships.

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