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Examining Extended Reality Instructional Tools for Virtual Field Trips in Nigerian High Schools

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Abstract. While experiential learning is central to geography education, field trips in Nigerian secondary schools are frequently constrained by insecurity, cultural barriers, and inadequate funding. As a scalable alternative, Extended Reality (XR)-enabled Virtual Field Trips (VFTs) present a promising solution. Yet, their successful classroom adoption may depend on students' digital literacy and gender-related factors. This study investigated: (i) the digital literacy levels of geography students; (ii) students' perceptions of XR instructional tools (XRITs) for VFTs; (iii) the influence of digital literacy on these perceptions; and (iv) the role of gender in shaping students' perceptions. A quantitative survey design was employed, using a multistage sampling technique to select 420 Senior Secondary III students from across Nigeria's six geopolitical zones. Data were collected through a validated 30-item instrument (Cronbach's α = 0.831) and analyzed using descriptive statistics (mean, standard deviation, and kurtosis) and inferential statistics (linear regression and t-test). The findings revealed that students generally held positive perceptions of XRITs, with no statistically significant gender differences. Students demonstrated moderate digital literacy, with strengths in critical thinking and self-regulation, but showed weaknesses in platform navigation and multimedia interaction. Interestingly, regression analysis showed no significant relationship between digital literacy and students' perceptions of XRITs, suggesting that initial engagement may be more influenced by the novelty and intuitive design of the tools than by digital proficiency. The study concluded that XR holds transformative potential for geography education in Nigeria. However, to realize this potential, systemic barriers must be addressed. It is recommended that XR adoption follow a context-sensitive approach, with coordinated multi-stakeholder investment in digital infrastructure to ensure equitable and sustainable implementation across schools.

Keywords: Extended Reality; Immersive Technology; Digital Literacy; Virtual Field Trips; Virtual Reality

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1. Introduction

The integration of technology-enhanced instructional tools has profoundly transformed global education, aligning it more effectively with the objectives of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 5 (Gender Equality). Over time, educational delivery has evolved from early broadcast media to sophisticated digital platforms such as Web-Based Instruction (WBI), mobile learning, and Artificial Intelligence (AI), thereby enhancing accessibility and promoting inclusivity (Košíková & Vašaničová, 2025).

Despite these global advancements, geography education in Nigeria continues to rely heavily on static instructional resources and teacher-centred approaches, limiting opportunities for interactivity and contextual learning. This reliance on traditional methods has been critiqued by scholars such as Adedokun-Shittu et al. (2020) and Ajaps (2015), who argue that it fails to capture the dynamic and inquiry-oriented nature of geography. Consequently, this limits the subject's potential to cultivate spatial thinking and contribute meaningfully to sustainability education.

Globally, geography education is increasingly embracing immersive technologies that enhance learners' understanding of complex environmental systems and spatial patterns. Scholars such as Goudie (2017), Meadows (2020), and the Geographical Association (2022) argue that geography's inherently interdisciplinary character makes it especially well-suited to address sustainability challenges through tools like geospatial mapping, remote sensing, and Extended Reality (XR).

Maude (2017) highlights that the true value of geography lies in its capacity for applied, experiential learning—most effectively realized through field trips. Traditionally regarded as a cornerstone of geography education (Hogan, 2020; Preston, 2016), field trips now face growing challenges related to cost, logistics, and accessibility (Firomumwe, 2022; Stojšić et al., 2021), especially in under-resourced contexts such as Nigeria. These limitations were further exacerbated by the COVID-19 pandemic, which exposed systemic vulnerabilities and accelerated the shift toward virtual alternatives.

Extended Reality (XR)—an umbrella term encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—is increasingly recognized as a transformative tool for overcoming educational limitations, particularly in resource-constrained contexts (Crogman et al., 2025; Tortora et al., 2025). Guo et al. (2021) define XR as a continuum that spans real to fully virtual experiences, offering immersive, interactive, and highly personalized learning environments. Sensorium (2022) and Arm (2022) highlight XR's ability to deliver context-aware, real-time engagement, thereby enhancing cognitive involvement and instructional effectiveness. Empirical studies by Tegoan et al. (2021) and Adedokun-Shittu et al. (2020) further validate XR's potential to boost learner motivation and improve content comprehension. In the Nigerian context—where mobile and visualization technologies are becoming increasingly accessible—XR-

enabled Virtual Field Trips (VFTs) present a promising innovation for enriching geography education. As Cliffe (2017) notes, these tools can surpass the limitations of traditional field experiences by offering enhanced scalability, safety, and pedagogical flexibility—qualities especially critical in under-resourced educational settings.

The pedagogical value of XR-facilitated Virtual Field Trips (VFTs) is well-supported by empirical evidence demonstrating their capacity to simulate complex geospatial environments and promote multisensory engagement. Studies by Evelpidou et al. (2022) and Hilmi and Yıldırım (2011) show that VFTs not only serve as effective substitutes for traditional field trips but also function as valuable preparatory tools that enhance students' conceptual understanding.

By enabling the visualization of dynamic geological and spatial phenomena, XR technologies foster deeper knowledge retention and greater learner motivation when compared to conventional textbook-based instruction (Marougkas et al., 2023; Tussyadiah et al., 2018). Despite these benefits, several challenges persist—particularly in developing countries—including motion sickness, limited infrastructure, and high implementation costs (Kourtesis et al., 2024; Msweli & Phahlane, 2025). These constraints underscore the importance of a strategic, pedagogically grounded approach to XR integration, ensuring its adoption is driven by instructional value rather than technological novelty.

Furthermore, the educational effectiveness of XR is closely tied to how well it is integrated pedagogically and the extent to which it facilitates meaningful teacher-student interactions. As Araújo et al. (2016) and Pianta (2016) emphasize, immersive environments alone are insufficient without structured scaffolding that supports autonomy, problem-solving, and critical thinking. Research by Belda-Medina and Marrahi-Gomez (2023), as well as Alhebaishi and Stone (2025), demonstrates that purposeful engagement with XR tools can yield significant benefits, including enhanced vocabulary acquisition, increased motivation, and improved long-term knowledge retention.

Emerging innovations—such as XR escape rooms (Mystakidis & Christopoulos, 2022) and blended VR-integrated STEM classrooms (Lee et al., 2022)—reflect the growing sophistication and diversification of immersive learning modalities. However, persistent challenges such as high costs, limited teacher preparedness, and the need for locally relevant content continue to hinder widespread adoption. These barriers highlight the critical importance of contextualizing XR implementation within specific educational ecosystems, particularly in Nigeria and other similarly resourced settings.

Extended Reality (XR) is emerging as a powerful tool for enhancing learning experiences, particularly among Generation Z students who are naturally inclined toward digital interaction. In the Nigerian high school context, XR offers significant potential for facilitating immersive, experiential learning—especially in subjects such as geography through Virtual Field Trips (VFTs) (Adedokun-Shittu et al., 2020). However, as Timotheou et al. (2023) argue, the successful

implementation and effective utilization of XR tools are closely linked to students' levels of digital literacy. Digital literacy, as defined by Yo (2021) and supported by Agina-Obu and Okwu (2023), encompasses the ability to access, evaluate, and use digital tools and resources proficiently. It involves navigating digital environments, critically assessing information, and engaging in purposeful communication through digital platforms.

While the growing availability of affordable smartphones and internet access has increased students' exposure to digital technologies, Oladosu et al. (2021) emphasize that meaningful academic outcomes from XR depend on the depth and quality of students' digital competencies. Digitally literate students are more likely to leverage XR's immersive features to improve memory retention, collaborate effectively, and develop a deeper understanding of complex concepts.

Conversely, limited digital literacy poses a significant barrier to unlocking the full pedagogical potential of XR. Without the necessary skills, students may find it difficult to navigate XR interfaces, assess the credibility of digital content, or engage meaningfully in interactive and collaborative tasks—all of which are central to XR-based learning. As highlighted by Martin and Grudziecki (2006), Hargittai (2016), Castellví et al. (2020), and Caled and Silva (2022), insufficient digital literacy undermines students' critical thinking abilities, increasing their vulnerability to misinformation and diminishing their capacity for independent analysis. This concern is particularly pronounced in XR environments, where content is often complex, data-rich, and presented dynamically (Kourtesis, 2024).

Additionally, the collaborative nature of XR—which frequently involves real-time communication, teamwork, and problem-solving—requires a level of digital fluency that students with low digital literacy may lack. As Wang et al. (2024) observe, this can lead to reduced engagement and diminished learning outcomes. Therefore, while XR offers a transformative avenue for reimagining education in Nigerian high schools, its effective implementation is critically dependent on students' digital readiness. Enhancing digital literacy is thus not merely a supplementary consideration, but a foundational prerequisite for meaningful XR integration in the classroom.

Beyond conceptual understanding, studies such as those by Lazou and Tsinakos (2023) and Yaseen et al. (2025) underscore digital literacy as a critical enabler for effective engagement with emerging digital technologies, including immersive tools like XR. The Technology Acceptance Model (TAM) developed by Davis (1989) posits that perceived ease of use and perceived usefulness are key determinants of users' willingness to adopt new technologies. In the educational context, digital literacy enhances students' capacity to navigate complex XR environments; however, it is not the sole factor influencing engagement (Lin & Yu, 2023). Students are more likely to interact meaningfully with XR tools when the content is intuitively designed, interactive, and closely aligned with their learning goals (Barbu et al., 2025). This suggests that while digital literacy is essential, the pedagogical quality and usability of XR applications are equally important in fostering meaningful learning experiences.

Additionally, the Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. (2003), expands this perspective by identifying four key factors influencing technology adoption: performance expectancy, effort expectancy, social influence, and facilitating conditions. These constructs highlight that, beyond individual abilities, system-level factors—such as infrastructure availability, institutional readiness, and curricular alignment—significantly shape students' perceptions and use of XR tools. Consequently, the implementation of XR in Nigerian geography education requires a renewed strategy grounded in a socio-technical perspective. This approach must consider both individual competencies and contextual realities to effectively address the current conditions in schools.

Lastly, the integration of XR technologies must address the persistent issue of gender disparities in digital engagement. Although the digital age has seen a narrowing gap between male and female competencies (Qazi et al., 2022), socio-cultural norms continue to influence access to and attitudes toward technology use. Immersive tools like 3D VR are praised for reducing learning anxieties (Lan et al., 2016); however, concerns about gender biases remain, particularly regarding usage patterns and equitable access.

While some studies (Loan, 2012; Onojah et al., 2021) report gender-neutral use of digital tools, others (Ellinger et al., 2023; Joel & Aride, 2006; Rajasekhar et al., 2018) highlight the ongoing impact of gender stereotypes and social conditioning. These mixed findings suggest that XR adoption strategies should move beyond simplistic binary gender assumptions and instead adopt an intersectional approach. Accordingly, this study conceptualizes gender as a moderating variable in examining Nigerian high school geography students' responses to XR instructional tools for Virtual Field Trips (VFTs).

1.1 Problem Statement

Field trips are fundamental to effective geography education, providing experiential learning opportunities that foster spatial reasoning and encourage real-world inquiry (Behrendt & Franklin, 2014). However, in Nigerian high schools, such experiences are increasingly limited by numerous challenges, including high financial costs, logistical difficulties, safety concerns, insufficient teacher preparedness, and broader systemic issues such as insecurity and cultural sensitivities (Adedokun-Shittu et al., 2020). These challenges are compounded by chronic underfunding in Nigeria's education sector, which consistently allocates less than 8% of the national budget—well below UNESCO's recommended 15–20% threshold (Federal Republic of Nigeria, 2025; UNESCO, 2015).

Consequently, many students are deprived of critical interactive learning experiences that support meaningful engagement with geographic concepts. Within this context, XR-enabled Virtual Field Trips (VFTs) have emerged as a scalable, cost-effective alternative (Crogman et al., 2025), capable of simulating real-world environments (Tortora et al., 2025) and addressing some limitations of traditional fieldwork (Timotheou et al., 2023). Nonetheless, the successful

adoption of XR in Nigerian classrooms is not assured. Two critical but underexplored barriers are students' digital literacy levels (Igwe et al., 2024) and gender disparities (Sufian et al., 2023). These factors may significantly influence how students engage with and benefit from XR technologies, potentially reinforcing existing educational inequalities. This study, therefore, critically examines the potential of XR tools in geography education, with particular attention to how digital literacy and gender may shape or constrain their impact.

1.2. Research questions

This study answered the following research questions:

1. What is the digital literacy level among geography students in Nigerian high schools?
2. What is the perception of geography students towards XR instructional tools for VFTs in Nigerian high schools?
3. What is the influence of digital literacy on the perception of geography students towards XR instructional tools for VFTs in Nigerian high schools?
4. How does geography students' gender influence their perception towards XR instructional tools for VFTs in Nigerian high schools?

1.3 Research hypotheses

The following alternate hypotheses were tested in this study at 0.05 level of significance:

H_1: Geography student's digital literacy level influences their perception towards XR instructional tools for VFTs in Nigerian high schools.

H_2: Male and female geography students have different perception towards XR instructional tools for VFTs in Nigerian high schools.

2. Materials and Methods

This study employed a quantitative survey design to investigate the use of XR instructional tools (XRITs) for Virtual Field Trips (VFTs) among high school geography students in Nigeria. The target population consisted of students enrolled in government-owned, co-educational secondary schools offering geography as a subject. A multistage sampling procedure was implemented to ensure national representation and alignment with the study objectives. First, stratified sampling was used to select one state from each of Nigeria's six geopolitical zones, capturing geographic diversity across the country.

Next, within each selected state, systematic random sampling identified five mixed-gender public high schools located in the state capitals, ensuring consistency in school type and an urban educational context. The third stage involved purposive sampling, where one school per state was chosen based on the criterion that VR tools had been previously or were currently used in teaching science subjects, ensuring relevance to XR-based instruction. Finally, cluster sampling was applied to select 70 Senior Secondary School III (SSS III) geography students from each chosen school during their geography practical sessions. This multistage process yielded a total sample of 420 students for the study.

Data were collected using a structured questionnaire adapted from Adedokun-Shittu et al. (2020) and expanded into a 30-item instrument titled the "Geo-XR for Instruction Questionnaire." The questionnaire consisted of three sections: Section A gathered demographic information; Section B assessed students' digital literacy levels; and Section C measured their perceptions of XR instructional tools. The instrument underwent validation for face and content validity by subject matter experts and demonstrated strong reliability, with a Cronbach's alpha of 0.831. Both Sections B and C employed a five-point Likert scale ranging from Strongly Agree to Strongly Disagree, with a benchmark mean score of 3.0 established as the threshold for agreement.

Data analysis involved the use of descriptive statistics—mean, standard deviation, and kurtosis—to address the research questions, conducted with SPSS version 28.0. To test the study's hypotheses, inferential statistics were applied: linear regression analysis examined the influence of digital literacy on students' responses to XR tools (Hypothesis One), while an independent samples t-test assessed whether gender significantly affected students' reactions (Hypothesis Two). Both hypotheses were tested at a significance level of 0.05.

2.1 Ethical considerations

The researcher ensured that the study adhered closely to established standards and ethical procedures for educational research. Given the sensitive nature of the study, permission was obtained from relevant authorities and participants, with confidentiality assured before, during, and after data collection. Participants were informed of their right to freely assent to or decline participation, thereby avoiding any form of coercion. Throughout the study, strict compliance with ethical guidelines was maintained, and all participant information was handled with the utmost care and confidentiality. Additionally, participants were supported during the study to minimize potential technostress. All sources that contributed to this research were properly cited and referenced. Ethical approval for the study was granted under the reference number [UERC/ASN/2023/2536].

3. Results

Answering research questions

The collected data were analyzed to address the study's research questions. The results are presented in tables, followed by detailed interpretation.

Research Question One: What is the digital literacy level among geography students in Nigerian high schools?

Assessing the digital literacy levels of these students provides essential insights into their ability to engage effectively with XR instructional tools (XRITs). This analysis serves as a foundational step in identifying gaps in digital competence that directly affect the effectiveness and inclusivity of XR integration within geography education.

Table 1: Digital Literacy Level of Geography Students in Nigerian High Schools

S/N	Items	Mean ($\underline{X}$)	S. D.	Kurtosis	
				Statistics	S. E
1.	I feel confident using digital tools like smartphones, tablets, and computers for learning.	4.12	1.140	1.942	.238
2.	I can easily find and retrieve academic information using the Internet.	3.63	1.401	-.325	.238
3.	I can evaluate whether online sources are credible and reliable.	3.55	1.424	-.600	.238
4.	I know how to use educational applications and platforms effectively.	3.44	1.425	-.704	.238
5.	I can troubleshoot basic problems when using digital tools.	3.55	1.499	-.873	.238
6.	I am comfortable using multimedia resources (e.g., videos, interactive apps) for schoolwork.	3.52	1.489	-.916	.238
7.	I frequently use digital tools to collaborate with classmates on assignments.	3.60	1.408	-.438	.238
8.	I understand how to protect my personal information when using digital platforms.	4.11	1.224	1.884	.238
9.	I can critically analyse digital content before using it for learning.	4.17	.899	4.793	.238
10.	I use digital tools to organize my school tasks and schedules effectively.	4.13	1.121	1.585	.238
Grand Mean		**3.782**			

The analysis of Table 1 revealed that the overall digital literacy level among geography students in Nigerian high schools was moderately high, with a grand mean of 3.78 on a 5-point Likert scale. This suggests that, on average, students possess a functional competence in using digital technologies for academic purposes. The highest mean scores were observed for statements such as "I can critically analyse digital content before using it for learning" (Mean = 4.17), "I use digital tools to organize my school tasks and schedules effectively" (Mean = 4.13), and "I feel confident using digital tools like smartphones, tablets, and computers for learning" (Mean = 4.12). These findings indicate a positive self-perception of digital literacy skills, particularly in areas requiring higher-order thinking and academic organization—both crucial for effective engagement with technology-enhanced learning tools like XR.

However, a closer examination of individual items highlights certain gaps in core digital competencies. The lowest mean scores appeared for statements such as "I know how to use educational applications and platforms effectively" (Mean = 3.44) and "I am comfortable using multimedia resources" (Mean = 3.52). These skills are vital for interactive learning experiences like XR-based Virtual Field Trips (VFTs), which demand ease in navigating multimedia platforms and educational software. The relatively low kurtosis values (-0.70 to -0.92) for these items suggest a flatter distribution, reflecting variability in student responses and inconsistency in skill levels. These weaknesses point to potential barriers that could limit the optimal use of XR instructional tools, as digital literacy is not uniformly strong across all necessary skill areas.

Additionally, items such as "I can critically analyse digital content" (kurtosis = 4.79) and "I understand how to protect my personal information" (kurtosis = 1.88) showed high positive kurtosis values, indicating a clustering of responses at the higher end of the scale. This reflects a subset of students with particularly strong abilities in evaluating digital content and practicing safe online behaviour—both critical for responsible engagement with immersive, data-intensive platforms like XR. Overall, while geography students demonstrate promising levels of digital literacy, targeted skill development is needed, especially in areas directly related to navigating and maximizing XR technologies. Addressing these gaps could substantially enhance the pedagogical impact of XR tools in Nigerian high schools.

Research Question Two: What are geography students' perceptions of XR instructional tools for Virtual Field Trips in Nigerian high schools?

Understanding students' perceptions of XRITs is key to their successful adoption and integration within Nigerian high schools. Exploring these perspectives can provide insight into how students engage with and respond to XR-based learning experiences.

Table 2: Geography Students' Perception towards XRITs for VFTs

S/N	Items	Mean ($\underline{X}$)	S. D.
1.	XR tools have helped me better understand lesson concepts.	4.12	1.107
2.	I found XR-based activities more engaging than traditional classroom lessons.	4.00	1.265
3.	XR experiences made me feel more connected to real-world practices.	3.70	1.453
4.	The use of XR could make learning geography more enjoyable.	3.54	1.428
5.	XR-based VFTs may increase my interest in geography as a subject.	3.63	1.514
6.	I was able to remember content better after using XR tools.	3.67	1.454
7.	XR learning environments helped reduce my anxiety about learning complex topics.	3.67	1.486
8.	XR-based VFTs could encourage me to ask more questions and participate actively in class.	3.86	1.429
9.	I feel relatively motivated to learn more when I explore contents on XR, than other platforms.	4.26	.969
10.	The immersive nature of XR helped me focus better during lessons.	4.20	1.017
11.	The engagement between my teacher and I is more engaging compare in XR-based classes, compared to other regular classes.	4.22	.934
12.	I did not experience any difficulty navigating the XR content.	4.18	1.059
13.	The quality of visuals and sound in XR made learning more effective.	3.84	1.397
14.	Access to the devices needed for XR-based learning at my school aid the use of the tools in our lessons.	3.51	1.458

15.	I would like to use XR tools more frequently in other subjects, including geography.	3.52	1.536
16.	I would recommend XR-based learning to other users.	3.72	1.481
17.	XR should be included in the regular geography curriculum.	3.82	1.367
18.	I am interested in learning more geographical topics through XR field trips.	3.89	1.391
19.	I believe XR-based instruction should replace some traditional field trips where logistics are challenging.	4.32	.882
20.	If given a choice, I would prefer XR field trips over textbook-based lessons.	4.26	.930
Grand Mean		**3.896**	

As shown in Table 2, geography students in Nigerian high schools hold an overwhelmingly positive perception of XR instructional tools (XRITs) for Virtual Field Trips (VFTs), reflected by a grand mean score of 3.90 on a 5-point Likert scale. This indicates strong enthusiasm for using XR to enhance geography instruction. The highest-rated items demonstrate a clear preference for XR over traditional teaching methods.

For example, students strongly agreed that XR-based instruction should replace some traditional field trips where logistical challenges exist (mean = 4.32), and many expressed a preference for XR field trips compared to textbook-based lessons (mean = 4.26). Additionally, XR was seen as enhancing motivation to learn (mean = 4.26), improving teacher-student interaction (mean = 4.22), and helping students maintain focus during lessons due to its immersive nature (mean = 4.20). These findings suggest that XR tools are not only engaging but also pedagogically effective in promoting active learning and interest in geography.

Beyond increased engagement, students reported that XR tools aided their understanding of lesson concepts (mean = 4.12) and were more engaging than traditional classroom lessons (mean = 4.00). While students generally felt that XR experiences helped them connect with real-world practices (mean = 3.70) and improved their content retention (mean = 3.67), these slightly lower scores indicate areas where XR applications could be further optimized to enhance cognitive outcomes. Moreover, XR learning environments were noted to reduce anxiety when learning complex topics (mean = 3.67) and encouraged greater class participation (mean = 3.86), highlighting positive emotional and social impacts in the classroom.

Despite this overall favourable response, some practical challenges emerged. Access to XR devices received a relatively lower mean score (3.51), underscoring infrastructural and resource limitations in some schools. Similarly, while students expressed moderate interest in using XR for other subjects (mean = 3.52) and generally found the quality of visuals and sound effective (mean = 3.84), these results suggest that XR's impact may vary across content areas and depend heavily on implementation quality. Additionally, the relatively high standard deviations for many items (often above 1.4) point to variability in student experiences. This variability likely reflects differences in individual digital literacy, school facilities, and the quality of instructional delivery.

In summary, the data indicate that geography students in Nigerian high schools respond positively to XR instructional tools for VFTs. They value XR's immersive and interactive qualities and its potential to enhance motivation, focus, and participation. However, the findings also highlight the need for improved access to technology, consistent quality in XR content, and broader integration strategies to ensure equitable and effective use of XR across different schools and subjects.

3.1 Hypotheses Testing

Hypothesis One: Geography student's digital literacy level influences their perception of XRITs for VFTs in Nigerian high schools.

Table 3: Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.032[a]	.001	-.001	.58370

a. Predictors: (Constant), Digital Literacy Level

Table 4: Analysis of Variance (ANOVA)

Model	Sum of Squares	*df*	Mean Square	F	Sig.
Regression	.146	1	.146	.430	.513[b]
Residual	142.415	418	.341		
Total	142.562	419			

b. Predictors: (Constant), Digital Literacy Level

Table 5: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	3.986	.140		28.402	.000	3.710	4.262
Digital Literacy Level	-.024	.036	-.032	-.655	.513	-.095	.048

To examine the influence of digital literacy on geography students' reactions to XR instructional tools (XRITs) for Virtual Field Trips (VFTs) in Nigerian high schools, a linear regression analysis was conducted. As shown in the Model Summary (Table 3), the Pearson correlation coefficient (R) was 0.032, with an R^2 value of 0.001, indicating that only 0.1% of the variance in students' reactions to XRITs can be explained by their digital literacy levels. This extremely weak relationship suggests that digital literacy is not a meaningful predictor of how students respond to XR-based VFTs. The negative Adjusted R^2 value (-0.001) further confirms that including digital literacy in the model does not improve its predictive power.

Moreover, the ANOVA results (Table 4) revealed a p-value of 0.513, which exceeds the standard significance threshold of 0.05. This indicates that the regression model is not statistically significant, and there is no evidence to reject the null hypothesis. In other words, no statistically meaningful linear relationship

exists between geography students' digital literacy and their reactions to XR instructional tools.

Further examination of the regression coefficients (Table 5) shows an unstandardized coefficient of -0.024 for digital literacy, with a p-value of 0.513, reaffirming the non-significant effect. The small, negative coefficient implies a negligible, statistically unreliable tendency for higher digital literacy to slightly decrease positive reactions to XR tools. Additionally, the 95% confidence interval for the coefficient ranges from -0.095 to 0.048, crossing zero, which strengthens the conclusion that digital literacy does not significantly influence students' responses to XRITs. Based on this regression analysis, it can be concluded that geography students' digital literacy levels do not have a statistically significant impact on their reactions to XR instructional tools in Nigerian high schools.

Hypothesis Two: Male and female geography students have different reaction towards XR instructional tools for VFTs in Nigerian high schools.

Table 6: Independent Sample t-test on Gender Difference in Students' Reaction towards XR Instructional Tools for VFTs

Gender	N	X	S. D	df	*t*	Sig. (2-tailed)	Mean Difference
Female	285	3.886	.567				
				418	*.537*	.592	0.327
Male	135	3.919	.617				

The mean reaction score for female students was 3.886 (SD = 0.567), while male students had a slightly higher mean score of 3.919 (SD = 0.617). Although males showed a marginally higher reaction to XR instructional tools, the mean difference of 0.033 is minimal and unlikely to be practically significant. Additionally, the independent samples t-test yielded a t-value of 0.537 with a p-value of 0.592 (Sig. 2-tailed > 0.05), indicating that the difference between male and female students' reactions is not statistically significant. Therefore, the null hypothesis—that there is no difference in reactions based on gender—was not rejected.

This lack of a statistically significant difference suggests that gender does not meaningfully influence geography students' responses to XR instructional tools for Virtual Field Trips in Nigerian high schools. Both male and female students demonstrate comparable levels of engagement and receptivity toward XR-based learning environments. Consequently, XR instructional strategies can be broadly implemented without the need for gender-specific adaptations, as student responses appear consistent across genders.

4. Discussion of Findings

The findings from this study reinforce the evolving narrative of global educational transformation, particularly within the frameworks of Sustainable Development Goals (SDG) 4 (quality education) and 5 (gender equality). The moderate-to-high digital literacy levels observed among Nigerian high school geography students suggest that they possess a functional command of digital tools. This aligns with global trends emphasizing technology-enhanced learning environments, as noted

by scholars such as Guo et al. (2021) and Sensorium (2022), who highlight the increasing role of immersive technologies in reshaping education.

Notably, the highest-rated digital literacy skills in this study—such as critically analyzing digital content and digitally organizing academic tasks—reflect the development of higher-order cognitive and metacognitive abilities. These competencies are essential for effective engagement with immersive platforms like XR, which rely on learners' abilities to navigate digital content and self-regulate their learning. This supports arguments by Tegoan et al. (2021) and Adedokun-Shittu et al. (2020) advocating XR integration as a means to enhance active learning and conceptual understanding, especially in experiential subjects like geography.

However, the study also uncovered underdeveloped competencies in crucial areas such as using educational platforms and multimedia resources. These gaps present significant barriers to the effective adoption of XR-based virtual field trips, which require seamless interaction with multimedia content and digital applications. This unevenness in student preparedness echoes concerns raised by Hargittai (2016) and Martin and Grudziecki (2006), who warn that disparities in digital literacy can hinder meaningful engagement in complex digital learning environments.

Interestingly, despite the importance of digital literacy, regression analysis revealed no statistically significant relationship between students' digital literacy levels and their reactions to XR instructional tools ($R = 0.032$, $p = 0.513$). This counterintuitive finding may be attributed to the novelty effect of XR, whereby students' enthusiasm stems more from the immersive experience than from their digital skills. It also suggests that even students with limited digital literacy may find XR engaging, likely due to the intuitive, user-friendly design of well-developed XR platforms. This aligns with Guo et al. (2021), who argue that XR can provide personalized, immersive learning experiences that transcend conventional digital proficiency barriers, at least during initial engagement.

The overwhelmingly positive student response to XR tools underscores XR's strong pedagogical potential in enhancing motivation, engagement, and focus, corroborating findings by Evelpidou et al. (2022) and Tussyadiah et al. (2018). Highlights from this study also emphasize XR's capacity to enrich geography lessons, substitute traditional field trips where logistical constraints exist, and foster improved teacher-student interaction. This supports the view of XR not merely as a content delivery mechanism but as a catalyst for pedagogical transformation, particularly in resource-constrained contexts like Nigeria (Cliffe, 2017; Hilmi & Yıldırım, 2011).

Nevertheless, variability in student responses—indicated by relatively high standard deviations—points to inconsistencies in XR experiences. These likely stem from unequal access to XR devices, differences in school infrastructure, and varying levels of teacher readiness, challenges documented by Firomumwe (2022) and Lee et al. (2022). Although students show enthusiasm for XR, infrastructural

limitations remain a significant barrier to its widespread adoption, reflecting broader concerns about cost and access in technology-enhanced education.

Gender analysis revealed no significant differences in reactions to XR tools between male and female students. This finding aligns with research by Qazi et al. (2022) and Onojah et al. (2021) indicating a narrowing gender gap in digital engagement among digital-native generations. It suggests that XR instructional strategies can be implemented broadly without gender-specific adaptations. However, this conclusion should be approached cautiously given persistent socio-cultural factors that may subtly affect access and usage, especially in rural or underserved areas. Future research employing an intersectional lens, as advocated by Rajasekhar et al. (2018), would provide deeper insight.

Taken together, these findings indicate that while digital literacy forms a crucial foundation for navigating XR environments, it alone does not fully predict students' receptivity to immersive technologies. Instead, factors such as design quality, interactivity, and contextual relevance of XR experiences play a more significant role in driving engagement. This aligns with theoretical frameworks like the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), which highlight that perceived usefulness, ease of use, performance expectancy, and facilitating conditions collectively influence technology adoption. Thus, students' willingness to embrace XR depends not only on technical skills but also on how well the technology aligns with their learning needs and context.

Consequently, effective XR integration in Nigerian geography education requires a dual approach: enhancing digital literacy through targeted interventions focused on multimedia navigation and application use, while simultaneously addressing infrastructural and pedagogical factors to deliver equitable, culturally relevant, and pedagogically sound XR experiences. This socio-technical perspective underscores the necessity of attending to both individual competencies and systemic supports to foster meaningful and sustainable educational innovation.

5. Conclusion

This study critically examined the reactions of Nigerian high school geography students toward XR instructional tools for virtual field trips, while also exploring the influence of digital literacy levels and gender. The findings reveal a nuanced landscape. On one hand, students exhibit moderately high digital literacy, especially in critical thinking and self-regulation—skills essential for immersive learning.

On the other hand, gaps in multimedia navigation and platform usage highlight uneven digital preparedness, which could limit the effective use of complex technologies like XR. Paradoxically, regression analysis showed no statistically significant relationship between students' digital literacy and their reactions to XR tools. This suggests that while digital literacy is conceptually important, it may not directly predict students' affective or behavioral engagement with XR

experiences. Instead, initial enthusiasm appears driven more by the novelty, intuitive design, and immersive qualities of XR platforms than by learners' digital fluency.

Furthermore, the strong positive reactions to XR tools across genders affirm their pedagogical viability for diverse learner groups in geography education. However, the study also underscores infrastructural inconsistencies, limited device availability, and gaps in teacher readiness that could impede the sustainable adoption of XR-based learning. Taken together, these findings suggest that while XR holds transformative potential, its successful integration requires a systems-thinking approach—one that balances technological innovation with equitable access, teacher empowerment, and alignment with curriculum goals.

5.1 Implications of the Study

The implications of this study suggest that while digital literacy can facilitate smoother engagement with XR technologies, its absence does not necessarily prevent positive learning experiences. Therefore, educators and designers should prioritize creating intuitive, user-centred XR experiences that accommodate a range of digital fluency levels. Additionally, positive student perceptions of XR do not automatically guarantee scalability or sustainability. Successful implementation must therefore consider infrastructure readiness, teacher competence, and equitable access—particularly in underserved regions.

Although this study found no significant gender differences in XR reception, intersectional barriers related to socio-cultural and geographic factors may still exist and should be addressed in future policy and research. Finally, the variability observed in student responses indicates that XR effectiveness is mediated by local contexts, including device availability, school culture, and teacher facilitation. This underscores the need for context-driven, rather than one-size-fits-all, approaches to XR integration in education.

5.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. XR tools should be thoughtfully integrated into the geography curriculum, starting with content that complements existing pedagogical approaches. Teachers must receive training not only on how to operate XR technologies but also on how to facilitate inquiry-based and experiential learning using these tools.
2. Given observed weaknesses in platform usage and multimedia navigation, student digital literacy programs should specifically target these areas. Scalable interventions could include practical workshops, gamified learning modules, and peer-led digital clubs.
3. To address device scarcity, schools and governments should consider shared resource models such as mobile XR labs, community digital hubs, or partnerships with edtech companies for hardware provision. Collaboration among multiple stakeholders is critical to the success of these initiatives.
4. XR experiences should be co-designed with educators and students to ensure alignment with local realities, cultural relevance, and curriculum

requirements. A participatory design approach can enhance adoption, usability, and sustained engagement.

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Appendix 1

Section A: Demographic Information
Gender: Male { } Female { }

Section B: Digital Literacy Level of Geography Students in Nigerian High Schools
Key: Strongly Agree (SA); Agree (A); Neutral (N); Disagree (D); and Strongly Disagree (SD).

S/N	Items	SA	A	N	D	SD
1.	I feel confident using digital tools like smartphones, tablets, and computers for learning.					
2.	I can easily find and retrieve academic information using the Internet.					
3.	I can evaluate whether online sources are credible and reliable.					
4.	I know how to use educational applications and platforms effectively.					
5.	I can troubleshoot basic problems when using digital tools.					
6.	I am comfortable using multimedia resources (e.g., videos, interactive apps) for schoolwork.					
7.	I frequently use digital tools to collaborate with classmates on assignments.					
8.	I understand how to protect my personal information when using digital platforms.					
9.	I can critically analyse digital content before using it for learning.					
10.	I use digital tools to organize my school tasks and schedules effectively.					

Section C: Geography Students' Perception of XR Instructional Tool for VFTs
Key: Strongly Agree (SA); Agree (A); Neutral (N); Disagree (D); and Strongly Disagree (SD).

S/N	Items	SA	A	N	D	SD
1.	XR tools have helped me better understand lesson concepts.					
2.	I found XR-based activities more engaging than traditional classroom lessons.					
3.	XR experiences made me feel more connected to real-world practices.					
4.	The use of XR could make learning geography more enjoyable.					
5.	XR-based VFTs may increase my interest in geography as a subject.					
6.	I was able to remember content better after using XR tools.					
7.	XR learning environments helped reduce my anxiety about learning complex topics.					
8.	XR-based VFTs could encourage me to ask more questions and participate actively in class.					
9.	I feel relatively motivated to learn more when I explore contents on XR, than other platforms.					

10.	The immersive nature of XR helped me focus better during lessons.					
11.	The engagement between my teacher and I is more engaging compare in XR-based classes, compare to other regular classes.					
12.	I did not experience any difficulty navigating the XR content.					
13	The quality of visuals and sound in XR made learning more effective.					
14.	Access to the devices needed for XR-based learning at my school aid the use of the tools in our lessons.					
15.	I would like to use XR tools more frequently in other subjects, including geography.					
16	I would recommend XR-based learning to other users.					
17.	XR should be included in the regular geography curriculum.					
18.	I am interested in learning more geographical topics through XR field trips.					
19.	I believe XR-based instruction should replace some traditional field trips where logistics are challenging.					
20.	If given a choice, I would prefer XR field trips over textbook-based lessons.					