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VIRTUAL FIELD TRIPS AND STUDENT ENGAGEMENT IN ECOLOGY IN SECONDARY SCHOOLS PRONE TO INSECURITY IN BENUE STATE, NIGERIA

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ABSTRACT

*This study examined students' engagement in ecology and the effects of virtual field trips on behavioural, emotional and cognitive engagement in secondary schools prone to insecurity in Benue State, Nigeria. A quasi-experimental non-equivalent control group pre-test/post-test design was adopted, involving 132 Senior Secondary II Biology students from four public secondary schools in Katsina-Ala, Kwande, Guma and Agatu Local Government Areas. Data were collected using the Student Engagement in Ecology Questionnaire and analysed using means, standard deviations and Analysis of Covariance (ANCOVA) at the 0.05 significance level. The descriptive results indicated moderate levels of behavioural (*M *= 3.03,* SD *= 0.58), emotional (*M *= 3.11,* SD *= 0.54) and cognitive engagement (*M *= 2.89,* SD *= 0.63) before the intervention. The ANCOVA results showed that virtual field trips had no statistically significant additional effect on behavioural engagement,* F*(1, 129) = 3.581,* p *= .061, partial* η^2 *= .027; emotional engagement,* F*(1, 129) = 0.120,* p *= .730, partial* η^2 *= .001; or cognitive engagement,* F*(1, 127) = 0.352,* p *= .554, partial* η^2 *= .003. All three null hypotheses were therefore not rejected. The findings indicate that, under the conditions examined, virtual field trips did not produce statistically significant improvements in the measured dimensions of engagement compared with conventional instruction. The study recommends cautious, context-sensitive use of virtual field trips as a supplementary means of providing access to ecological environments where insecurity restricts physical fieldwork, alongside further empirical evaluation of their educational effectiveness.*

Keywords: virtual field trips, student engagement, ecology, insecurity, secondary schools.

Introduction

The educational delivery system in parts of Benue State, Nigeria, is facing serious disruptions arising from persistent insecurity. This instability, which is characterised by recurrent bandit attacks and farmer-herder clashes, has precipitated a humanitarian crisis marked by widespread violence and mass displacement (Amnesty International, 2025). As of early 2025, at least 510,182 individuals were internally displaced across the state. This figure included over 500,182 recorded by the end of 2024 and an additional 10,000+ displaced in the ensuing months due to escalating attacks (Amnesty International, 2025). A notable incident occurred on 14 June 2025 in Yelewata community in Guma Local Government Area where gunmen killed up to 200 people and displaced over 3,941 others, leaving scenes of mass graves and abandoned villages in its wake (Amnesty International, 2025). Similar assaults, which often involve indiscriminate shootings and brutal close-range killings, have targeted communities in Gwer West, Agatu, Ukum, Kwande, Katsina-Ala, Logo and other Local Government Areas

(Amnesty International, 2025). Such armed security breaches compromise not only the physical safety of students but also the continuity of learning, particularly in practical subjects like Biology that traditionally rely on experiential activities.

In conventional pedagogical practice, the gap between ecological theory and direct observation in the implementation of the senior secondary school Biology curriculum is bridged by physical field trips, which are vital for enabling students to develop critical thinking and environmental awareness through direct engagement with ecosystems, biodiversity and the broader environmental dynamics (Field Studies Council, 2023; Green.org, 2024). However, in secondary schools affected by insecurity in parts of Benue State, the teaching of ecology is particularly constrained. Traditional excursions to forests, rivers and farms are often unsafe or cannot be undertaken, significantly minimising students' opportunities for behavioural engagement with ecological systems. This disruption is significant, as research shows that armed conflict and insecurity reduce access to vital educational activities and negatively affect both learning outcomes and overall school participation (Galindo-Silva & Tchuente, 2023; International Journal of Educational Development, 2022). Equally, the emotional and cognitive dimensions of learning ecology – such as developing curiosity about biodiversity, emotional attachment to environmental care, and critical thinking about ecological interactions – are hindered when teaching is confined to theoretical classroom instruction. Direct contact with nature is known to enhance curiosity, strengthen environmental attitudes, and improve retention compared to purely classroom-based learning (CEE, 2024; Field Studies Council, 2023). Given the adverse security realities that constrain physical field trips, virtual field trips present a robust alternative with strong potential to enhance student engagement. The potential of virtual field trips to bolster engagement is three-dimensional: behaviourally, it encourages students to interact with digital tools and participate in simulated data collection; emotionally, it can mitigate the trauma-induced apathy common in conflict zones by sparking curiosity and providing a safe space for discovery; and cognitively, it challenges students to apply higher-order thinking skills to solve environmental problems in a controlled, virtual setting (Fredricks et al., 2004).

To address these challenges, virtual field trips check the right box in offering a promising alternative, utilising digital tools such as interactive simulations, 360-degree videos and virtual reality platforms to provide immersive access to diverse ecosystems safely from the classroom (Semken & Williams, 2025). These approaches foster active participation and evoke emotional connections to nature, promoting the deeper cognitive processing necessary to bridge the gaps in student engagement exacerbated by insecurity (Fredricks et al., 2004; Mayer, 2022). This study is justified by the need to assess current engagement levels in ecology amid these disruptions and evaluate the efficacy of virtual field trips in enhancing behavioural, emotional and cognitive dimensions of student engagement with a view to informing resilient pedagogical strategies for science education in conflict-affected regions, promoting equitable access to quality learning despite ongoing security challenges in parts of Benue state, Nigeria.

Statement of the Problem

The study of ecology in secondary school Biology is fundamentally predicated on experiential learning. This entails students engaging directly with natural habitats to understand the

complexities of biodiversity and environmental interactions. However, in some parts of Benue State, schools have become theatres of significant insecurity, undermining Biology students' traditional "outdoor classroom". In Local Government Areas such as Guma, Logo, Agatu and Katsina-Ala, the persistent threat of armed attacks has effectively blocked the natural environment from academic exploration (Amnesty International, 2023; UNICEF, 2024), creating a profound pedagogical crisis. Biology teachers, fearful for their safety and that of their students, have largely abandoned physical field trips, resorting to purely theoretical, "chalk-and-talk" methods to teach inherently practical ecological concepts. A noticeable decline in student engagement across three critical dimensions can be observed as a result of this shift: behaviourally, students are denied the opportunity to practice essential scientific skills like sampling, observation, and data collection, leading to passivity; emotionally, the pervasive "culture of fear" and the trauma associated with living in conflict zones have eroded students' natural curiosity and affective connection to the environment (GCPEA, 2022); and cognitively, the lack of hands-on experience makes abstract concepts – such as energy flow and ecological succession – difficult for students to internalise, resulting in poor conceptual mastery and declining performance in external examinations such as the West African Examinations Council (WAEC) and the National Examinations Council (NECO). While virtual field trips have been proposed globally as a digital solution to physical barriers, their efficacy in the specific, resource-constrained and trauma-sensitive secondary schools of Benue State remains largely unexamined. Added to that, there is a paucity of empirical evidence to determine if virtual field trips can effectively substitute for physical field experiences in fostering engagement among students who are already psychologically burdened by insecurity. This study addresses these critical gaps in order to prevent a generation of science students in Benue State from graduating with a fragmented understanding of ecology, which would further widen educational inequality between secure urban centres and volatile regions. Accordingly, the problem of this study is to determine the extent to which virtual field trips can serve as a viable intervention for enhancing students' behavioural, emotional and cognitive engagement in ecology within these high-risk areas.

Objectives of the Study

The primary aim of this study was to explore the potential of virtual field trips as an alternative pedagogical tool to enhance student engagement in ecology within secondary schools affected by insecurity in Benue State, Nigeria. While the general objective was to investigate the levels of student engagement in ecology and the effects of virtual field trips on behavioural, emotional, and cognitive engagement among secondary school students in insecurity-prone areas of Benue State, Nigeria, the specific objectives were to

1. To determine the extent of behavioural engagement in ecology among students in secondary schools prone to insecurity in Benue State.
2. To assess the level of emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State.
3. To examine the extent of cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State.
4. To determine the effect of virtual field trips on behavioural engagement in ecology among students in secondary schools prone to insecurity in Benue State.

5. To investigate the effect of virtual field trips on emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State.
6. To examine the effect of virtual field trips on cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State.

Research Questions

The study was guided by six research questions, divided into descriptive questions that explore the current levels of student engagement in ecology and inferential questions that examined the effects of virtual field trips on engagement.

Descriptive Research Questions (Levels of Engagement)

1. To what extent are students behaviourally engaged in ecology in secondary schools prone to insecurity in Benue State?
2. What is the level of emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State?
3. What is the extent of cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State?

Inferential Research Questions (Effects of Virtual Field Trips)

4. What is the effect of virtual field trips on behavioural engagement in ecology among students in secondary schools prone to insecurity in Benue State?
5. How do virtual field trips affect emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State?
6. How do virtual field trips influence cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State?

Research Hypotheses

The study tested the following null hypotheses, which corresponded to the inferential research questions (RQ4-RQ6) on the effects of virtual field trips on student engagement in ecology.

1. Virtual field trips have no significant effect on behavioural engagement in ecology among students in secondary schools prone to insecurity in Benue State.
2. Virtual field trips have no significant effect on emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State.
3. Virtual field trips have no significant effect on cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State.

Theoretical Framework

This study adopted an integrated theoretical framework anchored in three key theories. These are Fredricks et al.'s (2004) multidimensional model of student engagement, Kolb's (1984) Experiential Learning Theory, and Mayer's (2021) Cognitive Theory of Multimedia Learning, emphasising the immersion principle (Makransky & Mayer, 2022). Central to the framework is Fredricks et al.'s (2004) Student Engagement Theory, which defines engagement as comprising behavioural (participation, effort, persistence), emotional (interest, enjoyment, belonging), and cognitive (mental investment, self-regulation, deep processing) dimensions. This model directly informs the assessment of current engagement levels in ecology

(descriptive objectives) and the evaluation of virtual field trips' impacts on these dimensions (inferential objectives and hypotheses), particularly in contexts where insecurity limits hands-on activities. Kolb's (1984) Experiential Learning Theory complements this by describing learning as a cycle of concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Physical field trips provide concrete experiences essential for ecology; in insecure settings, virtual field trips substitute these through simulated interactions, supporting behavioural participation, emotional connections, and cognitive integration (Klippel et al., 2019). Mayer's (2021) Cognitive Theory of Multimedia Learning explains the cognitive mechanisms, positing that multimedia fosters meaningful learning by promoting active processing. The immersion principle highlights how immersive virtual environments enhance presence, motivation, and engagement, making virtual field trips effective for ecology education in restricted contexts (Makransky & Mayer, 2022). These theories coalesce to frame virtual field trips as a resilient alternative that addresses engagement deficits caused by insecurity, with Fredricks et al. (2004) defining outcomes, Kolb (1984) validating experiential pedagogy, and Mayer (2021) elucidating multimedia processes.

Literature Review

The Concept of Ecology and the Importance of Field-Based Learning

Ecology is defined as the scientific study of interactions between organisms and their environments, encompassing key concepts such as ecosystems, biodiversity, food webs, nutrient cycling, and human impacts on natural systems (Odum & Barrett, 2005). Within secondary school biology curricula, ecology education seeks to develop students' understanding of environmental interdependence and to foster environmental stewardship. Field-based learning, which involves direct observation and inquiry in natural settings, has long been recognised as essential for effective ecology instruction. Authentic, hands-on experiences are provided through such approaches, thereby enhancing conceptual understanding, scientific skills, and appreciation of ecological complexity (Scott et al., 2017). Evidence from prior studies shows that students' knowledge retention, confidence in research abilities, and affective outcomes – such as interest in environmental science – are significantly improved by field courses (Fleischner, 2011; Scott et al., 2017). These experiential strategies align closely with constructivist pedagogy, as knowledge is constructed through real-world interaction rather than through abstract classroom instruction alone.

The Concept of Student Engagement

Student engagement represents a meta-construct reflecting the quality of students' involvement in learning and is widely recognised as a predictor of academic achievement, persistence, and positive attitudes towards schooling (Fredricks et al., 2004; Reschly & Christenson, 2012). Three interrelated dimensions constitute this construct: behavioural engagement, which includes active participation, effort, attention, and persistence in tasks; emotional engagement, which encompasses affective responses such as interest, enjoyment, avoidance of boredom, and a sense of belonging; and cognitive engagement, which involves mental investment, self-regulation, the use of deep learning strategies, and a willingness to exert effort for meaningful comprehension (Fredricks et al., 2004; Reschly & Christenson, 2012). In science education – particularly ecology – these dimensions are especially critical, since disengagement often arises when instruction remains overly theoretical and disconnected from real-world contexts. Deeper

processing of complex concepts, sustained motivation for inquiry, and long-term retention are promoted when students demonstrate high engagement (Fredricks et al., 2004).

Empirical Literature on the Effects of Virtual Field Trips on Student Engagement

The effects of virtual field trips on multidimensional student engagement have been examined in several empirical studies, particularly within contexts involving environmental exploration. Using a switching-replications design, Garcia et al. (2023) exposed primary school students to 360-degree virtual trips to locations such as zoos and wildlife areas. Significantly higher behavioural engagement, emotional engagement, and cognitive outcomes were recorded compared to regular video instruction. Similarly, Makransky and Mayer (2022) reported that middle school students who participated in an immersive Virtual Reality field trip experienced stronger motivational and cognitive engagement, largely attributed to increased presence and reduced distractions, thereby supporting the immersion principle in multimedia learning.

High school students' experiences were investigated by McGivney (2025), who found that Virtual Reality field trips to ecologically rich environments such as Antarctica evoked strong emotional engagement characterised by awe, curiosity, and enjoyment, while short-term intrinsic motivation and behavioural interaction with STEM content were also enhanced. In a quasi-experimental study, Alazmi and Alemtairy (2024) observed that immersive Virtual Reality field trips produced high levels of multimodal presence, which in turn fostered behavioural persistence, emotional connection, and cognitive engagement by reducing mental load and perceived effort. Collectively, these findings demonstrate the strong capacity of virtual field trips to influence behavioural exploration, emotional responses to nature, and deeper cognitive processing within science learning contexts similar to ecology.

Gap in Literature

Although substantial evidence has accumulated regarding the benefits of Virtual Field Trips for multidimensional engagement in science education (Chen & Zhang, 2023; Garcia et al., 2023; Makransky & Mayer, 2022; McGivney, 2025), and the disruption of practical ecology teaching in insecurity-affected regions such as Benue State has been clearly documented (Amnesty International, 2025; The ICIR, 2024), no empirical investigation has specifically examined the effects of Virtual Field Trips on behavioural, emotional, and cognitive engagement in ecology among secondary school students in insecurity-prone Nigerian contexts. Most existing studies have been conducted in stable or temporarily disrupted environments – such as pandemic-affected settings – in developed countries. Consequently, a significant contextual gap remains in relation to conflict-affected secondary education in Benue State, and this gap forms the central focus of the present study.

Methodology

The study adopted a quasi-experimental non-equivalent control group pre-test/post-test design involving 132 Senior Secondary II Biology students from four purposively selected public secondary schools in Katsina-Ala, Kwande, Guma and Agatu Local Government Areas of Benue State, Nigeria. The participants were selected from intact classes and assigned to experimental and control groups. Data were collected using the 30-item Student Engagement in Ecology Questionnaire (SEEQ), adapted from Fredricks et al. (2004), and a researcher-developed Virtual Field Trip Module (VFTM). The questionnaire measured behavioural,

emotional and cognitive engagement on a four-point Likert scale and was reviewed by three experts for content validity and pilot-tested with 40 students from a comparable school, with internal consistency assessed using Cronbach's alpha. Over eight weeks, the experimental group received ecology instruction supported by virtual explorations of forest, riverine and agricultural ecosystems, guided observation and reflective activities, while the control group received conventional classroom instruction. Both groups completed the questionnaire before and after the intervention, with equal instructional time provided. Descriptive research questions were answered using means and standard deviations, while the three null hypotheses were tested using Analysis of Covariance (ANCOVA) at the 0.05 significance level, controlling for pre-test scores. Data were analysed using IBM SPSS Statistics, Version 22.

Presentation of Results

Research Question One: To what extent are students behaviourally engaged in ecology in secondary schools prone to insecurity in Benue State?

Table 1: *Mean and Standard Deviation of Students' Pre-test Behavioural Engagement Scores in Ecology*

Variable	N	Mean	SD	Decision
Behavioural engagement	132	3.03	0.58	Moderate

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The analysis of pre-test scores for 132 students presented in Table 1 yielded a mean behavioural engagement score of 3.03 and a standard deviation of 0.58. Based on the study's decision rule, which classifies mean scores of 2.50–3.49 as moderate engagement, students demonstrated a moderate level of behavioural engagement in ecology before the intervention. This suggests that their participation, effort, attention and persistence in ecology learning were at a moderate level at baseline.

Research Question Two: What is the level of emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State?

Table 2: *Mean and Standard Deviation of Students' Pre-test Emotional Engagement Scores in Ecology*

Variable	N	Mean	SD	Decision
Emotional engagement	132	3.11	0.54	Moderate

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The analysis of pre-test scores for 132 students presented in Table 2 yielded a mean emotional engagement score of 3.11 and a standard deviation of 0.54. Based on the study's decision rule, which classifies mean scores of 2.50–3.49 as moderate engagement, students demonstrated a moderate level of emotional engagement in ecology before the intervention. This suggests that students' interest, enjoyment, positive attitudes and sense of belonging in ecology learning were at a moderate level at baseline.

Table 3: *Mean and Standard Deviation of Students' Pre-Cognitive Engagement Scores in Ecology*

Variable	N	Mean	SD	Decision
Cognitive engagement	132	2.89	0.63	Moderate

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The analysis of pre-test scores for 132 students presented in Table 3 yielded a mean cognitive engagement score of 2.89 and a standard deviation of 0.63. Based on the study's decision rule, which classifies mean scores of 2.50–3.49 as moderate engagement, students demonstrated a moderate level of cognitive engagement in ecology before the intervention. This suggests that students' use of learning strategies, self-regulation, efforts to understand complex ecological concepts and application of knowledge were at a moderate level at baseline.

Test of Null Hypothesis One: Virtual field trips have no significant effect on behavioural engagement in ecology among students in secondary schools prone to insecurity in Benue State.

Table 4: *Analysis of Covariance (ANCOVA) of the Effect of Virtual Field Trips on Students' Behavioural Engagement in Ecology*

Source	Df	Mean Square	F	p	Partial η²
Corrected Model	2	0.785	7.600	.001	.105
Pre-test behavioural engagement	1	0.347	3.366	.069	.025
Group	1	0.370	3.581	.061	.027
Error	129	0.103	—	—	—

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The ANCOVA results presented in Table 4 show that the effect of virtual field trips on students' behavioural engagement in ecology, after controlling for pre-test behavioural engagement scores, was not statistically significant, $F(1, 129) = 3.581$, $p = .061$, partial $\eta^2 = .027$. Since the p-value of .061 exceeds the 0.05 significance level, the null hypothesis was not rejected. This indicates that there was insufficient statistical evidence to conclude that virtual field trips had a significant effect on students' behavioural engagement in ecology.

Test of Null Hypothesis Two: Virtual field trips have no significant effect on emotional engagement in ecology among students in secondary schools prone to insecurity in Benue State.

Table 5: *ANCOVA Results for the Effect of Virtual Field Trips on Students' Emotional Engagement in Ecology*

Source	Df	Mean Square	*F*	*p*	Partial η²
Corrected Model	2	0.890	7.550	.001	.105
Pre-test emotional engagement	1	1.220	10.348	.002	.074
Group	1	0.014	0.120	.730	.001
Error	129	0.118	—	—	—

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The ANCOVA results presented in Table 5 show that the effect of virtual field trips on students' emotional engagement in ecology, after controlling for pre-test emotional engagement scores, was not statistically significant, $F(1, 129) = 0.120$, $p = .730$, partial $\eta^2 = .001$. Since the p-value of .730 exceeds the 0.05 significance level, the null hypothesis was not rejected. This indicates that there was insufficient statistical evidence to conclude that virtual field trips had a significant effect on students' emotional engagement in ecology.

Test of Null Hypothesis Three: Virtual field trips have no significant effect on cognitive engagement in ecology among students in secondary schools prone to insecurity in Benue State.

Table 6: *ANCOVA Results for the Effect of Virtual Field Trips on Students' Cognitive Engagement in Ecology*

Source	Df	Mean Square	*F*	*p*	Partial η^2
Corrected Model	2	1.976	10.772	< .001	.145
Pre-test cognitive engagement	1	3.615	19.707	< .001	.134
Group	1	0.065	0.352	.554	.003
Error	127	0.183	—	—	—

Source: Researcher's field survey data, analysed using IBM SPSS Statistics, Version 22.

The ANCOVA results presented in Table 6 show that the effect of virtual field trips on students' cognitive engagement in ecology, after controlling for pre-test cognitive engagement scores, was not statistically significant, $F(1, 127) = 0.352$, $p = .554$, partial $\eta^2 = .003$. Since the p-value of .554 exceeds the 0.05 significance level, the null hypothesis was not rejected. This indicates that there was insufficient statistical evidence to conclude that virtual field trips had a significant effect on students' cognitive engagement in ecology.

Discussion of Results

The findings showed moderate levels of behavioural ($M = 3.03$, $SD = 0.58$), emotional ($M = 3.11$, $SD = 0.54$) and cognitive engagement ($M = 2.89$, $SD = 0.63$) among students before the intervention. Although these means were above the midpoint of the four-point scale, they fell within the study's moderate engagement category. The findings should not be interpreted as evidence that insecurity has no adverse consequences for education in the study area. Rather, they indicate that students who participated in the study reported moderate engagement despite the challenging context. This pattern is plausible because insecurity may disrupt school attendance, continuity of instruction and access to practical learning without necessarily eliminating students' interest or participation in classroom lessons. Moreover, the schools selected for the study were accessible during data collection and had basic digital infrastructure. Students in severely disrupted or inaccessible schools may therefore be under-represented. The results cannot be generalised uncritically to all students affected by insecurity in Benue State. Fredricks et al. (2004) conceptualised engagement as multidimensional, with behavioural, emotional and cognitive engagement representing related but distinct aspects of students' involvement in learning. The comparatively lower cognitive engagement mean suggests that reported participation and interest should not automatically be equated with equally strong mental investment in ecological concepts. Nevertheless, the observed differences between the three means were not tested for statistical significance.

Research in another conflict-affected setting provides a useful contextual comparison. No (2026), studying secondary school students in conflict-affected areas of Myanmar, found that self-determination, emotional regulation, teacher support and community support were associated with student engagement. This suggests that engagement can persist under conditions of conflict, although the mechanisms sustaining it may differ across settings. The present study did not measure resilience, social support or students' exposure to insecurity, so these factors remain possible explanations rather than established causes of the observed engagement levels.

The three hypotheses produced a consistent pattern. Virtual field trips did not have statistically significant effects on behavioural engagement, $F(1, 129) = 3.581$, $p = .061$, partial $\eta^2 = .027$; emotional engagement, $F(1, 129) = 0.120$, $p = .730$, partial $\eta^2 = .001$; or cognitive engagement, $F(1, 127) = 0.352$, $p = .554$, partial $\eta^2 = .003$, after controlling for the respective pre-test scores. All three null hypotheses were therefore not rejected at the .05 significance level. The partial eta-squared values indicate small observed group effects. These results do not establish that virtual field trips have no effect; they show that the study did not demonstrate statistically significant advantages over conventional instruction on the three engagement measures.

This finding differs from some previous research reporting benefits from virtual field trips, but the studies are not directly equivalent. Makransky and Mayer (2022) found that middle-school students using head-mounted virtual reality reported greater presence, enjoyment and interest and achieved better immediate and delayed retention than students using two-dimensional video. Garcia et al. (2023), examining 360-degree video field trips among primary school pupils, found consistently greater increases in content recall than with regular video, although the difference was statistically significant at only one reported time point. Alazmi and Alemtairy (2024) also reported improved academic achievement and lower cognitive load following immersive virtual reality instruction. However, achievement, retention, cognitive load and presence are distinct outcomes from the three dimensions of engagement measured in the present study. These studies therefore support the potential of virtual field trips without demonstrating that they will invariably improve every engagement dimension.

The contrast between the present findings and previous studies suggests that the effects of virtual field trips may depend on the instructional approach, technological environment and learning outcomes assessed. Studies reporting positive effects often employed immersive technologies or examined outcomes such as presence, enjoyment, retention and academic achievement, which are distinct from the three dimensions of engagement assessed in this study. Conventional instruction may also sustain students' participation and interest, making the additional contribution of virtual field trips less pronounced. These differences caution against assuming that findings from other educational settings will necessarily apply to insecurity-prone secondary schools in Benue State.

Conclusion

Virtual field trips remain a useful alternative for giving students access to ecological environments that are otherwise unsafe or inaccessible. However, we cannot just assume they will be effective in insecurity-prone schools based on findings from entirely different contexts;

their value needs to be grounded in direct empirical evidence. The present study provides this context-specific data, highlighting that virtual field trips must be evaluated alongside the actual instructional conditions, available technological resources, and learning outcomes of the students for whom they are intended. Ultimately, insecurity should not be allowed to sever students' access to the experiential foundations of ecological education. Where physical fieldwork carries unacceptable risks, virtual alternatives offer a practical way to keep ecological observation and inquiry alive. That said, their educational value goes beyond simply providing technological access. They have to be deliberately woven into teaching through guided observation, critical questioning, reflection, and the direct application of ecological knowledge. Educational authorities and school leaders should therefore treat virtual field trips as part of a broader, context-responsive strategy for sustaining science education in conflict-affected communities. At the same time, we must recognise that digital representations cannot fully replace direct encounters with nature. The central imperative is to protect students' access to meaningful ecological learning without compromising their safety, whilst ensuring we never mistake mere technological provision for genuine pedagogical effectiveness.

Recommendations

The recommendations arising from this study are guided by the finding that virtual field trips did not produce statistically significant effects on students' behavioural, emotional or cognitive engagement. The findings therefore do not establish virtual field trips as an effective means of improving these dimensions of engagement. Nevertheless, given the security-related constraints on physical fieldwork in the study area, virtual field trips warrant consideration as a supplementary means of providing access to ecological environments, subject to further evaluation. Accordingly, the following recommendations are made.

1. Education authorities and school administrators should consider virtual field trips as a supplementary means of providing access to ecological environments where insecurity makes physical fieldwork unsafe or impracticable. Their adoption should not be based on an assumption that they will necessarily improve student engagement.
2. Biology teachers using virtual field trips should incorporate guided observation, inquiry-based questions, reflection and the application of ecological concepts. The selection of digital resources should reflect available infrastructure, internet connectivity and the instructional needs of students.
3. Researchers should investigate virtual field trips across larger and more diverse samples of insecurity-affected schools, examining implementation conditions and using complementary measures of student engagement and learning outcomes. This would help establish the circumstances under which virtual field trips provide educational benefits.

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