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CASE STUDY

Immersive learning in biology and environmental science: a case study of the Nature Lab virtual reality project

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ABSTRACT

Virtual reality (VR) is transforming science education by offering immersive, interactive experiences that enhance engagement and understanding of complex biological and environmental systems. However, its benefits and limitations compared to traditional in-person learning remain underexplored. This study directly compares the effectiveness of in-person and VR fieldwork in developing practical graduate skills valued by wildlife conservation employers. Zoology and Wildlife Conservation BSc undergraduates completed a bird monitoring survey at a local nature reserve and then repeated the survey in a simulated VR environment ('Nature Lab'). Student performance and achievement of intended learning outcomes were comparable across both settings, although each emphasised different, relevant skillsets. Students reported that Nature Lab provided a more inclusive and accessible learning experience, reduced the carbon footprint of fieldwork activities, and supported acquisition of valuable technological skills. These findings highlight VR's potential as a sustainable, complementary teaching tool adaptable to diverse programmes involving fieldwork.

KEYWORDS: quality education, learning technology, virtual reality, inclusive learning.

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Introduction

Fieldwork is a cornerstone of education in biological and environmental sciences, offering students direct engagement with the natural world that enables learners to observe ecological processes, collect data, and develop practical skills *in situ*. This fosters a deeper understanding of complex systems and variability in real-world conditions (Chitty & Hesp, 2024). Fieldwork can be defined as any component of the curriculum that requires exiting the physical classroom and learning via first-hand experiences (Haigh & Gold, 1993). Fieldtrips are essential for UK higher education (HE) students participating in geographical, biological, and environmental sciences, and feature prominently as a main teaching approach in national subject 'benchmark statements' (The Quality Assurance Agency for Higher Education, 2022).

In contrast, VR fieldwork is a rapidly evolving technology that can be defined as a digital resource allowing a user to visualise and interrogate a remote location using imagery and other materials, such as data, maps, and journal articles (Hurst, 1998; Klemm & Tuthill, 2003; Stainfield et al., 2000). The '3E framework'—enhance, extend, empower—was developed as a means for staff to consider aspects of their modules that could meaningfully adopt technology to benefit the learning and teaching experience through increased active learning (enhance), and further develop uses of technology that underpin more sophisticated, higher-level learning applied in professional contexts (extend and empower). The constant definer is that technology plays a central role in providing alternative strategies for engaging students in the study of the real world.

This rise of VR tools in an educational context is not just about replicating experiences; it is also driven by the need for more sustainable methods of teaching in the face of the current climate crisis. Universities, as educational leaders, have a moral and ethical responsibility to reduce their carbon emissions and protect fragile ecosystems. However, they are also businesses that must recruit students, leading to an arms race of exotic fieldtrips, despite the negative environmental impacts (e.g., Telford et al., 2024).

There is a clear and growing graduate employment crisis—both in the UK and globally—especially impacting young job seekers and early-career graduates, which disproportionately impacts early-career graduates. This imbalance is increasingly characterised not only by absolute unemployment but by a pervasive skills mismatch and underemployment, where a substantial proportion of degree holders occupy roles that do not necessitate high-level academic qualifications (Mainga et al., 2022). Globally, a decent work deficit remains a significant barrier as the generation of high-skill professional roles fails to keep pace with the rising volume of graduates; a trend that undermines the assumed link between higher education and upward social mobility (Portocarrero Ramos et al., 2025). Within the UK, these challenges are compounded by macroeconomic pressures and institutional bottlenecks that limit the availability of high-skilled entry-level positions, with recent data indicating that only 60.4% of graduates aged 21–30 are employed in high-skilled roles (Department for Education, 2024, Type of employment section, para. 2). This suggests that educators should prioritise developing curricula that will lead to employment, and if VR fieldwork can equip students with the same skillsets, it should be considered for its additional environmental, ethical, and financial benefits.

In addition to promoting sustainable teaching practices, VR fieldwork can also remove many barriers students face to in-person fieldwork. Not all physical learning is accessible or inclusive. For example, fieldwork to unfamiliar locations can induce anxiety in some participants, particularly in neurodivergent individuals, and some field sites cannot physically be accessed (Stainfield et al., 2000). Diversity and inclusion must be embedded into the curriculum (The Quality Assurance Agency for Higher Education, 2022), and VR environments diversify the ways students can engage with more flexibility (Yorke et al., 2025). Removing barriers to inclusion ensures that geographical, biological, and environmental sciences reflect the diversity of the world they aim to serve, fostering greater innovation and justice while preparing all learners—not just some—to engage with planetary challenges.

However, the shift toward technology-mediated or inclusive curricula must not come at the expense of core competency. Species identification skills are foundational to high-quality ecological research, especially in the wildlife conservation sector. Yet, many graduates emerge with weaker practical skills due to a shift toward theory-heavy programmes, condensed curriculum formats, and fewer sustained field experiences (Ashley-Smith, 2016; Blickley et al., 2013). This creates a critical tension: while VR offers a solution to the environmental and accessibility issues of traditional fieldwork, its efficacy in fostering these essential, high-level taxonomic and survey skills remains under-scrutinised.

To address this gap, we authentically assess the effectiveness of an assessment for Zoology and Wildlife Conservation BSc undergraduate students, carried out in two settings: (i) an in-person fieldwork environment, and (ii) a simulated VR environment. We evaluate student performance at demonstrating key practical ecology skills learned from their course and determine whether the intended learning outcomes are fully met in both scenarios. We specifically evaluate three intended learning outcomes:

1. **Apply practical survey skills:** accurately perform a point count survey, including species identification and abundance estimation.
2. **Demonstrate observational skills:** utilise both visual and auditory cues to identify a range of bird species and record observations of behaviour.
3. **Practise data recording and management:** systematically record survey data using a standardised methodology.

Methods

Study design and objectives

This study explored the use of a virtual reality (VR) bird survey tool, 'Nature Lab', as an alternative or enhancement to traditional field-based ecological skills training. Our primary aim was to evaluate the pedagogical effectiveness of immersive VR environments in delivering intended learning outcomes, and to assess student perceptions of accessibility, inclusivity, skill development, and engagement across both traditional and simulated learning settings.

Nature Lab development

To create Nature Lab, we developed a virtual reality simulation replicating a local nature reserve where students previously conducted an in-person bird survey. High-quality 360° images were captured at 5 designated bird monitoring sites along a mapped transect using a GoPro Hero Max camera. Audio data from each site was simultaneously recorded using Audiomoth sound recorders during the same period the in-field surveys were conducted. These assets were integrated using *Immersive Studio* (2023) to create an interactive simulation in which users could visually explore each survey point and listen to a five-minute ambient soundscape containing real bird vocalisations. Birds were digitally embedded into the simulation as still images to simulate sight-based detection. A total of eight students participated in the Nature Lab experiment. Each student was allocated a one-hour time slot to perform their virtual survey individually, and all participants were presented with the same five simulations in the same sequential order. During the experiment, students navigated the VR environment in a lab-based setting, performing the same bird survey protocol used in the field.

The Nature Lab experiment was conducted two months after the field surveys to minimise immediate recall. However, because the tasks occurred sequentially, participants were familiar with the environment when entering the Nature Lab. This design mirrors realistic pedagogy, where digital tools reinforce physical fieldwork, though it complicates direct comparisons of raw performance metrics.

Student feedback instrument

Following completion of both the in-person and virtual surveys, a structured feedback questionnaire was administered to all participating students. The purpose of the questionnaire was to evaluate student perceptions of both learning experiences and assess the Nature Lab simulation as a pedagogical tool. Survey items were designed to capture perceptions of enjoyment, confidence, skill development, accessibility, inclusivity, and sustainability. Both Likert-scale and open-ended questions were included to gather a combination of quantitative and qualitative data. Questions were aligned with the study's pedagogical goals and the intended learning outcomes (ILOs) of the survey activity: (1) application of practical survey techniques; (2) observational skill development; and (3) data recording and management.

Performance comparison and data analysis

To assess whether student performance differed across the two modalities, we compared bird species identification data collected during the in-field and VR-based surveys. For each detection, students recorded the sensory modality used (visual, auditory, or both). Data from all 8 students were analysed, comprising 129 detections in the field and 149 detections in the virtual environment. Per-student totals of correctly identified species were compared using a paired Wilcoxon signed-rank test. Differences in sensory modality usage were examined using a 2 × 3 contingency table and Pearson's chi-squared test, with Cramer's V used as a measure of effect size. All statistical analyses were conducted using R version 4.3.3 (R Core Team, 2025).

Results

In field surveys, students relied most heavily on combined visual and auditory cues (43.4% of detections), followed by sound-only detections (32.6%) and vision-only detections (24.0%). VR surveys showed a more balanced distribution with combined cues accounting for 35.6% of detections, sound-only for 34.9%, and vision-only for 29.5% (Figure 1).

Across students present in both methods, virtual totals tended to be higher for several students (Figure 2), but the paired comparison did not show a statistically significant difference (Wilcoxon V = 8, p = 0.182). Detection modality distributions were similar between field and virtual surveys ($\chi^2 = 0.99$, df = 2, p = 0.610) with a small effect size (Cramer's V = 0.06). These results suggest that both field and virtual survey methods elicit similar patterns of sensory cue utilisation among students, with no significant bias toward any detection modality in either environment. Overall, student species identification performance and modality usage were comparable between both settings.

Figure 1. Distribution of detection modalities (visual, sound, or both combined) used by students during in-person field and virtual surveys.

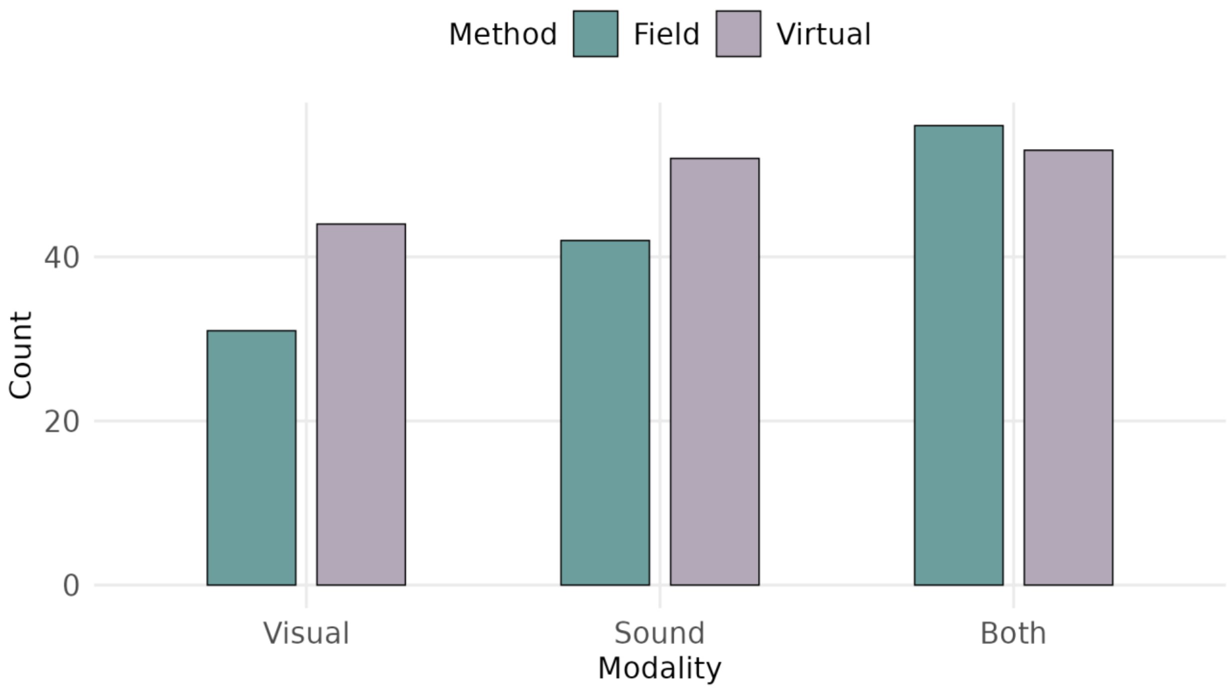
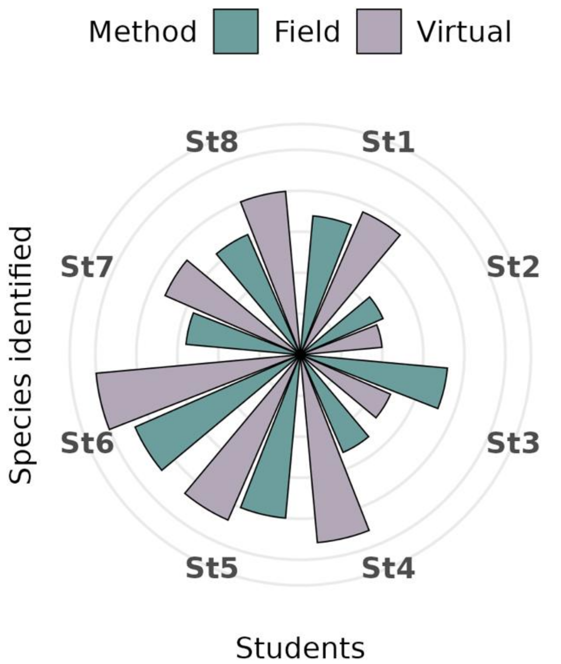


Figure 2. Student performance in species identification, comparing field and VR survey methods.



Student feedback

When asked, *'Do you feel your degree has equipped you with the skills you need to survey?'* 86% (n = 6) said yes and 14% (n=1) responded n/a, as they already felt equipped with the skills—therefore, all surveyors felt qualified to conduct the surveys. When asked to score their confidence with species identification on a scale of 1–10, 62% felt more confident in field settings compared with the VR environment, with confidence in the field averaging a score of 7.7, and in the lab averaging a score of 6.7. However, the level of enjoyment scored on the same scale was highly similar across both settings (average score of 9.4 for in the field, and 8.6 in the VR setting). When asked to comment on personal experience of using Nature Lab, responses were 100% positive (Table 1), and all felt their participation in the project was of personal value (Table 2).

Table 1. Text responses by student surveyors.

Survey question	Responses
How did you find using the Nature Lab?	'Very easy to use—like the in-person survey, but I could see more different species due to the accessibility. It would be useful for familiarising yourself with a site before going in person'. 'Good—very realistic and like being in the field. Easy to use and can retain the information without going into the field'.

	'Much more accessible, really enjoyed it! Different to being outside, it was relaxing'. 'The sounds were very similar, but it was harder to see birds in the simulation'. 'Had to adjust at first—more cryptic species are easier to pick up in VR'. 'It was an interesting experience testing my ID skills by sound. It was accessible and easy to use and allowed me to properly listen to bird species'.

Table 2. Text responses by student surveyors.

Survey question	Responses
Has this project been useful for you?	'Yes—it has really motivated me and piqued my interest to improve my bird ID skills. I gained valuable, transferrable skills that can help me with employment'. 'Yes—I could see what a real survey was like, and it built my confidence'. 'Yes—I can add it to my skills for future jobs'. 'Yes—it has further developed my bird ID skills'. 'Yes—it can be added to my CV'.

All student surveyors expressed that Nature Lab should be used as a teaching tool. When asked to rank which skills they thought were most important for conducting animal surveys, prioritised skills were different across both settings (Table 3). All but one student said they planned on going into a wildlife conservation-specific job (the one student said they were 'unsure'). 43% of students said that both virtual fieldwork and in-person fieldwork should be offered. 57% of students said that fieldwork should be offered i.e., virtual as an alternative. None of the students said that virtual fieldwork should replace fieldwork, but they all recognised the benefits of virtual fieldwork, ranking a reduced carbon footprint and increased inclusivity as the joint top two benefits. Second to these were the employability and transferrable skills acquired, and the promotion of sustainable teaching and learning.

Table 3. Mean student rankings of skills required for animal surveys under field and virtual reality (VR) conditions.

Skills	Field (mean rank)	VR (mean rank)	Change (VR - field)
Ability to identify species	1.8	1.0	–0.8
Data recording	3.4	3.4	0.0
Ability to navigate a map	4.0	8.6	+4.6
Knowledge of habitat	4.4	6.4	+2.0
Time management	5.6	6.8	+1.2
Knowledge of bird ecology	6.0	5.0	–1.0
Ability to use species ID books	6.2	4.4	–1.8
Ability to use AI apps	7.0	5.5	–1.5
Independence	7.8	6.8	–1.0
Communication	8.8	8.4	–0.4

Note: Rankings were assigned from 1 (most important) to 10 (least important). Values represent mean rank scores. The change score represents the difference between VR and field rankings (VR - Field). Negative values indicate that a skill was ranked as more important in VR (i.e., lower mean rank), whereas positive values indicate reduced importance in VR.

Discussion

Our study aimed to assess the effectiveness of VR fieldwork as an alternative to traditional in-person fieldwork for developing practical ecological skills. Our primary finding is that students demonstrated comparable performance in bird species identification across both survey methods. Students were able to satisfy the intended learning outcomes in both settings, with no meaningful difference in overall performance. The modalities used for identifying species was also found to be similar between the two environments. These results suggest that VR environments like Nature Lab can effectively replicate the core skill-based learning outcomes of in-person fieldwork. This provides strong evidence that VR fieldwork can support the same pedagogic goals as traditional fieldwork and be used with confidence by educators designing hybrid or alternative learning experiences. For skills-based disciplines such as Ecology, this creates opportunities to deliver practical training in a more flexible and inclusive way, without compromising learning quality.

Beyond these performance metrics, student feedback revealed key qualitative differences in experience across modalities. Several students indicated that the VR setting reduced stress and anxiety often associated with unfamiliar or inaccessible outdoor environments, especially for those with physical, mental health, or sensory barriers. This contributed to an overall sense that the VR experience was more inclusive and equitable. These findings align with recent research suggesting that virtual fieldwork can replicate the learning experience of the outdoors as closely as possible while offering a more accessible way for a wider range of students to engage with the discipline (Guillaume et al., 2025).

Importantly, students did not view VR as a replacement for traditional fieldwork but as a complementary tool with distinct strengths, especially in terms of accessibility and sustainability. While 3D virtual environments have been found to mimic on-location learning effectively, students often note that digital formats cannot fully capture fundamental social interactions with peers and staff that are specific to the field (Guillaume et al., 2025). This likely explains why none of the students supported replacing fieldwork outright, yet all endorsed the use of virtual fieldwork, with nearly half advocating for a hybrid model and others valuing VR as a standalone alternative for certain learners or contexts.

Beyond technical survey skills, the VR environment can facilitate the development of transferable competencies, including collaborative problem-solving, critical thinking, and spatial awareness (de Castro et al., 2026). Crucially, the virtual environment provides a 'low-stakes' environment where surveys can be paused, reviewed, and repeated without the logistical or environmental constraints of the field. This capacity to learn from mistakes in a controlled setting significantly fosters self-efficacy and skill confidence, and encourages experimentation—qualities central to the framework of inquiry-based learning (Adedokun et al., 2013; Pedaste et al., 2015).

The survey exercise had three specific intended learning outcomes that were all satisfied across both formats; however, feedback suggests the VR setting facilitated repeated reinforcement of these skills, which may be particularly beneficial for students who require more time to master technical tasks. The lack of significant difference in detection modality usage between field and virtual environments supports the validity of VR as a training tool for Ecology field skills. However, a significant limitation of this study is the small sample size, which limits the generalisability of our findings. This pilot study serves as a proof-of-concept and provides a strong foundation for future, larger-scale research where a more diverse cohort is needed to confirm these findings and explore their applicability across different student demographics and geographical locations.

A potential limitation of this study is the fixed pedagogical sequence, where the virtual task followed the in-person field survey. This may have introduced a familiarity bias, as students had already established a 'mental map' of the nature reserve and its avian community. This prior exposure likely acted as a scaffold, allowing students to navigate the VR environment with greater ease and focus more effectively on species identification. Future studies should employ a randomised crossover approach to isolate the impact of the VR interface from the benefits of environmental familiarity.

While our results are promising, it is important to acknowledge that not all fieldwork skills can be learned and practised via VR. Furthermore, the initial cost of setting up a VR field trip can be prohibitive for some institutions, particularly those in the Global South, which may rely on low-cost local trips. The controlled settings of the VR lab also cannot fully replicate the unpredictable and often challenging conditions of real-world fieldwork, such as changes in weather, terrain, and rare behaviour. Thus, while VR provides a powerful supplement, it should be viewed as an addition to—not a substitute for—authentic field experiences.

Improving graduate competence requires recommitting to hands-on, repetitive, mentored learning in real or simulated field conditions. Gamification is another valuable tool for consideration within an education context, because when thoughtfully integrated into a curriculum, it can transform species identification learning by making the task engaging, iterative, and inclusive (Vera-Morales et al., 2023), and drive motivation, strengthen memory, and build confidence (e.g., Aizprúa & Peña de Zamora, 2022). They can also promote sustainability (Dudok & Pigniczki-Kovács, 2023), which is increasingly relevant for institutions aiming to align teaching with sustainability and employability agendas, which students in this study also identified as important outcomes of the VR experience.

This project is a good case study for evidencing alternatives to fieldwork—something that came from the COVID pandemic and is here to stay (Bernstein, 2022; Firomumwe, 2022; Krause et al., 2021). VR can be utilised by any programme with a fieldwork component and does not need to be a replacement *per se* but can enhance existing trips by helping staff and students prepare for fieldwork in advance—without compromising safety, ethics, or access.

Students being unable to participate fully in outdoor fieldwork due to personal or logistical barriers is a common problem faced by university programmes—an issue completely mitigated by the VR experience. This highlights VR's role in widening participation in practical science education. One student specifically mentioned in their survey that they appreciated the release of in-person fieldwork limitations from the VR setting, and that being able to make and learn from mistakes boosts their confidence:

> [B]eing able to practice this and get feedback of how many are right and wrong is a great way to help us build our ID skills, it is hard for me to go outside sometimes so I appreciate something like this.

In real ecosystems you get just one chance at some observations. Simulations allow multiple iterations: you can run the same experiment with slight tweaks, compare outcomes, and test hypotheses. Immediate feedback helps clarify what went wrong or right and accelerates learning. Collectively, with all these benefits, when students and/or researchers eventually conduct real fieldwork, they will be more prepared, reflective, and effective.

Conclusion

This study demonstrates that immersive virtual reality (VR) environments like *Nature Lab* can effectively satisfy skill-based learning outcomes traditionally developed through in-person fieldwork. While our focus was on ecological field skills, the pedagogical benefits—such as repeated practise, immediate feedback, increased accessibility, and learner-driven pacing—are widely transferable across disciplines that involve experiential, spatial, or observational learning. Immersive technologies offer new ways to scaffold complex skills, build learner confidence, and widen participation. Virtual fieldwork aligns with sustainability goals by reducing carbon footprints and offering cost-effective, inclusive alternatives to traditional field trips. Importantly, virtual and in-person formats need not compete; rather, they offer complementary strengths that support more inclusive, flexible, and sustainable teaching practices. As institutions seek to future-proof curriculum design in response to pedagogical and societal challenges, immersive learning is a promising tool to reimagine practical learning and student engagement across the higher education sector.

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Disclosure statement

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