https://doi.org/10.5194/egusphere-2025-2248
Preprint. Discussion started: 30 May 2025

Digital Field Representations as a Holistic Approach to Experiential Learning in High Arctic Geoscience Field Education

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Abstract. Field-based education is a cornerstone of geoscience learning, offering students the opportunity to connect theoretical knowledge with real-world geological contexts. Yet, access to such experiences remains limited due to logistical, financial, environmental, and social barriers, especially in remote or extreme environments like the High Arctic. In response to these challenges, Virtual Field Experiences (VFEs) are emerging as promising tools to complement traditional fieldwork. In this study we investigate how VFEs contribute to experiential learning among students at the University Centre in Svalbard (UNIS) in Longyearbyen, Svalbard.

Using a mixed-methods approach grounded in experiential learning theory and the Technology Acceptance Model, we surveyed 66 students who used VFEs as part of geoscience courses at UNIS before and after physical field excursions. Results reveal that students found VFEs particularly valuable for pre-field orientation, spatial awareness, and post-field reflection. Students reported improved readiness, deeper conceptual understanding, and enhanced engagement. The virtual representations enabled them to revisit complex sites, identify overlooked features, and consolidate observations made during fieldwork. Importantly, most participants did not see VFEs as a replacement for traditional fieldwork but recognized their role in making field learning more inclusive, repeatable, and accessible.

We highlight how VFEs can reduce cognitive overload by familiarizing students with unfamiliar environments, thus helping to manage the "novelty space" often experienced during initial field exposure. Students expressed strong interest in broader applications of VFEs across courses and disciplines, particularly when enriched with interactivity and guided tasks. These findings suggest that digital field representations hold significant promise for expanding access to geoscience education and enhancing learning outcomes. Future research should explore co-design practices with students and educators to optimize VFEs for equity, sustainability, and pedagogical impact across diverse learning environments.

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1 Introduction

Field education, or field-based learning, is a cornerstone of geoscience education, enabling students to connect theoretical knowledge with practical skills (e.g., Lonergan & Andresen, 1988). This experiential approach is crucial not only for the development of disciplinary identities, but also for fostering social cohesion among students and educators in the field (Malm, 2020). Despite the established importance of hands-on field-based learning, advances in technology have led to the increased use of virtual field guides (VFGs) and other digital representations of geological environments (Horota et al., 2022, Pugsley et al., 2024, Bond and Cawood., 2020) The Covid-19 pandemic with severe restrictions on field-based learning greatly accelerated this development (Senger et al., 2021). VFGs and other digital tools are reshaping expectations for skill development among geoscience educators, offering new ways for learning (e.g., Evelpidou et al., 2021; Pugsley et al., 2021, Horota et al., 2023).

In geoscience education, fieldwork is frequently perceived as the pinnacle of education, the most meaningful and valued aspect of study programs. As a result, it can sometimes be difficult to raise and grapple with the challenges with, and barriers to, engaging in learning in the field (Malm et al., 2020; Marín-Spiotta et al., 2020; Nuñez et al., 2021). Field education has, for instance, been criticized for its inaccessibility to people with disabilities (Feig et al., 2019; Mol & Atchison, 2019; Stokes et al., 2019). Furthermore, alternatives to field-based learning have typically been limited and of poor quality (Carabajal et al., 2017). Field-based learning has also been criticized for its overvaluing of masculinity (e.g., demonstrations of strength/speed as signals of competence), often resulting in obstacles for women, trans-sexual and non-binary people to contribute to and find a place in the disciplinary culture of geosciences (Heimann & Johansson, 2023). Moreover, issues of safety in field-based learning related to differences in sexuality, gender, race, and gender identity may be inadequately addressed, resulting in student and staff monitoring their own activities due to perceived risks (e.g., avoiding drinking, staying with other women to avoid sexual harassment or violence) (Mattheis et al., 2022, Nuñez et al., 2021 Posselt & Nuñez, 2022; Stokes et al., 2015). Furthermore, the costs associated with field education also act as a barrier for students and institutions alike (Giles et al., 2020). Finally, the environmental consequences of travel, in particular air travel, have caused many geoscientists to weigh the benefits of learning in the field, with the potential impact of these activities (Pugsley et al., 2024).

In considering the challenges and barriers of field-based learning, the possibilities and potential of technology to broaden participation and accessibility warrants renewed consideration. Of particular interest has been the growth and development of digital tools, their use as supplementary/alternative pedagogical resources for geoscience teaching, and the possibility for widening access for field-based learning (e.g., Bonali et al., 2021; Feig et al, 2019; Moysey & Lazar, 2019; Whitmeyer et al., 2020; Pugsley et al., 2021). Cliffe (2017) acknowledged VFGs as invaluable assets in geoscience education, offering inclusivity, skill-building opportunities, and cost-effectiveness. They complement rather than replace real fieldwork, providing scalability, repeatability, and physical safety (Stott et al., 2014). Early use of VFGs and alternative assessments has been criticized as poorly developed and inadequate substitutes for fieldwork (for example, when offered to students with

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disabilities who may encounter barriers to participation) (Carabajal et al., 2017). The quality of VFGs continues to improve. Mead (2019) highlights the significant improvement in meeting student learning outcomes with interactive VFGs that feature adaptive feedback mechanisms. These digital resources engage students actively, enable multiple means of engagement (a core universal design for learning principles) and fosters deeper comprehension and retention of geological concepts (Hassan et al., 2019; Bimba et al., 2021). Importantly, Hay (2013) offers a valuable theoretical framework to support the integration of VFGs, emphasizing their role in providing authentic learning experiences by contextualizing theoretical knowledge within realistic geological scenarios. Despite documented skepticism among some geoscientists regarding the pedagogical value of digital field tools (e.g., Dolphin et al., 2019; Cliffe, 2017), VFGs represent a transformative approach in geoscience education, making possible expanded and improved accessibility, more varied means of meeting learning outcomes, and a bridge to link to abstract concepts and real-world applications.

Several studies report on students' experiences of VFGs in geoscience education. Guillaume (2023) found that students generally liked virtual fieldwork but missed being outdoors and socializing. Cliffe (2017) talked about how VFGs can be helpful, making learning more inclusive and engaging, but also mentioned difficulties in making and using them individual. Suthren (1998) and Dolphin (2019) changed perspectives looking into the virtual experiences broadly. Suthren (1998) focused on using computers in geoscience classes, while Dolphin (2019) suggested that we need to change how we teach geology. What this scholarship demonstrates is that VFGs can be powerful learning resources, in particular when educators support students' use and integrate and connect these tools with existing field teaching activities. VFGs are not a 'cure-all' but an enriching tool for student learning. However, significantly more research is needed to query how these tools can be used well and how prepared students and teachers are for the integration of VFGs into conventional curriculum.

Rather than engaging in a debate about investigating if VFGs should hold a place in geoscience education, or how effective they can be, this paper considers how and in what ways VFGs and other digital field representations can act alongside conventional field-based teaching activities to support student learning. Given the growth of digital tools in geoscience education, and the growing need for more accessible, varied and sustainable means of engaging in field teaching, we must better understand how prepared students are and how they perceive the use tools (in relation to their learning).

To investigate how students engage with digital field tools, this study focuses on the VR Svalbard platform, an interactive, web-based system developed at UNIS as part of the Svalbox initiative (Senger et al., 2021). VR Svalbard integrates drone-based photogrammetry, photospheres, maps, and 3D terrain data to produce immersive Virtual Field Experiences (VFEs) across Svalbard. These VFEs are structured as Virtual Field Guides (VFGs) and Virtual Field Tours (VFTs), enabling users to explore Arctic field sites remotely. As the digital infrastructure underlying this study, VR Svalbard serves as both a research tool and a pedagogical intervention, offering a scalable and inclusive model for enhancing field-based geoscience learning.

Hence, in this paper we address two research questions: 1) How do students perceive the usefulness of digital field representations in their field-based learning experiences in geoscience? 2) How do VFEs contribute to managing the novelty space in learning environments according to students' perspectives?

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1.1 Virtual Field Experiences in the context of Experiential Learning Theory

The theoretical foundation of this study is supported by Kolb's Experiential Learning Theory (ELT), which describes that learning is a process where knowledge is created through experience (Kolb, 1984). ELT emphasizes a cyclical model of learning, comprising four stages: concrete experiencing, reflective observation, abstract conceptualization, and active experimentation (Figure 1; Kolb, 1984). This cycle suggests that effective learning involves progressing through these stages and applying knowledge in real-world settings.

In geoscience field education, experiential learning plays a central role, as the discipline relies on the observation and interaction with natural environments to develop understanding of geological processes and practices (Healey & Jenkins, 2000).

Figure 1: The Experiential Learning Theory of Kolb (1984) in a four-stage cycle adapted for geoscience field-based learning with virtual field experiences. Parts of the figure was AI generated.

In the past decade, geoscience education and research have been transformed by the proliferation of digital tools that capture, model, and represent geological features (Buckley et al., 2008; Hodgetts, 2013; Pringle et al., 2016). This digital shift has enabled the development of Virtual Field Experiences (VFEs), which leverage technologies such as digital outcrop models

(DOMs), photospheres, photogrammetric reconstructions, and geospatial visualization tools (e.g., Westoby et al., 2012; Howell et al., 2014; Whitmeyer et al., 2010; Horota et al., 2024). The integration of these tools into teaching aligns closely with ELT. VFEs simulate immersive concrete experiences, enable reflective observation through annotated, re-visitable experiences, foster abstract conceptualization via spatial data interpretation, and support active experimentation by allowing students to explore and test ideas in virtual environments (Pugsley et al., 2021; Klippel et al., 2020). VFEs thus reframe fieldwork within a flexible, iterative, and inclusive experiential learning model (Guillaume et al., 2023; Cliffe, 2017; Needle et al., 2022; Hay et al., 2013).

Contemporary VFEs offer immersive and interactive experiences that mimic and extend real-world geological investigations (Klippel et al., 2020; Pugsley et al., 2021; Horota et al., 2024). Compared to earlier digital resources, often limited to static imagery or text, today's VFEs incorporate high-quality visuals, 3D environments, and geospatial layering. These features allow learners to engage with virtual field localities on demand, with increased realism and interactivity. As a result, VFEs can serve both as preparatory and reflective tools that enhance students' spatial reasoning, observational skills, and conceptual integration across scales.

By aligning with all stages of Kolb's ELT, VFEs function not merely as digital replicas of fieldwork but as pedagogically rich platforms that expand access to geoscientific learning. They offer scalable, repeatable, and inclusive alternatives to conventional field-based learning, addressing longstanding barriers while cultivating critical thinking and inquiry-based learning. In doing so, VFEs support the development of core competencies in geoscience education and represent a transformative evolution in how field experiences are conceptualized, delivered, and integrated into curricula.

1.2 Svalbard – year-round geoscience teaching

This study focusses on the University Centre in Svalbard (UNIS), an educational institution located in the Norwegian Arctic Archipelago of Svalbard (74-81ºN), situated between mainland Norway and the North Pole (Figure 2). Svalbard is renowned for its dramatic landscapes, geologically diverse terrain and a rich history of natural resource exploration and exploitation (e.g., Senger et al., 2019). The region's geological record spans over 1 billion years, capturing evidence of past orogenies, glaciations, climate change, and magmatic events, making it an exceptional natural laboratory for geoscientific research and teaching. Svalbard's main settlement, Longyearbyen (population 2500), located at a high-latitude position offers a unique setting to study sedimentary basins, deep-time paleoclimate, and tectono-magmatic events (Olaussen et al., 2025). This geological richness, combined with its accessibility during summer months, has cemented Svalbard's status as a great site for geoscientific related field-based education and research.

In this context, UNIS delivers Arctic education and research throughout the highly seasonal polar year that includes a four month long polar night. It integrates field-based learning into its curricula, providing students with opportunities to conduct hands-on studies in a remote Arctic environment fostering international collaboration and attracting students and researchers from across the globe. Its focus on experiential learning aligns with modern pedagogical approaches, emphasizing data collection, interpretation, and field safety in extreme conditions (e.g., Senger et al., 2021; 2025).

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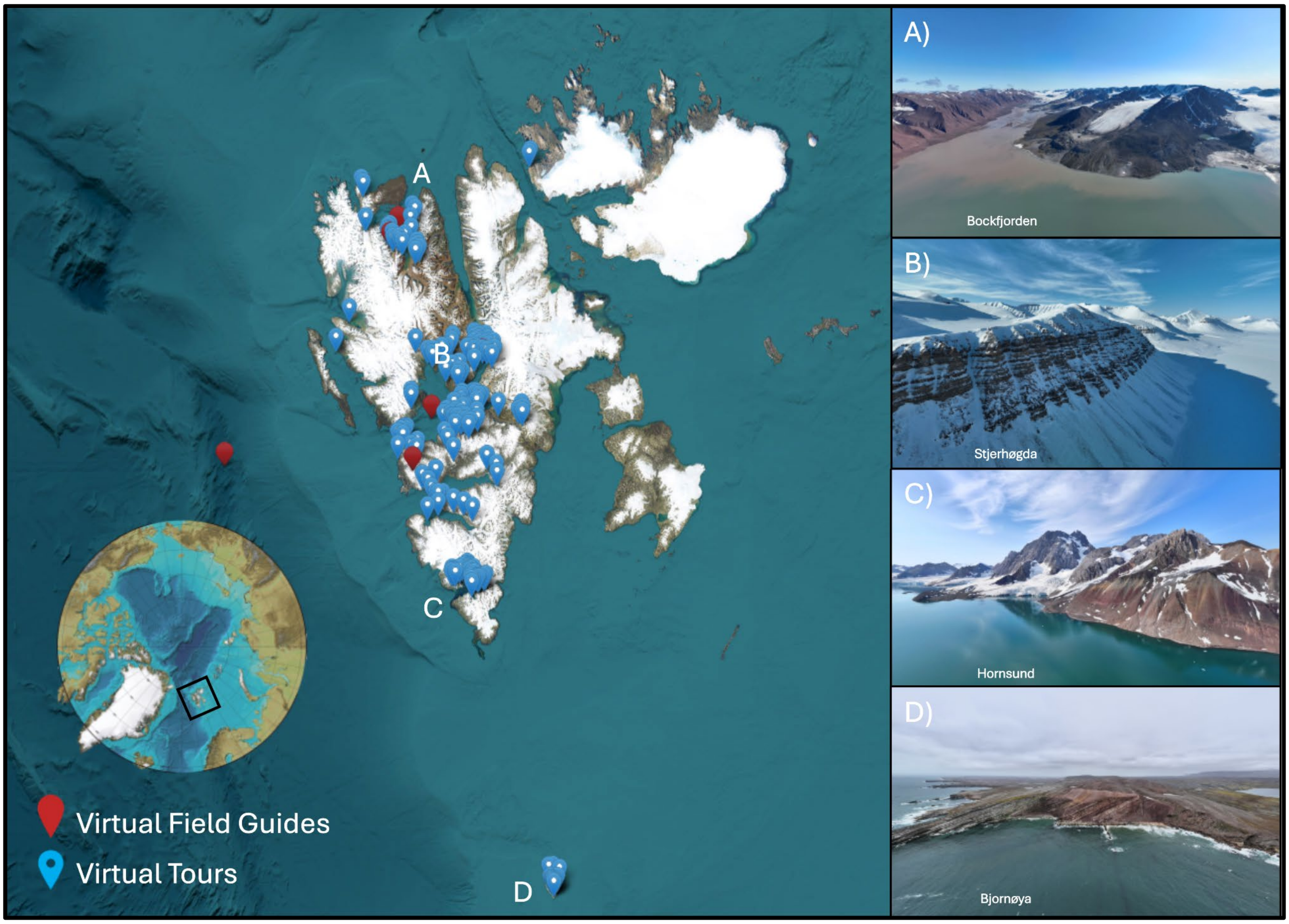

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Figure 2: Location of the Svalbard archipelago (black box on inset map, based on IBCAO; Jakobsson et al, 2008) displaying markers of available Virtual Field Guides (red, n=6) and Virtual Field Tours (blue, n= 175) from www.vrsvalbard.com/map. Images A, B, C, and D show the geological diversity of Svalbard's landscapes.

The VR Svalbard platform (Horota et al., 2024) represents a paradigm change to Arctic field education by integrating VFEs into geoscience learning. Developed as part of the UNIS-led Svalbox initiative (Senger et al., 2021; Betlem et al., 2023), VR Svalbard combines high-resolution drone imagery (photogrammetry and derived datasets, photospheres, map layers, etc.) to create VFEs through VFGs and (VFT) (Figure 3). These tools enable students and researchers to digitally explore remote Arctic landscapes, fostering accessibility and inclusivity while complementing physical fieldwork. This platform supports experiential learning by simulating field excursions, allowing users to investigate geomorphological and structural features, characterize geological features (e.g., orientation, bed thickness), and analyse spatial relationships. This integration of digital tools reflects a broader movement toward hybrid teaching methodologies, ensuring the sustainability and scalability of Arctic field education in a changing climate.

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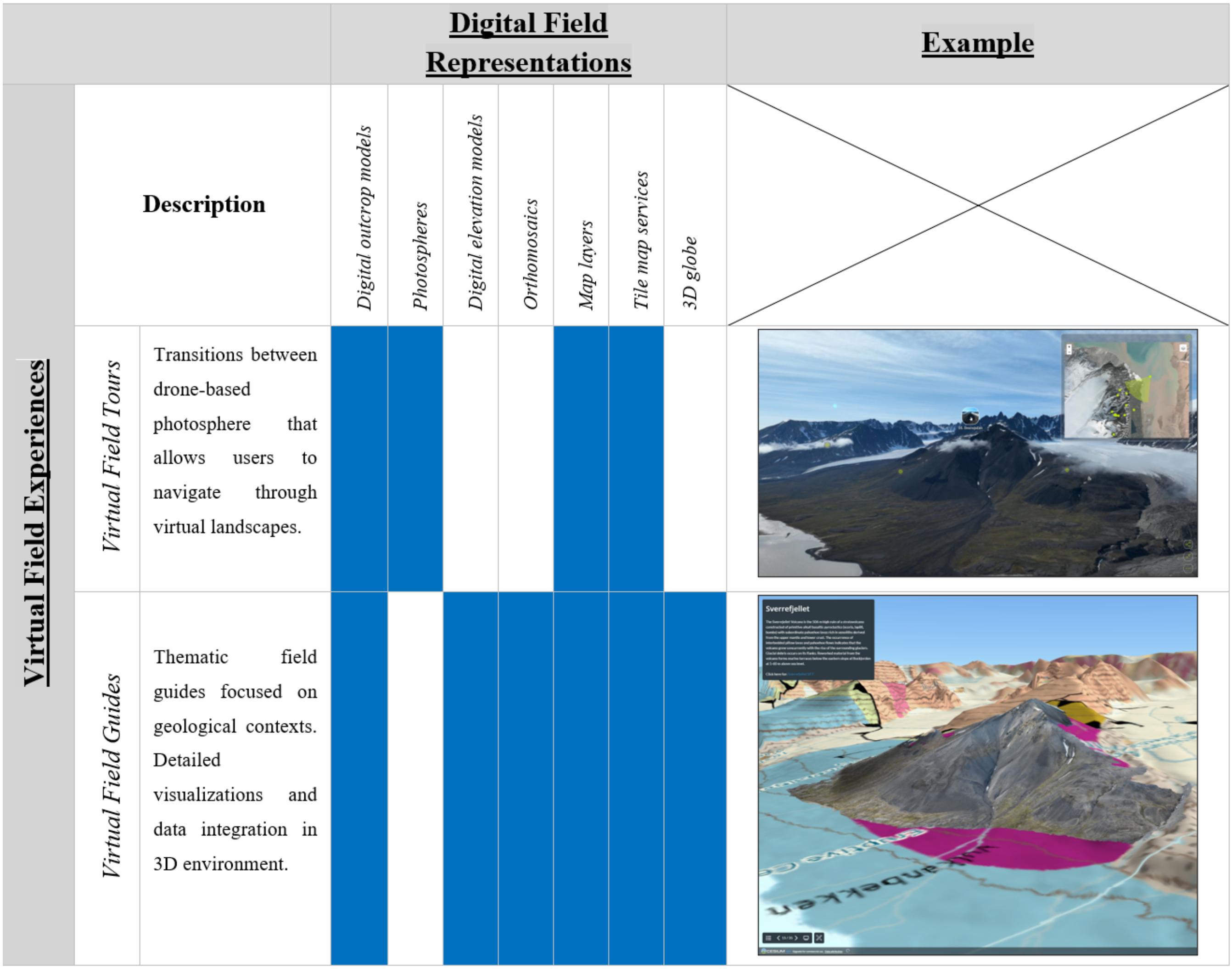

Figure 3: Overview of VR Svalbard Virtual Field Experiences and Digital Field Representations.

3 Data and Methods

3.1 Research design

We have adopted a mixed-methods approach to evaluate the integration of VFEs from the VR Svalbard platform into geoscience education at UNIS. The research design supports exploration of students' engagement with VFEs, focusing on both their perceived educational value and their role in shaping the learning experience. To this end, we pursue two key objectives: first, to evaluate the technological readiness and perceived usability of VFEs using the Technology Acceptance Model (TAM); and second, to assess students' learning experiences and outcomes through a structured questionnaire. This

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dual focus enables a holistic investigation into how students interact with, evaluate, and learn from digital field tools before and after participating in physical fieldwork.

The technology acceptance model (TAM), established by Davis (1989), proposes that two primary factors, perceived usefulness (PU), and perceived ease of use (PEOU), influence an individual's intention to adopt and use technology. PU reflects the extent to which a user believes the technology will enhance task performance, while PEOU refers to the degree of effort required to operate the technology. Together, these constructs shape behavioural intention (BI), the likelihood of future use. In this study, we employed TAM to systematically assess the perceived value of the VFEs (Appendix A), focusing on its role in enhancing geoscience education and its ease of integration into field-based learning.

To assess students' perspectives on the educational impact of VFEs, we designed a survey , incorporating Likert-scale questions and open-ended responses (Appendix B). The survey questions were designed to evaluate multiple conceptual areas, including students' ability to orient themselves geographically, navigate field settings, and develop observational skills. Additionally, the survey assessed how VFEs contributed to their preparedness for field activities, their ability to correlate and integrate different spatial scales, and their perception of the VFEs' effectiveness as complementary tools to traditional fieldwork. The voluntary web-based surveys were provided to all participants after their exposure to VFEs, enabling a comprehensive evaluation of how this virtual resource influenced their learning experience. By addressing diverse aspects such as spatial awareness, field readiness, and integration of virtual and real-world observations.

To further explore the educational value of VFEs, the survey also included sections addressing participants' perceptions before and after the fieldwork experience. The pre-fieldwork questions aimed to evaluate students' initial engagement, expectations, and the perceived usefulness of VFEs in enhancing their preparedness for field activities. These questions also examined the extent to which virtual exploration influenced students' interest and readiness for physical fieldwork. The post-fieldwork section, on the other hand, focused on reflecting upon the actual impact of VFEs on their learning outcomes, including their ability to integrate virtual insights with hands-on observations. Participants provided feedback on whether revisiting virtual field localities enhanced their understanding or contributed to their overall learning process. By comparing these pre- and post-fieldwork perspectives, the study captured the dynamic evolution of students' attitudes toward VFEs and their role in complementing traditional field-based education.

3.2 Study participants and data collection instruments

The study involved 131 students attending bachelor's, master's, and PhD-level courses at UNIS (Table 1). Participants were selected based on their participation in field-based courses at UNIS that incorporated VFEs into their curriculum. These courses span a range of topics, ensuring a sample representative of various subfields within geoscience and polar meteorology (Table 1). Participants provided informed consent and were briefed on the study's objectives and data collection processes.

The selection of UNIS courses allowed the study to target students with significant exposure to Arctic fieldwork, offering a unique context in which to evaluate the integration of VFEs into traditional field education.

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Course Code	Title	Year	Number students	VR Svalbard usage in course activities	ECTS	Level
AGF-213	Polar Meteorology and Climate	2024	16	DTL, FP, ON, H&S, PFA, and AA.	15	Bachelor
AGF-350/850	The Arctic Atmospheric Boundary Layer and Local Climate Processes	2024	19	DTL, FP, ON, H&S, PFA, and AA.	10	Masters/PhD
AG-209	The Tectonic and Sedimentary History of Svalbard	2024	15	DTL, FP, H&S, GVA, PFA, AA, and STP.	15	Bachelor
AG-222	Integrated Geological Methods: From Outcrop to Geomodel	2024	(Same as AG-209)	DTL, FP, H&S, GVA, PFA, AA, and STP.	15	Bachelor
AG-210	Quaternary and Glacial Geology of Svalbard	2023	17	DTL, ON, DCL, FP, H&S, GVA, PFA, AA, and STP.	15	Bachelor
AG-220	Environmental Change in the high Arctic Landscape of Svalbard	2023	20	DTL, ON, DCL, FP, H&S, GVA, PFA, AA, and STP.	10	Bachelor
AG-336/836	Rift Basin Reservoirs: From Outcrop to Model	2024	15	DTL, FP, H&S, GVA, PFA, AA, and STP.	10	Masters/PhD
AG-351/851	Arctic Tectonics and Volcanism	2024	14	DTL, FP, H&S, GVA, PFA, AA, and STP.	10	Masters/PhD
TOTAL			131			

Table 1: Number of students from Arctic geology and Arctic geophysics courses, integration of VR Svalbard Virtual Field Environments, course-Levels and educational value. Note that the courses AG-209 and AG-222 are run in parallel with the same students. ECTS = European Credit Transfer System. *DTL: Demonstration Tool in Lectures, FP: Fieldwork Planning, ON: Orientation and Navigation, H&S: Health and Safety Briefings, GVA: Guaranteed Virtual Field Access (to field sites in daylight and good visibility), DCL: Detecting Changes in the Landscape, PFA: Post-Fieldwork Analysis, AA: Assessments and Activities, STP: Students' Term Projects. ECTS = European Credit Transfer System (60 ECTS = 1 year of full-time study).

4 Results

The results presented in this study are based on data collected through questionnaire responses (Appendix A and B). Out of 131 students invited to participate, 69 agreed to the terms and conditions, and 66 completed the entire survey. The results are structured around four major themes: usage patterns, technology acceptance, perceived educational impacts, and comparative

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perceptions before and after fieldwork activities. These themes provide a holistic understanding of how VFEs using VR Svalbard influenced geoscience learning.

4.1 Usage patterns

The survey data reveal significant engagement with the VR Svalbard platform among participants. Of the 66 students who completed the survey, 86% reported having used the platform at least once. The use of VFEs was integrated into several contexts, demonstrating its broad applicability within field-based education. Notably, 71% of respondents used the VFEs during field preparation lectures, while 55% used them as part of post-fieldwork exercises. Additionally, 53% of students engaged with the platform independently out of personal curiosity, showing a high degree of self-motivated exploration (Figure 4).

Beyond course-integrated use, students also employed the tool for planning their own fieldwork (38%), revisiting specific field localities (53%), and extracting visual data for assignments or term projects (38%). This range of uses emphasizes the platform's flexibility in serving various pedagogical and research needs.

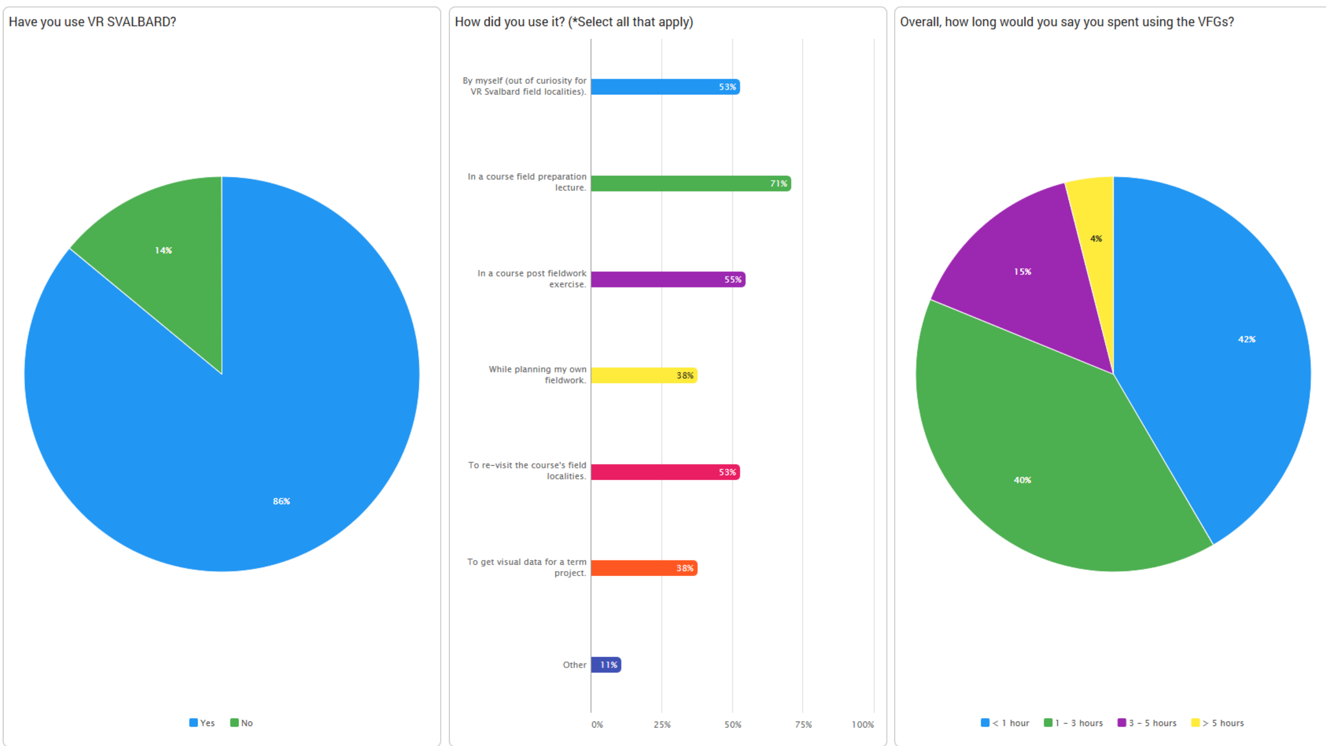

Figure 4: Usage Patterns of VR Svalbard: Engagement, Contexts of Use, and Time Spent on VFEs.

In terms of time spent, 42% of users reported engaging with the platform for less than one hour, 40% for one to three hours, 15% for three to five hours, and 4% for over five hours. These time ranges likely reflect the one-hour session typically allocated in class for VR Svalbard activities. However, it is especially encouraging to observe that more than half of students

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used the platform beyond the scheduled class time. This indicates that the resource successfully fostered self-directed learning and individual exploration, suggesting its effectiveness not only as a classroom tool but also as a meaningful extension of field learning. These varying engagement levels suggest the tool is accessible for both quick, surface-level exploration and more in-depth study.

4.2 Technology acceptance model

The evaluation of VR Svalbard's VFEs technical aspects was conducted using a TAM questionnaire designed to assess students' Perceived Usefulness, Perceived Ease of Use, and Behavioral Intention to Use (Appendix B). Respondents were asked to rate their agreement with statements addressing these aspects on a Likert scale from 1 (strongly disagree) to 7 (strongly agree). The dataset included responses from 54 participants who completed this section of the questionnaire.

Students rated the platform highly in terms of perceived usefulness. The highest-scoring items were "Using VR Svalbard would enhance my effectiveness in the field" and "I would find VR Svalbard useful in my field learning activity," each with a mean score of 6.0. This high ratings underscore students' belief that the platform positively contributes to their learning outcomes. Other positively rated items included the platform's ability to help complete field tasks more quickly and efficiently.

Perceived Ease of Use statements also scored well, with statements such as "Learning to operate VR Svalbard would be easy for me" and "My interaction with VR Svalbard would be clear and understandable" both receiving mean scores around 5.9 (Figure 5). Although students generally found the platform intuitive, slightly lower ratings were given for items related to flexibility and user control, suggesting opportunities for improvement in the interface and customization features.

Behavioral Intention responses indicated that students were likely to continue using the platform. Statements such as "I would recommend VR Svalbard to my peers" and "I would use VR Svalbard for future field activities" received high scores, reflecting a strong willingness among students to engage with the tool beyond a single course context (Figure 5). This finding is particularly significant, as it suggests the long-term adoption of VR Svalbard as a resource for students. Moreover, it indicates that students are not only receptive to technology but may also serve as advocates for its broader implementation within geoscience curricula.

Together, the high ratings across Perceived Usefulness, Perceived Ease of Use, and Behavioral Intention suggest that VR Svalbard meets key criteria for technology acceptance in educational settings. The platform was perceived as a useful, easy-to-learn tool that students intend to continue using, an important foundation for promoting digital literacy and innovation in field-based geoscience education. However, the slightly lower ratings related to control and flexibility indicate areas for design improvement, particularly in refining user experience to better support a variety of learning preferences and workflows.

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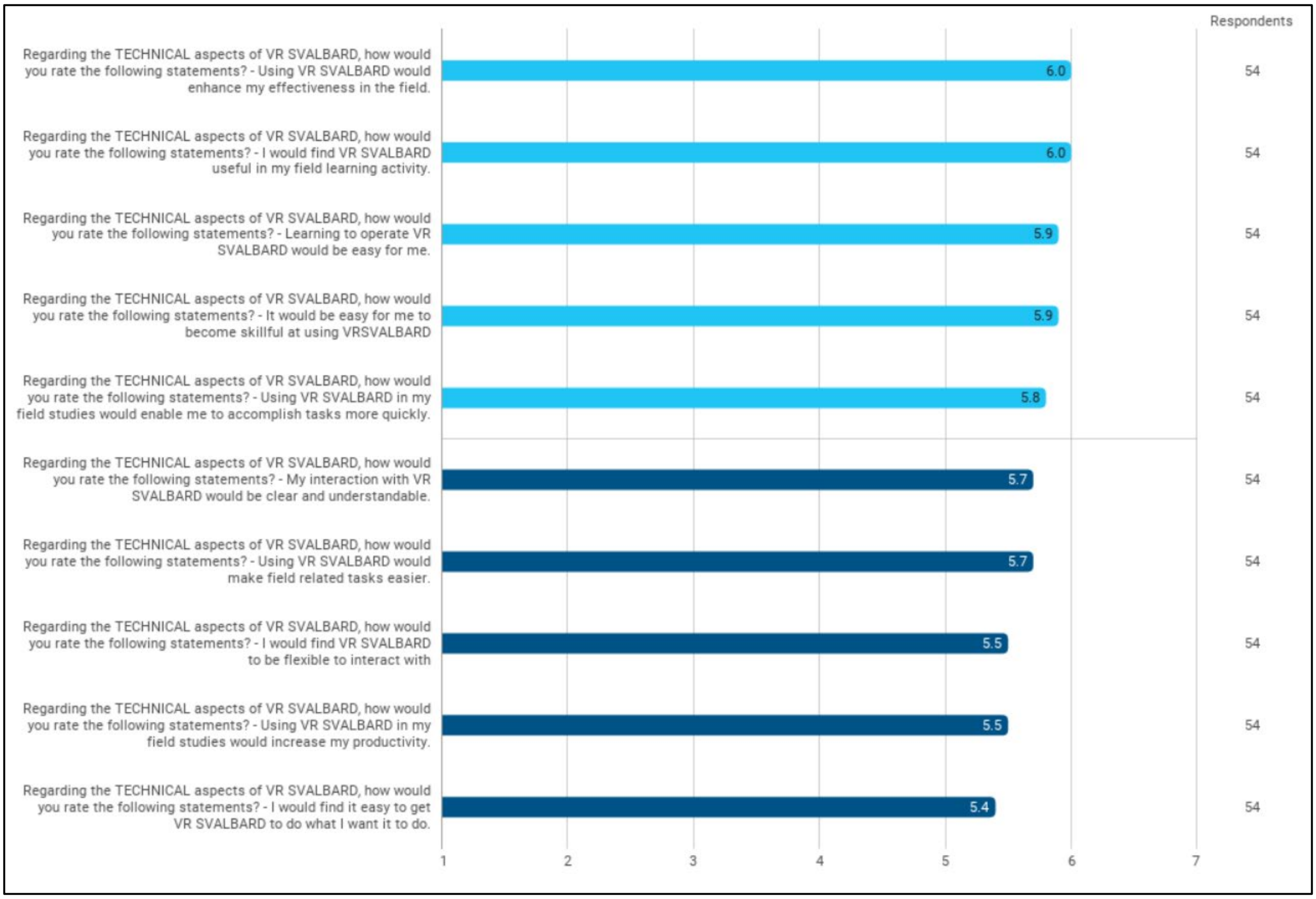

Figure 5: Likert plots of responses (n= 54), all starting with "Regarding the technical aspects of VR Svalbard, how would you rate the following statements?".

4.2 Perceived educational impact

This subsection presents an analysis of how students perceived the educational value of VFEs in relation to their geoscience learning. Drawing on quantitative Likert-scale responses and qualitative open-ended comments from Appendix B, the findings highlight how the integration of VFEs before and after field activities influenced student engagement, spatial awareness, immersion, preparedness, and perceived learning outcomes (Figure 6). These themes are further substantiated by the full distribution of responses presented in Figure 6, which provides a more nuanced view of how students positioned themselves across the same five-points Likert scale for each item.

Responses in this section were rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). This scale allowed students to express varying degrees of agreement with statements about their experiences with the VFEs.

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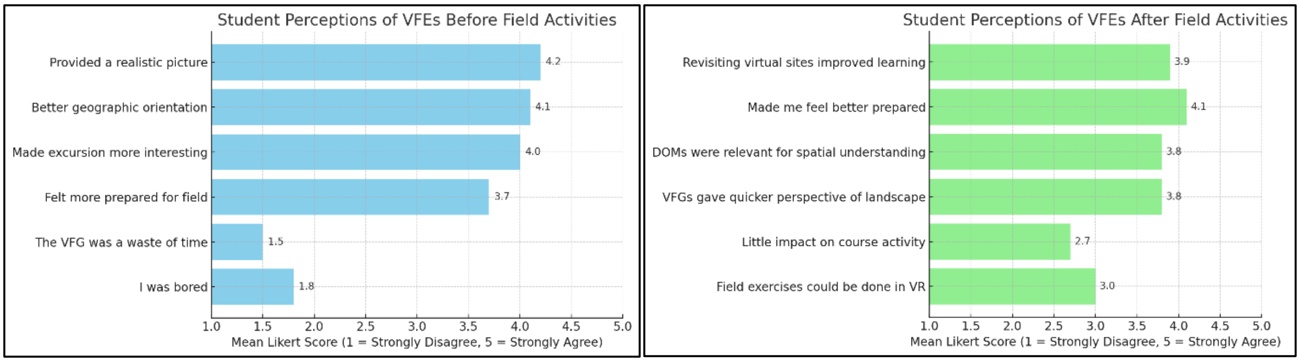

Figure 6: Mean Likert-scale responses (1 = strongly disagree, 5 = strongly agree) to selected statements about student perceptions of Virtual Field Experiences (VFEs) using VR Svalbard. The left panel shows responses before field activities, emphasizing the perceived realism, geographic orientation, and preparatory value of the VFGs. The right panel shows responses after field activities, highlighting how students reflected on the VFGs' role in reinforcing learning, spatial understanding, and field preparation. Results are based on 41 (pre-field) and 52 (post-field) respondents, respectively.

VR Svalbard was introduced into courses through a structured, two-phase integration strategy: pre-field and post-field activities. This deliberate inclusion aimed to optimize learning outcomes by scaffolding students' engagement with geoscientific content.

In the pre-field phase, instructors used VR Svalbard to orient students to Arctic landscapes and specific field locations. Activities included navigation exercises, spatial reasoning tasks, and exposure to realistic terrain models. These sessions helped students build mental models of field environments, thus increasing their confidence and readiness before the actual fieldwork.

In the post-field phase, VR Svalbard VFE served as a reflective tool. Students revisited sites virtually to reinforce learning, compare virtual models with real-world observations, and identify aspects they may have missed in the field. This allowed for deeper engagement with the material and supported students' ability to connect observations across scales and contexts.

4.2.1 Pre-field experiences and perceptions

Students' feedback before field excursions indicated a strong appreciation for the preparatory value of VR Svalbard. A key insight was that virtual previews of field sites made upcoming excursions more engaging, with a reported average score of 4.0 on the statement "Visiting the field localities virtually beforehand made the excursion more interesting." Students also reported enhanced spatial orientation and confidence. The average score of 4.1 for "I felt like I could possibly better orient myself geographically" suggests that VFEs contributed positively to students' mental preparedness. The realism of the virtual models was also acknowledged, with "The VFG provided a realistic picture of how the field localities looked like" scoring 4.2.

However, the platform was not universally praised. While most disagreed with the negative statement "The VFG was a waste of time" (mean score 1.5), a minority of students found the experience underwhelming or boring (mean score 1.8). This suggests a potential need for greater interactivity or clearer guidance on how to use the resource effectively.

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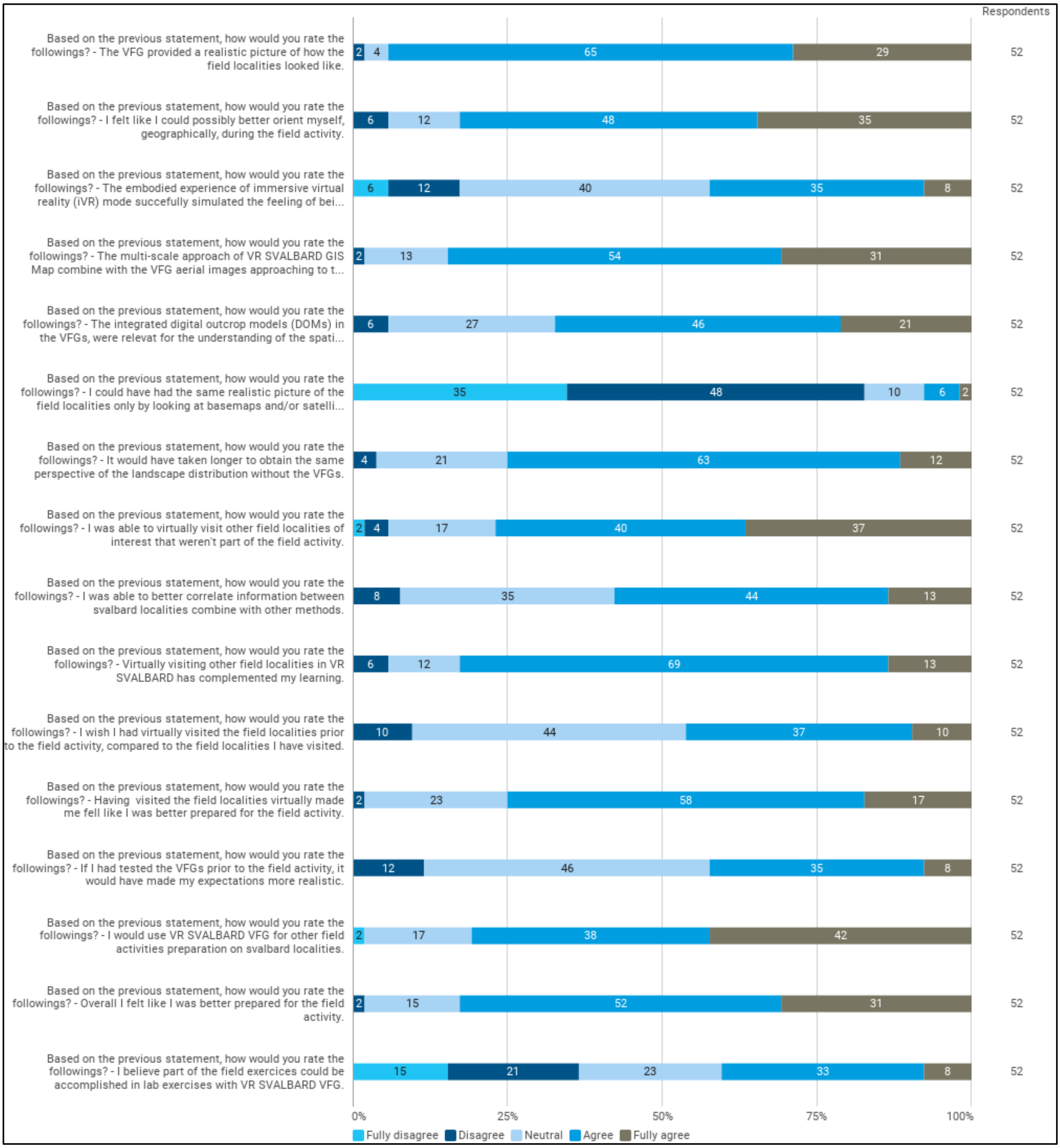

300 **Figure 7: Full distribution of student responses to VFE-related statements, rated on a 5-point Likert scale (1 = fully disagree, 5 = fully agree). The chart visualizes levels of perception across key dimensions including spatial awareness, immersion, and learning outcomes.**

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These mixed responses may also reflect a broader tension within geoscience education, namely, the persistent cultural perception that authentic learning occurs in the field, not on a screen. For students at UNIS, many of whom actively choose the institution for its reputation in Arctic field teaching, there may be an even stronger expectation that “real geology” happens outdoors. In this context, digital tools like VFEs may be undervalued or perceived as less legitimate, particularly when compared to the embodied, communal experience of being on-site in the High Arctic. Acknowledging and navigating these expectations is essential for successful integration of VFEs into field curricula.

4.2.2 Post-field reflections and learning consolidation

Following the completion of field activities, students reflected on the utility of revisiting field sites virtually. The average score of 3.9 for "Re-visiting field localities virtually had a positive impact on my field learning outcomes" highlights the tool’s value in reinforcing and consolidating knowledge.

Students emphasized the benefit of being able to compare field experiences with high-resolution virtual imagery. Many appreciated the integration of GIS data, digital outcrop models, and aerial views. The ability to visualize sites from multiple angles and return to specific locations post-fieldwork allowed students to identify patterns, refine interpretations, and gain additional insights.

Additionally, students felt that the VFEs improved their overall preparedness. The statements "Having visited the field localities virtually made me feel like I was better prepared" and "Overall, I felt like I was better prepared for the field activity" scored averages of 3.9 and 4.1, respectively.

4.2.3 Comparative insights: before vs. after fieldwork

A comparative analysis of students' pre- and post-field perspectives illustrates the complementary nature of the VFEs throughout the learning process. Initially, the VFEs helped students form expectations and visualize spatial relationships. After the fieldwork, the same tools supported reflection and the integration of physical and digital observations.

Interestingly, students perceived greater educational value in the VFEs after their physical field experience. This may reflect a growing awareness that limited field time, weather conditions, and the overwhelming nature of the Arctic landscape can make it difficult to fully absorb all necessary features in situ. The VFEs thus became more appreciated as a means to revisit, clarify, and extend observations that were either missed or briefly encountered in the field. This interpretation is supported by the higher engagement with VFEs post-field and by statements such as "Re-visiting field localities virtually had a positive impact on my field learning outcomes" (mean score: 3.9) and "Overall, I felt like I was better prepared for the field activity" (mean score: 4.1).

Moreover, while students were less enthusiastic about replacing fieldwork altogether with virtual tools (mean score: 3.0 for "I believe part of the field exercises could be accomplished using VR Svalbard"), they clearly recognized the supplementary value of VFEs as reflective and reinforcing components in the learning process.

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4.2.4 Enhancing spatial awareness and geographical orientation

Spatial reasoning is central to field-based geoscience, and many students perceived VFEs as improving this skill. A total of 83% of students (48% agreed, 35% fully agreed) responded positively to the statement "I felt like I could better orient myself," indicating that the platform supported geographic orientation during fieldwork. This demonstrates that VFEs effectively helped bridge the gap between map-based learning and physical navigation (Figure 7).

Similarly, 85% of students (54% agreed, 31% fully agreed) responded positively to the statement "The multi-scale approach of VR Svalbard GIS Map combined with the VFEs aerial images was relevant for the understanding of the spatial context," emphasizing the perceived value of combining DOMs, aerial imagery, and GIS layers in enhancing spatial understanding.

These responses reinforce the importance of integrating layered geospatial data into VFEs to strengthen students' spatial understanding (Figure 7).

4.2.5 Realism and immersion in virtual environments

Students generally found the VFEs realistic but moderately immersive. In response to the statement "The embodied experience of immersive virtual reality simulated the feeling of being in the field," 50% of students (35% agreed, 15% fully agreed) expressed agreement, while 12% disagreed. This indicates moderate satisfaction with the immersive experience and highlights opportunities to improve VR design and interactivity (Figure 7).

In contrast, when presented with the statement "I could have had the same realistic picture only using satellite images," 83% of students disagreed (48% disagreed, 35% fully disagreed). This strong rejection emphasizes the added value of the dynamic and interactive visual content provided by VR Svalbard compared to static visualizations Figure (7).

These findings suggest that while students appreciate the realism of the virtual field environments, further enhancements in interactivity and immersive technology could improve their ability to simulate in-field experiences.

4.2.6 Learning outcomes and preparation

The VFEs were highly regarded for their role in improving learning outcomes and field preparation. In response to the statement "Having visited the field localities virtually made me feel like I was better prepared for the field activity," 75% of students (58% agreed, 17% fully agreed) expressed a positive perception of the tool's preparatory value. Similarly, 83% of students (52% agreed, 31% fully agreed) agreed with the statement "Overall, I felt like I was better prepared for the field activity," demonstrating strong support for the effectiveness of VFEs in building confidence ahead of fieldwork (Figure 7).

The tool also helped students draw connections between different sites. For the statement "Virtually visiting other field localities in VR Svalbard has complemented my learning," 82% of students responded positively (69% agreed, 13% fully agreed), suggesting that the ability to explore a range of locations virtually enhanced their contextual understanding of Arctic geology (Figure 7).

These results underscore the value of VFEs in preparing students for field activities and expanding their conceptual grasp of spatial and geological relationships.

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4.2.7 Suggestions for improvement and broader use cases

Open-ended responses revealed several opportunities to improve the VFEs. Students suggested improved navigation, faster loading speeds, and more transitions between views. They also requested richer content, such as additional summer imagery, stratigraphic logs, and guided virtual tours.

In response to the statement "I would use VR Svalbard VFE for other field activities preparation," 84% of students (62% agreed, 22% fully agreed) indicated support for broader implementation across courses. This demonstrates not only satisfaction with the tool but a desire to see its usage expanded within other geoscience learning contexts.

Quotes from students further illustrate these insights:

"Seeing the site in summer helped me understand what was under the snow."

"We only saw 10% of the outcrop in spring—VR Svalbard showed the rest."

"It would be nice to have more interactive exercises and guided tours with the VFEs."

Such feedback underscores both the current strengths of the platform and the potential for future development. Students clearly value the tool, but they also see ways to make it more interactive, comprehensive, and aligned with field-based learning objectives.

5 Discussion

This study investigated how geoscience students interact with and respond to digital field representations, particularly when presented as VFEs through the VR Svalbard platform. An important first step in this investigation involved assessing students' perceptions of the technology itself, using the TAM framework. Results indicated high scores across all three dimensions, perceived usefulness, perceived ease of use, and behavioral intention, demonstrating that students found the VR Svalbard platform intuitive, relevant, and worth using repeatedly.

These findings are significant in two ways. First, they align with prior research showing that technology acceptance is a prerequisite for effective digital learning (Davis, 1989; Venkatesh & Bala, 2008; Teo, 2011). Although there is a widespread belief that students today, particularly in the wake of the COVID-19 pandemic, are inherently more comfortable and willing to use educational technologies, this assumption is not strongly supported by empirical evidence. If students struggle with navigation or doubt the utility of a platform, the cognitive effort required to overcome those barriers can overshadow the intended learning benefits (Ardito et al., 2006). As such, studies like this remain necessary to assess whether new digital

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tools, such as VR Svalbard, are not only accessible but also meaningfully integrated into students' learning experiences. Second, confirming high technology acceptance was essential for the integrity of this study: it ensured that the students' reflections on learning outcomes, engagement, and spatial reasoning were not confounded by frustrations with the interface or technical limitations. In other words, it created a clean foundation for evaluating the pedagogical potential of VFEs in field-based geoscience education.

5.1 How do students perceive the usefulness of digital field representations in their field-based learning experiences in geoscience?

The integration of VFEs into geoscience education has been met with positive reception from students, who perceive these digital tools as valuable supplements to traditional fieldwork. In our study, 83% of students agreed or fully agreed that VFEs enhanced their geographic orientation, and 85% found the multi-scale approach combining GIS maps and aerial imagery beneficial for understanding spatial contexts. These findings align with research showing that virtual representations support students' development of spatial skills and conceptual understanding (Cliffe, 2017; Arrowsmith et al., 2021).

Students also reported that VFEs contributed to their preparation for field activities, with 75% indicating that virtual visits made them feel better prepared. This perception underscores the role of digital tools in scaffolding learning experiences, allowing students to familiarize themselves with field sites before physical visits, a benefit also emphasized by Whitmeyer and Dordevic (2021) and Needle (2022). Such preparatory exposure can increase learner confidence, reduce anxiety, and enhance active engagement in the field (Markowitz et al., 2018).

Moreover, the ability to revisit virtual sites post-fieldwork was highlighted to reinforce learning and reflect on observations. This aligns with experiential learning theory, which emphasizes reflection as a key stage of the learning cycle (Kolb, 1984). The VR SVALABRD VFEs template thus supports a continuous loop of learning where digital field representations facilitate both preparation and post-field reflection, strengthening the link between classroom, virtual, and physical field learning.

5.2 How do VFEs contribute to managing the novelty space in learning environments, according to students' perspectives?

The concept of novelty space refers to the cognitive and emotional demands students face when encountering unfamiliar or first-time experiences in a learning environment, such as visiting remote, complex field sites (Gibson, 1979; Stainfield et al., 2000). In geoscience fieldwork, this novelty can be both motivating and overwhelming, particularly when environmental, spatial, and sensory stimuli are experienced all at once. Students in our study reported that VFEs helped mitigate these effects: 75% felt better prepared after using the virtual environments, and 83% felt more confident in geographic orientation. These findings suggest that VFEs helped reduce the novelty of the field by offering a controlled, repeatable, and cognitively digestible preview of the environment.

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Digital field representations contribute to managing the novelty space by providing structured exposure to unfamiliar environments before students encounter them physically. This preparatory experience allows students to build mental maps of spatial relationships and geological features, helping them focus cognitive resources on higher-order learning tasks once in the field (Needle et al., 2022). Such scaffolding is particularly important in Arctic or remote field sites where logistical complexity and environmental extremes can increase cognitive load.

Moreover, VFEs may serve to flatten the learning curve by reducing anxiety associated with the unknown. Several students in our study noted that seeing the terrain in virtual form beforehand helped them orient themselves and engage more meaningfully during the actual fieldwork. These outcomes support prior research showing that reducing novelty through prior exposure improves focus, recall, and reflection (Di Ioia et al., 2020; Horota et al., 2022).

However, it is equally important to recognize that some novelty can be pedagogically valuable. The challenge lies in managing it, not eliminating it. VFEs offer a way to calibrate the novelty space, easing the initial shock of the unfamiliar while preserving the experiential richness of the field.

5 Conclusions

In this study we have shown that VFEs, as delivered through the VR Svalbard platform, hold substantial potential for enhancing field-based geoscience education. Students at UNIS reported that these tools supported their learning by improving field preparedness, spatial awareness, and post-field reflection. By offering access to high-resolution, interactive, and scalable representations of Arctic field sites, VFEs address key challenges in accessibility, inclusivity, and sustainability in field teaching.

Importantly, student feedback indicates that the pedagogical value of VFEs lies not in replacing fieldwork but in complementing it, offering repeated, low-barrier opportunities to engage with field content across time and space. This affirms the potential of VFEs to scaffold learning in ways that align with experiential, iterative, and reflective educational approaches.

Beyond technical adoption, the integration of VFEs also holds cultural and structural significance for the geoscience education community. These tools challenge traditional assumptions about what counts as 'real' field learning by enabling more varied and inclusive modes of engagement. Students' perspectives suggest that digital tools, when thoughtfully integrated, can democratize access to field sites, support learner agency, and reduce barriers related to physical ability, scheduling, and prior experience.

This shift calls for continued dialogue between educators and students. As students may recognize the value of these digital tools before their instructors do, future research should explore how learners themselves contribute to shaping pedagogical innovation in geoscience. We recommend further inquiry into the co-construction of field learning environments, where student reflections, preferences, and feedback actively inform the evolution of field education practices.

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Data availability

The anonymous questionnaire used in this study—including both the Technology Acceptance Model (TAM) and educational impact components is available at the following link: (https://svar.uib.no/servlet/com.pls.morpheus.web.pages.CoreRespondentCollectLinkAnonymous). Individual student responses are not publicly available due to privacy and ethical considerations. Aggregated, anonymized data that support the findings of this study may be made available from the corresponding author upon reasonable request and in compliance with institutional guidelines.

This project was assessed and approved by the Norwegian Centre for Research Data (NSD, now Sikt, Norwegian Agency for Shared Services in Education and Research) under reference number 955880. The legal basis for processing personal data is informed consent in accordance with GDPR Article 6(1)(a). The assessment confirms that the processing is lawful provided it adheres to institutional data protection practices, with approval valid through 30 September 2025.

Author contributions

RKH conceived the study, developed the methodology, curated and analyzed the data, and wrote the original draft; CE, KS, MJ, and MAVK reviewed and edited the manuscript; KS and MJ also contributed to funding acquisition.

Competing interests

The authors declare that they have no conflict of interest.

Ethical statement

This study was conducted in accordance with ethical guidelines for research involving human participants. Ethical approval was obtained from the Norwegian Centre for Research Data (NSD, now Sikt – Norwegian Agency for Shared Services in Education and Research) under reference number 955880. All participants were informed about the objectives of the study and provided informed consent prior to data collection. Data were anonymized and handled in compliance with the General Data Protection Regulation (GDPR). The study adhered to institutional and national guidelines for responsible research practices.

Acknowledgements and funding

The authors would like to thank all the students who generously participated in the study and provided valuable insights. We are also grateful to the course coordinators at the University Centre in Svalbard (UNIS) for their support in integrating the research activities into their course structures. This research was made possible through funding from UNIS, which supported both the delivery of field-based courses and the PhD fellowship of the lead author (RKH). Additional support was provided by the iEarth Centre for Integrated Earth Science Education, which funded related pedagogical projects. The development and deployment of VR Svalbard and associated data acquisition were supported through the Svalbox and iEarth seed funding initiatives, which provided access to drones, digital equipment and field campaigns. Their combined support was instrumental in enabling this research at the intersection of digital innovation and Arctic geoscience education.

References

Abeyta, A., Fernandes, A. M., Mahon, R. C., & Swanson, T. (n.d.). The True Cost of Field Education is a Barrier to Diversifying Geosciences. https://doi.org/10.31223/X5BG70

Ardito, C., Costabile, M.F., De Angeli, A. and Lanzilotti, R., 2006, October. Systematic evaluation of e-learning systems: an experimental validation. In Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles (pp. 195-202).

Bimba, A. T., Idris, N., Al-Hunaiyyan, A., Ibrahim, S. U., Mustafa, N., Supa'at, I., ... & Ahmad, M. Y. (2021). The effects of adaptive feedback on student's learning gains. International Journal of Advanced Computer Science and Applications, 12(7), 68-80.

Bonali, F., Russo, E., Vitello, F., Antoniou, V., Marchese, F., Fallati, L., Bracchi, V., Corti, N., Savini, A., Whitworth, M., Drymoni, K., Mariotto, F., Nomikou, P., Sciacca, E., Bressan, S., Falsaperla, S., Reitano, D., Van Wyk De Vries, B., Krokos, M., … Tibaldi, A. (2021). How Academics and the Public Experienced Immersive Virtual Reality for Geo-Education. Geosciences, 12(1), 9. https://doi.org/10.3390/geosciences12010009

Bond, C.E. and Cawood, A.J., 2020. A role for virtual outcrop models in blended learning: improved 3D thinking, positive perceptions of learning and the potential for greater equality, diversity and inclusivity in geoscience. Geoscience Communication Discussions, 2020, pp.1-20.

Carabajal, I. G., Marshall, A. M., & Atchison, C. L. (2017). A Synthesis of Instructional Strategies in Geoscience Education Literature That Address Barriers to Inclusion for Students With Disabilities. Journal of Geoscience Education, 65(4), 531–541. https://doi.org/10.5408/16-211.1

Cliffe, A. D. (2017). A review of the benefits and drawbacks to virtual field guides in today's Geoscience higher education environment. International Journal of Educational Technology in Higher Education, 14(1), 1-14.

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, pp.319-340.

Dolphin, G., Dutchak, A., Karchewski, B., & Cooper, J. (2019). Virtual field experiences in introductory geology: Addressing a capacity problem, but finding a pedagogical one. Journal of Geoscience Education, 67(2), 114-130.

Feig, A. D., Atchison, C., Stokes, A., & Gilley, B. (2019). Achieving Inclusive Field-based Education: Results and Recommendations from an Accessible Geoscience Field Trip. Journal of the Scholarship of Teaching and Learning, 19(2). https://doi.org/10.14434/josotl.v19i1.23455

Gibson, J.J., 1979. The ecological approach to visual perception. Boston: Houghton Mifflin.

Giles, S., Jackson, C., & Stephen, N. (2020). Barriers to fieldwork in undergraduate geoscience degrees. Nature Reviews Earth & Environment, 1(2), 77-78. https://doi.org/10.1038/s43017-020-0022-5

Guillaume, L., Laurent, V., & Genge, M. J. (2023). Immersive and interactive three-dimensional virtual fieldwork: Assessing the student learning experience and value to improve inclusivity of geosciences degrees. Journal of Geoscience Education, 71(4), 462-475.

Hassan, M. A., Habiba, U., Khalid, H., Shoaib, M., & Arshad, S. (2019). An adaptive feedback system to improve student performance based on collaborative behavior. Ieee Access, 7, 107171-107178.

Hay, K. E., Marlino, M., & Holschuh, D. R. (2013, April). The virtual exploratorium: Foundational research and theory on the integration of 5-D modeling and visualization in undergraduate geoscience education. In International Conference of the Learning Sciences (pp. 214-220). Psychology Press.

Healey, M., & Jenkins, A. (2000). Kolb's experiential learning theory and its application in geography in higher education. Journal of geography, 99(5), 185-195.

Heimann, S., & Johansson, K. (2024). Gendered work in geoscience: Hard work in a masculine field. Gender, Work & Organization, 31(1), 16–35. https://doi.org/10.1111/gwao.13052

Horota, R.K., Rossa, P., Marques, A., Gonzaga, L., Senger, K., Cazarin, C.L., Spigolon, A. and Veronez, M.R., 2022. An immersive virtual field experience structuring method for geoscience education. IEEE Transactions on Learning Technologies, 16(1), pp.121-132.

Horota, R.K., Senger, K., Smyrak-Sikora, A., Furze, M., Retelle, M., Vander Kloet, M.A. and Jonassen, M.O., 2024. VRSvalbard–a Photosphere-Based Atlas of a High Arctic Geo-Landscape. First Break, 42(4), pp.35-42.

Klippel, A., Zhao, J., Oprean, D., Wallgrün, J.O., Stubbs, C., La Femina, P. and Jackson, K.L., 2020. The value of being there: Toward a science of immersive virtual field trips. Virtual Reality, 24, pp.753-770.

Kolb , D. 1984 . Experiential learning: Experience as the source of learning and development, New Jersey : Prentice-Hall.

Lonergan, N., & Andresen, L. W. (1988). Field-based education: Some theoretical considerations. Higher education research and development, 7(1), 63-77.

Malm, R. H., Madsen, L. M., & Lundmark, A. M. (2020). Students' negotiations of belonging in geoscience: Experiences of faculty–student interactions when entering university. Journal of Geography in Higher Education, 44(4), 532–549. https://doi.org/10.1080/03098265.2020.1771683

Marín-Spiotta, E., Barnes, R. T., Berhe, A. A., Hastings, M. G., Mattheis, A., Schneider, B., & Williams, B. M. (2020). Hostile climates are barriers to diversifying geosciences. Advances in Geosciences, 53, 117–127. https://doi.org/10.5194/adgeo-53-117-2020

Markowitz, D.M., Laha, R., Perone, B.P., Pea, R.D. and Bailenson, J.N., 2018. Immersive virtual reality field trips facilitate learning about climate change. Frontiers in psychology, 9, p.2364.

Mattheis, A., Marín-Spiotta, E., Nandihalli, S., Schneider, B., & Barnes, R. T. (2022). " Maybe this is just not the place for me:" Gender harassment and discrimination in the geosciences. PLoS One, 17(5), e0268562.

Mattheis, A., Murphy, M., & Marin-Spiotta, E. (2019). Examining intersectionality and inclusivity in geosciences education research: A synthesis of the literature 2008–2018. Journal of Geoscience Education, 67(4), 505–517. https://doi.org/10.1080/10899995.2019.1656522

Mead, C., Buxner, S., Bruce, G., Taylor, W., Semken, S. and Anbar, A.D., 2019. Immersive, interactive virtual field trips promote science learning. Journal of Geoscience Education, 67(2), pp.131-142.

Mogk, D.W. and Goodwin, C., 2012. Learning in the field: Synthesis of research on thinking and learning in the geosciences. Geological society of America special papers, 486(0), pp.131-163.

Mol, L., & Atchison, C. (2019). Image is everything: Educator awareness of perceived barriers for students with physical disabilities in geoscience degree programs. Journal of Geography in Higher Education, 43(4), 544–567. https://doi.org/10.1080/03098265.2019.1660862

Moysey, S.M. and Lazar, K.B., 2019. Using virtual reality as a tool for field-based learning in the earth sciences. Interdisciplinary perspectives on virtual place-based learning, pp.99-126.

Needle, M.D., Crider, J.G., Mooc, J. and Akers, J.F., 2022. Virtual field experiences in a web-based video game environment: open-ended examples of existing and fictional field sites. Geoscience Communication, 5(3), pp.251-260.

Nunez, A. M., Posselt, J. R., Hallmark, T., Rivera, J., & Southern, D. (2021). The organization of learning in geoscience fieldwork and implications for inclusion. Journal of Women and Minorities in Science and Engineering, 27(3).

Núñez, A.-M., Rivera, J., & Hallmark, T. (2020). Applying an intersectionality lens to expand equity in the geosciences. Journal of Geoscience Education, 68(2), 97–114. https://doi.org/10.1080/10899995.2019.1675131

Olaussen, S., Grundvåg, S.A., Senger, K., Anell, I., Betlem, P., Birchall, T., Braathen, A., Dallmann, W., Jochmann, M., Johannessen, E.P. and Lord, G., 2025. Svalbard composite tectono-sedimentary element, Barents Sea. Geological Society, London, Memoirs, 57(1), pp.M57-2021.

Posselt, J. R., & Nuñez, A.-M. (2022). Learning in the Wild: Fieldwork, Gender, and the Social Construction of Disciplinary Culture. The Journal of Higher Education, 93(2), 163–194. https://doi.org/10.1080/00221546.2021.1971505

Pugsley, J. H., Howell, J. A., Hartley, A., Buckley, S. J., Brackenridge, R., Schofield, N., ... & Vanbiervliet, J. (2021). Virtual Fieldtrips: construction, delivery, and implications for future geological fieldtrips. Geoscience Communication Discussions, 2021, 1-33.

Pugsley, J., Howell, J., Hartley, A., Buckley, S. J., Chmielewska, M., Naumann, N., ... & Brackenridge, R. (2024). Quantifying Virtual Field Trip Efficiency. PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science.

Senger, K., Betlem, P., Grundvåg, S. A., Horota, R. K., Buckley, S. J., Smyrak-Sikora, A., ... & Olaussen, S. (2021). Teaching with digital geology in the high Arctic: opportunities and challenges. Geoscience Communication Discussions, 2021, 1-39.

Stainfield, J., Fisher, P., Ford, B. and Solem, M., 2000. International virtual field trips: A new direction?. Journal of Geography in Higher Education, 24(2), pp.255-262.

Stott, T., Litherland, K., Carmichael, P., & Nuttall, A. M. (2014). Using interactive virtual field guides and linked data in Geoscience teaching and learning. Geoscience Research and Education: Teaching at Universities, 163-188.

Stokes, A., Feig, A. D., Atchison, C. L., & Gilley, B. (2019). Making geoscience fieldwork inclusive and accessible for students with disabilities. Geosphere, 15(6), 1809–1825. https://doi.org/10.1130/GES02006.1

Stokes, P. J., Levine, R., & Flessa, K. W. (2015). Choosing the geoscience major: Important factors, race/ethnicity, and gender. Journal of Geoscience Education, 63(3), 250-263.

Suthren, R. J. (1998). Virtual posters and virtual essays in geoscience courses. Computers & Geosciences, 24(7), 665-671.

Teo, Timothy. "Factors influencing teachers' intention to use technology: Model development and test." Computers & Education 57, no. 4 (2011): 2432-2440.

Venkatesh, V. and Bala, H., 2008. Technology acceptance model 3 and a research agenda on interventions. Decision sciences, 39(2), pp.273-315.

Westoby, M.J., Brasington, J., Glasser, N.F., Hambrey, M.J. and Reynolds, J.M., 2012. 'Structure-from-Motion'photogrammetry: A low-cost, effective tool for geoscience applications. Geomorphology, 179, pp.300-314.

Whitmeyer, S.J., Nicoletti, J. and De Paor, D.G., 2010. The digital revolution in geologic mapping. GSA Today, 20(4/5), pp.4-10.

Whitmeyer, S., Atchison, C., & Collins, T. (2020). Using Mobile Technologies to Enhance Accessibility and Inclusion in Field-Based Learning. GSA Today, 30(9), 4–10. https://doi.org/10.1130/GSATG462A.1

Whitmeyer, S.J. and Dordevic, M., 2021. Creating virtual geologic mapping exercises in a changing world. Geosphere, 17(1), pp.226-243.

https://doi.org/10.5194/egusphere-2025-2248
Preprint. Discussion started: 30 May 2025

Appendix A

Regarding the TECHNICAL aspects of VR SVALBARD, how would you rate the following statements?

	Extremely unlikely	Quite unlikely	Slightly unlikely	Neither	Slightly likely	Quite likely	Extremely likely
Using VR SVALBARD in my field studies would enable me to accomplish tasks more quickly.	1	2	3	4	5	6	7
Using VR SVALBARD in my field studies would increase my productivity.	1	2	3	4	5	6	7
Using VR SVALBARD would enhance my effectiveness in the field.	1	2	3	4	5	6	7
Using VR SVALBARD would improve my field learning performance.	1	2	3	4	5	6	7
Using VR SVALBARD would make field related tasks easier.	1	2	3	4	5	6	7
I would find VR SVALBARD useful in my field learning activity.	1	2	3	4	5	6	7
Learning to operate VR SVALBARD would be easy for me.	1	2	3	4	5	6	7
I would find it easy to get VR SVALBARD to do what I want it to do.	1	2	3	4	5	6	7
My interaction with VR SVALBARD would be clear and understandable.	1	2	3	4	5	6	7
I would find VR SVALBARD to be flexible to interact with	1	2	3	4	5	6	7
It would be easy for me to become skillful at using VRSVALBARD	1	2	3	4	5	6	7
I would find VR SVALBARD easy to use.	1	2	3	4	5	6	7
I intend to use VR Svalbard frequently in the future.	1	2	3	4	5	6	7
I will recommend VR Svalbard to others.	1	2	3	4	5	6	7
I plan to integrate VR Svalbard into my academic activities.	1	2	3	4	5	6	7
I would consider using other VR Systems based on my experience with VR Svalbard.	1	2	3	4	5	6	7

https://doi.org/10.5194/egusphere-2025-2248
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Appendix B

Based on your VR SVALBARD VFG experience BEFORE going to the field activity, how would you rate the following statements?

	Fully disagree	Disagree	Neutral	Agree	Fully agree
I was bored.	○	○	○	○	○
The VFG felt like a complete waste of time.	○	○	○	○	○
Visiting the field localities virtually beforehand made the excursion more interesting.	○	○	○	○	○
Visiting the field localities virtually beforehand had great impact on my final learning outcome.	○	○	○	○	○
I think visiting the field localities virtually prior to the excursion was not worth the time invested.	○	○	○	○	○

Based on your VR SVALBARD experience AFTER going to the field activity, how would you rate the following statements?

	Fully disagree	Disagree	Neutra	Agree	Fully agree
I was bored	○	○	○	○	○
The VFG felt like a complete waste of time.	○	○	○	○	○
I think visiting the field localities virtually beforehand would have little impact on my final learning outcome.	○	○	○	○	○
I think some of the field exercises could have been done in the preparation lecture using the VFGs.*	○	○	○	○	○
I wish I had more time in the field preparation lecture with VFGs to better prepare for the field excursion.	○	○	○	○	○
Re-visiting field localities virtually had little impact for course activity purposes.	○	○	○	○	○
Re-visiting field localities virtually had a positive impact on my field learning outcomes.	○	○	○	○	○

*What field exercises could have been done virtually?

	Fully disagree	Disagree	Neutral	Agree	Fully agree
The VFG provided a realistic picture of how the field localities looked like.	○	○	○	○	○
I felt like I could possibly better orient myself, geographically, during the field activity.	○	○	○	○	○
The embodied experience of immersive virtual reality (iVR) mode succefully simulated the feeling of being present at the field localities.	○	○	○	○	○
The multi-scale approach of VR SVALBARD GIS Map combine with the VFG aerial images approaching to the field localities, helped me better understand the scale and distribution of landscape.	○	○	○	○	○
The integrated digital outcrop models (DOMs) in the VFGs, were relevat for the understanding of the spatial distribution (3D), and scale of the landscape in field localities.	○	○	○	○	○
I could have had the same realistic picture of the field localities only by looking at basemaps and/or satellite imagery.	○	○	○	○	○
It would have taken longer to obtain the same perspective of the landscape distribution without the VFGs.	○	○	○	○	○
I was able to virtually visit other field localities of interest that weren't part of the field activity.	○	○	○	○	○
I was able to better correlate information between svalbard localities combine with other methods.	○	○	○	○	○
Virtually visiting other field localities in VR SVALBARD has complemented my learning.	○	○	○	○	○
I wish I had virtually visited the field localities prior to the field activity, compared to the field localities I have visited.	○	○	○	○	○
Having visited the field localities virtually made me fell like I was better prepared for the field activity.	○	○	○	○	○
If I had tested the VFGs prior to the field activity, it would have made my expectations more realistic.	○	○	○	○	○
I would use VR SVALBARD VFG for other field activities preparation on svalbard localities.	○	○	○	○	○
Overall I felt like I was better prepared for the field activity.	○	○	○	○	○
I believe part of the field exercices could be accomplished in lab exercises with VR SVALBARD VFG.	○	○	○	○	○