

Response to Editor and Reviewers

Dear Editor and Reviewers,

We would like to sincerely thank the editor and reviewers for their careful reading of our revised manuscript and for the constructive feedback provided during this final stage of review. We are grateful that the substantive concerns raised during the first review round were considered adequately addressed, and we appreciate the positive assessment that the manuscript is close to publication.

We have carefully considered all remaining comments and have revised the manuscript accordingly. In most cases, we have accepted the suggested changes directly. Where a comment raised an issue that was beyond the scope of our data, we have revised the text to avoid overstatement and to make the limitations of the study clearer.

Below, we provide a point-by-point response to the minor revisions and detailed line-level comments.

Minor revisions

1. Use of generative AI

Editor comment:

The caption of Fig. 1 states that “parts of the figure was AI generated.” The journal’s AI policy requires authors to name the specific tool used and clearly describe the purpose and extent of its use. Please include this information in the Acknowledgements section.

Response:

Thank you for this comment. We have revised the caption of Figure 1 to clearly specify the tool used and the extent of generative AI use. The revised caption now states that only the background illustrative images in Figure 1 were generated using ChatGPT with DALL·E. The four Experiential Learning Theory stages, figure labels, arrows, schematic structure, and pedagogical interpretation were created, edited, and verified by the authors.

We have also added a Generative AI disclosure to the Acknowledgements section. This disclosure identifies the tool used, explains that AI was used only to generate the background illustrative images in Figure 1, and provides the stage-specific prompts used to generate the images. We also clarify that the AI-generated elements are conceptual illustrations only and do not represent empirical data, actual students, field observations, or specific Svalbard localities.

Change made:

The Figure 1 caption and the Acknowledgements section have been revised to specify the AI tool used, the purpose of its use, and the limited extent of AI-generated content.

Revised manuscript wording added to the Acknowledgements:

“Generative AI disclosure. ChatGPT with DALL·E was used only to generate the background illustrative images included in Figure 1. These images were generated separately, using author-provided reference material and stage-specific prompts. The four Experiential Learning Theory stages, figure labels, arrows, schematic structure, pedagogical framing, manuscript text, data analysis, interpretation, and conclusions were produced, edited, and verified by the authors. The AI-generated elements are conceptual visual illustrations only and do not represent empirical data, actual students, field observations, or specific Svalbard localities.”

2. Costs associated with the VFE programme

Editor comment:

The authors make a convincing case for the positive impact of VFEs on students, including benefits related to accessibility, inclusivity, and sustainability. It would strengthen the manuscript, and broaden its relevance beyond a strictly High Arctic setting, to include some discussion of the costs associated with running such a programme, for example equipment, software licences, and staff time. Even a brief treatment of this would be a useful addition for readers considering adopting a similar approach.

Response:

Thank you for this useful suggestion. We agree that a discussion of costs strengthens the practical relevance of the manuscript, particularly for readers considering whether similar VFE programmes could be adopted in other institutional contexts.

We have added a new subsection titled “4.5 Practical experiences and costs.” This section describes the gradual development of the VFE programme at UNIS, including the acquisition of digital outcrop models since 2017, the development of aerial photospheres and the VR Svalbard platform from 2021 onward, and the approximate costs associated with platform development, maintenance, UAV equipment, and field logistics.

The new section distinguishes between the relatively moderate costs of maintaining a web-based VFE platform and the higher costs of acquiring field data in the High Arctic. This distinction allows the discussion to be relevant both to Arctic institutions and to geoscience programmes in less logistically demanding settings.

Change made:

A new subsection on practical experiences and costs has been added to the Results section. This

includes approximate costs for platform development, annual maintenance, UAV equipment, High Arctic field access, and course-level field budgets.

3. Quantitative outcomes enabled by VFE

Editor comment:

The conclusion states that “VFEs allow students to focus more fully on observation and interpretation during limited field time.” Did the authors observe or collect any evidence that VFE use — particularly after visiting an outcrop — enabled students to conduct more or better quantitative geological work than they would have otherwise? If any relevant data exist, including them would meaningfully strengthen this claim.

Response:

Thank you for raising this important point. We did not collect direct quantitative evidence showing that VFE use enabled students to conduct more, or better, quantitative geological work than they would otherwise have done. The data collected in this study relate to students’ perceived preparedness, spatial orientation, usefulness, ease of use, and reflective learning support, rather than direct measurements of quantitative geological field performance.

To avoid overstating the results, we have revised the conclusion to clarify that the claim is based on students’ reported perceptions rather than direct measurement of quantitative field outcomes. We now describe VFEs as having the potential to support observation and interpretation by increasing familiarity, preparedness, and confidence, while explicitly acknowledging that direct effects on quantitative geological work were not measured.

Change made:

The conclusion has been revised to avoid overclaiming and to distinguish clearly between perceived learning support and directly measured quantitative field performance.

Revised wording:

“A further consequence of integrating VFEs into field curricula is their potential to reduce the novelty space students experience when entering unfamiliar and demanding environments such as the High Arctic. In this study, students reported increased preparedness, spatial orientation, and opportunities for post-field reflection. While we did not directly measure improvements in quantitative geological field performance, these perceived benefits suggest that VFEs may help students enter field settings with greater familiarity and confidence, thereby supporting observation and interpretation during limited field time.”

4. Inclusivity and accessibility — a missed opportunity

Editor comment:

RC1 suggested including more discussion around the inclusivity and accessibility benefits of VFEs. The authors have added some material, but this remains underdeveloped relative to its potential. For example, some students — particularly those who are neurodivergent — may experience significant anxiety around novel social situations, including unfamiliar environments and fieldwork, which can make those experiences difficult or inaccessible. A VFE could function analogously to a “social story” (Gray & Garand, 1993), helping all students understand in advance what to expect and reducing anxiety. The authors may also wish to consider the role of virtual reality as a novel space in itself, and its potential impacts on learning outcomes — particularly given that 42% of users engaged with the VFE for less than one hour.

Response:

Thank you for this thoughtful suggestion. We agree that the accessibility and inclusivity implications of VFEs are an important strength of this approach and deserved more explicit acknowledgement.

We have expanded the Discussion to recognize that VFEs may support students who experience anxiety around unfamiliar field environments, social situations, safety procedures, or logistical uncertainty. This includes, but is not limited to, neurodivergent students and students with limited prior field experience. We now explicitly acknowledge that VFEs may function in a way that is partly analogous to preparatory “social stories,” by helping students anticipate what a field site, route, or activity may involve before entering the field.

At the same time, we have been careful not to overstate this point. Our study did not directly measure neurodivergence, anxiety, accessibility outcomes, or cognitive load. We therefore present these implications as promising directions for future research rather than as direct findings of the present study.

We have also added a brief acknowledgement that virtual environments may themselves constitute a form of novelty space, especially for students with limited prior exposure to digital or immersive tools. This point is particularly relevant given that 42% of users engaged with VR Svalbard for less than one hour.

Change made:

The Discussion and Limitations/Future Research sections have been expanded to include accessibility, neurodivergence, anxiety, social-story-like preparation, and the possible novelty effect of virtual environments.

Revised wording added to the Discussion:

“The accessibility implications of VFEs may also extend beyond physical access to field sites. For some students, including neurodivergent students or those with limited prior field experience, unfamiliar field environments, social situations, safety procedures, and logistical

uncertainty may increase anxiety and cognitive load before field activities begin. In this sense, VFEs may function partly like preparatory ‘social stories’ (Gray and Garand, 1993), allowing students to preview what a field site, route, or activity may involve before encountering it in person. However, virtual environments may also constitute a novelty space in themselves, particularly for students with limited exposure to digital or immersive tools. Given that 42% of users engaged with VR Svalbard for less than one hour, future research should examine how technological novelty interacts with field novelty and how both influence learning outcomes.”

5. Figures and text structure

Editor comment:

Several figures present readability issues. In Fig. 3, the Sverrefjellet box is unreadable — if it is not essential to the figure’s purpose, consider removing it. In Fig. 4, the percentage labels within the pie chart and bar chart, and the associated legend, are too small to read comfortably. Please increase the font size or otherwise revise for legibility. Fig. 7 appears at l. 307 but is not cited in the text until l. 333. Please ensure all figures are referenced before they appear in the manuscript. Finally, several paragraphs in sections 5.1–5.6 consist of only one or two short sentences. These would benefit from development or consolidation.

Response:

Thank you for these comments. We have revised the figures and text structure accordingly.

For Figure 3, the unreadable Sverrefjellet box has been removed because it was not essential to the purpose of the figure. For Figure 4, the font size of the percentage labels and legend has been increased to improve readability. We have also revised the placement and citation of Figure 7 so that it is cited in the text before it appears in the manuscript.

Finally, we reviewed Sections 5.1–5.6 and consolidated short paragraphs where appropriate. This has improved the flow and coherence of the Discussion section.

Change made:

Figures 3, 4, and 7 have been revised for readability, figure order, and correct citation. The Discussion section has been edited to reduce overly short paragraphs and improve paragraph structure.

Detailed line-level comments

l. 12–13. Consider noting here that fieldwork is also often inaccessible for people with disabilities, a point you address later in the introduction.

Response:

Thank you. We have revised the abstract to include physical barriers, including disabilities, among the factors limiting access to field-based education.

Change made:

The abstract now refers to “logistical, financial, environmental, physical (i.e. disabilities), and social barriers.”

l. 17. Replace “UNIS” with “the University Centre of Svalbard (UNIS)” on first use.

Response:

Thank you. We have revised the first use of UNIS to include the full institutional name. We use the official institutional name, the University Centre in Svalbard (UNIS).

Change made:

The full name of UNIS has been added at first use in the abstract and main text

l. 35. Add punctuation at the end of the sentence.

Response:

Thank you. The missing punctuation has been added.

Change made:

Punctuation corrected.

l. 45. Replace with “transgender.”

Response:

Thank you. We have corrected the wording.

Change made:

The text now refers to “transgender and non-binary people.”

l. 49–50. Consider adding a sentence acknowledging that students and institutions from the Global South are disproportionately affected by the high costs of fieldwork.

Response:

Thank you for this suggestion. We have added a sentence acknowledging that high fieldwork costs may disproportionately affect students and institutions in the Global South, where geoscience teaching budgets may be more constrained.

Change made:

A sentence has been added to the Introduction acknowledging the disproportionate impact of fieldwork costs on students and institutions in the Global South.

l. 73–74. This part of the sentence is difficult to parse — please revise for clarity.

Response:

Thank you. We have revised this sentence for clarity and readability.

Change made:

The sentence has been rewritten to clarify that VFEs can be valuable learning resources when educators support students’ use of them and integrate them with existing field teaching activities.

l. 76 and l. 410. “What scholarship?” — please clarify which scholarship is being referred to.

Response:

Thank you. We agree that the wording was unclear. We have replaced “this scholarship” with clearer wording, such as “these studies” and “previous studies,” depending on the context.

Change made:

Ambiguous references to “scholarship” have been clarified.

l. 85. Delete parentheses.

Response:

Thank you. The parentheses have been removed.

Change made:

Parentheses deleted.

Additional manuscript corrections made during revision

In addition to the editor’s listed comments, we also made several minor corrections identified during the revision process.

Data availability

We revised the Data Availability statement. The previous questionnaire link was removed because it no longer provides stable access. The statement now clarifies that the aggregated, anonymized data supporting the findings are presented in the contribution, while individual responses are not publicly available due to privacy and ethical considerations.

Ethical statement

We revised the ethical statement to clarify that the project was assessed by NSD/Sikt under reference number 955880 and that the study followed relevant institutional and national guidelines for responsible research practices, informed consent, anonymization, and GDPR-compliant data handling.

Appendix figure numbering

We added appropriate figure numbering and captions for the appendix materials, following the journal staff request. Appendix A and Appendix B are now labelled as Figure A1 and Figure B1, respectively, with appropriate captions.

Author affiliations

We checked and revised the author affiliations where needed to ensure that institutional units are correctly represented.

We thank the editor and reviewers again for their constructive comments and for the encouraging assessment of the manuscript. The final revisions have improved the transparency of the manuscript, especially regarding AI-generated figure elements, strengthened its practical relevance through the new cost discussion, clarified the limits of our evidence regarding quantitative field outcomes, and expanded the discussion of accessibility and inclusivity.

We hope that the revised manuscript is now suitable for publication in *Geoscience Communication*.

Sincerely,

Rafael K. Horota, on behalf of all co-authors.