

Reviewer comment

- *Our response*

RC1:

1. GENERAL COMMENTS

The authors present here an original research paper showing how they embedded the Strike and Dip (SaD) tool into an introductory geology course and how they evaluate its effectiveness through students' questionnaires combining quantitative and qualitative questions. The authors showed that, in general, the SaD app was positively perceived by students and that learners who were familiar with navigating geographical or gaming software, found it easier to use compared to students who were not. The authors also discuss the limitations, potential improvements of the SaD tool and perspectives in the discussion section. I am not familiar with learning statistics; therefore, I cannot judge on this aspect in this paper but instead, on its general shape and the technical parts along with the virtual experience itself. I support the publication of this work in the GC journal if the following (minor) comments can be taken into account:

- Few comments (suggestion/reformulation) are detailed and highlighted in the PDF (more concerning its current shape than its scientific content).

- Introduction part. I found the introduction section very long, and some sentences really dilute the main message of the manuscript. Few examples and suggestions to shorten a little bit this part of manuscript: L63-68: "Fieldwork is further challenged by an increasing awareness of harassment that is happening in the field, which is often targeting women and minority students and faculty who do not conform to the stereotypical mainstream conceptions of fieldwork, that is, it is a white, male-dominated domain. Marin-Spiotta et al. (2020) call out this issue, comparing it to the Vegas Rule, criticizing the understanding that "what happens in the field, stays in the field"." I found this part a little bit off the topic. Although this is a major issue and Marin-Spiotta et al. paper discussed it properly. I do not think such arguments serve the cause of developing virtual field trip experiences. L83: "... a niche product belittled by many "real" geoscientists". The end of this sentence again is getting slightly off the topic and marks a personal experience instead of a general trend from my numerous constructive exchanges with "real" geologists. I would try to reformulate these parts. The authors cite several times "under review" publications or "personal communications". I don't think this matches the journal policy. Are these papers published since then? L79: "Marshall et al. under review"; L80: "(numerous personal communications)".

- *Removed personal communications and anecdotal referencing*
- *Removed "real" geoscientists phrasing (formerly L83)*
- *Moved "Vegas rule" discussion down to Outlook section (formerly L63-68)*
- *Moved iVR material from introduction to Outlook section (formerly 93-108)*
- *Made introduction more concise*

- Question about the software access and license. I found the SaD app very promising and wanted to try, but unfortunately, I just found a demo at this web address: <https://sites.psu.edu/virtualfieldtrips/strike-and-dip/>, which does not allow me to use the SaD functionalities properly. So here are my questions: what is the license status of this app? Would it be open, free, open-source, which license, accessible to other teaching cursus? Maybe a word should be given on this aspect in the presentation section of the app and maybe in the perspectives. In addition, a web link (or links to videos) could/should be added in the paper (maybe I missed it?), so the readers can actually test the SaD app and follow the developments updates.

- *Software is now fully accessible (as in all “levels”) via the PSU site <https://sites.psu.edu/virtualfieldtrips/strike-and-dip/>*
- *iVR software is freely available for Quest headsets by request?*

- There are some missing information in the discussion part. For example, in L613, the authors do not mention several 3D models repositories that are now very common and from which it is easy to download high-resolution textured digital outcrop models, like Sketchfab, Open Topography, v3geo, etc. In the perspectives section (L715): same comment. This initiative already exist. Here are some references:

Riquelme, A., Pastor, J. L., Cano, M., Tomás, R., Benavente, D., & Jordá, L. (2020, June). Digitalisation of rock specimens and outcrops for training. In ISRM International Symposium- EUROCK 2020. OnePetro.

Métois, M., Martelat, J. E., Billant, J., Andreani, M., Escartin, J., & Leclerc, F. (2021). Deep oceanic submarine fieldwork with undergraduate students, an exceptional immersive experience (Minerve software). Solid Earth Discussions, 1-17.

Nesbit, P. R., Boulding, A. D., Hugenholtz, C. H., Durkin, P. R., & Hubbard, S. M. (2020). Visualization and sharing of 3D digital outcrop models to promote open science. GSA Today, 30(6), 4-10.

Or nonacademic paper: <https://sketchfab.com/blogs/community/using-3d-models-for-teaching-at-the-uq-school-of-earth-and-environmental-sciences/>

- *Phrasing edited to clarify that we also used Sketchfab in this project (above in Methods)*
- *Phrasing in discussion edited to state the value of platforms like Sketchfab and Open Topography*
- *Added citations provided by RC1 to this section and reference list*

- Here is a general question/comment to the authors; I would be glad to have their feedback about this. Why are you using the Right Hand Rule in the SaD software? This is generally something we show in a second phase when students are working with geological compass here in our introductory courses. Indeed, the RHR is a special case / a convention for structural measurements in the field and add a level of understanding and of complexity in 3D spatialization. Just taking the strike, the dip and the dip direction is pretty straightforward and does not require to use one or the other hand. Would it be possible to use the SaD tool in this way simple way? Just showing a virtual compass allowing the student to measure the dip and strike along with the dip direction?

- *Added text in the methods section (section 2.1) to clearly state that the RHR function within the SaD tool can be toggled off or on depending on user preference, without the hand, as RC1 inquires, the user is simply taking strike and dip measurements only using the compass*

RC2:

The authors present here an original and well-written paper that discusses the importance of field learning in geosciences by raising important questions about accessibility and difficulties in including different groups into field environments. The authors provide several references as to why these activities are important and that they should continue to be part of the teaching curriculum of geoscience courses. However, it points out that most field learning activities cost money, time, and are only accessible for those who are physically able to stay outside for long hours. The authors then come up towards the development of new digital technologies to solve place-based learning during COVID time, this digital solution supposedly remotely teaches the geological concept of Strike and Dip and improves spatial thinking skills through a virtual desktop-based active learning exercise. The tool is entitled the Strike and Dip Tool (SaD). The authors assess its effectiveness through students' questionnaires combining quantitative and qualitative questions.

Few comments suggestion/reformulation) goes as follows:

Introduction part. I found it a bit too long, following I highlight some off topic sentences or arguments with suggestions where it could be shorten out.

L54-68: The whole paragraph calls the attention to why field-based learning may impose challenges in accessing field locations. In between financial and mobility issues the authors points out to Marin-Spiotta et al. paper that properly approaches harassment issues targeting minorities and female geoscientists. However, it seems to me a bit off topic as I doesn't seems to be this the major motivation to bring access to field locations in a virtual format. I think this issue is related to a step prior to that. Even though these people would definitely benefit from virtual experiences it's not the issue itself that prevent the access to certain field locations.

- *Removed substantial portions (formerly L61-69) of the introduction section to make it more concise, including those suggested by RC2, these issues of accessibility and harassment are now discussed in the Outlook section rather than Introduction*

L82-83: “virtual and remote learning in the geosciences has remained a niche product belittled by many “real” geoscientists.” I would try to rephrase this part as it seems to me that “Virtual” is already referring to remote learning, plus it looks that it is your personal opinion rather than a fact that “it remained a niche product belittled by “real” geoscientist”, as you can also have many “real” geoscientists that are really interested in digital field learning experience especially after the COVID-19.

- *We have rephrased this section and removed the sentence regarding “real” geoscientists (formerly L82-83)*

L92-107: “Many studies remain anecdotal (e.g., Marshall et al., under review) but it is time to establish research frameworks and to connect place-based education with established assessments and practices in virtual and immersive learning”. It is confusing to me the way it is phrased, isn’t immersive also virtual, or you are making reference to being in the field? Please clarify. Also you make many references to iVR, however, isn’t the SaD tool in this paper only desktop based. How mentioning iVR is relevant to the development of the tool, can this be shortened? It build the expectation that the SaD is a iVR tool, only to find later that is not.

- *The iVR is indeed important to us, but not the focus of the study, so this has been removed from the introduction section (formerly 93-108). iVR is now only in the Discussion and Outlook sections*

L208-210: “With this tool, students can learn what strike and dip measurements are, learn the basics of field mapping using strike and dip, as well as practice taking measurements using a variety of geological structure types.” I think the students learn what Strike and Dip measurements are in the tutorial video or in previous lectures, only by using SaD tool itself the student cannot understand this concepts. Wouldn’t you agree? Maybe clarify here the pedagogical approach of watching the tutorial video, lectures and the reading activities prior to the dVR experience, as it is on the Procedure section.

- *We have rephrased these lines to try to clarify the “learning” through “interactive practice” that takes place by using the SaD tool*

- Here is a general question/comment to the authors;

In many ways, you approach iVR as a new digital tool that can provide place-based learning, different from the tested dVR in the paper (which can also be immersive). Does the hardware being use is the only thing that limits the immersive experience? Do you only consider iVR the type of visualization obtained through the use of VR goggles? If so, why exhaustively point out the differences and benefits of a technology that is not being tested in this paper?

- *We improved the writing to have less emphasis throughout the body of the manuscript on iVR since this study only explores the dVR experience, iVR is now focussed within the discussion and outlook sections only*

The SaD tool in the text is often discusses as this dVR experience, but in the discussion L506-508 you say the tool is “an entirely remote introductory field mapping exercise that was successfully completed by students during the COVID-19 pandemic” from which they improved they learning according to your results, do you consider the SaD tool the software or the entire method? If the entire method, don’t you think it should be clearer in the introduction the whole prodedure?.

- *Added clarifying text in the methods (sections 2.2.2 and 2.3) to address this comment and that we did not assess student learning in this study, but rather student experience*

Also, in the procedure section you describe that “Before the related laboratory lecture, students were assigned homework readings. During the lecture they were presented the standard introductory material on geologic maps and mapping, such as how to interpret the geologic rule of v’s, measuring and plotting strike and dip on a map, drawing contacts, and constructing basic cross-sections...”. How do you know that they didn't learned through this previous activities when comparing to the SaD tool/method ?

Citation: <https://doi.org/10.5194/gc-2021-16-RC2>

- *Clarified the text in section 2.2.2 to make more clear what was assessed in this study*
- *Survey tool used for assessment in this study is explained in section 2.3 and was designed to evaluate the students’ senses of perceived control, usage, representation, and learning efficacy using the SaD tool*