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Interactive comment on "Using PhET™ Interactive Simulation Plate Tectonics on Initial Teacher Education" *by* Bento Cavadas and Sara Aboim

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We would like to thank referee 1 for the analysis of the preprint version of our manuscript and for the time spent during the thorough revision of the paper.

We think the paper will benefit from the incorporation of the suggestions from referee 1. In the following lines, we explain our reply:

Referee 1: "Nevertheless, it is written in an elementary way since the research instruments are very simple and not really explored in the article. The data analysis is too simple: content analysis and descriptive statistical. There is also no reference to the validity and fidelity of the instruments used to gather data. (. . .) As such I considered the study can be published with a minor correction: - at least a better reference and a

clarification of the instruments used to collect data (. . .)"

Authors: We agree with referee 1 comments about the research instruments. As we stated in the paper, we used an educational resource to gather data about our students' performance. Initially it was our intention to use other research instruments, which was not possible. It is important to say that the educational resource was elaborated to be used with the physical presence of students and teachers in a classroom in order to allow the collection of field notes. However, COVID-19 pandemics did not allow the implementation of the educational resource in the classroom, which compromised field notes collection and data triangulation. Therefore, after reflection, we added a more detailed explanation about the elaboration and validity of the educational resource, as follows:

119. During that implementation, the educational resource was constantly improved concerning its scientific content, didactic sequence, task's approach and the use of the simulator's potentialities, following PST' feedback and teacher's reflections. It was also peer-reviewed by another TTI science education teacher. The internal validity (Cohen et al., 2007; Swain, 2007) of the resource was reinforced by its submission to an open scientific educational resources' repository. During peer-review, the resource was carefully evaluated by geology and other science education faculty teachers. This process improved the content validity (Cohen et al. , 2007; Fraenkel et al. 2012) of the educational resource, refining its format, the accuracy of the scientific content and questions so that they are clearly understood by the participants, as suggested by Swain (2017), which allowed to provide better explanations sustained by the data (Cohen et al., 2007).

Referee 1: "(. . .) a more precise description of the results, namely with a discussion with reference to the literature in the area (. . .)

Authors: We reinforced the discussion with a thorough comparison of the PST' results with literature in the field.

89. However, additional research to assess the impact of specific simulators on content knowledge is needed (Phuong et al., 2013).

267. B1 tasks have the advantage of moving PST away from common misconceptions about what happens when two tectonic plates push together, e.g. "(. . .), the size, speed, and/or relative position of the plates determines how they interact", "(. . .) both plates are pushed upward to form volcanoes" or "(. . .) for millions of years the larger tectonic plate is pushed upward" (Mills et al., 2017, pp. 303-304).

273. However, this task also had the advantage of moving PST away from common misconceptions about the processes that happen when two tectonic plates separate, e.g. "(. . .) an empty gap forms" or "(. . .) loose rock fills the gap that forms between them" (Mills et al., 2017, p. 303) since they could observe that when two tectonic plates separate, a rift is formed.

279. PST' performance achieved through replicating plate movements it's an example of Tan (2007)' idea that simulating reality allows a better analysis and study.

290. PST′ performance in the three inquiries was also very good, revealing suitable problem-solving skills which reinforces the importance of problem-based learning pedagogies (Tan, 2007).

295. Concerning C3 inquiry, PST performance was better when comparing with C1 an C2 tasks results. The selected example, which addressed to the San Andreas Fault, may have contributed to a better performance by students identifying the correct option, since it is part of the reality that students know because it's a geological subject commonly approached in high schools. This connection to real-world experiences is an important point to take into account in sims exploration (PhET, 2014).

320. These ideas and the results suggest PhET™ Plate Tectonics contributed to the PST' content knowledge about plate tectonics, therefore, adding a contribute to the lack of research about the impact of specific simulators on content knowledge (Phuong

et al., 2013).

322. Moreover, these statements are in line with one of the goals of PhET sims, which is to help students to develop and to assess their understanding and reasoning about science topics (PhET, 2014).

337. This statement is important to reflect on, because PhET's Approach to Guided Inquiry (2014) suggests, in point 6, that students should "share their ideas with their partner, working together to answer questions." This process could be committed by the situation described by the student.

Referee 1: "(. . .) It is necessary to assure it is ethically possible to publish images from a simulator that is not the property of the authors of the study. (...) - with the certainty that the images con be published."

Authors: We thank the alert of referee 1 about legal issues concerning image use. However, that was already verified by the authors.

In the PhET Interactive simulations online page, in the section "Licensing", it is mentioned that "All simulations available at http://phet.colorado.edu are open educational resources available under the Creative Commons Attribution license (CC-BY). Permission is granted to freely use, share, or redistribute PhET sims under the CC-BY license."

Moreover, in the section "Help Center" there is the following FAQ: "I am a researcher. Do I need a license to use PhET sims and publish research?", whose answer is "No license is needed for research use. Please let us know about your research by completing this form."

To confirm this situation, we sent an email to PhET Help Center, and asked them if we needed a license to use screenshots of PhET sims in the research. The answer was "No license is needed for research use. But you are required to attribute any sims/screenshots you include: PhET Interactive Simulations / University of Colorado

Boulder".

165. Figures 1 to 8 shown in this section are screenshots from PhET Interactive Simulations, University of Colorado Boulder.

Additional references:

Cohen, L., Lawrence, M., & Morrison, K.: Research methods in education (6th ed.). Routledge, 2007.

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Phong, T. D., Moreland, J. R., Delgado, C., Wilson, K., Wang, x., Zhou, C., & Ice, P.: Effects of 3D virtual simulators in the introductory wind energy course: A tool for teaching engineering concepts. Innovative Teaching, 2(7), doi: 10.2466/04.07.IT.2.7, 2013.

Swain, J.: Designing research education. Concepts and methodologies. SAGE Publications, 2017.

We expect that the previous clarifications and additions to the manuscript are according referee 1' suggestions.

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