

Reviewer 1

We thank the reviewers for the thoughtful and constructive feedback, which has helped us significantly improve the clarity, focus, and scientific value of our manuscript. Below we provide a point-by-point response to each major comment. Given that the manuscript has undergone substantial revision and reorganisation for clarity and alignment with the journal's aims, the comments have been carefully considered and integrated throughout the revised text where applicable. In many cases, the original passages referenced were rephrased, expanded, or relocated, thereby incorporating the reviewer's suggestions in an updated form. In the following sections, we respond point by point to the reviewer's major

Comment 1 – Clarify the Research Aim and Objectives

Response:

We fully agree with the reviewer that the research aim required clarification. As stated in the revised Introduction, our study has two primary goals:

- (1) To present the design and delivery of *Finding Gaia*, a gamified virtual science communication activity focused on climate change and seismic risk;
- (2) To evaluate the educational impact of this activity through a mixed-methods approach combining pre/post questionnaires and facilitator insight.

We have now made this explicit at the end of the Introduction to help guide the reader.

Comment 2 – Provide More Detail on the Activity Content and Learning Mechanisms

Response:

We appreciate this suggestion and have now added specific examples of the puzzles and challenges used in the game. Each challenge was designed around a specific scientific concept (e.g., the greenhouse effect, mitigation vs adaptation, the difference between weather and climate). Correct answers unlocked short explanatory segments delivered by the facilitator, reinforcing key concepts in climate science and risk awareness.

Comment 3 – Strengthen the Link Between the Activity and Climate Change

Response:

We thank the reviewer for highlighting this gap. The revised manuscript now provides a more detailed explanation of how climate change was thematically integrated into the game narrative and structure. Each room or stage of the game corresponded to a key theme in climate science, and progression through the game was dependent on solving challenges directly tied to those themes.

Comment 4 – Explain What Is (and Isn't) Replicable

Response:

Thank you for this important observation. We have clarified that the *game design itself is replicable* and can be adapted to various contexts. What is unique and less replicable is the **specific implementation context**, shaped by the COVID-19 pandemic (e.g., school closures, online-only delivery, limited student interaction). We now explain that while the structure and learning objectives can be reused or adapted, the specific conditions of the case study (including logistical and pedagogical constraints) contributed to its uniqueness.

Comment 5 – Critically Reflect on Limitations and Generalisability

Response:

We agree and have revised the Discussion to include a more detailed analysis of the study's limitations. These include the restricted evaluation format (due to screen-time constraints), the lack of long-term outcome assessment, and the limited generalisability due to the unique pandemic context. We have also acknowledged the absence of a control group and potential self-reporting bias in the student responses.

Comment 6 – Expand the Discussion on Short vs. Long-Term Engagement

Response:

We appreciate this comment and have expanded the relevant section to reference previous literature (e.g., Dichev & Dicheva 2017; Wouters et al. 2013) demonstrating that the impact of educational games increases with repetition and reflection. We also position our intervention as an *entry point* within a broader communication or learning strategy, rather than a stand-alone solution.

Comment 7 – Improve the Abstract

Response:

We have rewritten the abstract to better reflect the purpose, methods (including data collection), and outcomes of the study, while highlighting its relevance as a contribution to science communication practice during constrained conditions.

Comment 8 – Define Key Terms

Response:

We agree and have now included a concise definition of “gamification” early in the Introduction, drawing from Deterding et al. (2011), and explaining the difference between gamified learning and full-scale games. We also briefly define other terms like “escape room” and “serious games” where they appear.

Minor In-Text Comments

Response:

We thank the reviewer for these detailed suggestions. As the manuscript has been substantially revised, we carefully reviewed all minor comments and incorporated or addressed them wherever possible in the restructured version.

Reviewer 2

We sincerely thank Reviewer 2 for the insightful and constructive feedback, which has helped us improve the clarity, focus, and scientific value of the manuscript. Given that the manuscript has undergone substantial revision and reorganisation for clarity and alignment with the journal’s aims, the comments have been carefully considered and integrated throughout the revised text where applicable. In many cases, the original passages referenced were rephrased, expanded, or relocated, thereby incorporating the reviewer’s suggestions in an updated form. In the following sections, we respond point by point to the reviewer’s major

Comment 1 - need of more clarity and depth

Response from the Authors:

We appreciate this overall positive assessment. We agree that the original methods and results sections required greater clarity and depth. We have now significantly revised both sections to improve readability and provide a clearer explanation of the research process and outcomes.

In the **Methods**, we have clarified how the activity works in practice, including:

- A detailed description of the game structure (series of puzzles and challenges)
- The thematic focus of each stage (all related to climate change)

- The role of the facilitator, who introduces short scientific insights after each stage is completed

In the **Results**, we expanded the quantitative summary of pre-/post-survey data and substantially elaborated on the **qualitative thematic analysis**. We described the analytic procedure (coding, theme development, etc.) and presented five dominant themes that emerged from student responses.

Comment 2 - The research questions should be clearly presented and discussed.

Response from the Authors:

We fully agree. To clarify the aim of the study, we have now explicitly stated at the end of the Introduction that the paper aims to (1) present a case study in science communication using gamification during a specific context (the COVID-19 pandemic) and (2) report on its evaluation through a mixed-methods approach.

We also clarified that our intent is not to test or validate gamification as a pedagogical method in general, but to document and assess one specific experience.

Comment 3 - limited details about the activity itself.

Response from the Authors:

We thank the reviewer for this important observation. In the revised version, we added a clearer explanation of how the activity works and how learning is integrated into each phase. Specifically, we now explain that:

- Each stage of the game consists of a climate-related puzzle (e.g., energy transition, weather vs climate, prediction vs projection).
- Every correct answer unlocks a facilitator-led insight that expands on the scientific topic of that challenge.
- The activity was conducted entirely in Italian, to ensure accessibility for students.

These clarifications provide a more precise understanding of the game's pedagogical design and the learning mechanisms behind it.

Comment 4 - The discussion section could be more critical.

Response from the Authors:

We appreciate this thoughtful suggestion and have addressed it in the revised Discussion. We now cite relevant literature (e.g. Dichev & Dicheva, 2017; Wouters et al., 2013) to support the claim that single-session activities are most effective when embedded in a broader pedagogical framework. We also emphasise that while *Finding Gaia* is a one-off experience, it can serve as a valuable entry point for more sustained engagement.

Comment 5 – Replicability

Response from the Authors:

Thank you for this important comment. We clarified that while the **protocol itself is replicable**—i.e., the game can be reused and adapted—the **context in which it was developed and deployed** (i.e., fully online during a pandemic, with restrictions on interaction, specific digital tools, and student stress levels) is not easily replicable. These constraints shaped both design choices and student reception. We also note that the game could be adapted for in-person, hybrid, or different curricular contexts with appropriate adjustments.

Rewiever 3

We thank the reviewer for their careful reading and thoughtful suggestions. We are encouraged by the recognition of the manuscript's clarity and relevance and appreciate the opportunity to improve the paper further. Below, we address each specific comment.

1. Clarify the Aim and Objectives of the Study

Reviewer Comment:

“The manuscript does not clearly define the research aim and objectives; is it to create the game, to evaluate its impact or to highlight the contribution of gamification in geosciences communication? The authors should clearly point out the aim of the study early in the manuscript, ideally at the end of the introduction...”

Response from the Authors:

We thank the reviewer for this important observation. We agree that the original manuscript did not sufficiently distinguish the scope and purpose of the study. We have now clarified that our aims are twofold: (1) to **present** the gamified activity *Finding Gaia* as a science communication initiative developed during the COVID-19 pandemic, and (2) to **evaluate its impact** using a mixed-methods approach involving pre/post surveys and facilitator insights. The goal is not to validate gamification as a pedagogical method, nor to generalise its superiority, but rather to illustrate an innovative science communication experience shaped by unique pandemic conditions.

2. Add Detail on the Content and Learning Mechanisms

Reviewer Comment:

“While the authors provide some information on the features of the activity, they do not include details on the content and learning mechanisms... Including examples of puzzles or challenges and how they were used to address specific climate topics...”

Response from the Authors:

We appreciate this valuable suggestion. We have now expanded the Methods section to explain how the puzzles functioned as learning tools. Each stage of the virtual escape room presented a science-based riddle or logic task rooted in climate-related topics—such as the distinction between weather and climate, the greenhouse effect, or mitigation versus adaptation. When a team solved a challenge, they received a keyword or code that unlocked a short narrative segment or facilitation moment explaining a key concept. This interplay between game and instruction was intended to reinforce learning through engagement.

3. Strengthen the Connection Between the Activity and Climate Change

Reviewer Comment:

“Although the reader can make a connection when examining the outcomes, the activity's approach to addressing climate change is not clearly presented. Strengthening this connection between the thematic context and the activity design would enhance clarity and value for the reader.”

Response from the Authors:

We have revised both the Introduction and Methods sections to emphasise the central role of climate change in the activity's design. The educational content was structured around key dimensions of climate literacy—adaptation, mitigation, human–environment interactions, and the role of science in risk prediction. This content

was embedded in each puzzle and in the accompanying facilitation segments, creating an explicit and continuous link between gameplay and thematic learning.

4. Clarify the Issue of Replicability and Uniqueness

Reviewer Comment:

“The authors describe the experience as not replicable, stating this as a limitation and at the same time as a unique characteristic... Why is it not replicable?... Could the approach be adapted?”

Response from the Authors:

We acknowledge that our original statement may have caused confusion. To clarify: the **game design and structure are replicable**, and we believe they can be adapted to different learning contexts. What is **not replicable** are the specific boundary conditions of this pilot experience—such as the remote delivery format due to school closures, the digital platforms approved by schools, and the constraints posed by the COVID-19 pandemic. We have made this distinction explicit and discussed how the protocol could be transferred to other settings with suitable adjustments.

5. Provide a More Critical Discussion of Limitations

Reviewer Comment:

“The paper could benefit from a more critical discussion of the limitations, such as generalisability.”

Response from the Authors:

We agree with this recommendation and have significantly expanded our discussion of limitations. We now address the following points: the limited generalisability due to the pandemic context; the simplified evaluation survey (designed to reduce screen fatigue); the reliance on self-reported data; the absence of long-term outcome measures; and the lack of standardised benchmarks in the literature.

6. Improve the Abstract

Reviewer Comment:

“While the abstract of the manuscript provides valuable details on the context of the study, it only presents limited information on the study itself. I recommend the authors revise this to communicate the study’s scope, methods better and highlight the key findings.”

Response from the Authors:

We revised the abstract to ensure it includes a clearer statement of the study’s purpose, the evaluation method (pre/post surveys and qualitative analysis), the number of participants, and the main outcomes. The revised version more accurately reflects the content and structure of the manuscript.

7. Define Key Terms

Reviewer Comment:

“The manuscript uses different terms (for example, “gamification”) that may be unfamiliar to the typical readers. I recommend defining these terms early in the manuscript to eliminate any confusion.”

Response from the Authors:

We agree. We have now defined “gamification” early in the Introduction using a concise, peer-reviewed definition. Additional clarification has been provided for related terms such as “escape room”, “serious game”, and “facilitator”.

8. Expand the Discussion on Short vs Long-Term Engagement

Reviewer Comment:

“In the discussion section, the authors note that when single-session activities are complemented by sustained engagement over a longer period, they can support retention of complex topics. This is a valuable point that deserves further elaboration.”

Response from the Authors:

We have expanded our discussion of this topic. Drawing on prior literature (e.g., Wouters et al., 2013; Dichev & Dicheva, 2017), we now explain that single-session activities like *Finding Gaia* can serve as entry points to science engagement. Their impact is amplified when followed by classroom discussion, supplementary lessons, or reflective writing. This supports the broader pedagogical value of integrating gamified communication into sustained science education strategies.