

**Reviewer's comments are in black, followed by authors' replies in blue.**

Overall, it is a paper that focuses on a key issue; that is, although climate science has made remarkable progress, the key that is still missing is to apply climate change education in order to establish collaboration among different disciplines. In this regard, I think that the paper can send some strong messages. Yet, I think that the paper would benefit from a revision. On the one hand, it is written at many points as a research paper, but, on the other hand, when one reads the paper, they get the idea that it is a thorough description of a course. As such the paper needs some restructuring and more clarity.

We thank the reviewer for the thoughtful and constructive feedback, for the time invested in carefully reading our manuscript and the recognition that the topic is timely and our paper is important.

We acknowledge the reviewer's concern that the manuscript currently sits between a "research article" and a "course description" and needs more clarity. Our intention has been to document the development of a novel higher-education course through the lens of design-based research. In the revised manuscript, we will make the aim and contribution of the study more explicit and ensure consistency in how the study is framed within the design-based research approach. To achieve this, we will describe in more details how design-based research was applied in course design and discuss the new knowledge created based on the evidence collected during and following the first pilot of the course.

More analytically, the definition of design-based research given by authors and the four questions are consistent with the logic of design-based research. Yet, the first question is not addressed empirically, while the second and the fourth questions are addressed through the design and the pilot. Therefore, the first question should not have been stated as a research question. The outcome is inconsistent scope.

This is a valid point. We edit the manuscript by deleting the first research question and explain the topic as follows: "In addition to research questions, which will be answered based on empirical data, we analysed and summarised, based on previous research, what climate competencies are necessary for effective climate action in professional settings. These climate competencies have previously been mapped within Finnish society using input from experts across multiple sectors who coordinate, implement or monitor climate change mitigation and adaptation strategies and actions (Siponen et al. 2024)."

Another point is that the evidence is presented a bit weakly. Design-based research should not be only to design a course and evaluate the pilot but rather to perform the course in iterative cycles (starting with design, testing, refining and then testing again). If there weren't multiple repetitions,

then this is not design-based research but it seems more like a pilot study or a design case study. The authors thus need to state clearly how many times the course was repeated.

We acknowledge this limitation of the manuscript. To address this concern, we will revise Section 2.2 (Designing and producing the course content) to provide more structured and detailed evidence on how design-based research (DBR) was applied in planning and course design. We will also include an explanatory figure illustrating the DBR process in designing the course, including key stages of course design, piloting and exploration and learnings from the course design.

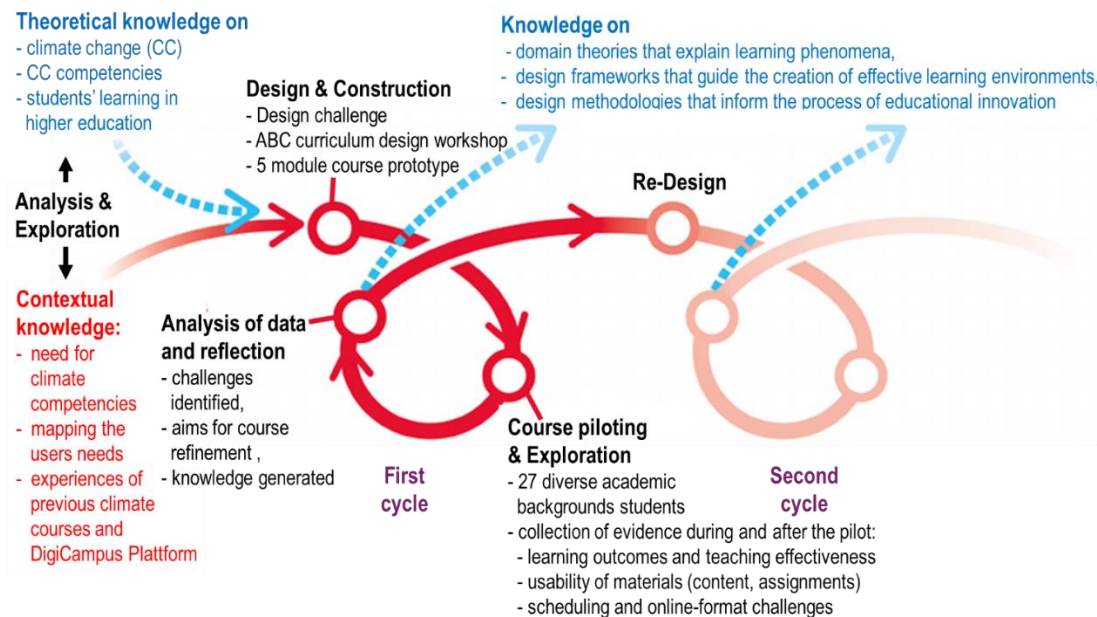


Figure 1. Design-based research process for the design, pilot and refinement of the course

We agree that design-based research is inherently iterative, involving multiple cycles of design, implementation and refinement. However, DBR projects are often conducted and reported in phases (e.g., development or pilot studies), in which initial cycles focus on the development and preliminary evaluation of an intervention. Therefore, this paper reports on the first cycle of the course as an initial or exploratory phase, providing useful information on design process, course usability and the generation of research-based knowledge. While a single cycle does not represent a complete DBR process, it offers valuable evidence for refinement and future iterations.

In the revised manuscript we will address this acknowledging that additional cycles are needed for full refinement and discuss the limitations associated with reporting on the first cycle of iteration only in Section 4 (Challenges and lessons learned).

Moreover, the authors attempt to answer questions without following a clear methodology. In order to answer those questions, it would require systematic data collection, an analysis method and the

reaching of design principles. Without these, it is the description of an experience. Therefore, it is framed as design-based research whereas it lacks the rigor of such research.

We'll include more methodological details in the revised manuscript. Beyond improving the course, the DBR process contributed to theoretical and methodological knowledge related to learning, design frameworks, and educational innovation. As presented in Section 3 Evaluation of the piloted course we collected data on learning outcomes and teaching effectiveness, usability of materials, both course content and assignments, course scheduling and challenges of online format through learning diaries, surveys and teachers' reflections during and after the course and analysed them. In addition to the data collected from multiple sources, content analysis of the course and members checks also provided valuable information for course improvement already before the first pilot. The collected evidence was not only used for the further development of the course but based on this evidence new knowledge was created. We will add a paragraph to Section 3.3 (Improvements after the pilot) with a thorough description of knowledge outcome on (1) domain theories that explain learning phenomena, (2) design frameworks that guide the creation of effective learning environments and (3) design methodologies that inform the process of educational innovation. In addition, we will discuss these knowledge outcomes in the frame of previous knowledge in Section 4 (Challenges and lessons learned).

To overcome these issues, the first question should be removed or structured much differently (for example, by identifying the literature). Moreover, the paper should provide more information about the iteration cycles and the data sources (such as feedback, performance and observations). Also, the approach should be more analytical as to how conclusions are reached. At the end, the paper should reach clear design principles.

Thank you for pointing us to these issues. We will address these suggestions and strengthen description of analytical approach and design principles as specified above.

#### **Minor comments:**

Line 15: before engage add "to"

Thank you for catching this, we corrected the text.

In line 5 in the Abstract, the authors state "This paper presents the development and pilot implementation of the graduate-level course Living with Changing Climate, designed to foster these competencies through transdisciplinary and practice-oriented climate change education". But a bit below they also state that: "Using a design-based research approach, this study explores the competencies essential for climate-informed decision-making, the challenges of developing an online course for diverse learners, and the key elements of effective course design and

implementation”. Yet, the aim of the paper should be stated with precision. What does this study aim to achieve drawing on the experience of the course? This should be loud and clear. I also recommend removing lines 18-20 as the Abstract should ensure to contain key aspects rather than details. It is also important to improve the Abstract, the sentences introducing to the topic of the paper are weak, while the Abstract lacks key conclusions.

We thank the reviewer for these valuable suggestions regarding the clarity and content of the Abstract. In the revised manuscript, we will strengthen the Abstract by stating the aim of the study more explicitly and precisely and highlighting the key findings and conclusions. Following the reviewer’s recommendations, we will remove lines 18-20.

After the research questions, the authors need to state briefly the importance of their study; that is, how insights from this study can advance education and what are the target audiences.

We will more clearly specify the significance and added value of our study for education following the research questions in Section 1 (Introduction).

It is stated that “Living with Changing Climate course was implemented on DigiCampus.fi, a shared online learning platform for Finnish higher education institutions”. Of course in-person learning would be impossible because students were from different departments, but the electronic learning platform is a fixed environment that provides very little flexibility in runtime and the opportunities for redesigning are restricted. How did the educators ensure that this kind of course delivery would still adhere to design-based research?

We acknowledge the reviewer’s concern that the online learning platform provides limited flexibility in runtime and may present challenges for ensuring students’ active participation and engagement. The first iteration of the course was implemented based on the initial design framework and the course was refined following the first pilot phase using the data collected during and after its implementation. To foster active participation during online sessions and enhance students’ engagement, we used varied types of engaging activities, including interactive tools (e.g., quizzes and polls), hands-on exercises, opportunities for peer interaction and collaboration, and a diverse range of learning material and assignments.