Chapter 6
Towards Student-Centered Climate Change Education Through Co-design Approach in Science Teacher Education

Maija Aksela and Sakari Tolppanen

Abstract Teachers have a crucial role to empower future makers—children and youth—for a sustainable future. A central question is how to promote understanding of current socioscientific issues (SSI), such as climate change, through pre-service and in-service science teacher education, and to help science teachers teach SSI at different school levels. Earlier research shows that there is a need to strengthen teachers' scientific literacy in the context of multidisciplinary climate change. In addition, it is known that children and youth, our future makers, wish for broader approaches, incorporating knowledge from different subjects, and learning about possible solutions to climate change. This article describes our experiences of the opportunities and challenges of the co-design approach through a design-based research framework, to build novel student-centered solutions. Two examples are given: i) an international in-service training model within a learning community (teachers, scientists and teacher educators), and (ii) the use of escape rooms in pre-service teacher training. The importance of both empirical problem analysis and theoretical problem analysis in a co-design approach is pointed out. A good co-designing process starts from the needs of the teachers or future teachers, allowing participants to find suitable roles and allocating enough time to manage the process.

Keywords Climate change · Student-centered education · Co-design approach · Design-based research · Teacher education · Science education

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6.1 Introduction

Education is seen as a key element of the response to current socioscientific issues (SSI), such as climate change, according to UNESCO (2017). There are "real and rapidly-evolving threats for humanity and striving to ensure that all generations understand the impact of climate change and are better equipped to take action to protect resources, the environment and the planet that sustains life" (UNESCO, 2017, p. 2). Teachers have a crucial role to empower future makers—children and youth—for a sustainable future. A central question is how to promote understanding on current socioscientific issues (SSI), like climate change, through pre-service and in-service science teacher education, and to help science teachers to teach it meaningfully at different school levels. There is a crucial need to find novel ways in science teacher education to empower future makers—children and youth—and to promote their actions as active citizens in society (Favier et al., 2021; Herranen & Aksela, 2019; Monroe et al., 2019). Future makers are the next generation who are going to make decisions to address the questions of global challenges (e.g., climate change). How can teachers address the multidisciplinary and current questions in their context? How can we make education holistic and transformative, aiming for a paradigm shift?

Various teaching strategies can be used in climate change education. Especially student-centered teaching approaches, which engage future makers and make climate change relevant for them, are seen as effective (Monroe et al., 2019). The recommendations of the ALLEA research-based report (Wilgenbus et al., 2020) points out that teacher education must support teachers in developing their Pedagogical Content Knowledge (PCK) (Fernandez, 2014), for example, promoting their scientific understanding of climate science, and implementing Inquiry-Based Science Education (IBSE), Nature of Science (NoS), and Project-Based pedagogies. Especially, Pedagogical Content Knowledge points out the interconnectedness of content knowledge and pedagogical knowledge (content, pedagogical, curricular, and assessment knowledge, and knowledge about students) in teachers' practices at the school level. In addition, teachers' beliefs act as filters between professional knowledge bases and their teaching at school level (Herranen & Aksela, 2019; Hume et al., 2019). According to Favier et al. (2021), teachers need generic *Pedagogical Knowledge (PK)* in climate change including knowledge about how to design and teach lessons in practice, *Content Knowledge (CK)* to understand the impacts of climate change, variations in different places, and knowledge about adaption solutions. How do we teach holistic and student-centered climate change education in practice?

How do we promote both a holistic approach to climate change and PCK (see Shulman, 1987; Cantell et al., 2019) through science teacher education? Could one way be to use the so-called co-design approach as a framework of design-based research (e.g., Aksela, 2019)? In such an approach climate change is studied with different partners, for example, teachers, future teachers, scientists, or teacher educators through pre-service and in-service science teacher education. How could such an approach be implemented in practice? Could collaborative training with international teachers or using popular escape rooms be an effective approach? What are the opportunities and challenges of a co-design approach in teacher education? In this article, we address these questions through two examples from Finnish science teacher education.

6.2 Towards Student-Centered and Holistic Climate Change Education

A co-design approach through design-based research (e.g., Aksela, 2019) as a framework contains both (i) theoretical problem analysis, and (ii) empirical problem analysis (see Fig. 6.1). First, we discuss the general things taken into account in the co-design of climate change education through science teacher education: (i) hurdles of impactful climate change education (Sect. 6.2.1), and (ii) holistic climate change education (Sect. 6.2.2).

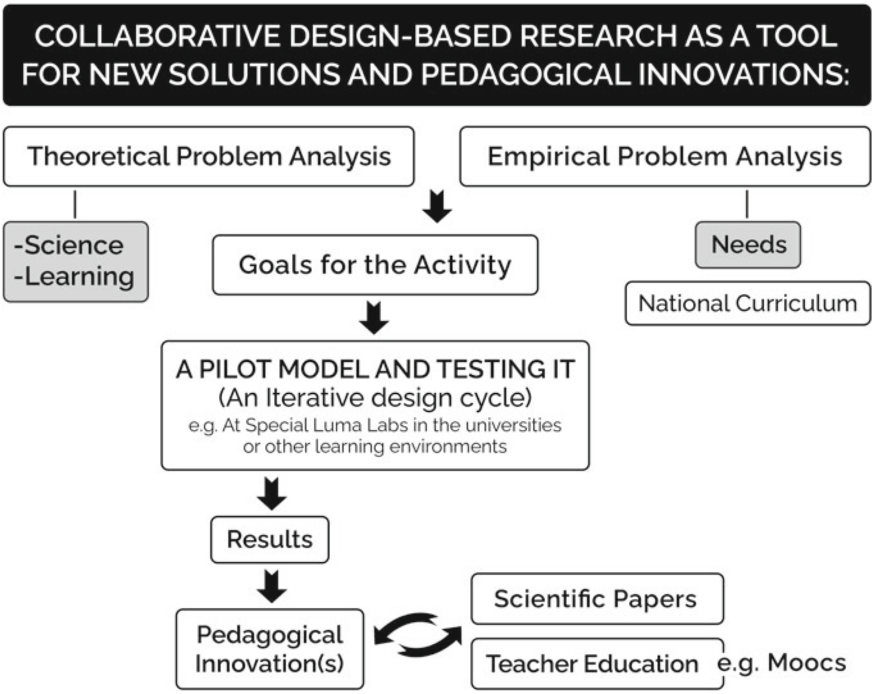

Fig. 6.1 Example of how design-based research has been carried out in the Finnish LUMA system (see https://www.luma.fi) and in its teacher education by applying Edelson's (2002) model (Aksela, 2019). Teachers or future teachers, scientists, and science educators have interacted through a co-design process. National curriculum means Finnish curriculum and its goals

6.2.1 The Hurdles of Impactful Climate Change Education

Ultimately, addressing climate change requires a transformation in how people think and act, as individuals, members of society, and as consumers of goods produced by businesses (e.g., Tolppanen & Kärkkäinen, 2021). Education can play a key role in this transformation process, but this is not an easy hurdle. First of all, numerous studies show that merely increasing students' knowledge about climate change is not sufficient to change behavior (e.g., Kollmuss & Agyeman, 2002). Therefore, scholars have pointed out that education cannot only focus on knowledge creation but rather, should aim for students to become action competent citizens—citizens who take action to mitigate climate change based on best knowledge and best available practices (Jensen, 2002; Jensen & Schnack, 1997). Though action competence is an ideal to strive for, there are many hindrances as to why people don't take more action to mitigate climate change. For instance, Steg and Vlek (2009) discuss how values and attitudes may limit pro-environmental action, while Gardiner (2006) discusses the challenges caused by the moral choice that comes with taking action, and Gifford (2011) presents psychological barriers that cause inaction. There is a vast body of research discussing these and other hindrances, so this chapter will not go into the details. Rather, we will give a brief overview to give readers an idea of the depth of these hindrances.

Studies show that one hindrance to taking action is that inaction may not have any immediate consequences on the environment or our lives, as consequences of carbon emissions are only seen in the long run (Gardiner, 2006). This can result in individuals postponing their actions, especially when a decision to take action contradicts personal or national interests. Another hindrance is that individuals tend to have different moral standards for themselves and for others, meaning that they may expect others to take more vigorous action than what they are willing to take themselves (e.g., Sternäng & Lundholm, 2011). Furthermore, individuals may prefer to blame other individuals or entities, seeing others as more responsible for climate change mitigation than themselves or their intra-group (Jang, 2013; Tolppanen & Kärkkäinen, 2021). In addition to the moral challenges of taking action, Gifford (2011) has highlighted psychological barriers, such as ideologies, perceived risks, and limited cognition, which also hinder climate change mitigation. In addition, some individuals may be overly optimistic about technology solving our problems (e.g., Bonaccorsi et al., 2020), while others are overly optimistic that politicians and governments can solve the related problems (e.g., Tolppanen & Kärkkäinen, 2021). It also seems that when individuals take personally responsible actions, they tend to take low-impact actions, rather than high-impact actions (Tolppanen et al., 2020). In other words, even when individuals understand the importance of action, they are good at coming up with reasons why *they* do not need to give up things that are dear to them. Yet, individuals tend to think that their lifestyles are more environmentally friendly than their neighbors, but especially more environmentally friendly than that of someone living in a different country.

As there are numerous challenges in solving climate change, as well as climate change education, it can be called a *wicked problem.* By nature, a wicked problem is a problem that does not have a simple solution to it, and any attempt at solving the problem will cause new, often unforeseeable, repercussions (Rittel & Webber, 1973). As no single solution will solve the problem and we cannot be certain which solutions are most useful, no stone should be left unturned when it comes to testing new pedagogical approaches. Therefore, we take the view that climate change education should be holistic, to address different dimensions of climate change, including not only the scientific aspects, but also the moral, psychological, and emotional aspects. In the next sections, we will discuss what holistic climate change education is, and the current state of climate change education.

6.2.2 Towards Holistic Climate Change Education

As climate change is strongly linked to political, societal, and scientific issues, many researchers have pointed out that climate change is one of the most important socio-scientific issues to address in schools (e.g., ALLEA, 2020; Dawson, 2015; Schreiner et al., 2005). International organizations share the view of the importance of school-based climate change education (see e.g., UNESCO & UNFCCC, 2016). To some degree, this has trickled down to the national curriculum, as climate change is present in the curriculum of many countries (see Dawson et al., 2021). However, the main focus of climate change education remains to be in knowledge creation (Dawson et al., 2021; Monroe et al., 2019). To some extent, the focus on knowledge creation is justified, as numerous studies from around the world have shown that the level of knowledge that students, in-service teachers, and pre-service teachers have on climate change is unacceptably low (e.g., Boon, 2010; Lambert & Bleicher, 2013; Ratinen, 2013). However, at the same time, we know that knowledge creation alone is not sufficient to change attitudes, behavior, or values (e.g., Kollmuss & Agyeman, 2002), and that both students and experts think that climate change education should go beyond scientific issues in order to be relevant (see e.g., Tolppanen & Aksela, 2018). This is also understood by the UN, as they've stated that climate change education should encourage students to "*re-evaluate [their] worldview and everyday behaviours*" based on what is needed to mitigate climate change (UNESCO, 2017, p. 36).

In order to do so, climate change education needs a socioscientific approach, not only touching on the scientific issues of climate change, but also the societal and economic aspects. Furthermore, this should be done in a holistic way. Tolppanen et al. (2017) have proposed that for climate change education to be holistic, it needs to: (i) increase knowledge; (ii) develop thinking skills; (iii) motivate students to take action; (iv) help reflect on and understand different values, worldviews, and social constructs; (v) help imagine and create an alternative future; (vi) understand the underlying barriers of inaction; and (vii) deal with emotions associated with climate change. The notion is that these goals could help create a paradigm shift in education (see Kagawa & Selby, 2010) and make it transformative (see Sterling, 2010). Though there is a wide acceptance among researchers that climate change education needs to be holistic, transformative, and aim for a paradigm shift, climate change education in schools and teacher education does not yet reflect these educational aims extensively. Furthermore, as there isn't a consensus on how holistic and transformative education can be reached (see Reid, 2019), there is a clear need to develop and test different types of student-centered educational approaches through teacher education to find out what works.

6.3 Co-design Approach as a Framework of Design-Based Research

A co-design approach as a framework of design-based research could be a fruitful way to promote student-based climate change education collaboratively with various partners. It is a fruitful tool to help (i) collaboratively design the framework of the programs for the given needs, (ii) set up a concrete action plan systematically step by step with different partners in practice, and (iii) organize teachers' or future teachers' training collaboratively in a novel way within the development process (Aksela, 2019). Collaborators include, for example, teacher educators, scientists, industry specialists, sponsors, teachers, future teachers, and other participants from different organizations. Its systematical phases (Fig. 6.1) may also help the partners who have executed limited educational research to better understand how to use the newest research to develop novel solutions in education. The partners form a type of a learning community in which all participants can learn from each other. It has been found to be a good way to promote PCK in many ways, for example, by matching the curriculum goals of teachers (Kelly et al., 2019; Tissenbaum et al, 2012) and increasing reflection and ownership by a teacher (Roschelle & Penuel, 2006).

When using co-design as an approach, seven characteristic features are recommended to be taken into account (Roschelle & Penuel, 2006, p. 606):

- it takes on a concrete, tangible innovation challenge;
- the process begins by taking stock of current practice and classroom contexts;
- it has a flexible target;
- it needs a bootstrapping event or process to catalyze the team's work;
- it is timed to fit the school cycle;
- strong facilitation with well-defined roles is a hallmark of it; and
- there is central accountability for the quality of the products of co-design.

There are many ways to use co-design through design-based research in practice. Different models are available for supporting development decisions carried out during design-based research (e.g., Sandoval, 2014). According to Edelson (2002) there are two parts that guide the process of design-based research and the decisions concerning the research: (a) theoretical problem analysis, and (b) empirical problem analysis (see Fig. 6.1).

Generally, design-based research (Edelson, 2002) has been carried out collaboratively and systematically, for example, in the following steps within the LUMA ecosystem (Fig. 6.1): (i) mapping out the needs together with the participants (empirical problem analysis: a needs analysis); (ii) mapping out new research information concerning the chosen theme, and synthesis (theoretical problem analysis); (iii) setting the aims of development together based on steps (i)—(ii); (iv) designing a pilot model (e.g., practical activities) for the object of development based on chosen aims; (v) testing the pilot model with the target group and refining it based on received results (cyclic model); (vi) describing the outcome of development, and reporting it; and (vii) disseminating new avenues and solutions, and offering education on them. Needs analysis can be done through a survey with teachers or content analysis of learning materials or curriculum framework. Usually, a researcher at a university, a teacher educator, or a future teacher carries out the synthesis and maps new research information concerning the topic for other partners of the program or projects. In collaborative meetings, steps (i) and (ii) are completed together, and the aims for development and the model for implementation with timetables are arranged together (Aksela, 2019).

The following characteristics of good design-based research guide its design and implementation process, and the report describes in detail (Aksela, 2019; Dede, 2004; Design-Based Research Collective 2003): (i) the correspondence of the design in and the needs of practical and education policy; (ii) the intertwining of the aims of the chosen intervention and developed theories; (iii) the cyclicity of the development between design, implementation, analysis, and re-design; (iv) the reliability of received results; (v) how the outcome of the development works in an authentic environment; and (vi) how the received results adapt to earlier theories and practical implementations.

6.4 Examples of the Use of Co-design in Science Teacher Education

Two examples of how to use co-design in the context of climate change education in science teacher education are given: (i) international teachers' climate change forum, and (ii) escape rooms in science teacher education.

6.4.1 Example 1: International Teachers' Climate Change Forum

The International Teachers' Climate Change forum for teachers or future teachers of all subjects and levels has been active since 2016 focusing on the following main questions: *How to make a better world together through education? How to teach multidisciplinary climate change? How can science help to solve issues connected to climate change?* The main goal is to develop teachers' and future teachers' ability to handle climate change in a pedagogically meaningful and versatile way, from the perspective of different disciplines, and also to consider different beliefs or attitudes. Another key objective is to build a multidisciplinary international network of teachers or future teachers at different levels of education, for teachers can share their ideas, experiences, and skills after the course. The network can then act as an active forum for teachers, climate educators, and climate scientists.

The International Teachers' Climate Change forum has had various forms in practice: (i) an online conference with talks and discussion (between 2016 and 2018); (ii) an open MOOC course before the camp and a science camp in Hyytiälä (in 2019), a forestry station for international multidisciplinary research of Earth systems ranging from the depths of soil to atmospheric processes; (iii) an open MOOC course before the seminar and an online two-day seminar (in 2020) because of the COVID situation; and (iv) an open MOOC, an online two-day seminar (in 2021) and partially connect to Global challenges course for students aged 15–19 because of the COVID situation. Participants from over 30 countries have taken part in the one-day event that deals with climate science, climate education, and the connection between them. The course has had specific programs that are co-designed with the participants, for example, an escape room in the context of climate change has been implemented.

The forum has been carried out in practice through a co-design process (see Fig. 6.1) in which teachers, scientists, and teacher educators—a learning community—design the event together. Then, they address the needs of teachers and their open questions (Empirical Problem Analysis; see Fig. 6.1). The questions and requests have been collected through the network before the events, and then their feedback has been collected after the events. For example, the teachers' feedback of fruitful things during the last forum:

> To exchange knowledge, to see the conference as an opportunity to reflect and connect with other teachers and lecturers, to get more confidence to start bigger collaboration. (Teacher 1)
>
> The experiences being shared. (Teacher 2)
>
> The information about teachers and schools experience and work. (Teacher 3)

An example of a feedback for the next forum:

> One idea could be to bring in more good practice examples of collaborations among teachers, universities, NGOs and municipalities that served the local communities' needs concerning climate change. The diversity of such collaborations similarly to the Carbon Tree project could provide teachers models [of] how to start their own projects. Another idea could be

> to run a workshop or lecture on how teachers can do such collaborative projects. Here I mean to provide teachers a basic toolkit [for] how to start and what are the major phases and obstacles when working with different stakeholders. Lastly, I wish to see maybe a workshop on how to conduct action-research in schools and what skills and support teachers should have to realize it. How can they fit something like this into their curriculum etc. (Teacher 4)

In addition, a survey study has been done to collect data on teachers' self-efficacy to teach climate change (Herranen & Aksela, 2019). The learning community also created its own Facebook group after the first camp. The active teachers who had participated earlier have been voluntary co-designers of the program. Most of them have also had their own workshops at the events. The role of scientists has the view of current research to the needs (Theoretical Problem Analysis; see Fig. 6.1) and science educators have given the current research of PCK questions in the context of climate change. The international climate education event *Towards Sustainable Future Together–Forum for Future Makers* is organized by the LUMA Science Helsinki group (a part of the national LUMA Centre Finland) and Institute for Atmospheric and Earth System Research (INAR). LUMA Centre Finland is a network of 11 universities and 13 centers (Aksela et al., 2020).

The active teachers from the forum have also co-designed the CLIMATE? Project (over 2020–2021) with us. The aim of which is to co-design and test pedagogical models for student-question-based climate change education with teachers from all over the world, by using an online platform. Student-centered teaching methods can be useful, for example, guided inquiry (Tolppanen & Aksela, 2018) to empower future makers. This project is part of our larger research-based climate change education program. During the project, teachers acquired concrete ideas and examples on how to use students' questions as part of their climate education, and discussed with other teachers their ideas and experiences in the classroom using student-question-based pedagogy. The goal was that teachers' self-efficacy for the pedagogy improves and student-question-based pedagogy (Herranen & Aksela, 2019) in climate change education is developed into new didactic models for teachers all over the world. Students' questions can be used as part of climate change education in classrooms to make the topic approachable for students, to activate students to learn, and raise hope for the future. The Finnish national core curriculum has also emphasized the importance of students' questions and climate in education. Teaching models were tested in schools between 2020 and 2021. A more detailed schedule was designed with the participants. There were registered participants from over ten countries.

6.4.2 *Example 2: Escape Rooms in Science Teacher Education*

At the University of Eastern Finland, future teachers have the opportunity to plan and pilot escape rooms as part of their pre-service teacher training. This is done as part of a course called *Education for a Sustainable Future*. During the course, pre-service teachers have 15 h of lectures on sustainability issues and climate change education, including tasks, such as examining their carbon footprint and reflecting on their environmental values, based on an environmental values questionnaire. During the course, the students also reflect on the bicycle model of climate change education (Tolppanen et al., 2017), and other educational models for sustainability education (e.g., Jeronen & Kaikkonen, 2002; Palmer, 1998). In addition to the lectures and individual tasks, students form learning communities, in which they develop a novel lesson on environmental education, which they then implement. Some students do their project on how to use escape rooms to develop climate change education. An escape room, or an escape game, is a game in which a team is locked in a room and need to find their way out by discovering clues, accomplishing tasks, and solving puzzles. Participants have a limited time to find their way out, pressuring them to solve puzzles fast. Traditionally escape rooms have been a leisure activity, but they have also found their way into education. For instance, escape rooms can provide an interesting learning environment to teach climate change issues, as a sense of urgency is built into them (Ouariachi & Wim, 2020). Figure 6.2 summarizes the paths of the co-design process during the course.

During the first stage of the design process, pre-service teachers carried out an in-depth problem analysis. The course lectures provide a backbone for this, but more in-depth research is done at the beginning of the project. Initially, the theory is broad,

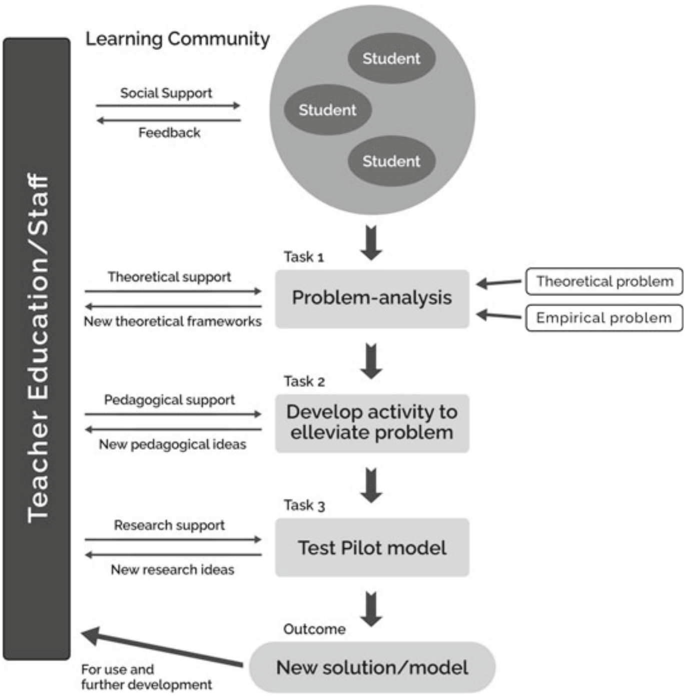

Fig. 6.2 Interactions between a learning community formed by students and personnel

as participants need an understanding of at least the science of climate change, how to mitigate and adapt to climate change, how escape rooms can be developed and used for educational purposes, what a good escape room consists of (gamification), and how an escape room on climate change could fit into the formal curriculum. As the time to acquire all this knowledge is limited, learning communities are implemented, as a team can divide tasks and support each other in the planning process. In these learning communities of four to six pre-service teachers, arranged outside of class-time, pre-service teachers share what they know and what they have learned about the dimensions needed to implement a meaningful escape room. In addition to helping develop social skills, such learning communities can also provide a good platform to discuss and debate challenging SSI issues related to climate change in a safe environment.

In the second stage, the pre-service teachers put their know-how into practice by developing an escape room for students. Before piloting their project, they can present their plans to the teachers and other students to get feedback. Through the feedback, they may become aware of some of the shortcomings in their plan and they also get more insight on whether the tasks in the game have sound climate knowledge. Based on the feedback, final modifications are made to the plan, before testing it out.

In the third stage, the pre-service teachers pilot their escape room with an authentic audience. To do so, they contact a school or a non-formal education program and invite a class or individual students to test out their game. As is common in escape rooms, the pre-service teachers can instruct the players during the game, through a microphone. As they can constantly see and hear what the students do during the game, they also get immediate feedback on whether the assignments in the game work in the way they had planned them to. After the game, they also have a feedback session with the students or may ask them to fill out a written feedback form.

Based on the above three stages, the pre-service teachers write a course report about their project. In this report, they highlight the relevant theoretical framework, justify their game design and evaluate how well the game accomplished its goals. Not only do these reports help the pre-service teachers compile what they have learned, but they are also used by the teachers to examine how escape rooms could be further developed. Below are a few excerpts from the reports to highlight how the pre-service teachers felt about using escape rooms in the context of climate change education:

> The task was not easy, as during the development process we realized how much more we need to learn about climate change and the already available teaching material. However, we felt that developing a game was suitable for the topic, as games bring fun and action into learning and can help get students interested in this challenging, and sometimes even depressing topic… In all, we feel that developing the game was an eye-opening experience, during [which] we learned a lot…We got a lot of good feedback from the students who tested the game. Based on the feedback, they really seemed to enjoy playing the game. (Group 1)

> Developing an escape room was challenging, but interesting. Many of the opportunities and challenges of escape rooms were only realized when it was being tested by our test group. We will certainly use escape rooms and the developed tasks in the future. We are one experience richer and we can use this new expertise in the future. Based on the feedback we

> got from the test-group, our game was challenging to the participants. We needed to give them a lot of clues for them to find their way out. The participants stated that the climate change educational goals need to be strengthened, but they found the game interesting, fun and something worth developing further. (Group 2)

As is seen in these excerpts, the pre-service teachers enjoyed developing escape rooms and learned a lot during the process, even though they did find it challenging. Developing a good game is not easy and typically requires several iterations, as is seen in the second excerpt. To advance the game-development process in the future, the teachers of the course can use the experiences gained and reported on by the pre-service teachers to help other pre-service teachers avoid some of the common pitfalls. This can also lead to scientific publications about using escape rooms in education, helping the learning community, as well as a broader community in game development.

6.5 Discussion and Conclusions

A central question was how to promote understanding of current socioscientific issues (SSI) like climate change through pre-service and in-service science teacher education, and to help science teachers to teach it meaningfully at different school levels. The examples given pointed out a co-design approach as a framework to better address the multidisciplinary nature of climate change through in-service and pre-service teacher education, and the importance of both empirical problem analysis (the needs) and theoretical problem analysis (see Fig. 6.1). The design-based research framework (e.g., Aksela, 2019) used can be used as a map to understand the process of co-design in the context of climate change through a learning community. This is fundamental to how the LUMA Centre is effective and resulted in the application of this phrase "Together we are more!".

Our experiences of the cases point out that the key to success is meeting the needs of the teachers and future teachers (empirical problem analysis) and creating a suitable timetable as addressed by Roschelle and Penuel (2006) and Aksela (2019). In addition, the facilitation with well-defined roles for the partners is crucial. Scientists and science educators provide a current view of the needs towards student-centered and holistic approaches to climate change. In addition, they are also learning from the teachers and future teachers. Our experience is that teachers will often use novel teaching methods easily in practice at the school level if they have good experience of it already during their in-service teacher education. In the future, more research is needed that focuses on the opportunities and challenges of a co-design approach in the context of teachers' PCK of climate change education.

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