The Internet and Higher Education 65 (2025) 100987

Contents lists available at ScienceDirect

The Internet and Higher Education

journal homepage: www.elsevier.com/locate/iheduc

Promoting university students' situational engagement in online learning for climate education

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ARTICLE INFO

Keywords:
Online learning
Distance learning
Climate education
Situational engagement
Optimal learning moments

ABSTRACT

Disengagement in online learning is known to pose a risk to student learning and wellbeing. In this paper, we first introduce the development and implementation process of a set of online university climate education courses aimed at enhancing student situational engagement through diverse learning activities. Second, engagement (conceptualized here as the co-occurrence of interest, skill, and challenge, i.e., optimal learning moments), and activities during the online courses were examined through ecological momentary assessment, and the relationship between them was investigated through two-level regression models. The results showed that the students were likely to experience optimal learning moments when they were formulating problems and ideating alternatives or designing solutions. Formulating problems and ideating alternatives can promote a student sense of competence, and by designing solutions, students can work with adequately challenging learning tasks. Thus, by implementing such activities in (online) teaching and learning, educators can contribute positively to student engagement.

1. Introduction

The role of engagement in educational contexts has received increasing attention (Vilhunen, Lavonen, Salmela-Aro, & Juuti, 2022; Fredricks, Reschly, & Christenson, 2019; Pöysä, Poikkeus, Muotka, Vasalampi, & Lerkkanen, 2020; Sinatra, Heddy, & Lombardi, 2015), and its role in learning and socio-emotional development is evident (e.g., Finn & Zimmer, 2012). The theory of flow has been used to understand human performance in a wide variety of task domains, including human learning (Csikszentmihalyi, 1990). Briefly, the theory of flow involves the argument that humans are more engaged in tasks when they find them to be challenging and interesting. For example, the literature shows that engaged students have better learning outcomes (Finn & Zimmer, 2012) and experience learning as more positive (Beymer, Rosenberg, Schmidt, & Naftzger, 2018; Schneider et al., 2016). Also, in a higher education context, the importance of engagement has been addressed. For example, Ketonen et al. (2019) propose that how educators can help students in converting repeated positive experiences into long-term study engagement should be investigated.

Especially during the COVID-19 pandemic, many higher education students faced severe challenges in terms of their study engagement due to the shift from traditional in-person learning to online learning environments (Salta, Paschalidou, Tsetseri, & Koulougliotis, 2022). However, after the COVID-19 pandemic, online learning has solidified its role in higher education. While online learning has many undisputable benefits, such as flexibility for participation, and diverse opportunities for interaction and collaboration (e.g., Almahasees, Mohsen, & Amin, 2021; Castro & Tumibay, 2021), it is also well known that distance education can hamper student engagement (Akar, 2024; Bergdahl, 2022; Bond & Bergdahl, 2022). Especially, during the pandemic, researchers reported a lack of engagement in online learning (Ferrer, Ringer, Saville, Parris, & Kashi, 2022). Moreover, it is known that one of the critical elements affecting the quality of online learning is the learners' engagement in the learning process (Robinson & Hullinger, 2008; Sinclair et al., 2017), highlighting its importance in online learning instructional design (Jung & Lee, 2018). However, there have been only few studies that report in detail what specific elements lead to students being engaged in online learning (Hoi & Le Hang, 2021; Yang,

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https://doi.org/10.1016/j.iheduc.2024.100987
Received 28 June 2024; Received in revised form 14 November 2024; Accepted 14 November 2024
Available online 19 November 2024
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Lavonen, & Niemi, 2018). Therefore, this study focuses on examining the factors that can trigger student engagement during higher education online learning, or more specifically, how different learning activities relate to students' experiences of situational engagement.

In this study, students' situational engagement is examined in the context of university online climate education. The online courses, focusing on the various aspects of climate change and sustainability, were designed to enhance student engagement and learning in climate related topics in higher education. Using ecological momentary assessment (EMA; Shiffman, Stone, & Hufford, 2008), we collected intensive repeated measures data to examine how students' situational engagement related to learning activities in authentic online learning situations. On a larger scale and with a future perspective, the aim of this study was to develop engaging online education for sustainability by recognizing the characteristics of higher education online learning situations that support student engagement in climate change related issues, thus enabling transformative learning for the future sustainability makers (Ruiz-Mallén, Satorras, March, & Baró, 2022).

1.1. Situational engagement

Engagement can be understood and defined in several ways, such as by dividing it into three dimensions: emotional, cognitive, and behavioral engagement (Fredricks, Blumenfeld, & Paris, 2004). An emotionally engaged student experiences positive emotional reactions while studying, such as interest, enthusiasm, and a sense of belonging. A cognitively engaged student enjoys challenges and wants to invest time and effort in learning to achieve their goals. On the other hand, behavioral engagement refers to the student's tangible actions and participation in activities or tasks. Furthermore, the definition of engagement may depend on whether engagement is examined at the micro or macro level. Micro level engagement refers to a student's engagement in a specific situation, task, or activity, while macro level engagement may refer to a student's engagement in a class, school, or society (Sinatra et al., 2015). In this study, engagement is examined at the micro level, referring to a situational construct that can vary based on a range of learning activities. Furthermore, we employed the concept of *optimal learning moment* as a construct of situational engagement, primarily focusing on the emotional and cognitive dimensions of engagement. Optimal learning moments are theorized to occur when students experience concurrently high situational interest, challenge (situational task demand), and skills (situational resources) to perform the task (Schneider et al., 2016; Schneider, Krajcik, Lavonen, & Salmela-Aro, 2020; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). Situational interest plays an important role in the manifestation of situational engagement, as it facilitates concentration on the current task and motivates the learner to engage cognitively, even in the face of challenging tasks (Hidi & Renninger, 2006; Schraw & Lehman, 2001). However, situational interest may not necessarily persist for long if the student perceives that they lack the competence and necessary skills for completing the task. Therefore, it is important for situational engagement that the student perceives themselves as being capable of managing the assigned task effectively, leveraging their knowledge, and applying their skills (Csikszentmihalyi, 1990). On the other hand, for the preservation of students' interest and learning, it is also crucial for the task to present appropriate levels of challenge (Csikszentmihalyi, 1990; Shernoff et al., 2003). Schneider et al. (2016) have characterized such situations as having high levels of interest, skill, and challenge, and have been referred to them as optimal learning moments because it is hypothesized that they will increase science learning and social and emotional development.

Student situational engagement can be measured in several ways but self-reported measures such as EMA questionnaires (sometimes also referred to as experience sampling method; Shiffman et al., 2008; Zirkel, Garcia, & Murphy, 2015), are predominantly used to understand student engagement (see e.g., Inkinen et al., 2020; Schneider et al., 2016), especially the emotional and cognitive dimensions of it. According to Shiffman et al. (2008) EMA "involves repeated sampling of subjects' current behaviors and experiences in real time, in subjects' natural environments" (p. 1). Thus, whereas retrospective questionnaires rely on the memory of participants and are thus open to recall bias (Duckworth & Yeager, 2015), EMA questionnaires are more reliable in capturing context- or situation-specific experiences in authentic settings, in real-time and on repeated occasions. To measure students' behavioral engagement in online learning, some previous research also used learning analytics and educational data mining (e.g., Caspari-Sadeghi, 2022; Nkomo & Nat, 2021).

1.2. Learning activities and student engagement

Classes or lectures can consist of several independent segments, including reviewing assignments, introducing new content, and working with independent activities. Burns and Anderson (1987) suggest that these segments create the context for teaching and learning, offering a valuable framework for analyzing activities in a range of educational contexts. The segments can be differentiated by their distinct purposes, activity formats, and topics or assignments. Moreover, learning activities are goal oriented, typically planned and managed by teachers, and often include teacher-student or student-student interaction and/or interaction with learning materials.

Previous research has shown that learning activities emphasizing students' active participation and knowledge construction can generally enhance their situational interest (Juuti, Loukomies, & Lavonen, 2019; Neito, Vilhunen, Lavonen, & Reivelt, 2023), situational engagement (Vilhunen, Lavonen, Salmela-Aro, & Juuti, 2022; Inkinen et al., 2019, 2020), and positive emotions (Vilhunen, Chiu, Salmela-Aro, Lavonen, & Juuti, 2023; Vilhunen, Tang, Juuti, Lavonen, & Salmela-Aro, 2021). However, in the context of higher education, there has been a limited amount of research on situational engagement in relation to different learning activities, and moreover, conceptualized as optimal learning moments. Atabek-Yigit (2024) found that among pre-service science teachers, optimal learning moments were more likely to occur during mini-testing and problem-solving activities than during lecturing. Also, Timonen, Juuti, and Harmoinen (2022) studied optimal learning moments among university students and found that situational engagement is typically related to learning enhancing emotions (i.e., feeling active, successful, happy, enjoyment and confident). Furthermore, they concluded that even though most research on optimal learning moments is conducted at the secondary level, the framework also seems applicable to higher education contexts.

To continue, online education presents its added challenges to implementing various learning activities, and thus to overall student engagement (Yang et al., 2018). As Akar (2024) stated, "One of the most significant issues with online education in research is that students disengage and eventually drop out of the course due to their inability to remain active in the online environment" (p.1). Rajabalee and Santally (2021) studied the relationships between university students' reported engagement, satisfaction and their overall performance in an online module. They found that the relationship between all, satisfaction, engagement, and overall performance, was positively correlated. In turn, Vo and Ho (2024) recognized that course clarity and task relevance had indirect effects on students' behavioral, cognitive, and affective engagement via their expectancy and task value beliefs. Various topics have been found to lead to risks in the success of online education engagement and completion (Kuo, Tsai, & Wang, 2021; Wei, Saab, & Admiraal, 2023). These include academic procrastination (Cheng & Xie, 2021), active participation challenges (Jia, Hew, Jiahui, & Liuyufeng, 2023), issues in course social interactions (Jeng, Bosch, & Perry, 2023) and finding effective online learning activities (Saqr, López-Pernas, Jovanović, & Gašević, 2023). To manage these issues, several strategies have been proposed and employed, such as gamification (Carrera & Ramírez-Hernández, 2018), enhancing peer-interaction (Zhou, Li, Xu, Holton, & Sato, 2023), creating a more self-directed learning experiences (Akar, 2024), and methods to cater for various styles of learning (Li & Zhou, 2018).

1.3. Climate education

This study was conducted in the context of university online climate education. The climate crisis poses urgent demands on higher education. Climate and sustainability related topics are often emphasized in curricular documents, but they are difficult to teach and to learn. Moreover, they are not necessarily engaging for young people because of their interdisciplinary, multifaceted, complex—and even terrifying—nature (Hines, Mervis, Mccartney, & Wible, 2013). Therefore, teaching and learning these topics require reformed pedagogical approaches (Hestness, McGinnis, & Breslyn, 2015). Climate change and climate education can be described as *grand challenges* due to their multidimensional nature (Beniston, 2013; Hines et al., 2013; Lavonen, 2022; Lieberknecht et al., 2022). The challenge of climate education is characterized by many interdependent components (e.g., Favier, Van Gorp, Cyvin, & Cyvin, 2021). First, the topic itself, the scientific basis of climate change, is challenging and complex (Monroe, Plate, Oxarart, Bowers, & Chaves, 2019; e.g., Pruneau, Khattabi, & Demers, 2010). Second, the educational component, such as the curriculum, and the societal component, such as the influence of media and peers' conceptions and attitudes, influence climate education. And third, as climate change scenarios evolve, and the societal, economic, and psychological contexts are changing, teachers are forced to focus on a moving target (Favier et al., 2021). Therefore, educational approaches need to be adapted and adjusted continuously. In addition, a special challenge arises from the fact that climate education typically aims to influence students' attitudes and behavior (Lavonen, 2022), hence underlining the importance of student engagement. In their review article, Monroe et al. (2019) identified two main strategies for overcoming the challenges of climate change education, namely making the education personally relevant and meaningful, and designing learning activities and educational interventions that are engaging for students.

Furthermore, the goals of climate change education may differ at different educational levels. The goals in primary and secondary education often focus on internal and personal factors, such as climate knowledge and awareness (e.g., Kuthe et al., 2019), attitudes, or pro-environmental behavior (see model for pro-environmental behavior by Kollmuss & Agyeman, 2002). Instead, in addition to the internal factors, the goals of climate education in higher education often address more external factors and complex issues, such as political and economic factors or socio-cultural aspects (e.g., Brundiers et al., 2021; Perkins et al., 2018; Salovaara & Hagolani-Albov, 2024; Wiek, Withycombe, & Redman, 2011). This is especially the case on those fields in which the higher education students already possess high climate awareness and pro-environmental attitudes, and pursue a career in climate change or sustainability related positions as future leaders and change-makers.

Overall, addressing simultaneously the issues related to university student engagement in online learning and climate change education requires careful consideration of educational practices. The literature relating to higher education crossing the complexities of climate change and sustainability education and the engagement issues in online education is limited. Much like the literature reviewed above, Tomas, Lasen, Field, and Skamp (2015) concluded that students engage well in experimental and praxis-oriented learning combined with hands-on activity components, in the context of sustainability education blended learning environments. Furthermore, Guajardo Leal, Valenzuela González, and Scott (2019) point out that in the case of their online energy sustainability course, general course satisfaction seemed to be a clear indicator of course engagement and completion. However, most of the previous research was based on cross-sectional survey data, and to our knowledge, no studies have yet examined student engagement at a situational level (and conceptualized as optimal learning moments) in the context of university online climate education.

2. Developing engaging online higher education – The Climate University

In this section, we introduce the development and implementation process of a set of jointly designed online university climate education courses, called the Climate University, which aims to enhance student engagement through diverse, research informed learning activities. Climate University is a network of 28 higher education institutions (HEIs), established in Finland in 2018. The collaboratively defined aim of the network is to be a forerunner in educating active sustainability makers for society and business, with a mission to educate society with the competencies needed to tackle the challenges of climate change and the sustainability crisis. The network has developed joint online education on climate change and sustainability topics. The network has been built on the collaboration between four HEIs in 2014–2016 when the first joint open online course on climate change, Climate.now, was published (Tolppanen, Kang, & Riuttanen, 2022). The course has become popular, in 2024 being taught at 11 HEIs in Finland, and abroad, for example in Sweden, Switzerland, Iceland, Greenland, Germany, and China. After that, 12 sets of open online course materials have been published. All courses are done in multidisciplinary collaboration between experts from a range of fields, such as climate science, education, management, engineering, biology, and philosophy, coming from several institutions in Finland and abroad. During the development phase of the courses, the pedagogical aim and approach was to ensure production of frequent and varied types of meaningful and engaging activities for students.

2.1. Climate education needs assessment

The Climate University course themes were decided in a collaborative, multi-stage process during 2018–2019. As a starting point for the process, the recommendations outlined in the report by Sitra, the Finnish Innovation Fund (Liljeström & Monni, 2015) on "The current state of university climate teaching in Finland" were used. These recommendations were: (1) Expanding climate education in universities: sufficient basic information for everyone, wider course selection and climate as a cross-cutting theme in education; (2) Inter-university collaboration: from overlaps to searching for synergy and investing in strengths; and (3) Universities and companies: expanding competencies via collaboration.

Based on these recommendations, a questionnaire was drafted to chart the needs of Finnish HEIs and stakeholders in relation to climate education. An assessment survey was conducted in spring 2019 and a summary report produced (Äijälä, 2019). The report highlighted the need to address the following thematic gaps in Finnish university level climate education: multi-disciplinarity, holistic understanding, impactful decisions, science communication, including the private sector and consumer perspective. Finally, new thematic courses were proposed and accepted based on the assessment process (Äijälä & Riuttanen, 2019).

2.2. Design principles of the courses

Once the themed courses were accepted, the collaborative process for defining common Climate University course principles was initiated. First, according to Climate University project goals it was outlined that the courses should: (1) address climate change, (2) be open to everyone, and (3) incorporate best pedagogic practices. To define the principles more clearly, a virtual workshop was held, at which the network members could propose course principles on a virtual whiteboard. The answers were then grouped, linked, and organized by the Climate University coordinators representing 11 network HEIs, resulting in a poster-format "Course Principles Tree". After the comment round, the answers and comments were analyzed, and a summary was produced by the network coordinators. The resulting course principles and their theorized contribution to student engagement are outlined in Table 1.

2.3. Course pedagogical principles and training workshops

As described above, implementing research informed and engaging pedagogical practices was a part of the course design process from the beginning. To support the course planning groups pedagogically, training workshops were offered to all the course working group members. Two instances of so-called ABC Workshops were organized, in June and October 2019. The design workshop concept is based on the Arena Blended Connected Curriculum (ABC) – workshop concept (Perovic, 2015), and the instructional design principles by Laurillard (2002, 2013), and furthermore, was adapted and modified for training use by pedagogical experts from The Centre for University Teaching and Learning at the University of XXX, who also acted as trainers in the two events.

The workshops offered information for the planning groups in topics on constructive alignment, blended learning, and MOOCs, but the focus was on variability in teaching and evaluation methods. The participants had previously listed their learning goals and the course content, and during the workshop, they were tasked to organize their course structure around various blended learning activities in the categories of *acquisition*, *collaboration*, *discussion*, *investigation*, *production*, and *practice*, each with a selection of ideas for learning activities on cheat-sheet cards.

From the workshops, the course planning groups received a canvas with course modules or structures and their planned activity and evaluation framework, to continue the planning work in Autumn 2019 and Spring 2020. The influence of the workshop on the activity and evaluation selections could clearly be seen in the curricula and syllabi of the new courses. The ABC Workshops also markedly advanced and supported the blended learning course design at a time when few teachers or other group members had any real experience of online learning and evaluation methods. The course learning designs were soon put to the test in 2020 by the COVID-19 pandemic, and the designs offered the new courses much needed resilience as well as a distinct advantage in terms of pre-planned blended learning plans, which could more readily be converted to a fully online format than traditional offline courses.

Based on the best practices gathered in and after the first ABC Workshop round, in September 2019, the following common pedagogic guidelines were outlined for the new and any future Climate University courses:

A. **Constructive alignment.** Special care should be taken to ensure that course objectives, methods and evaluation are aligned. I.e., methods are chosen appropriately to support the accomplishing of the learning objectives, and the evaluation measures the fulfillment of the selected learning objectives.
B. **Variability in teaching methods and evaluation.** Teaching and evaluation should cater for a range of learners, so variability in methods is encouraged, to support engagement of different learners. Evaluation should broadly and continuously measure the skills and knowledge objectives and direct and support learning during the course – A mix of summative and formative evaluation is preferred.
C. **Flipped and blended learning.** Most of the lecture, reading, and background material should be online, and the contact teaching possibilities should concentrate on questions, interaction, critical discussions, and group activities.
D. **Transparency in course practices and design.** It should be clear to teachers and students what the course practices are: what are the expectations and how is evaluation performed?
E. **Multi-disciplinary education.** Courses are designed to cater for a large variety of student backgrounds and should be kept as accessible as possible (flexible prerequisites, terminology clearly defined etc.).
F. **Social and cultural aspects of learning.** Social interaction is an integral component in learning, and social learning is incorporated in the courses' teaching methods. Social learning also synergizes with a multi-disciplinary approach, and students from different backgrounds should be encouraged to work together and have discussions.

The abovementioned guidelines are known to facilitate student engagement in several ways, as well as the components of optimal learning moments (interest, skill, and challenge). For example, previous research has shown that clear course alignment and structure can promote students' sense of competence, or feeling *skilled* (Vo & Ho, 2024). Furthermore, flipped learning is an efficient way to promote engagement, and especially *interest* in online education (Jia et al., 2023). Also, collaborative activities, entailing social and cultural aspects of learning, are typically thought of as being highly engaging for students (e.g., Jeng et al., 2023; Schneider et al., 2020; Zhou et al., 2023). This is because they can promote students' experiences of autonomy and relatedness (Deci & Ryan, 2012), and enable students to self-pace (Wei et al., 2023) and self-regulate (Cheng & Xie, 2021) their learning experience, and thus help students to manage the levels of *challenge* in learning processes.

Table 1
Climate University course principles.

Principle	Elements of the principle	Role in student engagement
Online learning	Open for everyone: CC licensed, open university Easy-to-use platform Accessibility in mind Quality visual design, attractive, clear, uniform Up to date High quality, diverse, engaging digital content	Clarity in course organization and instructional information can promote student engagement (e.g., Chen, Bastedo, & Howard, 2018; Vo & Ho, 2024).
Solid pedagogy	Goals-Methods-Evaluation aligned Flipped/blended learning Learning goals spelled out Diverse learning methods for different learners Transparent, diverse evaluation	Coherence in course alignment adds to course clarity, that is, students know what is expected from them (e.g., Vo & Ho, 2024). Diverse and appropriate learning methods facilitate engagement in versatile learning situations, see in more detail in section 2.3.
Multidisciplinary collaboration	Interaction between students, peer learning Mixed student backgrounds Group work Collaborative projects	Collaborative activities (e.g., Jeng et al., 2023; Schneider et al., 2020; Zhou et al., 2023), and especially, project-based learning entailing scientific and engineering practices are known to facilitate student engagement (e.g., Krajcik & Shin, 2014; Schneider et al., 2020).
Impactful, climate & sustainability focused	Solution and action oriented International Science basis Real-world cases	Meaningful and authentic real-world issues engage students in learning (e.g., Chen et al., 2018; Hew, 2016; Krajcik & Shin, 2014; Monroe et al., 2019).
Reflective	Reflecting [on] own values Hope, positive visions of future Dialogues Critical thinking of existing systems	Personally relevant topics and positive affects induce engagement (e.g., Vilhunen, Tang, Juuti, Lavonen, & Salmela-Aro, 2021; King, McInerney, Ganotice, & Villarosa, 2015; Monroe et al., 2019; Schneider et al., 2020).

3. Current study

With this study, we aim to identify learning activities that promote student engagement in online learning (conceptualized as optimal learning moments), by collecting data on university students' situational experiences on interest, skill, and challenge (i.e., the elements of optimal learning moments) in the context of online climate education courses. The research questions are as follows:

RQ1: How do learning activities affect the occurrence of optimal learning moments that students experience and report during online climate education courses?

RQ2: How do learning activities affect students' experiences of interest, skill, and challenge during online climate education courses?

4. Methods

4.1. Context

In the current study, data from five runs of four selected Climate University online courses, organized by the university of XXX, were studied during 2021 and 2022: namely, Climate.now, Leadership for sustainable change, Solutions.now, and Sustainable.now. The courses are described in more detail in Table 2. The courses were open to all students at the University of XXX, as well as students at other Climate University network HEIs. It was also accessible to students outside HEIs via the open university protocol. The language of the instruction was English. Each course lasted for one teaching period, that is seven weeks.

4.2. Participants and procedures

The data were collected in five individual online courses, and altogether 295 university students participated in the research activities. Two runs of Climate.now courses were studied, and at the University of XXX, it is a compulsory course for students of the master's program and doctoral program in Atmospheric Sciences, as well as students of the master's program in Environmental Changes in Higher Latitudes. However, most of the students came from other programs and thus participated in the course voluntarily. In addition, one round of other Climate University courses was also studied as described in Table 2.

Data on learning activities and students' situational engagement were gathered using EMA (Shiffman et al., 2008). The timing of the EMA data collections was partly random and partly predetermined by the research team to ensure the coverage of diverse learning activities in each course studied. Data were collected both during teaching activities and via the online learning platform. Students were asked to fill out the EMA questionnaire at least once during every lecture and again while working with their group. A link to the questionnaire was also included in the submission instructions for the group, as well as individual assignments such as learning diaries, and the students were instructed to answer before and/or after working on the assignment. In addition, the students received a notification to answer the questionnaire at a randomly selected point of the mandatory quizzes.

The number of times students were prompted to answer the EMA questionnaire varied between the courses: 12 times in Leadership for sustainable change course, 16 times in the Climate.now 2021 and in Solutions.now courses, 17 times in the Climate.now 2022 course, and 32 times in the Sustainable.now course. Altogether, students received 5107 opportunities to answer the questionnaire, resulting in 1401 EMA observations (average cluster size 4.75). Out of these, 25 answers were incomplete and were not included in the analysis. Average response rates were lowest for the Climate.now courses (21.6 % for 2021 and 23.7 % for 2022), higher in Sustainable.now and Leadership for sustainable change courses (34.9 % and 35.6 % respectively), and highest in Solutions.now course (47.2 %). The participation in research activities was voluntary, and informed consent was required from all those whose data were used as part of the study.

Table 2
The Climate University courses included in the study.

Climate.now • 2021: 104 students participating in research • 2022: 95 students participating in research	• Basics of climate change • Includes 4 online contact lectures/sessions to introduce the course main themes • Individual work (online materials), quizzes, weekly assignments, written personal learning summary and a groupwork project • In 2021, the project work was done in collaboration with the local observatory. The students ideated and designed exhibition items for a public climate change exhibition at the observatory. In 2022, the project work was about ideating concrete actions for the university's roadmap to climate neutrality. Both years, the final assignment included written report and final presentation.
Leadership for sustainable change • 2021: 55 students participating in research • Taught jointly with XXX University, University of XXX, and XXX.	• Sustainability challenges and leadership • Includes 3 online contact lectures/sessions: one for course introduction, one for setting up the groupwork, and one for project presentations • Individual work (online materials), quizzes, weekly assignments, and peer-review of other students' hand-ins • Students divided into small groups to complete a project work to develop a climate leadership plan for a real-world organization or a case, chosen per their interest and submitted as written report and final presentation.
Solutions.now • 2021: 9 students participating in research • Taught jointly with XXX and XXX	• Project-course to ideate solutions for challenges given by collaborating organizations • Includes 4 online lectures/sessions to introduce and workshop the challenges and to present them to the collaborators • Mentoring sessions with teachers once a week • Individual and self-organized groupwork (online materials), constructing a learning portfolio • Students divided into small groups to complete their respective collaborator challenges, consisting of written report and final presentation.
Sustainable.now • 2021: 32 students participating in research • Taught jointly with University of XXX	• Foundations of sustainable development • Weekly online session including a short lecture and groupwork time for weekly study material reflection • Individual work (online materials), quizzes, weekly assignments • Students divided into small groups to ideate sustainability actions, inspired by the weekly readings and discussions. Project hand-in consists of written report and final presentation.

4.3. Measures

4.3.1. Optimal learning moments

In the EMA questionnaire used on Climate University online courses, situational engagement was measured as the elements of optimal learning moments, using the following questions: "Were you interested in what you were doing?", "Did you feel skilled at what you were doing?", and "Did you feel challenged by what you were doing?". Each course had the same questions, but a different scale was used at the beginning of the data collection: A five-point Likert scale was used in the Climate.now and Leadership for sustainable change courses, and a seven-point Likert scale was used in Solutions.now and Sustainability.

now. During the development process, the protocols were harmonized to use only the five-point scale. A situation was considered to be an optimal learning moment if student experiences of interest, skill, and challenge were all above the mid-point of the scale. Thus, each of these scales were first dummy coded as dichotomous variables to analyze how learning situations were associated with each of the elements of optimal learning.

4.3.2. Learning activities

Since the courses studied had different topics, themes, and designed activities, it was relevant to include slightly different activity items in the questionnaires. For example, inquiry-specific activity items were included in the courses emphasizing investigations and modelling, whereas ideating-specific items were included in the courses in which the focus was on designing solutions. Thus, each course had some unique questions, but for this study, only options available in all courses were included in the data. Each EMA questionnaire contained several items about the general learning activities, collaboration, and design activities when the students were answering the questionnaire. These were multiple choice questions, and students were instructed to select all the learning activities that best described the activities they were involved in, at the moment they received the link to the questionnaire. The general learning activities used in this study included listening to lectures, answering online quizzes, reading, writing, and calculating. In terms of collaboration, students answered whether they were currently studying alone or collaborating with others. And finally, the design-focused activities included in this study were formulating problems and ideating alternatives, designing solutions, and evaluating ideas or solutions. These three activity categories represent different phases of the design process (e.g., Korhonen, Kangas, & Salo, 2022). In the first phase, the problem is recognized and defined. Second, possible solutions are ideated and designed. And third, the solutions and ideas are evaluated and refined. Such design-focused activities are characterized by nonlinear, collaborative, hands-on processes in which students generate creative solutions to open-ended, real-life design challenges (Korhonen et al., 2022).

4.4. Analyses

Having multiple measures of a single variable means that the situational observations are nested within the students. This hierarchical structure was taken into consideration using multilevel modelling, in which it is acknowledged that responses within an individual may be more similar than responses between individuals. In other words, multilevel regression analysis allows the disentanglement of within- and between-level variability (Snijders & Bosker, 2012). To answer RQ1, a two-level multiple logistic regression model was created to analyze the relationship between different learning activities and optimal learning moments. To answer RQ2, additional three logistic regression models were used to examine the relationship between learning activities and each element of optimal learning moments (i.e., interest, skill, and challenge) independently. The analyses were carried out with Mplus 8.6 software (Muthén & Muthén, 2017). Two-level analysis was used, as the EMA observations were nested within students. Thus, the first level of analysis was the momentary level, and the second level of analysis was the individual level. Students' self-reported learning activities were used as predictors at the momentary level. Furthermore, to analyze if there was a difference in how each course affected student engagement, the courses were used as independent predicting variables on the individual level in the models.

4.5. Limitations

This study focuses on online learning in the context of university climate change education. Since climate change plays such a critical role in our lives, university students may find it to be an interesting, meaningful, and personally relevant topic, all affecting student engagement. Thus, the findings from this study are not fully generalizable to other learning contexts and topics.

Missing data can reduce the validity of the current study (Shiffman et al., 2008). First, some students in each course chose not to participate in the research. This is likely to have been due to some personal characteristics that influenced their willingness to participate, resulting in a sample that may not optimally represent the student population. Second, some missing data in EMA studies is typically due to participant drop-out (i.e., to participants no longer responding to the questionnaires), with certain participant characteristics or experiences again likely affecting their withdrawal. As learning engagement is known to be connected with learning persistence (Jung & Lee, 2018), it is possible that the drop-outs had lower sense of engagement as students who persisted on the course, biasing the overall engagement rates. Third, some EMA responses were missing in between the data collection period. The participants were allowed to skip questionnaires if it disturbed their current activities too much. This might have led some to ignore EMA notifications during the most engaging situations. Overall, it is very likely that the instances of missing data were not entirely random, thereby decreasing the study's validity and generalizability. Additionally, in general, self-report questionnaires have some typical limitations, such as social desirability bias and potential misinterpretation by participants (Duckworth & Yeager, 2015).

Finally, it is worth noting that this study was limited to investigating students' self-reported experiences of situational engagement (conceptualized as the co-occurrence of interest, skill, and challenge), which is *hypothesized* to promote learning and social and emotional development (Schneider et al., 2016). That is, the examination of actual learning or developmental outcomes or how situational engagement influenced these was beyond the scope of this study and should be addressed in future research.

5. Results

Overall, students reported experiencing simultaneously high levels of interest, skill, and challenge, that is, optimal learning moments (OLM), in 21.0 % of all the situations in our data (see Table 3). However, there were differences in the number of optimal learning moments and its elements between different courses. Furthermore, the proportion of these experiences was notably higher during some activities than others (see Table 4). Also, Table 4 presents the proportion of moments during which students reported experiences of high interest, skill, or challenge.

5.1. Learning activities related to optimal learning moments

According to a two-level multiple logistic regression analysis model (see e.g., Muthén & Muthén, 2017), the probability of optimal learning moments varied significantly between different learning activities, as well as between courses (see Table 5). At a momentary level, the learning activities accounted for 6.1 % of the variation (R^2) in the likelihood to experience optimal learning moments. The students were more likely to experience optimal learning moments when they were

Table 3
Number of EMA observations and proportion of optimal learning moments and moments with experience of interest, skill, or challenge on Climate University online courses.

Course	*n*	Proportion of moments (%)			
		OLM	Interest	Skill	Challenge
Climate.now 2021	358	17.6	57.5	49.4	37.2
Climate.now 2022	361	17.2	61.2	45.7	39.3
Leadership for sust.	235	15.7	52.3	48.5	37.4
Solutions.now	67	19.4	55.2	46.3	32.8
Sustainable.now	356	31.8	73.0	57.0	60.7
In total	1386	21.0	61.1	50.1	43.4

Table 4
Number of EMA observations and proportion of optimal learning moments and moments with experience of interest, skill, or challenge during each self-reported learning activity.

Learning activities	*n*	Proportion of moments (%)			
		OLM	Interest	Skill	Challenge
Listening to a lecture	460	18.7	52.9	46.7	40.0
Answering a quiz	190	27.4	66.8	55.8	54.2
Reading	284	21.4	67.3	49.6	47.8
Writing	285	21.1	64.9	54.0	42.1
Calculating	62	11.3	61.3	38.7	46.8
Collaborating with other students	419	20.8	66.6	50.8	42.9
Formulating problems and ideating alt.	123	39.0	74.8	61.8	61.8
Designing solutions	97	44.3	75.3	57.5	69.1
Evaluating ideas or solutions	142	34.5	75.7	57.0	58.3

As EMA observations were nested within students, and several independent variables could have a simultaneous effect on students' experiences, situational engagement was analyzed further using two-level multiple logistic regression models.

Table 5
Two-level multiple logistic regression analysis with optimal learning moment as a dependent variable.

Independent variables	OR	95 % CI	*p*
Momentary level ($R^2 = 0.061$)			
Listening to a lecture	0.808	0.547–1.192	0.282
Answering a quiz	1.461	0.972–2.194	0.068
Reading	1.014	0.619–1.660	0.957
Writing	1.066	0.700–1.624	0.765
Calculating	0.724	0.282–1.858	0.502
Collaborating with other students	0.883	0.593–1.316	0.541
Formulating problems and ideating alternatives	2.218*	1.108–4.087	0.023
Designing solutions	2.551**	1.285–5.063	0.007
Evaluating ideas or solutions	1.191	0.675–2.100	0.546
Individual level ($R^2 = 0.105$)			
Course (compared to Sustainable.now)			
Climate.now 2021	0.680*	0.520–0.887	0.005
Climate.now 2022	0.603***	0.470–0.773	< 0.001
Leadership for sust.	0.717*	0.553–0.928	0.012
Solutions.now	0.820	0.668–1.005	0.055

Sustainable.now was chosen to be a reference course because it had the highest ratings in optimal learning moments, interest, skill, and challenge.
OR = odds ratio; CI = confidence interval.
*** $p < .001$. ** $p < .01$. * $p < .05$.

formulating problems and ideating alternatives (OR = 2.218, 95 %CI [1.11–4.09], $p = .023$), or designing solutions (OR = 2.551, 95 %CI [1.29–5.06], $p = .007$). That is, during these activities, students were more than twice as likely to be situationally engaged, compared to other activities. At an individual level, students in the Sustainable.now course were more likely to experience optimal learning moments than students in other courses (Table 5). The differences between courses explained 10.5 % of the individual level variance (R^2) in experiencing optimal learning moments.

5.2. *Learning activities related to students' interest, skill, and challenge*

According to a two-level multiple logistic regression model (see e.g., Muthén & Muthén, 2017), there were no statistically significant momentary level differences in students' likelihood of experiencing interest by different activities (Table 6). However, at an individual level, students were more likely to experience interest in the Sustainable.now course than in any of the other courses.

Based on a model with the experienced skill as a dependent variable (Table 7), students were more likely to feel skilled when they were formulating problems and ideating alternatives (OR = 1.741, 95 % CI [1.01–3.00], $p = .046$). Compared to the students in the Sustainable.now course, the students on Climate.now 2022 course were less likely to feel skilled (OR = 0.420, 95 % CI [0.21–0.86], $p = .017$).

Based on a model with challenge as a dependent variable (Table 8), students were more than three times more likely to experience challenge when designing solutions (OR = 3.300, 95 % CI [1.62–6.74], $p = .046$) than when working with other activities. Students in the Sustainable.now course were significantly more likely to experience challenge than students in other courses (see also Table 4).

Table 6
Two-level multiple logistic regression analysis with **interest** as a dependent variable.

Independent variables	OR	95 % CI	*p*
Momentary level ($R^2 = 0.038$)			
Listening to a lecture	1.203	0.815–1.775	0.352
Answering a quiz	1.291	0.791–2.105	0.307
Reading	1.214	0.781–1.888	0.389
Writing	1.403	0.935–2.104	0.102
Calculating	1.721	0.816–3.627	0.154
Collaborating with other students	1.169	0.742–1.844	0.500
Formulating problems and ideating alternatives	1.547	0.825–2.901	0.174
Designing solutions	1.388	0.511–3.769	0.520
Evaluating ideas or solutions	1.390	0.589–3.281	0.453
Individual level ($R^2 = 0.038$)			
Course (compared to Sustainable.now)			
Climate.now 2021	0.436**	0.126–0.694	0.005
Climate.now 2022	0.337*	0.141–0.805	0.014
Leadership for sust.	0.250**	0.099–0.681	0.006
Solutions.now	0.174*	0.033–0.903	0.037

Sustainable.now was chosen to be a reference course because it had the highest ratings in optimal learning moments, interest, skill, and challenge.
OR = odds ratio; CI = confidence interval.
** $p < .01$. * $p < .05$.

Table 7
Two-level multiple logistic regression analysis with **skill** as a dependent variable.

Independent variables	OR	95 % CI	*p*
Momentary level ($R^2 = 0.018$)			
Listening to a lecture	0.802	0.578–1.114	0.188
Answering a quiz	1.301	0.839–2.017	0.239
Reading	0.957	0.681–1.345	0.802
Writing	1.281	0.931–1.762	0.128
Calculating	0.740	0.349–1.570	0.433
Collaborating with other students	1.086	0.777–1.520	0.628
Formulating problems and ideating alternatives	1.741*	1.011–2.997	0.046
Designing solutions	0.950	0.422–2.137	0.901
Evaluating ideas or solutions	1.053	0.629–1.761	0.845
Individual level ($R^2 = 0.036$)			
Course (compared to Sustainable.now)			
Climate.now 2021	0.553	0.271–1.131	0.105
Climate.now 2022	0.420*	0.205–0.858	0.017
Leadership for sust.	0.607	0.259–1.423	0.240
Solutions.now	0.547	0.138–2.175	0.392

Sustainable.now was chosen to be a reference course because it had the highest ratings in optimal learning moments, interest, skill, and challenge.
OR = odds ratio; CI = confidence interval.
* $p < .05$.

6. Discussion

In this study, we introduced the development and implementation

Table 8
Two-level multiple logistic regression analysis with **challenge** as a dependent variable.

Independent variables	OR	95 % CI	*p*
Momentary level ($R^2 = 0.081$)			
Listening to a lecture	0.681	0.452–1.024	0.065
Answering a quiz	1.652	0.996–2.738	0.052
Reading	1.282	0.843–1.949	0.245
Writing	1.007	0.711–1.426	0.970
Calculating	1.600	0.819–3.124	0.169
Collaborating with other students	1.071	0.735–1.560	0.722
Formulating problems and ideating alternatives	1.581	0.810–3.084	0.179
Designing solutions	3.300**	1.615–6.744	0.001
Evaluating ideas or solutions	1.377	0.791–2.398	0.258
Individual level ($R^2 = 0.126$)			
Course (compared to Sustainable.now)			
Climate.now 2021	0.302***	0.160–0.572	< 0.001
Climate.now 2022	0.254***	0.205–0.858	< 0.001
Leadership for sust.	0.313**	0.153–0.641	0.002
Solutions.now	0.153**	0.037–0.622	0.009

Sustainable.now was chosen to be a reference course because it had the highest ratings in optimal learning moments, interest, skill, and challenge.
OR = odds ratio; CI = confidence interval.
*** $p < .001$. ** $p < .01$.

process of university online climate education courses and examined how different learning activities within these courses relate to student situational engagement. We conceptualized situational engagement as optimal learning moments in which students simultaneously experience high levels of interest, skill and challenge. The empirical results of the study are based on the real-time data collected using EMA and analyzed through two-level logistic regression models.

6.1. The probability for being situationally engaged varies between different activities

Our results indicate that students' experiences of situational engagement vary significantly in terms of different online learning activities. Most probably, students experience situational engagement when they formulate problems and ideate alternatives or design solutions. Such design-focused activities are phases of design processes, in which students engage in nonlinear, multifaceted hands-on activities (Sawyer, 2018; Sheridan et al., 2014). These activities are also characterized by the inquiry approach, asking questions and modelling. They act as a pathway for the student to construct their own understanding of the resources available, and to work independently (Laurillard, 2013). Thus, it seems evident that such scientific and engineering practices that are also pertinent for professional scientists and designers, and authentic in terms of scientific knowledge construction (National Research Council, 2012; Schneider et al., 2020), also engage university students for learning. Furthermore, these findings are well in line with previous studies suggesting that authentic practices and student active role in learning promote student engagement (Inkinen et al., 2019; Johnson & Delawsky, 2013; Schneider et al., 2020; Tomas et al., 2015; Vilhunen, Lavonen, Salmela-Aro, & Juuti, 2022).

In previous research, the importance of student collaboration is often emphasized in terms of promoting engagement (Inkinen et al., 2019, 2020; Krajcik & Shin, 2014; Schneider et al., 2020). Also in our data, the highest scoring engagement activities of the courses studied predominantly comprised various peer-activities, aligning well with previous studies in the context of higher education (Jeng et al., 2023; Jia et al., 2023; Zhou et al., 2023). However, the findings from this study suggest that the collaboration per se is not sufficient for student engagement. Our results indicate that collaborating with peers has no significant effect on their experiences of situational engagement. Instead, some activities that typically occur *within* collaboration, namely formulating problems and ideating alternatives or designing solutions, do promote engagement. The collaborative activities of the courses studies here bring in additional elements, such as the groups' self-determined choice of their project topic and being critically reflective by both formulating their challenge and finding the best solutions to resolve it. Autonomy in choosing a project topic can further enhance the learning so it becomes more personally relevant (Monroe et al., 2019), and critical reflection has been suggested as a way to enhance deep learning (Choi et al., 2023). Thus, as suggested in the literature and the findings from this study, various design activities with self-determination and social engagement should be emphasized in crafting situational engagement. Furthermore, the findings from the current study, together with previous research, imply that such activities that have been recognized as beneficial for engagement in the contexts of face-to-face learning or in secondary education, also promote engagement in the context of university online education (Yang et al., 2018).

Overall, the levels of student engagement in this study were relatively high (21 % of all the situations). This suggests that the development process of Climate University courses has been successful in terms of engaging university students in online learning. On the other hand, we acknowledge that the topic itself – climate change – is most probably relatively engaging for most of the students who chose to enroll in the courses. This means that students would already experience quite high macro level engagement (Sinatra et al., 2015) which would again promote their micro level, or situational, engagement. Macro level engagement implies that students have high personal interest (Hidi & Renninger, 2006) in the topic, and thus they can persist, or engage, in learning activities even if they are challenging. Thus, future research should focus on studying university students' engagement in versatile contexts to shed more light on the complex interplay between learning activities, situational engagement, and individual disposition.

6.2. The balance between skills and challenge is key for engagement

By looking at situational engagement through its elements – interest, skill, and challenge – it is possible to examine in more detail why some learning activities are engaging for students while others are not. In terms of interest, we found no significant difference between different activities. Also, students reported experiencing situational interest relatively often throughout the activities, again suggesting that students' high individual interest in climate change-related topics might have impacted their appraisals of learning situations.

According to our findings, the roles of skill and challenge seem more relevant in terms of creating optimal learning moments (i.e., situational engagement) in climate education. As discussed above, formulating problems and ideating alternatives, and designing solutions seem to be the most engaging learning activities for students. When students report formulating problems and ideating alternatives, they also experience being more skilled than during any other activity, whereas designing solutions was considered to be the most challenging activity for students.

Finally, it is worth noting that we do not suggest that all the learning situations within a course or any educational context should be situationally engaging, or optimal learning moments, as conceptualized here. That is, the objective of course designing and implementing cannot be that all the students would experience high levels of interest, skill, and challenge in all the learning situations. This would most probably be too exhausting for students, or too monotonous to envelop a whole complex topic and its dynamic contexts, typical of climate and sustainability related courses. Having fluctuations between the differently engaging activities, with a full understanding of what is the purpose between the functions, could emphasize the feeling of being skilled, and moreover, becoming sufficiently skilled (Schneider et al., 2020) through the learning activities. Fluctuation of intensity also synergizes with cycling of learning activities (Avery et al., 2020) and applying pedagogic design patterns to courses (Laurillard, 2013). Moreover, situational engagement can be considered to be a longitudinal construct in which its elements are built on each other, one by one (Vilhunen, Lavonen, Salmela-Aro, & Juuti, 2022). Thus, when designing a learning pattern, such as a structure for a lecture or a course, a teacher can first implement elements that arouse interest, followed by activities that make students confident about their skills (e.g., formulating problems and ideating alternatives), and finally, introduce the most challenging learning activities (e.g., designing solutions). Thus, in future studies, more attention should be paid to the longitudinal dynamics of the various elements of situational engagement. We not only see the relevance to online climate change education with this, but also to the challenge of enhancing engagement and motivation towards the issues and ultimately to creating pro-sustainability behavior (Hansmann, 2010) through actual experiences of successful challenge completion.

6.3. *Situational engagement within different courses*

At a course level, we found that one of the courses, namely Sustainable.now, was significantly more engaging for students than other courses studied here (31.8 % of all the situations being engaging). Students also experienced the most interest, skill, and challenge during this course. This is interesting because all Climate University courses were developed according to the same pedagogical principles (see section 2.3.), and similar, engagement-promoting learning activities were implemented in all the courses. Thus, even though the main aim of this study was to examine situational engagement between different learning activities and not between these specific courses, we consider that discussing the possible reasons behind this finding might shed more light on how to craft optimal learning moments in online learning environments. We believe that autonomy and relatedness, as well as course clarity, might have played a role in students' experiencing Sustainable.now as the most engaging course. First, during this course, the students were divided into groups at the beginning of the course, and students had an opportunity to choose a group in an iterative process in which they first chose a theme they wanted to work on, and within the themes, they introduced themselves to each other in break-out rooms and autonomously, around shared interests, formed the groups. Contrarily, in other courses the groups were formed at a later stage of the course, and/or students did not have an opportunity to influence which group they went to. Thus, we hypothesize that the theme selection and group formation processes can influence students' experiences of autonomy and relatedness that can again facilitate their situational engagement (Deci & Ryan, 2012).

Furthermore, the Sustainable.now course had a clear weekly structure, which might have also made it easier for the students to follow. In other courses, there were many separate overlapping and consecutive activities to work with. This goes in line with the findings of Vo and Ho (2024), who argue that course clarity, that is, students' ability to access course organization and instructional information, promotes student engagement. They suggest that clear guidance can enhance students' sense of competence, which again corresponds to *skill* in the terminology of optimal learning moment theory. Furthermore, while climate change as a topic is typically perceived as complex and cognitively challenging (Pruneau et al., 2010), our findings, together with previous research suggest that student engagement in a climate learning context can be promoted by creating activities in which the learners can self-pace (Wei et al., 2023) their learning experience with the asynchronous tasks of the studied courses, and self-regulate (Cheng & Xie, 2021) their learning by formulating their course project assignment topics. Overall, this finding suggests that when designing online education, it is also worth looking beyond the situational learning activities, as instructional design and organization of the course structures and practices may have an equally important role in promoting university students' engagement in online learning contexts. Finally, it should be emphasized that the roles of autonomy, relatedness and course clarity in situational engagement were not examined per se in the current study. However, given their potential role in engagement, we see the need to investigate these factors in more detail in future research.

7. Conclusion

The empirical evidence in this study expands the existing research on university students' situational engagement in online learning contexts. This study introduced the development and implementation process of online Climate University courses, and examined how learning activities are related to student situational engagement within these courses. According to our findings, Climate University has succeeded well in developing and implementing engaging activities in online education. Thus, we argue that online courses and activities within them should be planned carefully, to avoid student disengagement and even drop-out which is too often the case in higher education online courses (Akar, 2024). Based on the results of this study, design-focused activities requiring independent processing or construction of information seem especially relevant for student engagement. For example, formulating problems and ideating alternatives can promote a student's sense of competence, and by designing solutions, students can work with adequately challenging learning tasks. Thus, by implementing such activities in (online) teaching and learning, educators can positively contribute to student engagement. Overall, the results provide valuable insights for climate education researchers and practitioners to promote situational engagement in online learning contexts, as well as for Climate University network to continue developing online education of future sustainability makers.

CRediT authorship contribution statement

Elisa Vilhunen: Writing – original draft, Methodology, Investigation, Conceptualization. **Veli-Matti Vesterinen:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Mikko Äijälä:** Writing – original draft, Resources. **Janne Salovaara:** Writing – review & editing, Resources. **Joula Siponen:** Writing – review & editing, Resources, Investigation. **Jari Lavonen:** Writing – review & editing, Funding acquisition, Conceptualization. **Katariina Salmela-Aro:** Writing – review & editing, Funding acquisition, Conceptualization. **Laura Riuttanen:** Writing – original draft, Resources, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgements

This work was supported by the Research Council of Finland [grant number 340791, PI Markku Kulmala, and grant number 340794, PI Katariina Salmela-Aro, "Learning of the competencies of effective climate change mitigation and adaptation in the education system (ClimComp)"; and, grant number 336138, PI Katariina Salmela-Aro; "TeensGoGreen"]. In addition, we want to thank Climate University students and teachers taking part in the study.

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