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Lessons learned from developing the transdisciplinary master's-level course "Living with changing climate"

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Abstract. Effective climate services require professionals who possess the competencies to interpret complex climate data, engage meaningfully with users, and support informed decision-making. This paper presents the development and pilot implementation of the graduate-level course Living with Changing Climate, designed to foster these competencies through transdisciplinary and practice-oriented climate change education. Developed collaboratively by experts in climate science, impact modelling, climate services, and educational sciences, the course aims to strengthen climate action competencies relevant to professional contexts. It is offered as part of the Nordic Master in Environmental Changes at Higher Latitudes (EnCHiL), the University of Helsinki's Master's Programme in Atmospheric Sciences, and the Climate University network. The course integrates climate change science, the use of climate data, and the principles of climate services, with a strong emphasis on real-world application. Using a design-based research approach, this study explores the competencies essential for climate-informed decision-making, the challenges of developing an online course for diverse learners, and the key elements of effective course design and implementation. Insights gained from the pilot phase and student feedback provided valuable guidance and highlighted critical issues, the resolution of which substantially improved the final version of the course. This work highlights the role of higher education in advancing user-centred climate services by equipping learners with the knowledge and skills necessary for proactive climate adaptation and mitigation across sectors.

1 Introduction

According to the World Meteorological Organization, climate service is defined as *"… the provision and use of climate data, information and knowledge to assist decision-making. Climate services require appropriate engagement between the recipient of the service and its provider, along with an effective access mechanism to enable timely action."* (WMO, 2025). Moreover,

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an efficient climate service i) understands the demand side (i.e., end user needs), ii) bridges the gap between climate science and sector expertise, iii) co-produces climate services to address end-user needs, iv) communicates effectively to achieve final outcomes, and v) monitors and evaluates the usefulness and usability of the service (WMO, 2025).

To support effective climate services, as well as adaptation and mitigation actions, climate change education (CCE) must equip professionals with essential climate change competencies. These competencies include knowledge, skills, attitudes and values (Riuttanen et al., 2021) that enable them to interpret complex climate data, understand climate variability, engage users meaningfully and make informed decisions. An interview study with climate experts and leaders in Finland (Siponen et al., 2024) highlighted the need for future climate experts to develop a systemic and holistic understanding of climate change within their professional fields. Key competencies include understanding global value chains, strategic planning using climate scenarios, and strong leadership and communication skills to inspire action and learning of competencies, all of which are essential for delivering user-focused climate services. As a highly complex issue, climate change is first and foremost a collective challenge and therefore, skills are needed in building and managing communities of climate change experts as well as engaging effectively with other experts across fields and contexts.

Integrating climate change into the education system remains a challenge due to its complexity and interdisciplinary nature which makes it difficult to integrate within discipline-based education system, including higher education (e.g., Jorgensonn et al., 2019; Roussell and Cutter-Mackenzie-Knowles, 2020; Eilam, 2022). Due to its complex and multifaceted nature, climate change education should be transdisciplinary, and taught using a holistic approach (Tolppanen et al., 2017). Thus, higher education provides a more suitable context for comprehensive climate change education (Salovaara et al., 2025). Furthermore, in addition to climate change science education, universities should integrate climate change mitigation and adaptation education in all disciplines (Moltan-Hill et al., 2019).

The course *Living with Changing Climate* was developed to promote proactive adaptation and accelerate green transition in an ecologically sustainable way. The motivation for developing and piloting this novel course was based on the needs described above, i.e., to enhance climate action competencies and support the adaptation of society to climate change. To ensure comprehensive coverage of relevant topics, an expert group with extensive cross-disciplinary knowledge in climate science, climate data analysis, impact assessments, climate services, and education was involved in its creation. The main aim of the course was to educate students in climate-informed decision making, providing the knowledge and skills needed for climate action in professional settings, such as helping companies and public authorities implement climate change mitigation and adaptation.

The course has been designed as part of a graduate-level curriculum. It is a compulsory course in the curriculum for the Nordic Master in Environmental Changes at Higher Latitudes (EnCHiL), a double degree master's programme offered in a Nordic

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collaboration. Additionally, it is an optional course in the curriculum of the Master's Programme in Atmospheric Sciences (ATM-MP) at the University of Helsinki.

The course was also designed to be part of the Climate University curriculum. Climate University is a network of Finnish higher education institutions collaborating on climate and sustainability education, in cooperation with schools and working life supported by various funding sources and communal interest of the participating higher education institutions. The core of the collaboration is to provide open-access educational resources on climate change and sustainability topics and to offer joint courses on these topics. While primarily aimed at higher education students, many courses are also available to continuous learners via open universities. The courses are often co-taught by several higher education institutions, fostering transdisciplinary teaching and collaboration both nationally and internationally. The pedagogy of Climate University courses has been co-designed with educational experts and taught using collaborative teaching methods, which have been found highly engaging for learners (Vilhunen et al., 2025). Climate University network has cross-study agreements among 29 member institutions, allowing students to take courses from each other's curricula free of charge and include them in their studies.

Design-based research addresses complex educational challenges by engaging in systematic, iterative, and sustained design and refinement of innovative learning solutions, with the dual aim of improving practice and generating theoretical insights (Edelson, 2002; Design-Based Research Collective, 2003; Barab & Squire, 2004). The research questions guiding the development of the *Living with Changing Climate* course are based on Edelson's (2002) design-based research model. This model emphasizes the generation of three interrelated types of theoretical contributions: domain theories that explain learning phenomena, design frameworks that guide the creation of effective learning environments, and design methodologies that inform the process of educational innovation, in this case, the development of a new type of climate education course. Following this research model, the design research for our course focuses on the following research questions:

1. Outcome theories: What climate competencies are necessary for effective climate action in professional settings?
2. Context theories: What challenges arise when designing a novel online course on climate change aimed at supporting climate action in professional settings?
3. Design framework: What are the key characteristics of a successful online course on climate change that facilitates climate action in professional environments?
4. Design methodologies: What are the characteristics of an effective design process for a real-life-oriented online course on climate change intended to promote climate action in professional contexts?

By analysing the course design and pilot phase, this study aims to answer the last three research questions.

This paper presents the design and development of the novel master-level course *Living with Changing Climate* created within the Climate University network. It outlines the key challenges encountered, and lessons learned during the co-creation and pilot phase of the course. The following section details the course development process, the educational principles applied,

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and the implementation of the pilot. Evaluation of the pilot phase enabled us to improve the course before its final launch, as described in Sect. 3. Section 4 summarizes the main challenges encountered during co-creation and highlights the key lessons learned. These insights offer valuable guidance for the design and delivery of future climate-oriented courses, particularly in online and interdisciplinary learning environments.

2 Course development and piloting

2.1 Planning the course and assembling the team

The course *Living with Changing Climate* was designed and produced as part of the academic research project *Learning of the competencies of effective climate change mitigation and adaptation in the education system* (ClimComp), funded by the Research Council of Finland. The planning process for the course began in late 2020.

The course production started in 2021, following the project's funding, by a multidisciplinary team including researchers and teachers from the project partners: the Institute for Atmospheric and Earth System Research (INAR) at the University of Helsinki (UH), the Department of Educational Sciences (EDU) at the UH, the Finnish Meteorological Institute (FMI) and the Department of Geography at Ludwig-Maximilians-Universität München (LMU), which served as a project collaborator. Since the course aimed to integrate the expertise of atmospheric scientists, such as climate modellers, impact modellers and climate service developers, into the field of educational sciences, the expert group responsible for designing and piloting the course required broad cross-disciplinary competence. This included expertise in climate science, data analysis, the applicability of methods in impact assessments and climate services, educational design, online learning, as well as pedagogical and didactic knowledge. Furthermore, online teaching required innovative approaches in both the methodology and the content of the course materials. In addition to close collaboration with educational scientists, engagement with various end-users, such as private companies, regional authorities, and cities facing and dealing with current and future adaptation needs was also essential.

2.2 Designing and producing the course content

The course design process began in May 2021 and included a total of 28 documented design meetings. Additionally, notes from the annual meetings of the course advisory board were available and contributed to the overall understanding of the co-design and co-development process. To analyse the course development, a document analysis approach was applied, following the methodology outlined by Corbin and Strauss (2008). This approach provided insights into the design process of the course *Living with Changing Climate*. The co-design process was further interpreted using Bowen's (2009) framework for document analysis. For instance, the design team studied the structure of existing online courses and their structure on the Climate University platform to align plans more effectively with the courses offered, create synergies and avoid overlap. The information and insights were identified in the documents through skimming (superficial examination), reading (thorough examination), and interpretation (Corbin and Strauss, 2008). The existing course materials, recent findings in climate science, current concerns about climate action and reviews of existing data platforms and open datasets applicable to teaching were

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reviewed several times to identify all essential aspects that would support the design of the course structure and materials. The meetings served as workshops for innovative thinking that enabled co-design of the course, including intended learning outcomes, course content, assignments, teaching methods, and evaluation strategies. However, we must acknowledge that document analysis had limitations in our study, such as a lack of detail in internal meeting documents and potential selection bias, as the course developers also taught and evaluated the course. To address these issues, we employed researcher triangulation. Thus, the authors participated in various stages of the project and collaborated closely to interpret findings, using shared experiences to reduce the risk of bias arising from reliance on a single method, source or investigator (Patton, 1990).

The course design was based on the principles of previous Climate University courses (see Vilhunen et al., 2025). The learning objectives were defined taking into account the previously identified user needs gathered through interactions and surveys conducted in earlier projects, as well as competence mapping conducted within the ClimComp project (Siponen et al., 2024). To strengthen the pedagogical background of the production team and support the course design process, an ABC (Arena Blended Connected) curriculum design workshop was held in collaboration with educational experts from UH Centre for University Teaching and Learning in October 2021. The ABC curriculum design method (Young and Perovic, 2016) is a 90-minute, hands-on, rapid-development workshop designed for module and program teams. It facilitates course development by guiding participants in designing learning activities aligned with module specifications and intended learning outcomes. The workshop resulted in a visual 'storyboard' outlining the course structure and pedagogical approach.

When designing the course, in addition to the learning objectives, several other critical aspects were also considered, such as how the course would be arranged (in class or online), what methods and materials would be incorporated to achieve the defined learning objectives and how the resources would be distributed for developing the material. In addition, the intended learning outcomes, the course materials and assignments, and the methods applied had to be aligned with the diverse skills and prior knowledge of students.

The main goal of the course was to educate students in climate-informed decision making, equipping them with the skills to utilize open climate and weather data for real-life mitigation and adaptation actions and thereby to build the climate competence of society (see Supplement 1 for detailed learning outcomes). This meant gaining knowledge of 1) the causes and complexity of climate change, 2) the variability and regionality of climate change impacts, adaptation needs, unavoidable loss and damage, main uncertainties (such as tipping points), and future scenarios and their links to mitigation efforts, 3) available data (e.g., reanalyses, observations, and data from coordinated global and regional climate model experiments) and applications (e.g., the WMO Climate Atlas and C3S applications) and how these can be used in problem solving, and 4) the principles of climate services with emphasis on co-design. Additionally, we aimed to familiarize students with real-life actions and action gaps in climate change adaptation and mitigation at private companies and public organizations, and to co-create a climate service together with users.

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At the beginning of 2022, the goal was set to pilot the new course in spring 2023 and publish it officially in autumn 2023 (Fig. 1). Simultaneously, the course modules were defined and lead authors and co-authors were appointed.

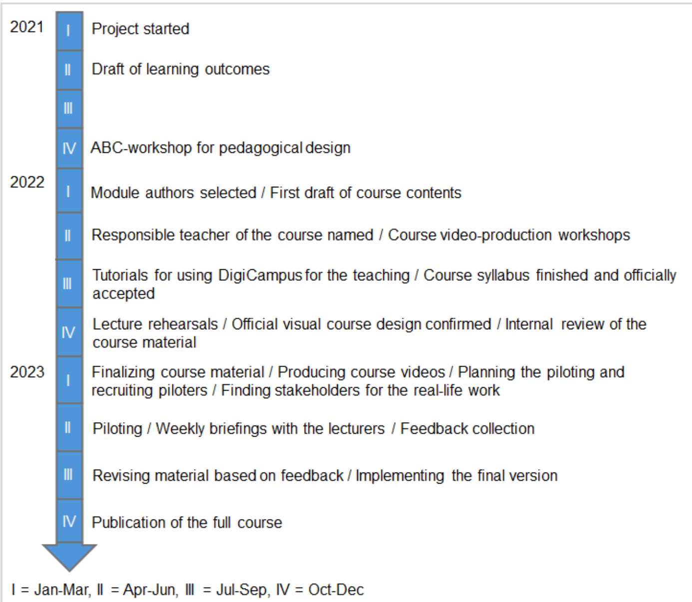

Figure 1: Timeline of the course production.

During spring and summer 2022, the modules were framed and developed starting with the creation of assignments, course material, workload estimates, instructions and requirements for the real-life project, grading criteria and the weekly schedule. The team discussed these elements during the production meetings. As a result of this design process, the pilot course was structured into five modules (Fig. 2):

- Module 1 (Introduction) introduced the need for climate change mitigation and the green transition, as well as the importance of adaptation, providing examples of proactive adaptation through video materials. Key concepts such as extreme event attribution, co-designing climate risks, and impact analysis were introduced. Students participated in a variety of climate-focused activities including viewing IPCC videos, reflecting on personal climate actions, exploring adaptation stories, and analysing a real-life case study. These tasks fostered critical thinking, self-reflection, group collaboration and research skills. By the end of the module, students had developed a deeper understanding of climate change impacts, adaptation strategies, as well as the role of individuals and communities in promoting sustainability. They also learned to interpret scientific data and frameworks, such as green finance and extreme event attribution, enhancing their ability to connect theoretical knowledge with practical climate solutions.

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- Module 2 (Weather and climate) offered a concise overview of the basics of climate change. It clarified the conceptual differences between weather and climate, explained the physical drivers of climate change, the link between climate change and human-induced emissions, regional aspects and impacts of climate change, key open questions such as climate sensitivity and safe zones for avoiding tipping points, the modelling framework used for projecting climate change, and the measures needed to keep the global-mean temperature within 1.5 °C of the preindustrial level. Students engaged in practical exercises, including analysing July temperature statistics in Helsinki, assessing the effects of uniform warming on temperature frequency, and interpreted climate extremes based on IPCC findings. These activities developed their skills in data analysis, statistical reasoning, and scientific interpretation. By calculating radiative forcing and estimating equilibrium temperature changes, students applied climate physics concepts. They also reflected on key climate terms and assessed the implications of climate change on renewable energy production in Finland. This multidisciplinary approach strengthened their understanding of climate systems, uncertainty in projections and the socio-environmental relevance of hydropower and other energy sources in a changing climate.

- Module 3 (Where to find data) introduced, through numerous examples, sources of reliable weather and climate data available online, including both observational and climate model data. Emphasis was placed on hands-on exercises to help students explore and interact with these data sources. Students explored various platforms for accessing weather and climate data, including FMI Open Data, ICOS Carbon Portal, WEkEO, C3S Toolbox and the IPCC Interactive Atlas. They practiced data retrieval, statistical analysis and visualization using tools like Excel, Python and Panoply. Activities involved working with local observations, greenhouse gas concentrations, satellite SST data, reanalysis datasets and seasonal forecasts. These tasks helped students develop skills in trend interpretation, identifying anomalies, and comparing scenarios, while reinforcing the importance of data quality and reliability in forecasting and climate impact assessments.

- Module 4 (Decision making & applications) explored how climate and weather data are used in decision-making processes and showcased a variety of openly available online weather and climate applications (e.g., from C3S or IPCC) that support the practical use of such data. Students explored European climate services provided through the Copernicus programme, including tools for monitoring, forecasting and emergency management. Using interactive applications and datasets, they worked with fire danger indicators, hydrological forecasts and climate projections, practicing data interpretation, regional analysis, scenario comparison, uncertainties evaluation in model outputs. Additionally, students designed a comprehensive monitoring service for hydropower production, integrating observational data, forecasts, and climate projections, enhancing their understanding of operational climate services and their role in adaptation planning.

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- Module 5 (Project work) emphasized practical learning by offering students hands-on experience with user engagement through a real-life case study. Working in teams of 2-4, students planned, conducted and reported interviews with private companies or public organizations to explore their needs and strategies related to climate change mitigation and adaptation. The collaborative group work fostered multidisciplinary learning, enabling students from diverse academic backgrounds to approach climate related challenges from a multiple perspective. Students collaborated with stakeholders to explore how weather and climate data are used in practise and to identify operational and decision-making needs by applying course knowledge of weather and climate data and their applications. They developed research, development and communication skills while addressing real-world decision-making needs, enhancing their understanding of climate services and stakeholder engagement in adaptation planning.

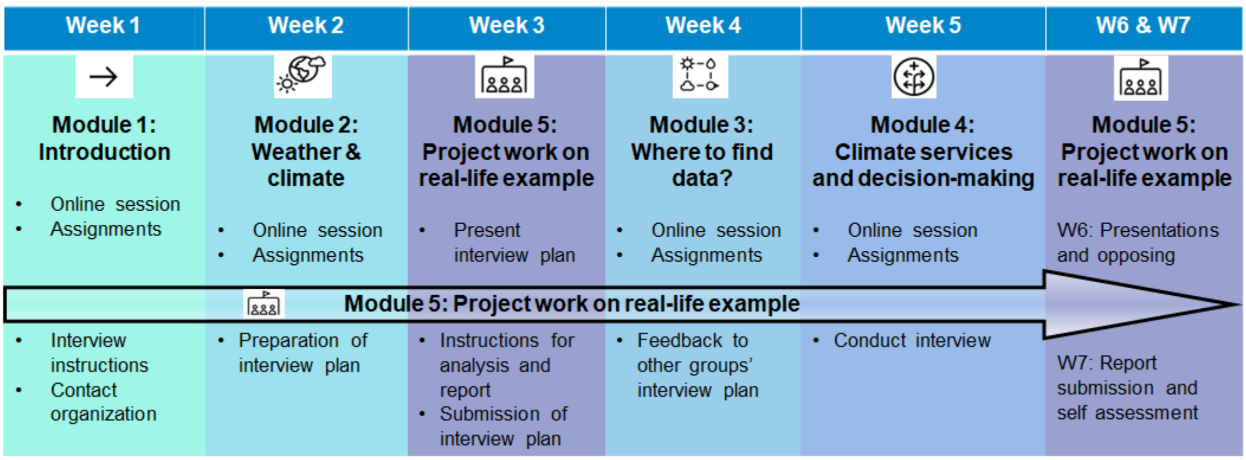

Figure 2: Schedule of the piloted course in spring 2023. Detailed descriptions of the modules' contents are provided in Sect. 2.2.

The assignments were designed based on the prior expertise of climate experts, focusing on the most common climate change–related questions and challenges faced by different societal actors in their work. By identifying these questions and challenges, it was possible to design and align the assignments across the modules so that they support the main learning objectives. The diverse backgrounds, knowledge, and skills of the target audience were considered alongside the course's intended learning outcomes, resulting in assignments of varying difficulty levels, from exercises that required only basic natural sciences background to more advanced assignments requiring complex science knowledge. The assignments included various types of exercises, such as:

- false/true statements,
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- watching an IPCC video on climate change mitigation, and listing five ways to promote personal climate actions or adopt more climate friendly lifestyle,
- downloading and processing publicly available weather and climate data,
- analysing long-range forecasts and models uncertainties,
- exploring user-driven applications from C3S, and
- assessing climate change impacts across different European regions.

In parallel, the course syllabus (see Supplement 1), which outlined the course level, objectives, learning outcomes, completion and grading methods and prerequisites of the course, was completed and submitted to the faculty council for approval in autumn 2022. Once the course materials were developed, each module underwent an internal review by the producers of other modules by the end of 2022. This process helped ensure coherence, clarity and the avoidance of content duplication. To enhance the learning experience, the team designed and produced educational videos for each module in early 2023. These short videos featured either filmed interviews with experts or users discussing specific topics, such as carbon footprint calculators and climate services used by an energy company, or screencast videos and teaching videos introducing various topics, such as climate change, future possibilities and limitations of negative emission technologies, climate models and seasonal forecasts.

2.3 Course platform and technical issues

Like all Climate University courses, the *Living with Changing Climate* course was implemented on DigiCampus.fi, a shared online learning platform for Finnish higher education institutions. DigiCampus was developed to promote collaboration and shared goals among higher education institutions. The platform supports joint studies across participating institutions, massive open online courses (MOOCs), as well as projects, networks and collaborative initiatives coordinated by universities. It also enables cross-institutional learning opportunities. The Moodle-based platform allows for the integration of diverse learning materials, including text, images, and videos, as well as interactive components such as discussion forums, assignment submission and assessment tools, and quizzes.

Since the climate scientists involved in designing the course had no prior experience with DigiCampus, a dedicated training session was organized to support their onboarding. Additionally, the platform's online support channel was used to resolve occasional technical challenges. Overall, the availability of a robust and well-established digital learning environment significantly facilitated the successful implementation of the course.

2.4 Course piloting: where, when and how

To evaluate the course's effectiveness and identify areas for improvement before its official launch, a pilot was conducted in spring 2023 with a smaller group of students and volunteer participants. The pilot group included 27 students from diverse

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academic backgrounds, including natural sciences, social sciences and communication. However, quite a few students dropped out already in the early phase of the pilot and only 9 completed the course.

The pilot aimed to assess whether the course met its intended learning outcomes, evaluate the effectiveness of the learning approaches, and determine the accessibility and usefulness of the course content, assignments and video materials. We also aimed to identify potential challenges related to course scheduling and technical aspects arising from the online teaching format. The pilot ran for seven weeks and included six interactive weekly sessions, as one session was cancelled due to a public holiday. The modules were not taught in a strict sequential order: project work for Module 5 began at the start of the course, while Modules 1-4 were taught concurrently (Fig. 2). This structure led to a somewhat demanding and complex schedule. Student feedback on the course content and overall experience was collected during and after the pilot. Based on this feedback, several improvements were implemented to optimize the course before its official launch, as described in the following section.

3 Evaluation of the piloted course

In design-based research, iterative cycles of design, enactment, analysis and redesign are essential in both improving educational interventions and generating theoretical insights. To understand how the course functioned in authentic learning settings, formative evaluation was embedded during and after the pilot phase, providing guidance for subsequent refinements. Aligned with Nieveen's (1999) framework, the quality of the intervention was examined using four key criteria:

(i) practicality, which measures how usable the intervention is in settings for which it has been designed,

(ii) effectiveness, which measures how well the intervention achieves the desired outcomes,

(iii) relevance, which measures how well the intervention aligns with prior scientific knowledge (also referred to as content validity), and

(iv) consistency, which measures how well the components of the intervention are connected to each other (also referred to as construct validity).

During the evaluation, the primary focus was on the course's relevance, internal consistency and practical applicability. A comprehensive assessment of its effectiveness would have required a controlled testing environment and a significantly larger pilot group, both of which were beyond the scope of this pilot implementation. The evaluation concentrated on key aspects, such as course content and materials, learning moments, scheduling and technical aspects. Both students and teachers were invited to provide feedback and suggestions for improvement. All feedback was carefully analysed and used to refine the course content and materials prior to its official release.

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3.1 Feedback collection

Students were invited to complete the course evaluation by providing feedback through learning diaries and surveys, both accessible via the DigiCampus platform. Participation was voluntary and only responses from students who gave explicit consent were included in the study. The learning diaries were completed during the pilot phase, with students submitting reflections after each course module to share information about their learning experiences. The written diaries followed a set of standardized questions tailored to each module. These prompts helped teachers monitor how students perceived the course content in relation to their prior knowledge, the learning environment and the difficulty and complexity of the material.

The questions in the diary (see Supplement 2) aimed to assess:

(1) the clarity and usability of the competencies acquired in the respective module,

(2) the relevance of learning outcomes for future studies and climate-related work,

(3) the coherence between the course modules and the project work on a real-life example, and

(4) the workload required by different parts of the course (e.g., individual study materials, assignments, learning diaries) and their perceived difficulty levels.

In addition, questions regarding students' background, motivations for participating in the pilot and expectations for the course were included.

To collect additional feedback, an anonymous online survey was conducted at the end of the pilot phase. The survey contained 16 questions, primarily designed to assess students' experiences and perceptions using a five-point Likert scale, ranging from *Fair* to *Excellent* or from *Strongly disagree* to *Strongly agree*, depending on the question. In addition to overall course evaluation, the Likert-scale items explored how instructional approaches supported the development of the intended competences, the study effort required relative to the credits earned, and the effectiveness of course materials, videos, assignments, group work and weekly teaching sessions in helping students achieve the learning outcomes. The survey also included questions on the usefulness of information flow through the learning platform. To complement the quantitative data, five open-ended questions were included to capture participants' background, detailed experiences and suggestions for improvements. Examples of these prompts included: *"Which factors in the course served to promote accessibility of the teaching, encourage participation and reduce discrimination?"* or *"What would you improve in the course?" and "Other comments?"*.

3.2 Feedback received

A total of eight learning diaries were submitted and seven students responded to the feedback questionnaire. The students who took part in the pilot have had diverse academic backgrounds, ranging from natural sciences and mathematics to engineering, social sciences and communication. Consequently, the feedback provided helped the production team assess whether the course was appropriately designed for students with varying levels of prior knowledge. According to the responses, the course

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generally required an appropriate amount of work (approximately 135 hours) to complete (n=4), while one student reported spending slightly less time and two slightly more. Overall, students rated the course as good (n=3) or satisfactory (n=4) and indicated that the teaching methods, i.e., lectures, group work, online study and assignments, supported their learning (n=4), though two students disagreed with this statement. Suggestions for improvement were mainly related to the course schedule, as well as the number and difficulty of assignments:

“The timeline of the course with the order of assignment deadlines and linked lectures was a bit off, so I would reorganize that.”

“The deadlines and the requirements of the assignments were sometimes not very clear. Otherwise, it was a nice course.”

“The assignments were often difficult, and instructions were not accessible..."

In their learning diaries, students reflected on how understandable, useful and challenging each module was. Overall, all modules were considered understandable, the learning materials and assignments useful, and the intended learning outcomes well covered. However, some assignments were found to be challenging, particularly by students from non-natural science backgrounds. The structure of the content and the connections between modules were also emphasized in the feedback:

“The module connected well to the previous modules in terms of providing hands-on tools and explaining how they can be used in decision making. “

“This module builds nicely on the knowledge base created in the first two modules. It also leads to thinking about the project work and how this kind of data can be used in practice.”

Students found the real-life project interesting and valuable but noted that it would have been more effective to start working on it after completing Modules 1-4, rather than in parallel with them:

“The interview provided very good understanding of the industry and thus was a positive experience, although making the report and plan took quite a lot of time.”

” ... the most useful part was planning and conducting the interview, because I believe I might do that in my thesis and probably will be a useful skill in work life too. Also, having to think about their needs and wants and what to do about that is good practice for work life.”

“For the (real-life) project it would have been helpful to have the Module 4 before doing the interview because we probably would have adjusted our interview plan according to the information given in the module.”

All the feedback received was carefully considered and used to improve the course materials and to improve students’ learning experiences, as illustrated in the following section.

3.3 Improvements after the pilot

Design challenges and corresponding solutions were identified through the analysis of course learning diaries, surveys, and individual reflections from the multidisciplinary team of experts involved in the course design. The initial co-created description of these challenges and solutions was further refined using inductive content analysis (Elo and Kyngäs, 2008). To

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enhance the reliability of the analysis, member checks were conducted. Following the content analysis phase, in which challenges and solutions were organized and reformulated, the course designers reviewed and provided feedback on the findings. Based on their input, the course content and structure were iteratively refined until consensus was reached.

The feedback received revealed several key areas for improvement, including a) the set-up and execution of the course and the creation of optimal learning moments, b) the effective use of the online teaching environment to support climate science education and promote concrete climate action, and c) the volume and difficulty level of assignments. Building on this feedback, along with teachers' own reflections on the challenges encountered during the pilot phase, further refinements were made to enhance the final version of the course.

For example, the final course schedule was substantially reorganized based on feedback from pilot students and insights from teachers, drawing on both their teaching experience and professional background. The assignments were partly redesigned and reduced in number, and the grading process was simplified. To make the assignments more accessible to students from diverse academic backgrounds, instructions for Modules 2-4 were clarified, and tasks were redesigned to rely less on advanced mathematical or computational skills. Additionally, support sessions were added for the assignments in Module 2 and 3 to provide further guidance. To strengthen the integration between modules and prepare students for the real-life projects, a comprehensive assignment based on an existing real-life case, i.e., Kemijoki hydropower climate services delivery project, was embedded across Modules 1-4. In Module 1, students studied strategies and created a roadmap outlining mitigation and adaptation goals for the Kemijoki hydropower company. In the Kemijoki assignment from Module 2, the focus was on applying climate scenarios and understanding their implications for future hydropower production, including how these scenarios are used in planning and decision-making. In Module 3, students analysed 30 years of observed climate data near Kemijoki, conducting similar analyses to those used in the real case. In Module 4, students examined the climate service developed for the Kemijoki hydropower company, assessed potential changes, risks, and impacts over the coming decades, and proposed a data-based service for hydropower, applying knowledge gained in previous modules. To deepen students' understanding of climate service development and user engagement, the focus of the real-life project in Module 5 was slightly adjusted. Rather than simply examining how weather and climate data are used in organizations and businesses, the emphasis shifted toward identifying gaps in climate change adaptation and mitigation actions and co-creating climate services in collaboration with selected users from various sectors, such as companies and organizations. These users were identified through previous collaborations and were engaged in advance by the course teachers.

To promote engagement and a sense of community in the online learning environment, group formation was revised to occur twice during the course. During the first lecture, if more than 30 students attend online, one responsible teacher and two assistants are present to support interaction and coordination. The first grouping takes place in week 1, and is designed to facilitate collaborative assignments, helping students to find mutual support and engage in collective learning, thereby reducing

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isolation and encouraging sustained participation and commitment throughout the course. The second grouping takes place in week 5, when students start working on the real-life project, allowing formation of new teams based on project interests.

Ultimately, the final course timeline and structure were developed as illustrated in Fig. 3. Following these refinements, the course was officially published in October 2023 and subsequently delivered at the University of Helsinki.

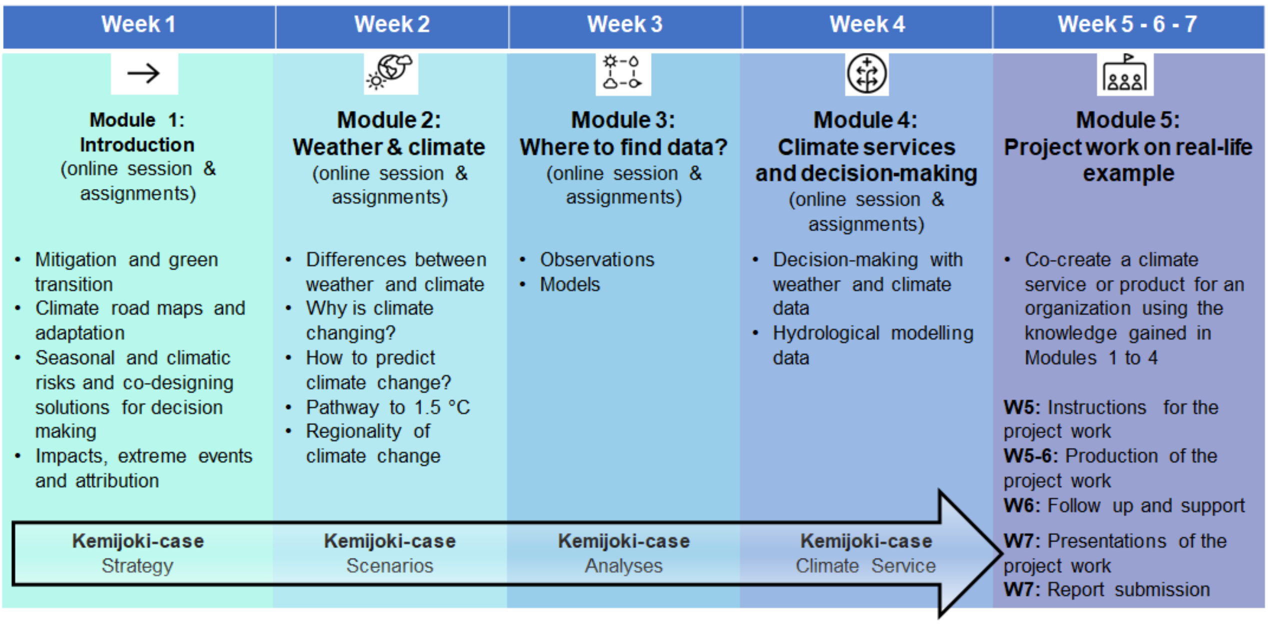

Figure 3: The reorganized course structure and schedule as published in the final version of the course.

4 Challenges and lessons learned

Designing an educational course with a specific scope shares many similarities with developing climate services. In both cases, the process follows a structured design and development cycle aimed at delivering outcomes that effectively meet the needs of end users (Fig. 4).

The primary goal was to create a novel course that strengthens students' climate expertise by fostering their understanding of the causes and complexity of climate change, and by enabling the application of climate data, analyses, and tools to support data-driven decision-making and climate action. This required integrating the knowledge of climate modellers, impact modellers, and climate service developers and overcoming challenges such as combining expertise from climate and educational sciences and selecting appropriate data sources and climate applications. To meet this need, experts from diverse fields were invited to co-develop and pilot the course, bringing interdisciplinary experience on science, data and climate

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services and transdisciplinary education. The learning objectives and activities were co-designed through multiple collaborative meetings, to ensure the course content reflected a broad, integrated perspective.

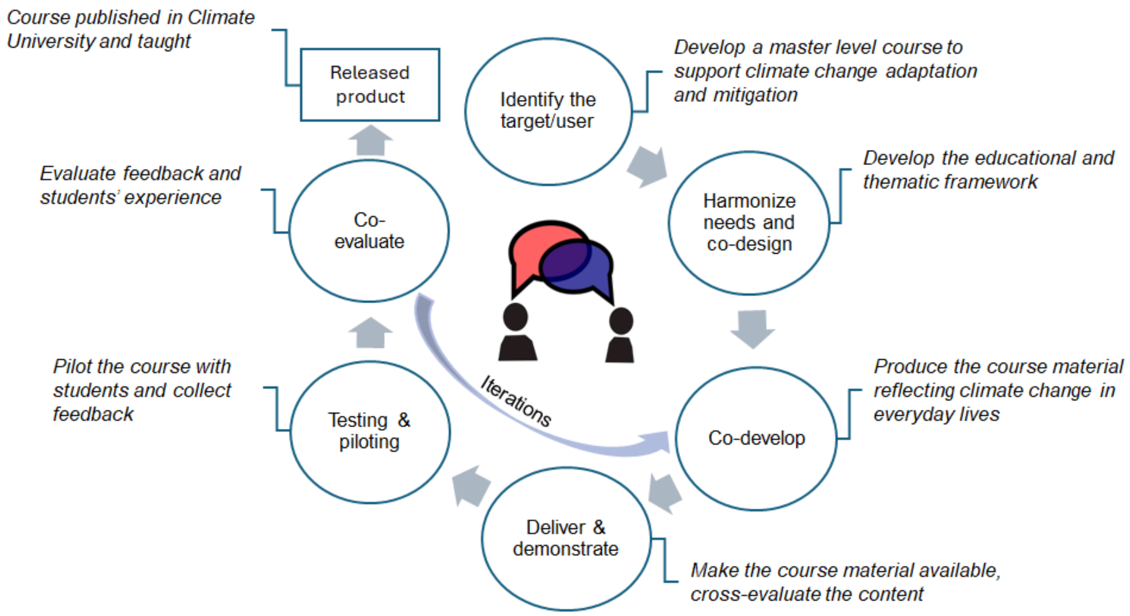

Figure 4: Parallel processes in the co-creation of a climate service and an educational course, emphasizing shared principles.

Design documentation and expert reflections revealed several key challenges in course development. These were refined through inductive document analysis, leading to the identification of three interconnected areas of design challenges, each addressed with practical solutions co-developed by the multidisciplinary team.

1. Challenges related to teaching transdisciplinary climate expertise and linking the broad range of topics.
Solution: Assemble a team of experts from various disciplines and educational sciences to co-design the course ensuring that the content reflects a genuinely transdisciplinary approach.

2. Challenges related to ensuring relevance to climate action in professional context.
Solution: Conduct interviews with end-users (e.g., companies, city authorities and other organizations) to understand their needs and use of climate information.

3. Challenges related to designing an online course for students with diverse academic backgrounds.
Solution: Create adaptable course materials and assignments tailored to varying skill levels and academic background.
These interconnected challenges and their solutions are discussed in detail below.

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4.1 Teaching transdisciplinary climate expertise and linking the broad range of topics

Developing a novel online course that teaches transdisciplinary climate expertise and integrates a broad range of topics in a collaborative manner requires a shared understanding of existing concepts as well as alignment with previously developed courses. To ensure both scientific rigor and pedagogical relevance, the course was co-designed by experts in climate science, impact modelling, climate services and educational sciences. It was essential that this diverse expertise is actively engaged not only in the initial design phase but throughout the entire development process of the course. Collaboration and ongoing development of the course can be supported through design workshops, and analysis of course feedback and experiences after each implementation.

During the design of the course, reviewing prior materials and reaching consensus on the course's difficulty level and its connections to other offerings proved time-intensive but critical for setting appropriate development goals. Here, the challenge of transdisciplinarity was closely associated with the challenge of designing the course for students with diverse academic backgrounds. Identifying the target student audience, including their backgrounds and learning needs, was a key factor for the course's success.

Collaboration with educational experts and teachers experienced in using blended and online learning environments was also vital in designing the course. In a digital format, teachers must consider effective strategies for fostering engagement and creating optimal learning moments. This includes carefully selected content formats, designing engaging questions that stimulate curiosity and critical thinking, deepening understanding and building relevant skills. For example, a hands-on session was integrated into the lecture to familiarize students with existing climate applications and their practical relevance. This approach not only enhanced students' understanding but also increased their motivation to use climate applications for mitigation and adaptation purposes. In climate change education, computational and data relevant skills should be emphasized, and assignments optimized for online delivery.

Piloting the course was seen essential for refining its goals, improving pedagogical approaches used and ensuring the technical functionality, especially regarding compatibility with expected dataset download requirements. Piloting the first version of the course proved extremely valuable and provided critical insights. Feedback from students and volunteers highlighted areas for improvement, from course setup and the online learning environment to the creation of effective learning moments. These insights informed meaningful adjustments and refinements to both course content and scheduling (see Sect. 3.3) enhancing the overall learning experience.

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4.2 Ensuring relevance to climate action in professional context

As highlighted by the interview study with climate experts and leaders, future climate professionals need to develop a systemic and holistic understanding of climate change within their professional fields (Siponen et al., 2024). To address this need, a deliberate decision was made to provide students the opportunities to engage directly with users, such as companies and organizations, through real-life project work and study visits. Organizing such activities requires identifying suitable partners and defining clear learning goals and structures for the visits to ensure meaningful interaction. Ultimately, this engagement proved highly valuable in helping students to understand the practical challenges of addressing climate change in a societal context.

Given the societal relevance of the course topic, identifying real-world use cases was relatively straightforward. However, early engagement with users is essential. Teachers should initiate contacts well in advance to define suitable challenges aligned with course objectives. Ideally, users should benefit from the students' work and be available for introductory meetings even before the course officially begins. Discussions between students and user representatives should begin early enough, to ensure mutual understanding and alignment regarding climate service needs. Once real-life project assignments are introduced and selected, students can form groups based on their interest in climate action and the user profiles. Teachers, however, should ensure balanced group sizes and diverse expertise within each group, as also user needs are often multidisciplinary in nature.

4.3 Designing an online course for students with diverse academic backgrounds

Another key challenge was accommodating students' diverse academic backgrounds and skill levels. For example, a student with a social sciences background excelled in assignments requiring qualitative reasoning but struggled with basic climate physics equations. This highlights the need for assignments that support varied disciplinary strengths and learning styles.

The online format of the course introduced further challenges. Students were less likely to ask questions during lectures than in a classroom setting and teachers lacked visual cues to assess comprehension, making it more difficult for teachers to identify when clarification was needed or if students are following the lecture.

Given the course's transdisciplinary nature and divers student backgrounds, two considerations emerged. First, the prerequisite knowledge required for the course (such as prior completion of other Climate University courses) should be clearly communicated to potential students, not only listed on the course webpage but also emphasized during initial lectures. At the same time, prerequisites should not be overly restrictive. Instead, the course should offer layered content, ranging from introductory overviews to more advanced material with up-to-date references. Additionally, some of the required background information can be included on the course platform as optional material to support students lacking specific foundational

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knowledge. For example, following the pilot stage, a short section on basic statistics was added for students who had not completed the Climate University statistics course.

To ensure effective online teaching, the teacher should actively engage students during lectures. While asking questions during lectures is a common approach, the pilot revealed that students were often hesitant to respond, possibly due to fear of being wrong or unfamiliarity with the online platform. Better results were achieved when using interactive online tools, such as short quizzes or polls related to the lecture topic, and through group work on specific issues, fostering interaction and deeper understanding. However, this approach requires teachers to be familiar with these tools and to provide clear instructions to students on their use.

5 Conclusion

In conclusion, the development and piloting of the *Living with Changing Climate* course demonstrate how higher education can play a pivotal role in strengthening user-centred climate services by equipping students with transdisciplinary climate action competencies. The design-based research process revealed both opportunities and challenges in integrating climate science, climate services, and user engagement into a coherent online learning environment for diverse learners. While the small-scale pilot limits the generalizability of findings, the iterative refinements offer practical strategies for addressing disciplinary diversity, enhancing online engagement, and linking academic learning with real-world climate service needs. More broadly, this work illustrates how transdisciplinary climate education can serve as a model for building professional capacity for adaptation and mitigation across sectors, thereby advancing both climate literacy and the societal relevance of climate services.

Data availability

All the material of Living with changing climate course is available at https://www.climateuniversity.fi/living-with-changing-climate/.

Supplement link

The link to the supplement will be included by Copernicus, if applicable.

Author contributions

All authors have been involved in the course development. VA, GH, KN, MA, MR, MJ, RP, YI and BA produced the course material. VA, HG, MA, MR, MJ and PR piloted the course. AV prepared the original manuscript draft with input from MA,

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GH, KN, MR, MJ, RP, VVM, YI and RL. AV and AM produced the figures. All co-authors reviewed, edited or commented on the final manuscript. RL and GH procured funding for the ClimComp project.

Competing interests

The authors declare that they have no conflict of interest.

Ethical statement

The study follows the ethical guidelines of the University of Helsinki, and no ethical clearance was required.

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The review statement will be added by Copernicus Publications listing the handling editor as well as all contributing referees according to their status anonymous or identified.

References

Barab, S. and Squire, K.: Design-based research: Putting a stake in the ground, J. Learn. Sci., 13, 1–14, https://doi.org/10.1207/s15327809jls1301_1, 2004.

Bowen, G. A.: Document analysis as a qualitative research method, Qual. Res. J., 9, 27–40, https://doi.org/10.3316/QRJ0902027, 2009.

Climate University: https://www.climateuniversity.fi/, last access: November 2025.

Corbin, J. and Strauss, A.: Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, 3rd edn., Sage, Thousand Oaks, CA, USA, 2008.

Dasgupta, P.: The Economics of Biodiversity: The Dasgupta Review, full report, HM Treasury, London, UK, https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review, 2021. Last access: February 2024.

Edelson, D. C.: Design research: What we learn when we engage in design, J. Learn. Sci., 11, 105–121, https://doi.org/10.1207/S15327809JLS1101_4, 2002.

Eilam, E.: Climate change education: the problem with walking away from disciplines, Stud. Sci. Educ., 58, 231–264, https://doi.org/10.1080/03057267.2021.2011589, 2022.

Elo, S. and Kyngäs, S. H.: The qualitative content analysis process, J. Adv. Nurs., 62, 107–115, https://doi.org/10.1111/j.1365-2648.2007.04569.x, 2008.

IPCC: Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R., and Zhou, B., Cambridge University Press, Cambridge, UK, and New York, NY, USA, https://doi.org/10.1017/9781009157896, 2021.

Jorgenson, S. N., Stephens, J. C., and White, B.: Environmental education in transition: A critical review of recent research on climate change and energy education, J. Environ. Educ., 50, 160–171, https://doi.org/10.1080/00958964.2019.1604478, 2019.

Master's Programme in Atmospheric Sciences (ATM-MP), University of Helsinki: https://www.helsinki.fi/en/degree-programmes/meteorology-atmospheric-and-climate-system-sciences-masters-programme, last access: November 2025.

Molthan-Hill, P., Worsfold, N., Nagy, G. J., Leal Filho, W., and Mifsud, M.: Climate change education for universities: A conceptual framework from an international study, J. Clean. Prod., 226, 1092–1101, https://doi.org/10.1016/j.jclepro.2019.04.053, 2019.

Nieveen, N.: Prototyping to reach product quality, in: Design Approaches and Tools in Education and Training, edited by: van den Akker, J., Branch, R. M., Gustafson, K., Nieveen, N., and Plomp, T., Kluwer Academic Publishers, Boston, MA, USA, 125–136, 1999.

Patton, M. Q.: Qualitative Evaluation and Research Methods, 2nd edn., Sage, Newbury Park, CA, USA, 532 pp, ISBN 0803937792, 1990.

Riuttanen, L., Ruuskanen, T., Äijälä, M., and Lauri, A.: Society needs experts with climate change competencies – What is the role of higher education in atmospheric and Earth system sciences?, Tellus B, 73, 1–14, https://doi.org/10.1080/16000889.2021.1917862, 2021.

Rousell, D. and Cutter-Mackenzie-Knowles, A.: A systematic review of climate education: Giving children and young people a "voice" and a "hand" in redressing climate change, Child. Geogr., 18, 191–208, https://doi.org/10.1080/14733285.2019.1614532, 2020.

Salovaara, J. J., Vesterinen, V. M., and Siponen, J. O.: Envisioning educational pathways for climate change competencies: Insights from a Delphi study, J. Environ. Educ., 56, 195–207, https://doi.org/10.1080/00958964.2025.2471966, 2025.

Siponen, J., Salovaara, J. J., Santala, M., Vesterinen, V. M., Tolppanen, S., Lauri, A., and Riuttanen, L.: Climate change competence – a view of professionals advancing climate change action, Environ. Educ. Res., 1–23, https://doi.org/10.1080/13504622.2024.2431200, 2024.

Stott, P., Stone, D., and Allen, M.: Human contribution to the European heatwave of 2003, Nature, 432, 610–614, https://doi.org/10.1038/nature03089, 2004.

The Design-Based Research Collective: Design-based research: An emerging paradigm for educational inquiry, Educ. Res., 32, 5–8, https://doi.org/10.3102/0013189X032001005, 2003.

Tolppanen, S., Cantell, H., Aarnio-Linnanvuori, E., and Lehtonen, A.: Pirullisen ongelman äärellä – kokonaisvaltaisen ilmastokasvatuksen malli [Dealing with a wicked problem – A model for holistic climate change education], Kasvatus, 5, 456–468, 2017.

Vilhunen, E., Vesterinen, V. M., Äijälä, M., Salovaara, J., Siponen, J., Lavonen, J., and Riuttanen, L.: Promoting university students' situational engagement in online learning for climate education, Internet High. Educ., 65, 100987, https://doi.org/10.1016/j.iheduc.2024.100987, 2025.

World Meteorological Organization: What are climate services?, https://gfcs.wmo.int/site/global-framework-climate-services-gfcs/what-are-climate-services, last access: February 2025.

Young, C. and Perović, N.: Rapid and creative course design: As easy as ABC?, in Procedia – Social and Behavioral Sciences, 2nd International Conference on Higher Education Advances, HEAd'16, Domenech, J., Vincent-Vela, M., Peña-Ortiz, R., de la Poza, E., and Blazquez, D. (eds), València, Spain, 21–23 June 2016, 2016.