Chapter 4

Digital Technologies for Climate Education

A Scoping Review of Empirical Studies

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Introduction

Since the signing of the Kyoto Protocol in 1997, the countries of the European Union have made an intensified effort to prevent climate changes caused by industrial development. The EU and international organizations such as the United Nations have undertaken several major ecological and sustainable initiatives in the last two decades. Such initiatives as the Green Climate Fund (2010), the UN's 2030 Agenda of 17 Sustainable Development Goals (SDGs), and the Green Deal strategy (2019) directly aim to improve the climate situation globally. However, in addition to large-scale solutions, it is equally essential to educate

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people on climate change, ecological issues, and their countermeasures. Climate change impacts all aspects of human life (Ofori et al., 2023). Awareness of its effects and consequences, both potential and already occurring, seems crucial not only in the broad debate on the environment but also in the sphere of education. This necessity is a challenge for modern education institutions. The challenge lies in how environmental education can and should be conducted.

Researchers have questioned the necessity of using technology in environmental teaching and learning (Greenwood and Hougham, 2015), naming the fact that computer-mediated technologies tend to distort the human-environment relationship as a reason for that (Bowers, 2006). Furthermore, some educational institutions' implementations of new technologies are negatively labeled *technosolutionism* or are even considered a form of greenwashing, i.e., the deceptive presentation of exaggerated or false claims about these institutions' environmental practices (Stein, 2023). However, many studies show not only the necessity of environmental education but also the efforts undertaken, particularly by higher educational institutions (HEIs) worldwide, to teach about climate change and environmental issues (Li and Liu, 2022; Xabregas and Brasileiro, 2023).

HEIs Higher educational institutions play a vital role in climate-related education because they not only build knowledge through research but also provide possible solutions, thereby equipping both current and future leaders with the tools necessary to confront environmental challenges (Leal Filho et al., 2023). However, problems with climate education at universities do exist and need to be addressed. As stated previously, universities are responsible for educating on climate change, thereby building students' environmental awareness and allowing them to recognize environmental processes and problems, all of which leads to pro-environmental behavior and protective ecological behavior in everyday life (Kousar et al., 2022; Yeung, 1998).

In studies focused on educational process it is mentioned that university courses related to health and engineering do not cover climate change issues, even though these areas are closely linked to the environment (Axelithioti et al., 2023; Palmeiro-Silva et al., 2021). Nevertheless, research indicates that students are aware of the importance of these problems, even if they are not part of curricula. Students recognize human interference with nature as the main cause of climate change (Nadeem and Nawaz, 2023).

In studies focusing on teachers in connection with environmental issues, it was observed that even though some teachers had general knowledge about climate change, they often had an ambiguous or wrong understanding of the concepts of climate change, global climate warming, greenhouse effects, and the interrelatedness of these issues (Wan et al., 2023). This shows the necessity of conducting a broader information campaign about environmental issues that targets teachers.

Learning and teaching about climate change is complex. Studies suggest that teacher education is the first challenge in implementing effective climate change education. Research states that teachers must develop an extensive knowledge base in order to design and carry out effective climate education (Favier et al., 2021), and such efforts are necessary at every level of education. The second challenge in introducing environmental education into didactic practice is that it requires an interdisciplinary approach, whereas current research clearly shows that it is inherently a multidisciplinary endeavor (Mohan et al., 2023) that requires a broad spectrum of competencies. Studies show that international policies for sustainability education are expected to be introduced in educational processes; however, barriers to doing so can be observed both at the level of curricula and in the education system as a whole (Parry and Metzger, 2023).

As for the means of building students' awareness, different positions are taken by researchers. There is a worldwide discussion regarding sustainable pedagogy at higher-education institutions, but the nature of the content that should be included in climate change education (Fuertes-Camacho et al., 2019) and how it should be conveyed (Seatter and Ceulemans, 2017) is well established. The Burns Model of Sustainability Pedagogy introduced a set of elements to be included in university courses: ecological design, systemic and interdisciplinary learning, active and engaged learning processes, and attention to place-based learning (Burns, 2009). It is clear that sustainability education at higher levels of education requires varied pedagogical approaches so that students may gain broad experience of environmental issues through methods such as problem-based learning and experiential learning (Missimer and Connell, 2012). Also, action-oriented learning processes have been shown to foster thinking across disciplines (Loeber et al., 2007). Such approaches are consistent with the constructivist learning perspective, in which students are challenged to develop responses to defined problems, eventually deriving solutions through case studies and

active participation involving brainstorming, dialogue, and teamwork (Seatter and Ceulemans, 2017). More profound engagement is also possible through critical self-reflection (Elder et al., 2023).

Another aspect considered in many studies on climate change education is the use of information and communication technology (ICT) in environmental education. The urgency of climate change and the rapid development of ICT both represent a challenge for higher education institutions (HEIs) as they are forced to reconsider their traditional ways of teaching (Versteijlen and Wals, 2023). For example, teaching formats such as webinars could reduce the carbon footprint of students and staff. Researchers also mention some activities undertaken by university students or teachers that involve forms of transport that generate environmental problems and are considered to have a social impact on the environment (Baer, 2023; Shields and Lu, 2023). Online education tools, such as online classrooms and tutorials, can provide significant advantages, such as reduced need for infrastructure and reduced carbon emissions (Alla and Chen, 2017). However, researchers are aware that certain obstacles must be overcome when introducing ICT in environmental education: structural barriers, i.e., lack of support and incentives for interdisciplinary teaching and community-based research; cultural barriers, understood as biases towards specific disciplines, or lack of experience and knowledge about interdisciplinary or experiential teaching; and, finally, financial barriers, namely insufficient resources (Wade et al., 2020).

Despite the complexity of climate education and the myriad opinions regarding its effective implementation, awareness of the gravity of climate-related issues prompted us to look for examples of digital tools used in climate education at the higher education level. The research questions for this chapter are as follows:

RQ1: Does climate education use digital tools in higher-education teaching processes?

RQ2: Which digital tools are implemented in climate education in higher education?

The answers to these research questions allowed us to achieve the objective of our paper: to reveal the digital tools used in higher-education climate education that have been presented in the literature in the last five years.

Methods and Materials

This section describes the sequential phases of the analysis undertaken. Given the broad thematic spectrum encompassed by this investigation, the scoping review methodology was used, incorporating the initial five stages of the methodological framework articulated by Arksey and O'Malley (2005), with subsequent refinements of Levac (2010). While initially tailored for use in medical science, the scoping review framework, which encompasses educational tools and methodologies, has also been used in educational research (Adnan and Xiao, 2023; Jaleniauskiene and Kasperiuniene, 2023; Sormunen et al., 2022).

The scoping review was conducted to investigate the implementation of tools and teaching methods in teaching about climate change at higher-education institutions. According to Arksey and O'Malley's (2005) methodological framework, the research steps can be described as follows:

- formulation of research questions,
- identification of appropriate academic works,
- selection of pertinent studies,
- systematic charting of collated data,
- compilation and explication of ascertained outcomes.

HEIs' didactic processes, focusing on climate change as the topic of courses in these institutions. The next step was to find scientific papers relevant to the topic which had been published in the last five years (2019 to 2023) by searching the Scopus and Web of Science databases. We decided to use these two databases because they are the most extensive abstract and citation databases for academic literature. We did not search for papers in the Google Scholar database because although this database covers every document which contains the defined keywords, it also includes works that are not necessarily scientific or peer-reviewed. Combinations of the following search terms and subheadings were considered appropriate for the conducted study: "Climate change", "Climate education", "Climate AND education", "Climate change AND education", and "higher education" or "HEI". Quantitative search results for the defined key phrases are presented in Table 1.

Next, we defined inclusion and exclusion criteria to limit the resources found. We restricted the original research papers (published between January 2019 and November 2023) to those written in English that describe tools (including digital tools) and methods used in higher-

Table 1: Key search phrases and search results in Scopus and Web of Science databases.

	Scopus	**Web of Science**
"Climate change" AND "higher education"	530	493
"Climate education" AND "higher education"	11	8
"Climate change" AND education AND hei	27	15
"Climate" AND education AND hei"	45	19
Total:	613	535

education teaching. We did not use any further exclusions regarding, for instance, study type (e.g., book chapters or editorials), or methodologies (e.g., expert reviews, systematic reviews, scoping reviews, and narrative reviews). While searching for relevant papers that would later be used for the data extraction, we first removed papers that appeared in both databases. At that point, the initial number of 1148 papers was reduced to 766. The next step was title scanning. For further analysis, we agreed that a paper title should include a type of tool or method used in climate change education, and that this information should be combined with the field of study in which this tool or method was implemented. We eliminated all papers with unrelated titles. The number of papers remaining after title scanning was 320.

The next step was analysis of the papers' abstracts. We asked such questions as: Is this paper relevant to this study? Does it focus on higher education? Does it present information on teaching tools and methods? Is this study original? We eliminated all papers showing any form of a literature review. This reduced the total number of papers qualified for inclusion to 113. The last stage of elimination focused on access to the full papers. Since not every paper was accessible as a full text in the online databases, we established the final number of 61 papers in the study.

During the analysis of the included publications, Cicha and Rutecka's (2023) catalog of methods and digital tools used in higher education was utilized. This catalog identifies 29 categories of tools and methods applied in teaching and learning. During this review, one or more categories from the list were assigned to the publications analyzed in this study. Not all categories from the previous catalog could be assigned. In the publications that qualified for the study, we found only 18 methods and tools of modern digital education of the 29 identified in Cicha and Rutecka's catalog (2023). Some publications focus generally on frameworks without specifying the exact tools used or on frameworks

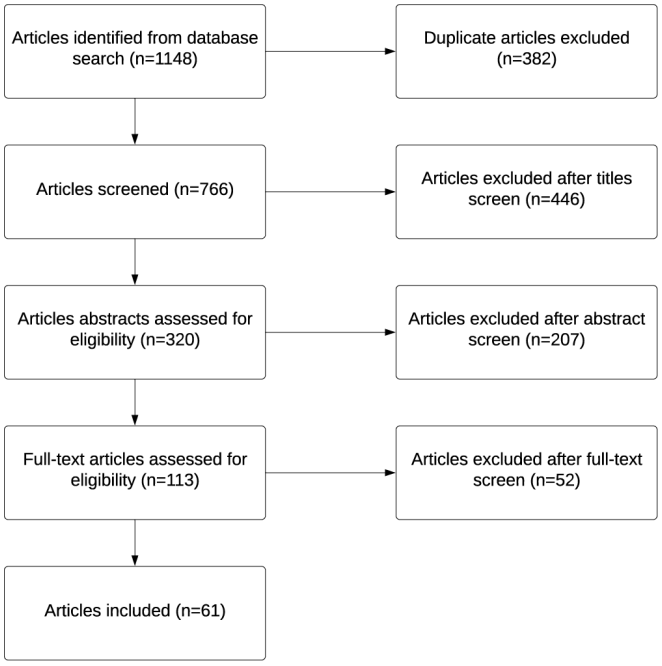

Figure 1: Steps in the elimination of papers in the conducted research.

that do not employ any tools. Such frameworks include COIL (Collaborative Online International Learning) and CLEWs (Climate, Land-use, Energy and Water Systems), which were either combined in a single category or included in another adequate category.

Results

The first result obtained during the scoping review was quantitative information about the number of papers in which authors indicated the type of digital tool and the scope of its use in climate education. Unfortunately, considering that the scoping review included publications from a period of five years, the number of papers describing the usage of digital tools in environmental education is low (only 61). When trying to categorize digital tools used in climate change education, we noticed that there are 17 specific categories and an "Other" category that contains tools that do not fit into any other category. The categories used to assign digital climate education tools in higher education refer to the previously conducted study on the use of digital techniques in higher

education (Cicha and Rutecka, 2023). Figure 2 shows the categories and the number of studies that reported their use in climate education.

Within the methods listed in the catalog, the most frequently used is the game-based approach, especially with serious games designed for education purposes. Game-based learning is about developing new concepts and skills through digital and non-digital games (Adipat et al., 2021). This method is considered advantageous in increasing students' motivation and engagement (Adipat et al., 2021), teamwork and team building (Dichev and Dicheva, 2017), and risk-taking and experimentation (Martí-Parreño et al., 2016). In the analyzed studies, game-based teaching built on, for example, role-playing environments, was pointed out as beneficial for students in terms of decision-making (Stoeth and Carter, 2023), familiarizing students with the complex interactive characteristics of such systems (Thompson et al., 2022), and increasing students' engagement concerning climate change-related issues (Vázquez-Vílchez et al., 2021).

Video communication refers to tools for real-time audiovisual transmission. As for the use of video communication in climate education, the possibility of increasing internationalization by exchanging experiences and views on climate change in a global environment is pointed out as an advantage (Falkenberg and Joyce, 2023). Other advantages include expanding students' knowledge on environmental issues (Straßer et al., 2023) and more efficient access to and use of up-to-date information (Baptista et al., 2021). It is worth mentioning that many

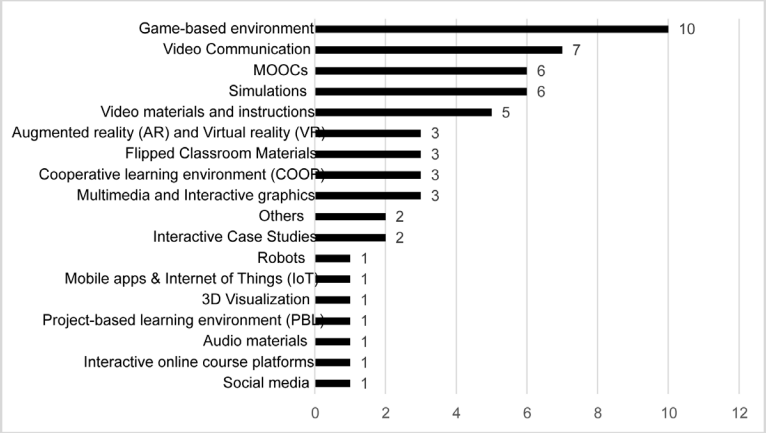

Figure 2: Digital tools for sustainable education.

of the analyzed studies were conducted during the COVID-19 pandemic, therefore the use of certain ICT solutions was not a carefully planned educational choice but was forced by the situation in many cases. Nevertheless, students' use of video communication tools allows them to avoid carbon-intensive transport and overcome barriers in research participation (Elder et al., 2023).

An interesting form of teaching about climate change is simulation. By using specially designed tools in, for instance, architecture studies, students can improve their building designs by simulating their environmental costs (de Gaulmyn and Dupre, 2019). Also in engineering, active learning is supported by simulations of energy management platforms for smart and green building design (Apichayakul et al., 2020). Technological progress has allowed universities to introduce Massive Open Online Courses (MOOCs) in teaching practice. This technology is considered one of the most engaging for students (Senevirathne et al., 2022) and it has been demonstrated that implementing MOOCs in environmental education can support networking development (Senevirathne et al., 2021) and attract participants within low-resource contexts (Barteit et al., 2019).

The use of video-based materials and tutorials in the climate change teaching process (indicated five times in the studied papers) refers, for instance, to implementing environmental films paired with viewer-response activities such as reflections and discussions to create emotional engagement (Esmail and Matthews-Roper, 2022). Video materials have also been used as additional elements of broad educational projects (Membrillo-Hernández et al., 2023). Multimedia and interactive graphics (indicated three times) are also used as tools for illustrating climate change issues (Cotton et al., 2023). Despite the simplicity of their use, in the analyzed studies they are used less often than video materials.

Using tools classified as Augmented reality (AR) and Virtual reality (VR) is a very interesting solution in the context of climate education. However, although this solution can be used for various purposes, it does not appear often enough in the papers we have analyzed. In Pavlova et al. (2020), for example, the authors suggest using virtual reality technologies to learn foreign languages, including specialized vocabulary that is helpful in understanding environmental issues. Membrillo-Hernández et al. propose the use of virtual reality to transfer the environment known as the Global Classroom, i.e., classes on an international scale operating in an online environment, to the Metaverse (Membrillo-Hernández, Cuervo-Bejarano, Mejía-Manzano, et al., 2023), and geoscientists have

proposed learning with the AR/VR-based "GeoTrails" tool, which offers students virtual field trips (Maloney et al., 2023).

Flipped classroom materials are educational materials, such as previously recorded video lectures, that are prepared and made available to students electronically. This method of delivering materials minimizes waste and reduces the carbon footprint associated with printing materials (Mulla and Ratnayake, 2020). Thanks to the fact that materials are made available to students before face-to-face classes, they have time to become familiar with the material and can implement active learning strategies for the classroom (Tomas et al., 2019). This approach increases students' engagement, and they perform better and demonstrate increased awareness of climate issues (Jeong et al., 2021).

Studies have noted that students' engagement was higher when they carried out projects collaboratively or created teams that could compete with each other. One example of a cooperative learning environment (COOP) was a board game in a virtual space that students played in teams (Vázquez-Vílchez et al., 2021). This approach was also used in an international educational project that involved seven European universities (De Stefani and Han, 2022).

Other methods mentioned in the study included Interactive Case Studies (indicated 2 times), Social media (1), Interactive online course platforms (1), Audio materials (1), 3D Visualization (1), Mobile apps & Internet of Things (1) and Robots (1). Project-based learning environments were also rarely mentioned (1), but Problem-based Learning (PbBL) was mentioned six times. In the analysis, project-based learning and problem-based learning were classified as variations of the Challenge-based learning (CBL) approach, which appeared in 17 studies, but the primary form of conducting educational activities for students was not indicated. The advantage of the challenge-based approach is students' involvement in designing solutions for real environmental and social problems. Two publications describe the use of the COIL method, which is dedicated to teaching about climate change problems in an online environment and is based on cooperation between groups of students from universities in different countries (Membrillo-Hernández, Cuervo-Bejarano and Vázquez-Villegas, 2023; Membrillo-Hernández, Cuervo-Bejarano, Mejía-Manzano et al., 2023). One publication describes a method of working with students using online tools to carry out a sustainability audit (Emblen-Perry, 2019); another describes the use of eye-tracking, (Södervik and Vilppu, 2021). These tools were not previously included in the catalog (Cicha and Rutecka, 2023).

Discussion

The methods found in the papers we analyzed primarily suggest that teaching should be associated with challenges and increase student engagement in facing real-world problems (Gregory and Lewin, 2023). The described methods include student-centered learning (Van Heuvelen et al., 2020), active learning (Bartlett et al., 2022; Emblen-Perry, 2019; Leichenko and O'Brien, 2020), experiential learning also called learning by doing (Elder et al., 2023; Wade et al., 2020), and collaborative learning (Capetola et al., 2022; Versteijlen and Wals, 2023). The studies also emphasize the importance of interdisciplinarity as it gives students a broad perspective (Capetola et al., 2022; Wade et al., 2020). Essential competencies in the field of solving climate problems include effective communication skills (Wade et al., 2020), which can be successfully developed thanks to digital tools. In this case, digital tools can also help in international communication and strengthen cooperation between students of different cultures, thus helping them to discover other points of view. Unfortunately, according to the analyzed publications, ICT tools are often not utilized for this purpose. Among the publications that qualified for the study, some focused on Challenge-based Learning (CBL) or indicated that digital tools or online tools had been used to implement teaching under the CBL model. CBL uses a mix of basic digital tools, such as videos or online communication.

Several recurring themes were observed in the publications for which we have analyzed the full text but which we did not ultimately include in the study because they did not specify a particular teaching method or tool. These studies primarily focused on the carbon footprint of international travel and of commuting to on-campus classes (Versteijlen and Wals, 2023). It was also frequently noted that climate change and sustainable development issues are not sufficiently addressed in study programs and course curricula, and that there are discrepancies in students' climate change awareness depending on a university's location or students' gender, age, or study program.

The research by Versteijlen and Wals (2023) was generally dedicated to sustainability-oriented blended learning; these authors analyzed 38 papers to determine the methods by which blended learning is introduced into the education process. They revealed various types of flipped classroom learning with the usage of online discussions and quizzes, physical and virtual labs, video lectures, interactive online textbooks, gamification, etc. Although the topics (e.g., Project management, English,

ICT, Medical science) of the courses that applied blended learning were not directly connected to climate change, through the use of online or blended learning each of these courses reduced negative effects on the environment by allowing the students not to travel to their HEIs to study.

Although they are not based on digital tools, two of the most interesting and frequently mentioned approaches to teaching about climate change and sustainable development that were revealed in the analyzed publications are Arts-based approaches and Living Lab. The latter was mentioned in the rejected studies as many as six times. Universities can reflect society on a micro scale, thus they are an excellent field for conducting research and testing innovations as a "living laboratory" (Martek et al., 2022). As the research shows, this approach is currently implemented on a small scale and often fragmentarily, but researchers postulate that this state should be changed.

Crosling et al. (2020) explored academic university staff's knowledge of sustainability, their attitudes to it, as well as the pedagogical approaches they use to educate their students. Crosling et al.'s study resulted in a list of pedagogical techniques that are used to conduct education on sustainability development. The most frequently used techniques they revealed include case study analyses, experiments, scenario development and analysis, organizing sustainability development days (at local, regional, and national levels), training sessions and awareness campaigns. Although this study was not dedicated to digital tools and not many applications of e-learning were mentioned, we believe that these conclusions are a great contribution both to climate change education in general and to digitalization of this education in particular. Most of the techniques presented in the study of Crosling et al. (2020) can be used either completely online or with blended learning. While being still effective for educational purposes, they would help diminish the carbon footprint by allowing students and teachers to stay at home instead of traveling to their place of study/work.

With a need to take a closer look at carbon footprints and traveling issues, as an important part of climate change awareness increase and education we could refer to the work of Nikula et al. (2023), which explores the internationalization of higher education and offers a few valuable observations. On the one hand, it turns out to be more emission-intensive to send teachers abroad to work in joint programs or other forms of transnational education than to employ local teaching staff. On the other hand, sending teachers abroad may have a smaller environmental cost than international travel for a large number of students. Although

international transport was not the topic of our research, we believe that our work, together with the other studies discussed in this paper, may contribute to the formation of effective principles of environmental education and, moreover, of environmental behavior in general.

Finally, an interesting conclusion was drawn from Kelly et al.'s (2023) research about teaching and learning for sustainability science. These authors revealed a connection between people's willingness to take action to support green policies and their previous experiences with the consequences of climate change. People may feel separated from the effects of climate change because they either live far from places which, as they believe, are most affected by climate change, or because they think climate change is something that will happen in the future. While reducing physical distance to the consequences of climate change is hardly possible, it is important to reduce people's psychological distance and raise awareness about sustainability and climate change, among others, through learning at HEIs. In addition to that, Yu et al. (Yu et al., 2020) highlighted the necessity of not only raising awareness but also building and increasing students' motivation to undertake pro-environmental actions (e.g., turning lights off after use or recycling garbage). In support of both these ideas, Fang (2021), after correlating students' awareness with their pro-environmental behavior, states that students' higher awareness of climate problems leads them to be more willing to take pro-environmental actions.

Conclusions

This scoping review identifies a significant but limited number of papers (61) published over the past five years that specifically addressed the use of digital tools in climate education at higher-education institutions. A diverse array of digital tools is being utilized in climate education, with game-based environments, video communication, MOOCs, simulations, and video materials being some of the most prevalent. The use of digital tools in climate education is found to be beneficial for increasing student motivation, facilitating international collaboration, enhancing knowledge on environmental issues, and providing up-to-date information. Tools like serious games and simulations are particularly noted for their effectiveness in engaging students with complex environmental issues. Despite the advantages, there are challenges in integrating digital tools into climate education, including structural barriers (such as a lack of interdisciplinary team teaching), cultural barriers (such as biases about

specific disciplines), and financial constraints. The research underscores the importance of active, experiential, collaborative, and challenge-based learning approaches in climate education.

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