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Heatwaves Awareness Education through Online Learning (HEAT)

WP2 - Deliverable n. 2.1a

Title:

Analysis of Current Climate Change Education Frameworks: Inventory of literature, national and international standards, reports, and books, referring to teaching climate change focusing on online education.

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Methodology

In order to create an inventory regarding the existing literature on climate change education and its teaching practices, researchers followed a series of steps for searching and organizing their findings. These steps are described below:

1. **Keyword selection:** Two coders agreed on the keywords that will be used for their research. These keywords were: “climate AND change AND education”, “teaching AND practices AND for AND climate AND change”, “sustainable AND education”.
2. **Search Engine selection:** The two coders defined the search engines on which they conducted their research and searched various platforms of published papers, books, and journals. The search engines they finally worked with were: Scopus, Taylor & Francis, and Google Scholar.
3. **Temporal Scope:** The search was done chronologically from the most recent publications to the oldest ones. In particular, the two coders focused on the publications of the last decade.
4. **Screening Process:** Publications were found based on their title and then on their abstract. As long as it was judged by the two coders that the title and the abstract were consistent with the requirements, they proceeded to the analysis of the entire publication. The coders gathered almost 180 publications. However, after the complete analysis, only 80 publications corresponded to the required criteria which were that the publication would include applied and assessed innovative methodology/ies and teaching practice/s for climate change education and those were the ones included in the inventory.
5. **Analysis:** During the analysis, the coders identified the research methodology, the size and type of the research sample and finally the research results regarding teaching practices for climate change education.
6. **Data Organization:** Finally, all the gathered data were organized in a database using Microsoft Excel.

Research findings

Throughout the research process, the researchers observed recurring methodologies and research findings. In particular, in terms of methodology, it is obvious that thematic analysis, questionnaires, pre- and post-tests and quasi-experimental designs dominated. Regarding the results for teaching practices, these could be organized into the following groups:

1. **Learning Methodologies:** These can be divided into two subcategories:

1a. Inquiry Based Learning: the learning process that engages students by making real-world connections through exploration and high-level questioning. Although in bibliography there are different ways to describe the inquiry based learning process (in 5 stages, in 7 stages and using different terms for each stage), the most of the papers propose the five stages framework (5e) (Friesen, 2013):

- a) **Engage:** students are engaged with a challenging situation, prior knowledge is activated, questions are provoked.

- b) Explore: students investigate the phenomenon, prior knowledge is challenged, ideas are created.
- c) Explain: students explain the phenomenon, knowledge is gained and applied.
- d) Elaborate: students apply their knowledge towards new situations.
- e) Evaluate: students reflect on their knowledge and the learning process assessment.

Inquiry Based Learning was the learning methodology found in 8 out of the 80 analyzed publications (10%). An exceptional example of the utilization of inquiry-based learning for teaching about climate change is the work by Busch, Henderson & Stevenson (2018) (code 38 in the database). The findings of this article imply that a lesson plan for climate change designed using inquiry-based learning can raise students' awareness regarding climate change, cultivate "climate change behavior" and motivate students to take action. The same conclusions were reached by Namdar (2018) (code 23 in the database), who claimed that through inquiry-based learning activities, the content knowledge of students was increased, while at the same time they were positively influenced as future decision-makers.

1b. Experiential Learning: This refers to the process of *learning by doing*. By engaging students in hands-on experiences and reflection, they are better able to connect theories they learned in the classroom and their knowledge to real-world situations (Gentry, 1990). This learning methodology was found in 4 publications out of the 80 (5%) included in the database. Characteristically, the article by Karpudewan & Mohd Ali Khan (2017) (code 35 in the database) indicates that experiential learning enables students to socially construct knowledge about climate change and at the same time satisfy their three basic needs: competence, autonomy and relatedness.

2. Learning Practices: In this category the researchers included all publications that were focusing on learning practices. This category is also subdivided in two groups:

2a. Authentic Learning Practices: A style of learning that encourages students to create a tangible, useful, quality outcome to be shared with their world (Herrington, 2014). This practice is followed in 7 publications (8,8%). The article by Jordan et al. (2019) (code 30 in the database) clarifies that students not only can be motivated about climate change, but they as well increase their trust in scientific data and scientific processes regarding climate change.

2b. Socioscientific Reasoning Practices (SSR practices): These practices focus on preparing students to form an opinion about Socioscientific Issues (SSI).¹ They consist of four elements: recognizing the complexity of SocioScientific issues (SSIs), the multiple perspectives around SSIs, the need for an ongoing inquiry around SSIs, and skepticism around different parties' claims made about SSIs (Sadler, 2011). This practice isn't clearly stated in specific articles; however, it is usually applied combined with other practices or methodologies. The article by Drewes, Henderson and

¹ Socioscientific issues (SSI) refer to complex and controversial scientific topics that have social, ethical, and moral implications. For example, climate change is a pressing global issue with scientific, economic, and social dimensions. Teaching about climate change enables students to understand the scientific evidence, explore the causes and consequences, and evaluate potential solutions and policies.

Mouza (2018) (code 32 in the database) utilizes SSR practices to teach climate change as an uppermost socioscientific issue. Incorporating decision-making, argumentation and conceptual mobility into teaching, proved to enable students not only to understand the main ideas and concepts of climate change but also to gain an increased understanding of the effect of human activity on this phenomenon.

3. Digitalization Techniques: This category includes these publications that were addressed to online education about climate change and in the description of their research and teaching methodology various digitalization techniques were used. For example, in their article Cox, Kelly and Yetter (2018) (code 27 in the database) utilize remote-sensing activities to teach about climate change. This approach turned out to be highly successful, as it managed to engage introductory and advanced students in authentic and relevant analysis of satellite data to explore climate change.

4. Indoor/Outdoor workshops: This category includes publications that were based on workshops in order to teach about climate change. Almost every such workshop was designed and developed by combining a learning practice or a learning methodology. Betul Cebesoy and Karisan (2022) in their research (code 24 in the database), suggested that an outdoor workshop at the forest, contributed to a better construction of the participants' cognitive structures and their conceptual understanding of climate change, as this teaching approach enhanced empathy skills and increased climate change awareness.

5. National and international standards: After the inventory based on the existing literature for the last 10 years was completed, the researchers went in search of national and international standards regarding climate change education. Behind thorough research in international literature and global organizations' documents (e.g. WHO, UNESCO, UN, UNICEF), some general guidelines about climate change education have been identified. Such an example is the report "Getting every school climate-ready: how countries are integrating climate change issues in Education" (UNESCO, 2021), being a review of the National Curriculum Frameworks of 100 countries on climate change education, end up with seven recommendations for climate change education:

1. Climate change education should be a core curriculum component in every country.
2. Greater focus on climate change content is needed in the curricula of countries most responsible for climate change.
3. Climate change education should be integrated across all levels and disciplines of learning.
4. Teachers and school leaders need to be prepared to teach climate change.
5. Climate change education must equally focus on 'head', 'heart', and 'hands' – and teachers need to be ready.
6. Climate change education should be woven into diverse aspects of countries' policies and programmes.
7. Ministries of Education and Environment can and should work together to boost climate change education.

More specific guidelines are included in the framework of the 2020 review of the Nationally Determined Contributions (NDCs) under the Paris Agreement with the title

“Integrating Action for Climate Empowerment into Nationally Determined Contributions” (UNESCO, 2020). This report aims to provide countries with advice on how to enhance ambition and address the six elements of ‘Action for Climate Empowerment’ (ACE) – Education, Training, Public Awareness, Public Access to Information, Public Participation, and International Cooperation – in their respective NDCs. According to this report, education enables people to understand the causes and consequences of climate change, to make informed decisions, and to take appropriate actions to address it. Education seeks to achieve profound, long-term changes in climate change understanding, particularly among young people. It involves developing educational curricula, training of trainers and teachers and adequate pedagogies. The results of a successful programme would ultimately reflect to a population whose deep-seated appreciation of the climate challenge leads to greater national action and commitment. In order to achieve the above recommendations, education for climate change should:

- Promote, facilitate, develop and implement formal, non-formal and informal climate education programmes that encourage climate-friendly behaviour, focusing on both mitigation and adaptation.
- Include climate change at all levels and across disciplines in both school and higher education curricula, as well as in technical and vocational education and training (TVET) and adult education, addressing the entire population.
- Develop pedagogical resources/materials that consider different knowledge systems, including indigenous knowledge, as well as local languages.
- Implement quality pre-service and in-service teacher training focused on climate change.

In conclusion, the literature regarding climate change education of the last decade includes a wealth of learning methodologies and practices. Through the research it becomes very clear that there are many good practices, implemented and assessed, that could be used as a basis in order to produce more innovative educational materials for climate change education. Combining prosperous learning methodologies and practices from this literature review with UNESCO’s guidelines for climate change education could help us produce an innovative international educational framework for climate change education that will focus on helping students to understand and address the causes and impacts of the climate crisis, empowering them with the knowledge, skills, values and attitudes needed to act as agents of change.

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Inventory of literature, national and international standards, reports, and books, referring to teaching climate change

Code	Journal	Paper title	Writer	Date	Sample number	Method	Sample grade	Practices
1	Journal of science teacher education	A Study of Teacher Candidates' Experiences Investigating Global Climate Change Within an Elementary Science Methods Course	Emily Hestness, J. Randy McGinnis, Kelly Riedinger & Gili Marbach-Ad	23 Feb 2017	Sixty-three undergraduate Elementary Education majors	quantitative and qualitative methods (Questionnaire/ Drawings/Journal Entries)	undergraduate Elementary Education majors	Authentic Learning
2	International Journal of Science Education	Assessing Elementary Science Methods Students' Understanding About Global Climate Change	Julie L. Lambert , Joan Lindgren & Robert Bleicher	17 Nov 2011	One hundred and forty-nine participants	KGCC Instrument (Knowledge of global climate change)/qualitative method	Undergraduate students/pre service teachers	inquiry-based science lessons
3	Journal of Science Teacher Education	Awakening the Scientist Inside: Global Climate Change and the Nature of Science in an Elementary Science Methods Course	Juanita Jo Matkins & Randy L. Bell	01 Mar 2017	15 students (all female)	qualitative method/ observation/workshets	undergraduate students	inquiry-based science lessons
4	International Research in Geographical and Environmental Education	Climate change and sustainable development perceptions of university students in Lahore, Pakistan	Obaidullah Nadeem & Mariyum Nawaz	16 Dec 2022	400 students	Review of ineternational and local studies about perceptions for climate change	undergraduate students	discussion about climate adaption in one of the core courses
5	The Design Journal An International Journal for All Aspects of Design	Climate Change. Design Teaching for a New Reality	Paul Micklethwaite & Robert Knifton	06 Sep 2017	62 visitors	qualitative method/ observation	elementary and secondary students	Authentic Learning Activities in Science Museum

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6	Journal of Science Teacher Education	Climate Change Professional Development: Design, Implementation, and Initial Outcomes on Teacher Learning, Practice, and Student Beliefs	Nicole A. Shea, Chrystalla Mouza & Andrea Drewes	21 Feb 2017	81 participants	qualitative method/ interview/in-case study analysis	middle school teachers/ high school teachers/higher education teachers/informal science teachers	Research project
7	The Sociological Quarterly	Doing Our Part: Teaching about Environment and Climate Change	Julie A. Pelton	03 Mar 2022	There is no reference	bibliography research	There is no reference	discussion questions/summary of the key facts/role-playing
8	Journal of Geoscience Education	EarthLabs: Supporting Teacher Professional Development to Facilitate Effective Teaching of Climate Science	Katherine K. Ellins, Tamara Shapiro Ledley, Nick Haddad, Karen McNeal, Anne Gold, Susan Lynds & Julie Libarkin	09 Jul 2018	23 participants	qualitative method (observation/interviews)	teacher leaders	Earthlabs (combination of visualization technologies and authentic learning activities -workshops)
9	Environmental Education Research	Escape rooms as tools for climate change education: an exploration of initiatives	Tania Ouariachi & Elving J. L. Wim	20 Apr 2020	There is no reference	exploratory study	There is no reference	gamification-escape rooms
10	Research in Science & Technological Education	Examining Taiwanese students' views on climate change and the teaching of climate change in the context of higher education	Yuh-Yuh Li & Shu-Chiu Liu	22 Jan 2021	146 participants	preand post-course surveys including Likert-type, multiple choice and open-ended questions	undergraduate students	inquiry-based environmental course

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11	International Research in Geographical and Environmental Education	Exploring the pedagogical content knowledge of Danish geography teachers: teaching weather formation and climate change	Søren Witzel Clausen	19 Jul 2017	4 participants	case study	geography teachers	power point presentations, group work and worksheet, and practical work
12	Environmental Education Research	Identifying effective climate change education strategies: a systematic review of the research	Martha C. Monroe, Richard R. Plate, Annie Oxarart, Alison Bowers & Willandia A. Chaves	13 Aug 2017	959 unique citation	systematic review	citation records addressing climate change education.	engaging in deliberative discussions, (2) interacting with scientists, (3) addressing misconceptions, and (4) implementing school or community projects. Suggestions for addressing controversial topics like climate change
13	Journal of Geography in Higher Education	Learning to teach climate change: students in teacher training and their progression in pedagogical content knowledge	Tim Favier, Bouke Van Gorp, Jakob B. Cyvin & Jardar Cyvin	19 Jul 2021	There is no reference	qualitative methods- observation/Likert scale/online survey/interviews	pre service teachers	research posters/workshops
14	Journal of Geoscience Education	Navigating Climate Science in the Classroom: Teacher Preparation, Perceptions and Practices	Susan M. Buhr Sullivan, Tamara Shapiro Ledley, Susan E. Lynds & Anne U. Gold	14 Jun 2018	877 participants	qualitative/quantitative method	middle and high school teachers	short-duration workshops

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15	International Journal of Science Education, Part B Communication and Public Engagement	Polar Bears or People? Exploring Ways in Which Teachers Frame Climate Change in the Classroom	K.C. Busch	07 Apr 2015	25 lesson/7 participants	semiotic discourse analysis methods	teachers	projects inspiring e Social Discourse—local scale, impact on humans, and connections to social, economic, and political processes
16	Applied Environmental Education & Communication	Potential of ‘future workshop’ method for educating adolescents about climate change mitigation and adaptation: a case from Freistadt, Upper Austria	Oliver Gerald Schrot, Johannes Traxler, Ariane Weifner & Michael M. Kretzer	11 Sep 2020	41 participants	case study	students	Future workshop method
17	Environmental Education Research	Probing into the sources of ignorance: science teachers’ practices of constructing arguments or rebuttals to denialism of climate change	Asli Sezen-Barrie, Nicole Shea & Jenna Hope Borman	30 May 2017	24 participants	semistructured survey	K-12 teachers	argumentation about anthropogenic climate change
18	The Journal of Agricultural Education and Extension Competence for Rural Innovation and Transformation	Secondary agriculture teachers’ knowledge, beliefs and, teaching practices of climate change	Hui-Hui Wang, Devarati Bhattacharya & Bryanna J. Nelson	04 Dec 2019	258 participants	22-item survey to capture secondary agriculture teachers’ conceptions, beliefs, and practices about GCC.	secondary agriculture teachers	authentic learning outside classroom

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19	International Research in Geographical and Environmental Education	Teachers' understanding of the interconnectedness of soil and climate change when developing a systems thinking concept map for teaching and learning	Luiza Olim de Sousa, Emerentia Antoinette Hay & Danica Liebenberg	29 Aug 2019	teachers of six primary schools	research study	primary schools teachers	systems thinking concept map
20	Planet	Teaching and learning uncertainty in science: the case of climate change	Brendan Hall	15 Dec 2015	There is no reference	open-ended, semi-structured interviews	academics and educators	teaching through the complexity of earth-system
21	Journal of Geography in Higher Education	Teaching anthropogenic global climate change (AGCC) using climate models	Drew Bush, Renee Sieber, Mark A. Chandler & Linda E. Sohl	09 Sep 2019	115 participants	seventeenquestion online survey	educators	geospatial data, visualizations, analysis tools and models
22	Journal of Geoscience Education	Teaching Earth Signals Analysis Using the Java-DSP Earth Systems Edition: Modern and Past Climate Change	Karthikeyan Natesan Ramamurthy, Linda A. Hinnov & Andreas S. Spanias	14 Jun 2018	There is no reference	qualitative method/observation /worksheet after workshop/pre workshop questionnaire	undergraduate students of Earth Science and electrical engineering	Java-Digital Signal Processing/Earth Systems Edition (J-DSP/ESE)
23	Research in Science & Technological Education	Teaching global climate change to pre-service middle school teachers through inquiry activities	Bahadir Namdar	08 Jan 2018	102 participants	pre-test–post-test	pre service teachers	Inquiry based activities
24	Research in Science & Technological Education	Teaching the role of forests in mitigating the effects of climate change using outdoor educational workshop	Umran Betul Cebesoy & Dilek Karisan	12 Aug 2020	20 participants	pre-and post-test	pre service teachers	outdoor workshop

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25	Journal of Geoscience Education	The Teaching of Anthropogenic Climate Change and Earth Science via Technology-Enabled Inquiry Education	Drew Bush, Renee Sieber, Gale Seiler & Mark Chandler	13 Jun 2018	There is no reference	review study	There is no reference	realistic scientific inquiry into AGCC (laboratory, digitalised tools, data analysis)
26	Journal of Geoscience Education	Undergraduate Climate Education: Motivations, Strategies, Successes, and Support	Karin B. Kirk, Anne U. Gold, Tamara Shapiro Ledley, Susan Buhr Sullivan, Cathryn A. Manduca, David W. Mogk & Katryn Wiese	14 Jun 2018	440 participants - survey 234 participants-workshop	Survey - questionnaire/workshop -pre and post test	faculty members	including focusing on solutions, using local contexts, teaching with scientific data, embracing that controversy is an integral part of teaching about climate change, and employing effective communication strategies
27	Journal of Geoscience Education	Using Remote Sensing and Geospatial Technology for Climate Change Education	Helen Cox, Kimberle Kelly & Laura Yetter	14 Jun 2018	74 participants	Pre- and post-course surveys	students	remote-sensing exercises
28	Environmental Education Research	What effective design strategies do rural, underserved students in STEM clubs value while learning about climate change?	Kristie S. Gutierrez, Margaret R. Blanchard & K. C. Busch	08 Feb 2022	200 participants	pre-post survey and structured written reflections	school students	lessons designed based on Expectancy-Value-Theory
29	Journal of Geoscience Education	Using Remote Sensing and Geospatial Technology for Climate Change Education	Helen Cox, Kimberle Kelly & Laura Yetter	14 Jun 2018	74 participants	Pre- and post-course surveys	students	remote-sensing exercises

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30	Applied Environmental Education & Communication	Using authentic science in climate change education	Rebecca Jordan, Amanda E. Sorensen, Rachael Shwom, Jennifer Meta Robinson, Cynthia Isenhour, Steven Gray, Mary Nucci & Diane Ebert-May	20 Feb 2018	There is no reference	review study	There is no reference	authentic learning
31	Journal of Geoscience Education	“Stickier” learning through gameplay: An effective approach to climate change education	S. Pfirmman, T. O’Garra, E. Bachrach Simon, J. Brunacini, D. Reckien, J. J. Lee & E. Lukasiewicz	06 Jan 202	41 participants	In person assesement control/reading	students	Gamification-Role play
32	International Journal of Science Education	Professional development design considerations in climate change education: teacher enactment and student learning	Andrea Drewes, Joseph Henderson & Chrystalla Mouza	10 Nov 2017	There is no reference	intrinsic case study	There is no reference	mixed SSR practices decision making/debate/conceptual mobility
33	Environmental Education Research	From action to intra-action? Agency, identity and ‘goals’ in a relational approach to climate change education	Blanche Verlie CCR 15	23 Sep 2018	There is no reference	empirical examples	There is no referenece	intra-active approach to climate change education
34	Environmental Education Research	Experimentation with a socio-constructivist process for climate change education	Diane Pruneau , Helene Gravel , Wendy Bourque & Joanne Langis	03 Jun 2010	39 participants	semi-structured individual interviews	Junior High school students	experimental learning/socio-constructivism

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35	International Research in Geographical and Environmental Education	Experiential-based climate change education: fostering students' knowledge and motivation towards the environment	Mageswary Karpudewan & Nur Sabrina Mohd Ali Khan	16 May 2017	62 participants	quasi-experiment	students	experiential-based activities
36	Planet	A component-based approach to open educational resources in climate change education	Simon K Haslett & Jonathan Wallen	15 Dec 2015	There is no reference	empirical examples	There is no referenece	component-based approach: photographs/video/s mall objects
37	Children's Geographies	A systematic review of climate change education: giving children and young people a 'voice' and a 'hand' in redressing climate change	David Rousell & Amy Cutter-Mackenzie-Knowles	24 Jun 2019	There is no reference	systematic literature review process	There is no reference	participatory, interdisciplinary, creative, and affect-driven approaches
38	Environmental Education Research	Broadening epistemologies and methodologies in climate change education research	K. C. Busch, Joseph A. Henderson & Kathryn T. Stevenson	30 Oct 2018	There is no reference	interest, methods, and cross-disciplinary research	There is no reference	socio-constructivism/inquiry based activities
39	Children's Geographies	Education for what? Shaping the field of climate change education with children and young people as co-researchers	Amy Cutter-Mackenzie & David Rousell	26 May 2018	135 participants	funded project Climate Change + Me	young people and children	co-researching with students

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40	Educational Review	Digital media, political affect, and a youth to come: rethinking climate change education through Deleuzian dramatisation	David Rousell, Thilinka Wijesinghe, Amy Cutter-Mackenzie-Knowles & Maia Osborn	10 Sep 2021	There is no reference	qualitative method/ observation	secondary school students	Deleuze's method of dramatisation/co-developing a climate change education App
41	CURATOR THE MUSEUM JOURNAL	Climate Change Education at Nature-Based Museums	JANET K. SWIM, NATHANIEL GEIGER, JOHN FRASER, AND NETTE PLETCHER	Jan 2017	230 accredited institutions.	membership-wide study	employee in the midst of the program and those who had an employee scheduled to attend in the	Nature-Based Museum/ authentic learning activities
42	Environmental Education Research	Conceptualizing climate change in the context of a climate system: implications for climate and environmental education	Daniel P. Shepardson , Dev Niyogi , Anita Roychoudhury & Andrew Hirsch	03 Nov 2011	There is no reference	review of the literature	There is no referenece	interpret, analyze, explain, and evaluate historical data and model-based data projections
43	Environmental Education Research	Climate change education: quantitatively assessing the impact of a botanical garden as an informal learning environment	Daniela Sellmann & Franz X. Bogner	12 Jul 2012	108 Bavarian high school students	multiple-choice questionnaires in a pre-post-retention test design	10th graders (High school students)	botanical garden as an informal learning environment
44	British Journal of Educational Technology	The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education	Gustav B. Petersen , Sara Klingenberg, Richard E. Mayer and Guido Makransky	2020	102 participants	pre- to post-assessment/observation	seventh and eighth grade students	virtual field trips (VFTs) involving scenarios within the investigation phase of an inquiry-based learning (IBL) climate change intervention.

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45	British Journal of Educational Technology	The role of transformative leadership, ICT-infrastructure and learning climate in teachers' use of digital learning materials during their classes	Marjan Vermeulen, Karel Kreijns, Hans van Buuren and Frederik Van Acker	2017	544 participants	questionnaires	teachers from the Dutch primary, secondary and vocational education	ICT-infrastructure (technical and social)
46	AMERICAN METEOROLOGICAL SOCIETY	CLIMATE CHANGE EDUCATION THROUGH TV WEATHERCASTS Results of a Field Experiment	Xiaoquan Zhao, Edward Maibach, Jim Gandy, Joe Witte, Heidi Cullen, Barry A. Klinger, Katherine E. Rowan, James Witte, and Andrew Pyle	There is no reference	There is no reference	field study	There is no reference	on-air and onlive Tv Weatherforecast
47	Journal of Education for Sustainable Development	Any Sign of Virtual School Garden Exchanges? Education for Sustainable Development in School Gardens since 1992: A Systematic Literature Review	JOHANNA LOCHNER, MARCO RIECKMANN AND MARCEL ROBISCHON	2019	158 peer-reviewed articles	systematic literature review process	There is no reference	school garden activities
48	Environmental Education Research	Experimentation with a socio-constructivist process for climate change education	Diane Pruneau , Helene Gravel , Wendy Bourque & Joanne Langis	03 Jun 2010	39 participants	Initial and final interviews	Students	socio-constructivist and experiential activities

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49	Environmental Education Research	From action to intra-action? Agency, identity and 'goals' in a relational approach to climate change education	Blanche Verlie CCR 15	23 Sep 2018	45 participants	quotations from students, observations	students	intra-active approach less anthropocentric
50	The Journal of Environmental Education	Identifying and addressing students' questions on climate change	Sakari Tolppanen & Maija Aksela	20 Mar 2018	There is no reference	qualitative content analysis	16–19 –year-old international students	open-ended questions
51	Simulation & Gaming	GREENIFY: A Real-World Action Game for Climate Change Education	Joey J. Lee Pinar Ceyhan William Jordan-Cooley Woonhee Sung	2013	26 adults from two graduate-level courses at a large private university in New York	pre- and postimplementation survey Semistructured interviews recorded various player data related to gameplay	adults from graduate level courses	action-based learning crowdsourcing empathy-based action real-world action game social networking
52	Simulation & Gaming	A Climate Change Board Game for Interdisciplinary Communication and Education	Klaus Eisenack	1 August 2012	students (age 15-18) at different schools, students (age 20-30) at four German universities	Analysis of information obtained mainly by participant observation and facilitation experience.	school students university students	interdisciplinarity mitigation negotiations board gaming
53	Technology and Health: Promoting Attitude and Behavior Change	Virtual reality as a promising tool to promote climate change awareness	Géraldine Fauville, Anna Carolina Muller Queiroz, Jeremy N. Bailenson	13 March 2020	No reference	This chapter reviews 13 papers addressing the use of IVR to promote environmental literacy and accounts for the current state of research in this field	No reference	IVR

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54	Educational and Developmental Psychologist	Climate crisis learning through scaffolded instructional tools	Janelle M. Bailey Sonia Jamani Timothy G. Klavon Joshua Jaffe Svetha Mohan	19 Oct 2021	Over three hundred (N = 313) middle school (Grades 6-8) and high school (Grades 9-12) students enrolled in Earth and environmental science classrooms in the	MEL scaffold baMEL scaffold	middle school students high school students	scientific reasoning argumentation scaffold learning
55	Environmental Education Research	ICT tools in environmental education: reviewing two newcomers to schools	G. Fauville, A. Lantz-Andersson R. Säljö	11 Mar 2013	No reference	Literature review	No reference	environmental education and digital media ICT in classrooms digital tools
56	Sustainability	SolarSPELL Assessment: Impact of a Solar-Powered Digital Library as a Teaching-Learning Resource on Climate Change	Laura Hosman Marcela Georgina Gómez Zermeño Lorena Alemán de la Garza	17 August 2020	seven school principals and 62 teachers and volunteers	five instruments were applied that are part of the DIAPASON, a battery of quantitative and qualitative research instruments focuses on the assessment pedagogic quality of the educational innovation resource	school personnel and volunteers	digital library

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57	Climatic Change	Learning about climate change in, with and through art	Julia Bentz	7 August 2020	70 students aged between 16 and 18 years of a public art high school in Lisbon, Portugal, in two different art and climate change projects.	qualitative research/ participant observation / notes /facilitated group dialogues and fish-bowl discussions /group dialogues and discussions were recorded / recordings were transcribed, and transcripts, notes, and students' written reflections and artist statements were then coded.	art high school students	Arts-based methods
58	International Journal of Education in Mathematics Science and Technology	Argumentation as a Strategy for Increasing Preservice Teachers' Understanding of Climate Change, a Key Global Socioscientific Issue	Julie L. Lambert, Robert E. Bleicher	23 August 2016	59 teachers enrolled in an elementary science methods course at a large southeastern United States Hispanic-serving university.	pre- and post- test /End-of-Course Questionnaire	pre-service teachers	Scientific argumentation
59	European Journal of Teacher Education	Promoting critical thinking through mathematics and science teacher education: the case of argumentation and graphs interpretation about climate change	Marta Romero Ariza Antonio Quesada Armenteros Antonio Estepa Castro	11 Aug 2021	80 pre-service teachers	qualitative approach	pre-service teachers	Scientific argumentation

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60	Applied Environmental Education	Building teachers' self-efficacy in teaching about climate change through educative curriculum and professional development	Christine Jie LiMartha	22 May 2019	Phase I train the facilitators from project learning tree Pilot: 17 Science teachers Revised version: 96 Science teachers Phase II facilitator-led workshops for teachers	Pre- and Post-educator workshop survey for phase I and II participants	teachers	workshops
61	Sustainability	Inquiry-Based Learning on Climate Change in Upper Secondary Education: A Design-Based Approach	Sebastian Brumann Ulrike Ohl Johannes Schulz	17 March 2022	In total, 34 teachers and 433 students participated in the 34 seminars that were included in these two main cycles (14 seminars in cycle 1 and 20 seminars in cycle 2). In total, together with cycle 3, 769	Focus Group Discussions Semi-Standardised Written Teacher Survey Participant Observation	Secondary teachers and students	inquiry-based learning, seminars
62	Climatic Change	Teaching climate change in middle schools and high schools: investigating STEM education's deficit model	Eric Plutzer A. Lee Hannah	25 July 2018	1500 science teachers from public US middle and high schools	probability survey	Science teachers from middle and high school	STEM education

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63	Environmental Education Research	Climate change education in the humanities classroom: a case study of the Lowell school curriculum pilot	Alana Siegner Natalie Stapert	17 May 2019	116 students 5 teachers/stuff	mixed-methods case study design / quantitative and qualitative data / Student surveys (multiple choices and open response / Teacher/staff semistructured interviews / Classroom observations	students teachers/school stuff	Climate change curriculum implemented via an integrated social studies and language arts framework
64	International Journal of Science and Mathematics Education	The evaluation of role playing in the context of teaching climate change	Nadja BelovaTimo Fei	March 2014	students (age 15-17) coming from different middle, comprehensive, and grammar schools.	GT approach according to Strauss & Corbin (1990) in order to evaluate the role-playing exercises	students	lesson-plan, role playing argumentation
65	Journal of Geography	Combining Geography, Math, and Science to Teach Climate Change and Sea Level Rise	Ray Oldakowski Ashley Johnson	21 June 2017	120 fifth grade students from three different schools	a pretest and posttest comprised of questions measuring knowledge relevant to the lesson in terms of geography, math, science, and spatial skills	fifth grade students	STEM based curriculum
66	Frontiers in Psychology	Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change	David M. Markowitz Rob Laha Brian P. Perone Roy D. Pea Jeremy N. Bailenson	30 November 2018	270 participants from four different learning settings (highschool, college students,	pre- and post-test assessments	highschool students, college students, adults	immersive virtual reality

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67	EURASIA Journal of Mathematics, Science and Technology Education	Teaching Climate Change Science to High School Students Using Computer Games in an Intermedia Narrative	Glenn Gordon Smith Metin Besalti Molly Nation Allan Feldman Katie Laux	13 December 2018	511 highschool students	pre- and post-online survey on students' beliefs about climate change & EOU surveys that contained open-ended questions related to the games	highschool students	The curriculum, Climate Change Narrative Game Education (CHANGE), used a local, place-based approach using scientific data gathered from the Gulf of Mexico coast and incorporated (a) computer games, (b) a scientifically web-based science fiction novel about future Gulf coast residents, and (c) hands-on laboratory activities.
68	Addressing the Challenges in Communicating Climate Change Across Various Audiences	Climate Change Education Through DST in the Age Group "10–13" in Greece	Paraskevi Theodorou Konstantina Christina Vratsanou Ilias Nastoulas Effrosyni Sarantini Kalogirou Constantina Skanavis	03 October 2018	459 students in the 4th, 5th, 6th and 7th grades of school in Athens	pre-post questionnaires	students in the 4th, 5th, 6th and 7th grades of school in Athens	lectures combined with instructional comics with the means of digital story telling (DST)
69	Climate Change and the Role of Education	Taking Current Climate Change Research to the Classroom—The "Will Hermit Crabs Go Hungry in Future Oceans?" Project	Christina C. Roggatz Neil Kenningham Helga D. Bartels-Hardege	29 November 2019	68 primary school and lower secondary school pupils	anonymous self-assessment questionnaire before and after the experimental session	primary school and lower secondary school pupils	outreach project that takes authentic up-to-date research to the classroom though experiment

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70	Renewable and Sustainable Energy Reviews	Using empirical science education in schools to improve climate change literacy	Prashant Kumar Jeetendra Sahani Nidhi Rawat Sisay Debele Arvind Tiwari Ana Paula Mendes Emygdio K.V. Abhijith Vina Kukadia Kathryn Holmes Sebastian Pfautsch	4 March 2023	103 students from two cohorts (years 5–6 and 7–9)	multi-functional quantitative assessment, including pre- and postsession quizzes	students 5-6 and 7-9 years old	technology-enhanced STEM education, immersive learning
71	Global Engineering Education Conference (EDUCON)	STEM Lab on Climate Change with Simple Handson Experiments	T. P. Nantsou G.S. Tombras	11 May 2022	551 science teachers of the MOOC 42 K-6 students	quantitative and qualitative research, students' questionnaires, teachers' interviews, field observations in the school lab	science teachers, K-6 students	Learning-by-Doing, hands-on experiments
72	Vol. 16 No. 1 (2022): Proceedings of the 16th European Conference on Games Based Learning	Climate4Kids: A Gamified App Teaching about Climate Change	Sonja Gabriel Bernhard Schmölder	29 September 2022	No reference	Playtesting and evaluation of the app is planned for the fall of 2022 when pupils of some chosen schools will be introduced to the app and use it in classroom teaching. The results of this evaluation will be used for adapting and improving Climate4Kids.	No reference	Digital game-based learning, gamification

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73	Journal of Chemical Education	Engaging K–8 Preservice Science Teachers through an NGSS-Based Climate Change Project	Xisen Wang Yujuan Liu	7 April 2023	184 university students	pre-knowledge survey, post-activity assignment	university students	Interdisciplinary/Multidisciplinary, Demonstrations, Internet/Web-Based Learning, Reactions
74	Frontiers in Education	Learning science locally: Community gardens and our future	David Lloyd Kathryn Paige	8 August 2022	primary students (aged 6-7 and 9-10) and their teachers	Teacher assisted students to reflect, record, write, and illustrate their experiences in the community garden. The researchers analyzed the work samples for common themes and these are used to organize the children’s personal comments on their community garden experience	primary students and their teachers	transdisciplinary approaches, hands'on experience
75	Environmental Education Research	‘It’s a gassy world’: starting with students’ wondering questions to inform climate change education	Asli Sezen-Barrie Anica Miller-Rushing Elizabeth Hufnagel	14 May 2019	middle school students from fourteen different middle school science classrooms	qualitative multiple-case study, 165 students’ written artifacts and 7 teachers interviews	middle school students	teacher education, wondering questions, emotional experience
76	LUMAT General Issue	Innovation in the teaching-learning process of global climate change through the collaborative wall	Ricardo-Adán Salas-Rueda Gustavo De-La-Cruz-Martínez Clara Alvarado-Zamorano Estefanía Prieto-Larios	3 May 2021	74 high school students from the National Preparatory School No. 7 “Ezequiel A. Chávez” who took the Biology IV	questionnaires	high school students	educational virtual spaces

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77	Social Science Information	Extreme environments: An educational framework for arts-based field research	Laura Shine Scott Hessels	11 November 2021	students from School of Creative Media in Hong Kong	Analysis of students' interviews before the course begins as part of the vetting process, midway while on the expedition, and again as part of the university course evaluation at the end	students	blended learning, expeditionary learning, experiential learning, immersion pedagogy, interdisciplinary education, social and digital resources, technical workshops, information arts theory
78	Electronics	Utilizing Educational Robotics for Environmental Empathy Cultivation in Primary Schools	Dimitris Ziouzos Dimitrios Rammos Tharrenos Bratitsis Minas Dasygenis	30 September 2021	50 6th grade students from primary school in Athens	behavioral observation	6th grade students	constructivism, learning strategy of the educational scenario combined the problem-solving method through STEAM activities

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79	International Journal of Science Education	The influence of causal knowledge on the willingness to change attitude towards climate change: results from an empirical study	Giulia Tasquier Francesca Pongiglione	10 July 2017	<p>The first sample is represented by 23 voluntary students from different schools (grades 12 and 13; 17–18 years old).</p> <p>The second experience was in class at a science-oriented secondary school in Bologna. The 25 students involved were younger (aged 16–17, 11th grade) and did not choose to attend the course (being instead co-opted by their teacher), and so are identified as Non-Volunteers</p>	pre- and post-questionnaires	12th and 13 grade students, 11th grade students	multidimensional laboratory-course