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Worldwide effects of climate change education on the cognitions, attitudes, and behaviors of schoolchildren and their entourage

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Worldwide effects of climate change education on the cognitions, attitudes, and behaviors of schoolchildren and their entourage

A systematic review

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Abstract
Climate change is a pressing global issue, and educating young generations about its causes, consequences, and potential solutions is crucial for fostering sustainable practices; mitigating and adapting to its impacts. Despite many efforts, the effects of climate change education on the cognitions, attitudes, and behaviors of schoolchildren and their surrounding communities, and the kind of interventions that are more effective for different populations and settings, are still poorly known. We conducted a systematic review encompassing a detailed qualitative and quantitative analysis of studies published until 2023, in 13 databases and five different languages, focusing on the impact of climate change education interventions targeting schoolchildren aged 5 to 19 years and their entourages. A rigorous search strategy resulted in a final selection of 146 articles from diverse geographical locations, educational frameworks, and intervention and assessment methodologies. Findings from the systematic review shed light on a highly dynamic body of research and educational practices, with a high diversity of original theoretical and practical strategies and analysis frameworks. Moreover, most documents (>80%) showed positive effects of the described interventions for the cognitive, attitudinal, or behavioral outcomes they analyzed. The cognition outcomes (knowledge and awareness) were clearer and more predominant than the effects on emotions and intent (attitudes) or habits and actions (behavior), which illustrates the so-called knowledge-behavior gap. We draw an overview of research and educational practices in climate change and report the efficient and innovative practices (e.g., intergenerational learning, student-centered pedagogical strategies) when the literature permits it. Competition (vs. collaboration) & fear/anger (vs. hope) emotions dampen positive outcomes for climate change behaviors while local, personally relevant, and transversal interventions or fostering strong links to nature, give promising positive outcomes. However, we highlight a probable publication bias, i.e., researchers and journals tend to preferentially publish original interventions showing positive effects as opposed to negative or null results. Therefore, for climate change education to become the motor of positive change that we hope for future generations, it appears crucial that the actors of this field strengthen the CCE community of practices (national curriculum, materials, and teachers' training), report more systematically all context-specific educational intervention results and use a more common language in their evaluations of educational practice outcomes.

Keywords
Primary school, Secondary School, Climate change, Climate Education, Sustainable development education, Teachers

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Résumé
Le changement climatique est un problème mondial urgent. Éduquer les jeunes générations sur ses causes, ses conséquences et ses solutions potentielles est crucial pour favoriser des pratiques durables, atténuer et s'adapter à ses impacts. Cependant, les effets de l'éducation sur le changement climatique sur la cognition, les attitudes et comportements des élèves et de leurs communautés environnantes sont encore mal connus, ainsi que le type d'interventions efficaces. Dans cette étude, nous présentons une revue systématique qui consiste en une analyse qualitative et quantitative complète des études publiées jusqu'en 2023, dans 13 bases de données et cinq langues différentes, mettant l'accent sur l'impact des interventions en éducation au changement climatique ciblant les élèves âgés de 5 à 19 ans et leur entourage. Une stratégie de recherche rigoureuse a abouti à une sélection finale de 146 articles provenant de diverses régions géographiques, cadres éducatifs et méthodologies d'évaluation. Les résultats de la revue systématique revèlent un domaine de recherche et de pratiques pédagogiques particulièrement dynamique, utilisant une grande diversité de developpement théoriques originaux et de pratiques éducatives innovantes, ainsi que de nombreuses methodologies d'analyse. De plus, la majorité des études (>80%) affichent les effets positifs des interventions pédagogiques analysées sur les facteurs cognitifs, les attitudes et comportements. Malgré tout, nous retrouvons l'effet, connu dans la litérature, de fossé entre la connaissance et les comportements : les effets sur la cognition (connaissance et prise de conscience) sont plus clairs et plus régulièrement notés que les effets sur les émotions et les intentions (attitudes), ou enfin sur les actions et les habitudes (comportement). Nous dressons un panorama des pratiques pédagogiques et de recherche, et, quand la litérature le permet, nous reportons l'efficacité des pratiques innovantes (telles que les pratiques d'apprentissage intergénérationnelles et les stratégies d'éducation centrées sur les élèves). La compétition (à opposer à la collaboration) et les émotions de peur ou de colère (à opposer à l'espoir) ont tendance à entraver l'adoption de comportements respectueux du climat. Les interventions comprenant des aspects locaux, liés à l'expérience personnelle des élèves, transversales, ou favorisant des liens étroits avec la nature donnent des résultats prometteurs. Cependant, nous mettons en évidence un probable biais de publication, les chercheurs et les journaux scientifiques tendant à publier préferentiellement les interventions à caractére original, avec des résultats positifs. Afin que l'éducation au changement climatique devienne le moteur du changement positif que nous espérons pour les générations futures, il semble crucial que les acteurs de ce domaine renforcent la communauté de pratiques en matière d'éducation au changement climatique (programme national, matériel et formation des enseignants), rendent compte plus systématiquement de tous les résultats des interventions éducatives spécifiques au contexte et utilisent un langage plus commun dans leurs évaluations des résultats des pratiques éducatives.

Mots-clés
École primaire, École secondaire, Changement climatique, Éducation au climat, Éducation au développement durable, Enseignants

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Introduction

Our modern way of life brought unprecedented economic, social, and well-being improvements to today's developed countries. Still, it also brought unprecedented global threats due to the transformation of the Earth's surface and atmosphere (UNESCO, 2010) According to UNESCO (2005), sustainable development requires building a different vision of the world; one that reconciles economic growth, social development, and environmental protection in a manner that improves everyone's quality of life, including that of future generations, and allowing them a respectful relationship with a preserved biodiversity. Education plays a fundamental role in sustainability, and thus the importance of "Rethinking and revising education from nursery school through university to include a clear focus on the development of knowledge, skills, perspectives, and values related to sustainability" (UNESCO, 2005) Consistently, there has been growing interest in the past decades in Education for Sustainability in an effort to meet the United Nations' Sustainable Development Goals (SDGs). One critical aspect of the required transformation toward sustainability is the fight against global warming, which has become increasingly urgent. Climate change is a global concern that requires coordinated action and cooperation at all levels, in all corners of the world (UNESCO, 2018). Consistently, to meet these goals, SDG 13 which involves taking immediate action to combat climate change and its impacts, places particular emphasis on an urgent effort to "improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning" (Target 13.3 of SDG).

Indeed, for a while, there has been a scientific consensus regarding the causal effect of human activities on climate change. Global warming is unfortunately expected to continue, and immediate efforts to mitigate and adapt to changes in natural, social, and economic systems are required (IPCC, 2022; UNESCO, 2018a). Education is at the core of our ability to adapt and respond to the challenges imposed by global warmings, such as food insecurity, the rise of sea level, droughts, extreme weather events, and more, most of which disproportionately affect developing world regions (Unfccc, 2007) Consistently, Article 12 of the Paris Agreement on Climate Change (2016) encouraged all involved Parties "to enhance Climate Change Education [CCE], training, public awareness, public participation and public access to information".

Article 6 of Action for Climate Empowerment (ACE), in 2016 identified six factors that are pivotal to the success of the world's efforts against climate change, and education is one of them (UNESCO & UNFCCC, 2016). In addition to recognizing the pivotal role of education in the fight against global warming, the ACE offers a flexible framework that promotes local empowerment while acknowledging that every country's situation is different in the face of global warming and thus the need for appropriation of this framework. Moreover, given that communities are at the frontlines of most sustainability challenges (i.e., poverty, and climate change) local appropriation of

sustainable development initiatives including climate change is critical to their effectiveness (UNESCO, 2017). UNESCO also published a guide for schools on climate action known as the Whole School Approach (WSA), which rests on the idea that "we all have a role to play in addressing climate change, and ESD should promote the knowledge, skills, and values needed to act towards a more sustainable future (UNESCO, 2016). It invites educational institutions to take action toward climate change mitigation and adaptation in every aspect of school life, develop a culture of sustainability, and involve every stakeholder and community member in acting on climate change (UNESCO, 2016). The WSA also proposed that given the environmental, economic, social, cultural, ethical, political, scientific, and technological implications of climate change, climate action should (1) be included in all subjects, not only in science and social science courses, (2) education should be oriented towards building critical, creative and future-thinking skills and (3) learning must be action-oriented (about, though, and from action). Finally, it underscored the importance of monitoring change (UNESCO, 2016) an essential aspect of success in combating climate change that has represented important difficulties (UNESCO, 2017). More recently, (UNESCO, 2020) identified, among other sustainability learning objectives, *cognitive* (learning and understanding different aspects of climate change, including the contribution of human activities to climate change), *socio-emotional* (understanding the social economic, and ethical implications of climate change, the personal impact of one´s behaviors on the world's climate, and collaborating with others and behavioral domains and) and *behavioral* (ability to assess climate change's impact, as well as that of their actions, make decisions and act in ways that area climate-friendly) learning goal to protect against climate change.

According to a report from UNESCO, by 2019, almost all countries in the United Nations Framework Convention on Climate Change (UNFCCC) had addressed climate change education to some extent. Europe and North America, Asia, and the Pacific were the regions that reported having addressed climate change education the most, followed by Latin America, Africa, and the Arab States. About half of those who reported having addressed climate change education had privileged formal education settings, and cognitive learning objectives, which were addressed more frequently than socio-emotional and behavioral learning goals. Additionally, climate change education content focused more on mitigation and adaptation than on impact reduction or early warnings. According to this report, most data were qualitative bringing important difficulties in monitoring global progress (UNESCO, 2018b).

Soon after, the IPCC and UNESCO brought attention to the urgency of acting in the face of unprecedented acute changes caused by human activities that are accelerating climate change, making its dramatic consequences already visible to everyone (UNESCO, 2020) The IPCC (2022) report recently pointed out that "given the amount of time that children spend in school settings, adapting educational infrastructure and programs to climate change is highly important". UNESCO continues to recognize climate change education and its critical transformative power (UNESCO, 2018a). However, education is not sufficiently integrated into mitigation and adaptation policies across parties. Moreover, given the

difficulty in evaluating its effects, we still lack information on evidence-based best educational practices (Monroe et al., 2016) which limits the impact of well-meaning educational interventions. Adding complexity to this, "monitoring of progress needs to be context-specific, recognizing countries' starting points and education sector plans, helping them link their national education agendas with regional and global agendas" (UNESCO, 2021).

Human activities leading to unsustainable consumption patterns, population growth, habitat destruction, waste, and pollution exceed the carrying capacities of Earth's ecological systems (Rousell & Cutter-Mackenzie-Knowles, 2020) The effects of anthropogenic climate change are already affecting the global biosphere, sometimes with extreme effects that further contribute to changing existing ecosystems and existing inequalities. Climate change effects include flooding, fires, heat waves, and other events that nowadays impact every ecosystem, species, natural resources, and human-made infrastructure (water and energy supply, transportation, etc.). Climate change effects on the human population depend, among other things, on countries' ability to take mitigation and adaptive actions to prevent and deal with its consequences (Aral & López-Sintas, 2022) Importantly, climate change intensifies already existing stresses among human societies; those already experiencing greater hardship tend to live in countries where governments are less accountable to them and, in turn, convey less trust and have less governability. Consequently, these governments are less effective in mobilizing resources and people to mitigate and adapt to climate change, making its consequences especially dire to already marginalized populations. Also, there are multiple examples of maladaptive decisions where climate change risks are transferred to other, less affluent regions (Flora et al., 2014; Pereira et al., 2022) Paradoxically, societies with fewer financial, technological, and institutional resources are required to make greater efforts to cope not only with food and energy insecurity but also with the expected impact of climate change (IPCC, 2022) Finally, differences in climate change impact also vary depending on people's livelihoods (e.g., farming, fishing), socio-economic status (e.g., people with low income), ethnicity (indigenous groups), sex, or age (e.g., children and youth who appear to be somewhat powerless in stopping a situation that affects their future quality of life) (IPCC, 2022). Climatic effects are unevenly distributed across the globe depending on geographical location, development status, and living conditions (IPCC, 2022) which require different approaches to assessing climate change educational interventions and consequences.

Humanity's long-term survival depends on its ability to find and prioritize more immediate and efficient solutions before losing the window of opportunity (IPCC, 2022) The latest IPCC (2022) report identifies three inter-dependent systems: climate, biodiversity, and human societies, which can potentially interact to either disturb or sustain life on the planet. Sustainable life requires (1) identifying solutions, (2) determining their impact, and (3) bringing these solutions into practice to mitigate and adapt to global warming. Adaptation efforts are required from everyone, individually and collectively, to cope with and build resilience to face global warming (Ojala, 2012) including school settings where children spend an important part of their lives (CSSF,

2022; Paci-Green et al., 2020). There is no one model, as effective actions depend on the existing conditions of each region, country, and human population in terms of natural resources, human-made infrastructure, and social life. On the positive side, many experts and non-experts are committed to this task. Unfortunately, while there is abundant knowledge on how to effectively intervene, this information is scattered across different fields and is insufficiently organized. In this sense, knowledge integration and systematization represent our best opportunities to identify and bring educational solutions into practice that are context-specific and effective in mobilizing behavioral changes.

Following differential assessment, today's youth is more likely to suffer the negative consequences of climate change than the generations before them (Kuthe et al., 2019) Without mitigation, children born in 2020 will experience around seven times more climatic extremes compared with people born in 1960 (Thiery et al., 2021) Moreover, in the future, they will be the ones making policy decisions on the subject; thus, it is important to emphasize the transmission of this knowledge to younger generations in the hope of empowering them to take control of their present and future as much as possible. The need for educational intervention to protect the environment is hardly new. A recent systematic review of English-written publications indicated that there is literature on climate change education from the USA (United States), Canada, and Europe, followed by Australia and Africa, the Pacific Islands, and, finally, Asia and Latin America (Rousell & Cutter-Mackenzie-Knowles, 2020; UNESCO, 2018b) indicating the need for more research on educational interventions in areas of the world that are being hit hardest in light of all aspects discussed above. It also indicated that despite this experience, young people's understanding of climate change is generally limited and imprecise and that most of these interventions have limited success in affecting students' actual behavior, as opposed to mere theoretical knowledge and beliefs (Rousell & Cutter-Mackenzie-Knowles, 2020) despite some success in promoting awareness and attitude change.

There is a broad agreement that climate education is needed to help the younger population deal with global warming's immediate impacts and grapple with the uncertain long-term effects of climate change. Education on climate change experience, though abundant, is not necessarily effective in changing children's behavior to meet our window of opportunity. The situation calls for an exhaustive analysis not only of educational strategies, but of the kind of interventions (e.g., school-based, e-learning, alternative), the behavioral mechanisms involved (knowledge, attitude formation, emotional response, habit formation, etc.), the interactions between them, and their level of success, to identify effective and contextualized interventions. To this end, we conducted a systematic analysis of educational interventions emphasizing types of intervention (curriculum-based or extra-curricular interventions such as zoos, museums, technology-based), intervention strategies (aiming at knowledge, beliefs, attitudes, habits, emotions), intervened population (relevant socio-demographics) and the success of the interventions on changing cognitions, emotions, and behaviors regarding climate change. More specifically, we focused our analysis on intervention strategies while controlling for types of intervention as follows:

1. What curricular and extracurricular activities (types of intervention) are used to teach about climate change mitigation and adaptation?

2. What intervention strategies (e.g., pedagogical tools, theoretical approaches, settings, and contents) are used to teach about climate change mitigation and adaptation?

(3) What intervention strategies are more effective in attaining changes in cognitions, attitude, and behavior when controlling for type of interventions?

(4) How do intervention strategies and educational settings contribute to creating different responses across children and youth's age group/socio-economic/gender/countries/cultural backgrounds?

2. Methods

2.1. Search Strategy

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) Electronic databases[1] were systematically searched up to May 2020. The search strategy was restricted to English, Spanish, French, German, and Portuguese, and there were no publication date restrictions. MeSH terms and topic heading titles were used for other database searches. A panel of experts in education, psychology, medicine, climatology, and natural science experts (n = 12) was asked to provide relevant keywords or expressions in several languages (English, Spanish, French, and Portuguese) that we could include to perform our systematic search. The systematic search was completed using the following terms: (child* OR teen* OR adolescent OR *school* OR parent* OR famil* OR youth OR young OR juven*) AND ((climate* OR sustainab* OR "global warming" OR "green" OR "global heating") AND (educat* OR teach* OR learn* OR class* OR train* OR qualif* OR course*)). Complete search terms and syntaxes are presented in Appendix 1. As intervention studies might not be published in the peer-reviewed literature, we accessed gray literature for conference proceedings and evaluation reports. We registered the systematic review protocol in the International Prospective Register of Systematic Reviews PROSPERO (under the code CRD42023408819).

Our document screening was systematized according to the Population, Intervention, Outcome (PIO) format for two different lines of inquiry (mitigation on one part and adaptation on the other). The population included worldwide primary and secondary schoolchildren from 5 to 19 years old and their entourage, i.e., household-family and teachers); Intervention referred to educational interventions aimed at modifying cognitions, attitudes, and behaviors on climate; and Outcomes were changes in cognitions, attitudes, and behaviors about climate change).

[1] Including Web of Science, Embase, ScienceDirect, Educational Resource Information Centre ERIC, PROQUEST, SPRINGER, PsycINFO, Informit Humanities, in addition to UNESCO extensive production, AND impact Evaluation Databases: e.g., 3ie Impact Evaluation repository, Asian Development Bank: Independent Evaluation, World Bank: Independent Evaluation Group's, African Development Bank: Evaluation Reports.

2.2. Study selection

After removing duplicates, two independent investigators screened the title and abstracts, whereas the whole team screened the full text of the documents. Each record was fully read by two author experts to determine the eligible articles for evaluation. An independent third-author expert resolved any disagreements. We performed the abstract screening process in CADIMA software from the Julius Kühn-Institut (Kohl et al., 2018) We included any type of study assessing educational interventions aimed at modifying cognitions, attitudes, and behaviors on climate (e.g., curriculum-based or alternative interventions such as museums, technology-based, knowledge-based, affect-driven, behavioral-oriented) in worldwide primary and secondary schoolchildren (from five to 19 years old) and their entourage (household-family and teachers).

2.3. Data collection and analysis

We extracted the general characteristics of each study, including the first author's name, year of publication, funding source, study design, the country where the study was conducted and the authors' affiliation, description of the locality, followed by the (P) population characteristics subject-participants: targeted populations, sample size, maximum and minimum age, mean age, sex, ethnic and socioeconomic group, special characteristics, particular conditions, disabilities, setting, rural/urban origin, the (I) characteristics of the intervention: type of intervention and all the details of duration, intensity and period length, time elapsed between the intervention and test, time elapsed between the post (last) measurement and sustainability over time curricular/ extracurricular, outdoor/indoor, in-person/online, mitigation/adaptation, declared theoretical framework, climate change topics, if local climate change issues were present, discipline (e.g., natural sciences classes, social sciences classes, etc.), normative climate change educational framework, and (O) outcomes: number of outcomes, type of outcome, analysis technique, horizon of change, results obtained for each outcome, success of the intervention, if controversy regarding climate change was part of the evaluation of the outcome and limitations of the study. We organized weekly team meetings to oversee the coding process, resolve discrepancies, and standardize the table and our coding criteria.

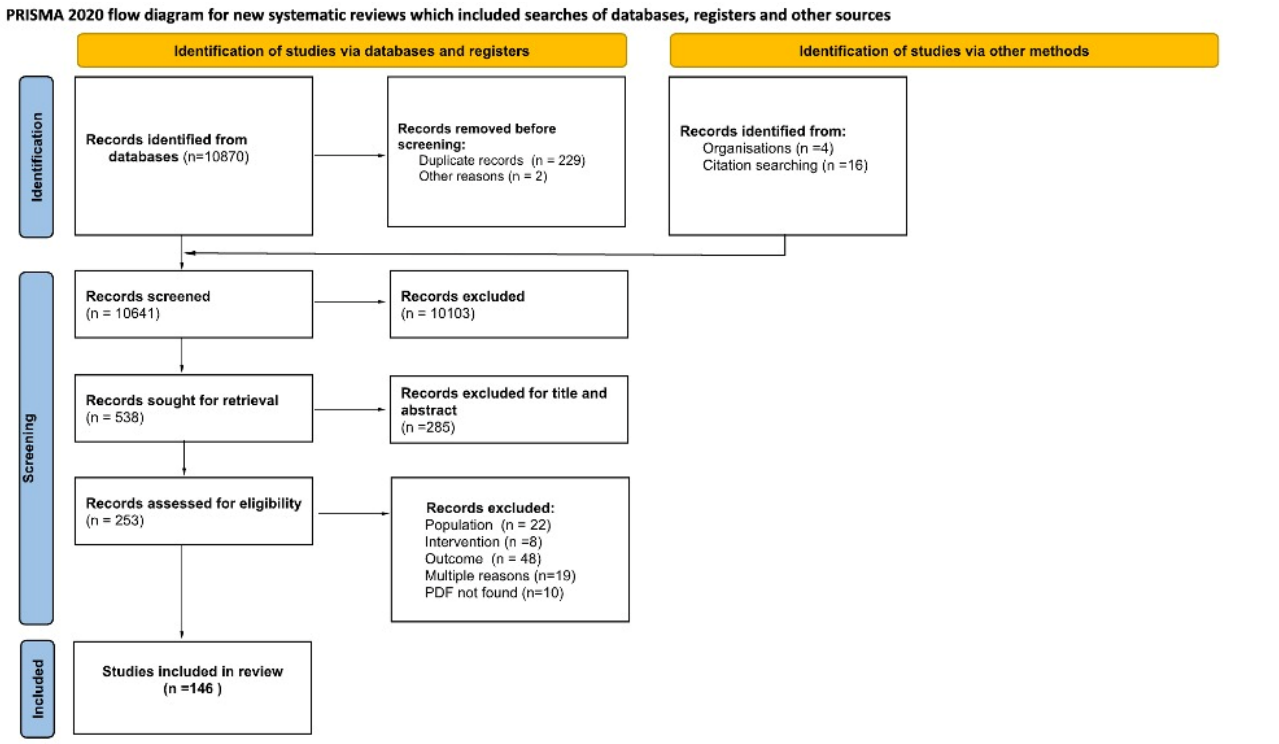
2.4. Data synthesis

We synthesized the characteristics of included studies, reporting their primary outcomes categorized by cognitions, attitudes, and behaviors. Additionally, we created summary tables showing current evidence and knowledge gaps. The study identification and study selection process are presented in the PRISMA flow diagram in **(Figure 1)**. An initial database search yielded an aggregate of 10,870 potentially relevant records. Then, 253 studies remained for the comprehensive full-text evaluations. Experts suggested 20 additional papers fitting the purpose of the review.

3. Results

The study identification and selection process are visually summarized in the PRISMA flow diagram **(Figure 1)**. Initially, our database search yielded a total of 10,870 potentially relevant documents. After removing duplicates, 10,641 unique documents remained. A meticulous evaluation of titles and abstracts based on predefined inclusion and exclusion criteria led to the exclusion of 10,103 documents, leaving us with 538 studies for comprehensive full-text assessment. Out of these 538 articles, 146 studies met the inclusion criteria for this systematic review. By comparison, other complementary reviews, such as Nepras et al.'s (2022) and Monroe et al.'s (2019), screened 850 and 1091 publications, respectively, and included 43 and 48 studies, while our study screened 10641 publications and included 146 studies (i.e. 3 times more than previous complementary reviews) **(Figure 1)**.

Figure 1. PRISMA 2020 Flow Diagram for new systematic reviews



Note: PRISMA 2020 Flow Diagram for new systematic reviews which included searches of databases, registers, and other sources. Abstract-Title and Full-text Screenings were performed by at least two different expert reviewers (a third one disentangled potential conflicts).

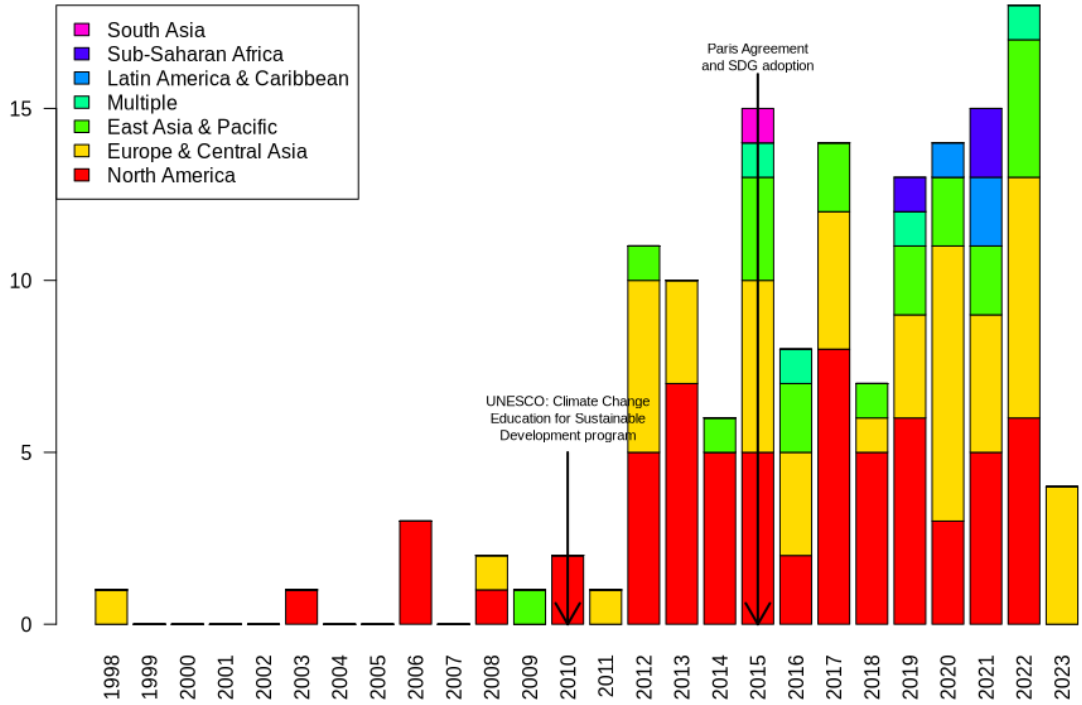
Source: Authors.

3.1. Characterization of the papers

3.1.1. Evolution

The publication dates of the included articles span from 1998 to 2023. However, it is worth noting that 92% of the documents were published after 2012, with six to 18 documents published yearly from 2012 to 2022 (Figure 2). Also, while most of the studies concerned North America up to 2014, publications from Europe and Eastern Asia (mostly China) became prevalent in the last five years. Almost all the studies concerning other regions, such as Africa, Latin America, or Eastern Asia were published after 2015.

Figure 2. Number of documents by year and region where the intervention is carried out



Note: Two main events in climate change education policies are added: the launch of the Climate Change Education for Sustainable Development program by UNESCO in 2010 and the adoption of the Paris Agreements and SDGs in 2015. Note that the search was done in the first quarter of 2023, hence the lower quantity of documents.

Source: Authors.

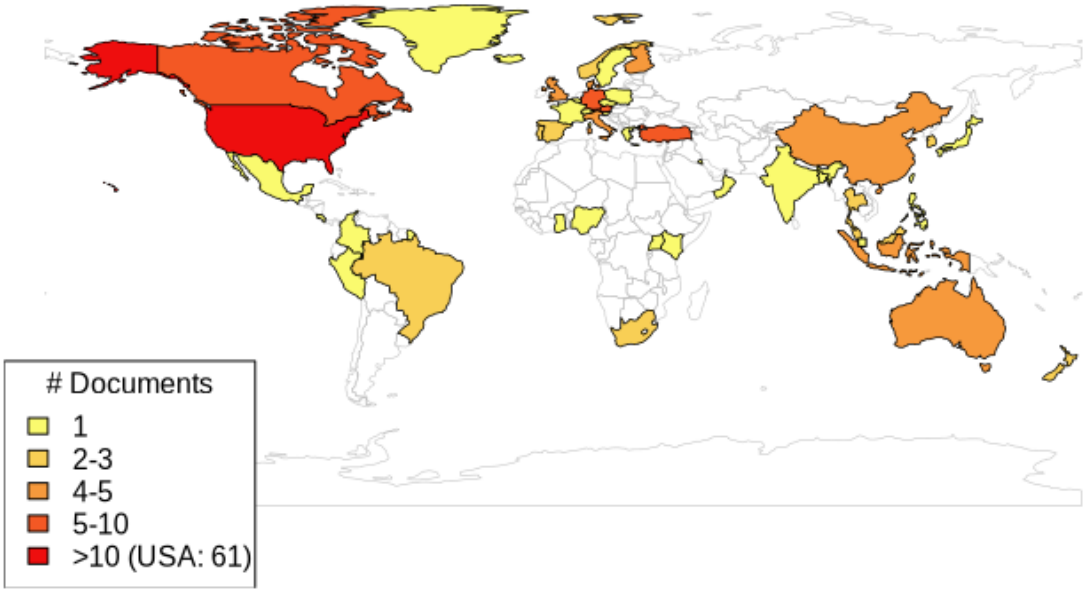
3.1.2 Climate change topics

Pedagogical interventions included in this analysis revolved around diverse topics. Some of the most frequently mentioned included climate change and weather (e.g. what is climate change, how is it different from weather, its causes, and consequences, 14.5%), human behavior and sustainability (e.g. human contribution to increase or prevent climate change, 12.5%), greenhouse effect (11,8%), energy management and conservation (energy sources, conservation of energy, 9%), carbon cycle (i.e. carbon footprint, carbon sequestration, carbon gases, 8.4%), biodiversity (endangered ecosystems, wildlife, loss and importance of biodiversity, 6.7%), global warming (6.4%), oceans (i.e. rise of sea level, ocean acidification, 3.4%), waste management and pollution (3%), extreme weather events (i.e. wildfires, floods, droughts, 3%) and others (6.1%), arctic science, glacial, ice melting (2.7%), atmosphere and ozone depletion (2%), water (2%) and others (6.1%). In addition to these, approximately 6% of the studies maintained a broad approach to climate change, without any reported sub-topic.

3.1.3. Geography and languages

The 146 studies have diverse geographical origins, with 61 papers originating from the United States, and smaller numbers from Turkey (n = 10), Austria (nine), Germany (eight), Canada (six), Australia, China, Finland, and The United Kingdom (five each), Denmark, Indonesia, Italy (four each), Brazil, Malaysia, Norway, South Africa and South Korea, (three each), New Zealand, Portugal, Spain, and Thailand (two each) and Bangladesh, Belgium, Colombia, Costa Rica, Czech Republic, France, Greece, Ghana, Greenland, Iceland, India, Japan, Kenya, Kuwait, Mexico, Nigeria, Oman, Peru, Philippines, Poland, Singapore, Slovenia, Sweden, Switzerland, Taiwan, Uganda (one each) (**Figure 3**). After the screenings, none of the papers systematically reviewed were from NGOs and 99% of the papers were in English. This indicates that many studies from Global South still lack measured outcomes regarding interventions, mostly discussing interventions but not the results.

Figure 3. Number of articles by country



Note: Note that 2023 represents only the first quarter of this year.

Source: Authors.

The countries considered here are the countries in which the intervention takes place. A study may be considered in more than one country in the case of international pedagogical interventions. The authors of these documents are usually based in the same countries as the origin of the research (only 6% of the studies were conducted in a country without any author from this specific country).

We used a simplified version of the World Bank classification of country incomes (2016) to analyze the differences between high-income countries (United States, Canada, Western Europe, Singapore, Taiwan, and South Korea), upper-middle-income countries (Turkey, China, Malaysia, South Africa, Brazil, Thailand and Mexico), and lower-middle-income/low-income countries (Indonesia and Bangladesh). 79% of the documents described studies conducted in high-income countries, 17 % focused on the intermediate-income group, and only four studies (1.3%) concerned the lowest-income countries. Two studies concerned more than one group (Arya & Maul, 2016; Gladwin et al., 2022).

3.1.4. Discipline/Scientific Fields

The types of studies encompass a wide range of literature, including qualitative, quantitative, and mixed-methods research, representing various disciplines across the natural sciences, social sciences, and education. More than half of the educational interventions occur in Natural Sciences (57%) but also Mixed (13%) and STEM (10%), while Social Sciences are much less represented (2%). This lack of representativeness in all disciplines is an issue given that climate change is a global transversal and civilizational problem affecting all sectors, regions, and professions. Social and educational studies have advocated for not restricting climate issues to natural science education but instead considering the social dimension of the issue (Dal et al., 2015; Taylor & Jones, 2020)(Dal et al., 2015; Damico & Baildon, 2022; Taylor & Jones, 2020). Transdisciplinary climate change education can obtain positive outcomes because students understand the holistic nature and importance of this environmental issue (Deisenrieder et al., 2020; Keller et al., 2019a; Kubisch et al., 2022).

3.1.5 Population Characteristics

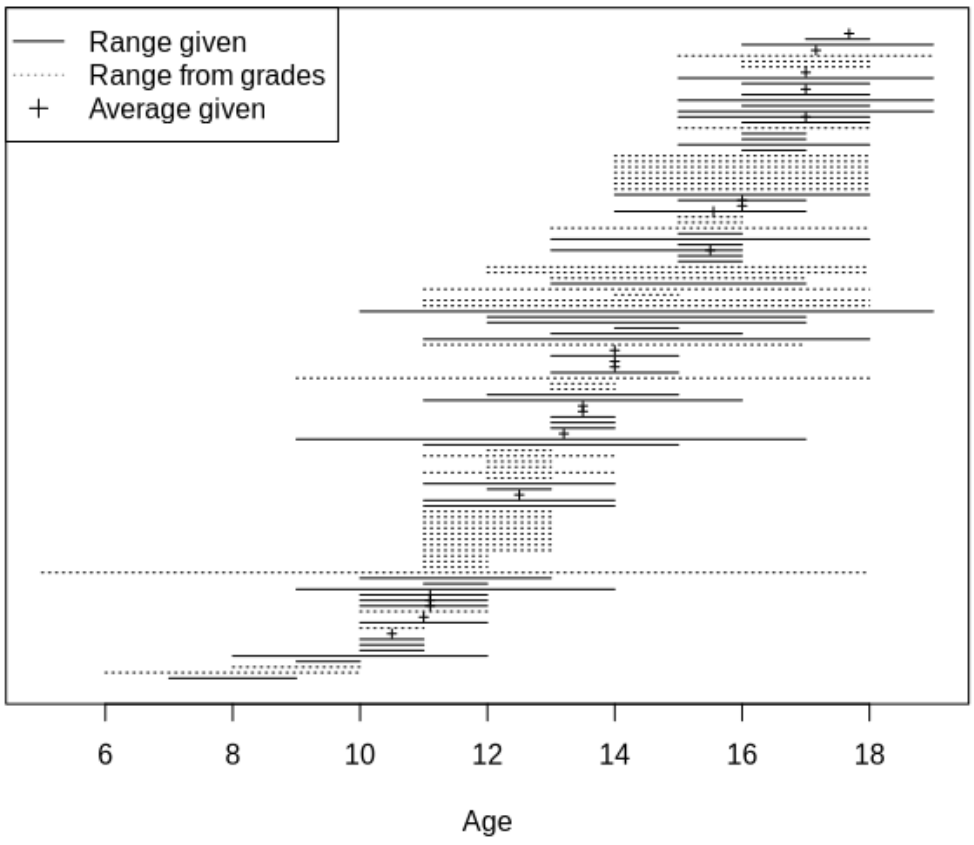
The participant demographics within the included studies showcased a diverse range of profiles, reflecting the multifaceted nature of climate change education. Predominantly, the studies in this review focused on students (78.1%) with relatively few documents dealing with teachers (total: 15.7%, pre-service teachers: 6.1%) or children's parents (1.4%). It is worth noting that a subset of articles extended their examination to encompass a broader demographic, incorporating teachers, students and individuals within the family network (4.8% of the studies concern more than one population category), thereby offering a more holistic perspective on the influence of climate change education. Moreover, we believe that effectively intervening teachers may have a larger effect in the long term since teachers have the potential to indirectly affect all future children they teach, making these studies of particular importance (see sections 3.2.1 and 3.5.6). Altogether, the 146 studies in our review collectively involved an extensive participant pool, with an estimated total of at least 30,925 individuals, with 897 teachers (including 466 pre-service teachers) and 30,028 students, contributing to the results.

3.2. Socio-demographic factors

3.2.1. Age and Intergenerational Learning

Among the student participants, age diversity was evident, spanning from 5 to 19 years old **(Figure 4)**. 32% of the documents concerned the 4-11 years range, 65% the 12-15 years range, and 41% for the 16-19 range. Please note that a document may concern more than one age range and some documents concerning students did not have any information about the age of the participants. This wide age range underscores the comprehensive scope of climate change education, accommodating various stages of cognitive and emotional development.

Figure 4. Schoolchildren's ages found in interventions (in years)



Note: Each segment or cross refers to a study.

Source: Authors.

There are two main findings regarding age. On the one hand, the purposeful exchange of resources and learning between older and younger generations known as intergenerational learning (S. Hu & Chen, 2016a) to transfer knowledge, attitudes, or behaviors from children to parents may be a promising method for overcoming social or ideological barriers to climate concerns (Lawson et al., 2019)). In addition to this, other studies that focused on intergenerational learning (S. F. Hu & Chen, 2016; Li et al., 2022; Parth et al., 2020; Trott, 2020) identified positive outcomes in response to this type of intervention. In particular, there is evidence of intergenerational learning effects on climate change knowledge (Parth et al., 2020; Trott & Weinberg, 2020), as well as mitigation and adaptation behavioral intentions (S.F. Hu & Chen, 2016; Li et al., 2022; Williams et al., 2017), revealing some evidence of a multiplier effect from the younger to the older generation. On the other hand, there are no specific age-based results concerning the different effectiveness of climate change education interventions (except for one study in which older students showed greater changes than younger students after the intervention, (Li et al., 2022).

3.2.2. Gender

The studies included in this review featured a balanced representation of genders. Only three USA-based interventions reported the inclusion of non-binary populations. Six studies established gender-differential results of climate change education interventions. Among these six studies, there is no consensus on the associated cognitive, attitude, and behavior outcomes. (Feldpausch-Parker et al., 2013) found that girls' knowledge of climate change topics increased more than boys' knowledge, and (K. T. Stevenson, Peterson, et al., 2018) found that girls were more likely to support adaptation and mitigation measures, but (Li et al., 2022) found the contrary concerning knowledge. For the entourage, (Li et al., 2022) found that mothers changed their knowledge, attitudes, and practice scores more than fathers after a school-based intervention program against heatwave and climate change, while (Lawson et al., 2019) showed that fathers displayed greater gains in climate change concern than mothers after an intervention designed to build climate change concern among parents indirectly through their middle-school children. Regarding the potential for intergenerational climate change learning (i.e., learning from children to parents), two studies showed that daughters were more effective than sons in fostering climate change concerns among their parents (Lawson et al., 2019; Li et al., 2022).

3.2.3. Ethnicity and Socioeconomic Status

Regarding ethnicity, it is notable that the reporting of participant ethnicity was more prevalent among studies conducted in the United States than in any other country. These studies included participants from various ethnic backgrounds, including African American,

Hispanic, Asian/Pacific Islander, Caucasian, and Native American, among others. While our results must reflect a variety of ethnic and cultural backgrounds, the fact that ethnicity was reported practically exclusively in the United States limits to some extent the generalizability of presented conclusions across ethnicities in other multicultural societies. Moreover, the "ethnic" categories used in the United States are very specific to this country and difficult to compare to other countries. Similarly, when studies report most Han participants in China (Li et al., 2022) or the proportion of Malay, Chinese, and Indians in Malaysia, the information is very specific to the country where the studies are conducted, and it is difficult to make sense of them at an international scale.

Moreover, a minority of studies reported on the socioeconomic status of their student participants. Specifically, some studies indicated that their participants were part of government-assisted programs, such as those providing free or reduced-cost lunch. This insight into socioeconomic backgrounds sheds light on the potential disparities in access to climate change education and its effects on diverse socioeconomic groups.

While the information about socioeconomic status and ethnicity was scarce, we found 17 studies explicitly directed toward vulnerable populations (minorities and/or economically disadvantaged). Vulnerable people or countries not only contribute the least to carbon emissions, but they continue to suffer disproportionately (Callahan & Mankin, 2022; IPCC, 2022). Climate change impacts more vulnerable populations through several pathways: such groups are less accounted for in the interventions to mitigate and adapt to the impacts of climate-induced disasters; they have fewer resources to reduce exposure against and recover from an extreme event (crop loss, sea level rise, landslide, etc.) or a climate-related food shock (e.g., increased prices, market changes); living conditions are per se exposing those population (suboptimal infrastructures, limited healthcare access) but also insufficient information and education about climate change, its impacts, and adaptative strategies(Ngcamu, 2023). Therefore, we can only encourage researchers to keep working specifically on the strategies to address climate change education toward minorities and economically disadvantaged communities, in particular concerning education for the adaptation to climate change.

3.2.4. Special Needs and Disabilities

It is noteworthy that, despite the comprehensive examination of climate change education, only (Dormody et al., 2020) and (Dormody et al., 2021) reported the inclusion of students with special characteristics or disabilities ("special needs"). Moreover, neither of these two studies developed any further the specificities (nor the lack of specificities) of teaching climate change to this population. This omission may reflect a gap in the current literature regarding

the intersection of climate change education and individuals with specific needs. Even though there is not yet an indication that differentiated educational approaches may be needed, future research may benefit from addressing this aspect to ensure inclusivity and accessibility in climate change education efforts.

3.2.5. Political Views

While special characteristics and disabilities were not prominently featured in the studies, just a few articles from the United States did explore the political views among student participants such as Democrats, Republicans, or others. This aspect reflects the multifaceted nature of climate change education, acknowledging the potential impact of political ideologies on climate-related attitudes and behaviors. However, on average, (Lawson et al., 2019; K. T. Stevenson, Peterson, et al., 2018; Walsh & Tsurusaki, 2018) show that politically conservative parents or students are less likely than others to support mitigation actions. With climate change education interventions, relatively greater climate change concern gains can be obtained across those target groups (Lawson et al., 2019).

3.2.6 Urban vs Rural

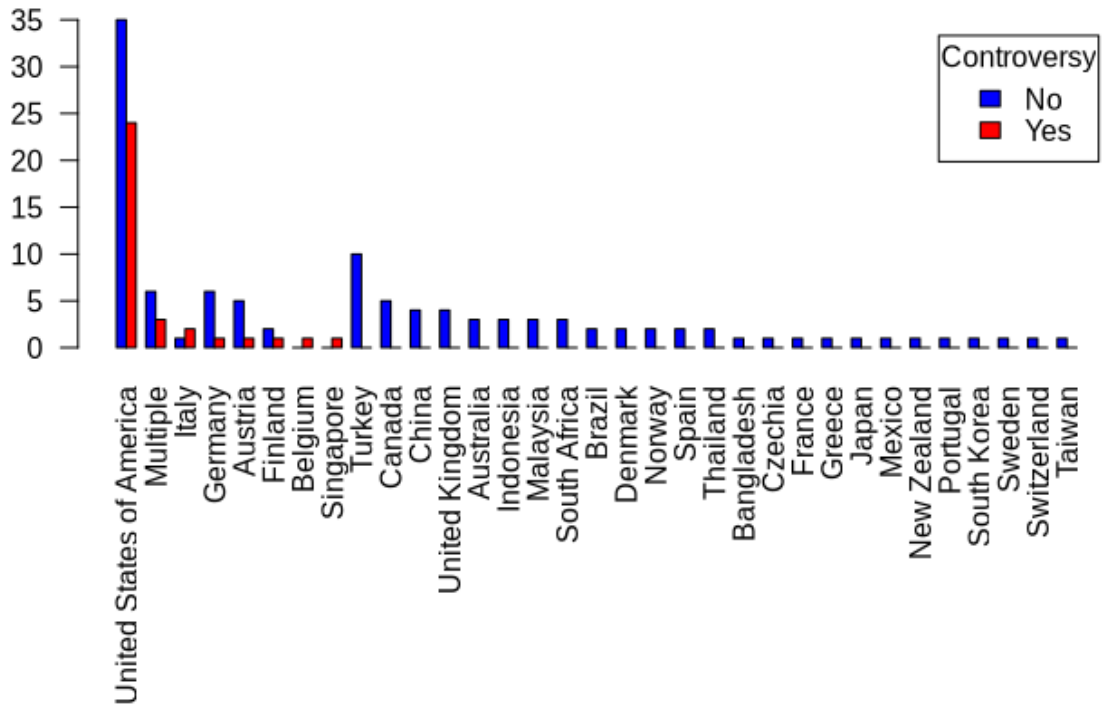
Finally, most interventions on climate change were delivered in urban contexts (59.8%), and only 4.6% of studies report that they were implemented in rural contexts, 11.1% reported that they were implemented in both contexts, and 24.3% of the studies are marked as non-applied for this item. This result may indicate a need to extend CCE to rural settings.

3.3. Controversy and misconceptions

3.3.1 Controversy

70.6% of the documents with a particular focus on the societal controversy that climate change might not be happening or might not be human-induced are studies from the United States, while 40.4% of the studies are made in the United States (2 fifth of the studies from the United States directly deal with this controversy). Based on the other studies concerning this, we found three out of nine studies from multiple countries, two out of three from Italy, one study out of six studies from Austria, one out of seven studies from Germany, one out of three studies from Finland, and the only Belgian and Singaporean studies **(Figure 5)**.

Figure 5. Presence (red bars) or Absence (blue) of controversy-centered intervention about climate change education per country (units: number of studies)



Source: Authors.

The focus on controversies structures a great part of the climate change education literature in some countries, particularly the United States. This is likely due to a large part of the public discourse in the media and the political arena which is not in agreement with the scientific consensus (Boykoff, 2007a, 2007b; Nisbet & Myers, 2007; Zamith et al., 2013) Anthropogenic global warming has unfortunately been highly misrepresented and politicized in some media. United States and British television news and newspaper coverage have perpetrated substantial informational bias deviating from the scientific consensus on anthropogenic global warming (Boykoff, 2007b; Brüggemann & Engesser, 2017) Almost a third of articles in the United States press still contain a contrarian voice (Schmid-Petri et al., 2017) Therefore, considering that the United States is the most represented country in the climate change education literature, researchers should acknowledge these national specificities when reproducing methodologies or referring to studies conducted in the United States. Moreover, researchers might consider avoiding expressions like: "controversial issue" or "controversial nature of the topic", referring to anthropogenic climate change, when they publish in international journals, as it can be in certain contexts a socially controversial

topic (Schubatzky & Haagen-Schutzenhofer, 2022) e.g. in the United States, (Nisbet & Myers, 2007) but may not be generalizable to other countries (Zamith et al., 2013) and it is not a scientifically-controversial topic (Cook et al., 2018a).

Furthermore, it may be worth mentioning that the scientific literature that we review here is not exempt from misconceptions concerning these controversies. For instance, (Chang et al., 2018) mentioned, "How the climate changes naturally were also discussed, so that the perception that it is mainly due to human-induced causes was firmly emphasized as a false belief". While the greenhouse gas mechanism is a natural process that indeed allows life to prosper on earth, recent climate change is the process by which human activities, through anthropogenic greenhouse gas emissions, enhance this phenomenon, with deleterious consequences to human societies and ecosystems. The scientific consensus (both in terms of publications and climate scientists) is now that climate change is mainly due to human-induced causes (Cook et al., 2018a) while the contribution of human activities to recent climate change is nearly 100% (IPCC, 2021).

Some climate change topics chosen to focus the climate change intervention can be inadequate or confusing. For instance, focusing on seismic activity from a climate change education point-of-view (Silva et al., 2021) can be in some cases misleading because the effects of climate, extreme rainfall, or tides have been shown to have a second-order impact on seismic activity: tectonic loading is by far the main driving force of earthquakes. The climate change communication in those interventions shall be clear: even if in some (Ekström et al., 2006; C. Liu et al., 2009; Swindles et al., 2018) links exist between climatic changes and earthquake frequency at multi-decadal to millennial timescales, on a specific day, the climate has no link with the occurrence of an earthquake, i.e., there is no “earthquake weather”. Moreover, current research is under progress to further study links between seismic activity and climate but it is still poorly known. Climate change education is shown to affect people’s perception of linkages between different environmental hazard risks, which makes crucial the most accurate communication about natural disasters and non-climatic drivers as well.

3.3.2. Misconceptions

Many misconceptions exist about climate change and can be common across countries or different generations. For example, misinformation about anthropogenic global warming has confused the public, particularly in the US, and underscored support for climate mitigation policies (Cook et al., 2018b). Aivelo and Uitto (2015) uncovered how schoolbooks for instance frequently perpetuate outdated models and perspectives concerning genetics and heredity. Furthermore, (Busch, 2021) underscored that the presentation of uncertain frameworks regarding climate change can influence the attitudes and beliefs of students, introducing biases and misunderstandings into the students’

perception of foundational scientific topics. Common misconceptions in schoolbooks, teachers or students include confusion between the greenhouse effect and recent climate change, between weather and climate, but also between the ozone hole problem and the climate change problem, or even volcanoes/solar activity being a predominant factor of the recent climate change (Bonilla & Quesada, n.d.; Choi, 2015).

We confirm those statements in the studies systematically reviewed here. In our sample, around 35 papers (approx. one out of five) analyzed the importance of tackling misconceptions. Of those papers, at least nine included refutation-oriented approaches in their interventions and assessed their results. All nine articles found increased knowledge after "debunk" interventions, which can be strengthened by visual materials (Bozdogan, 2011) or by following a constructivist approach (Karpudewan & Mohd Ali Khan, 2017).

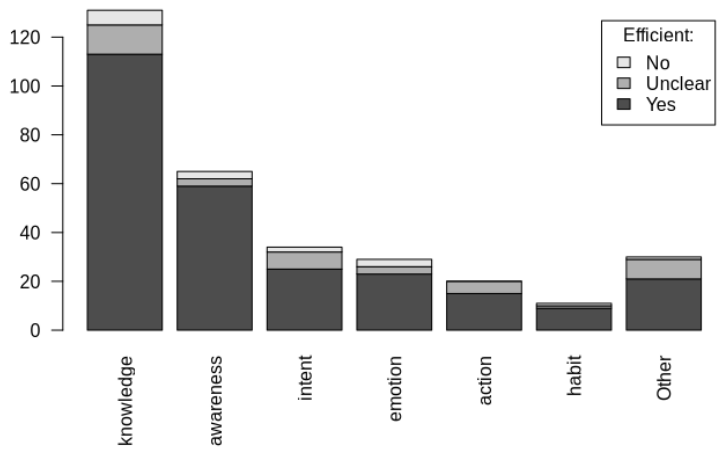
In conclusion, it is highly recommended to include debunking misconceptions or common misinformation with, for instance, updated resources for communicators and educators who teach climate science and/or critical thinking (Cook et al., 2018a).

3.4. Knowledge-behavior gap

3.4.1. Outcomes

As for Population and Interventions, we observed a very large variability of considered outcomes. To systematically explore this variability, we divided the presentation of the outcomes into Cognitions (knowledge and awareness), Attitudes (intent and emotions), and Behaviors (actions and habits) about climate change **(Figure 6)**.

Figure 6. Number of studies with outcomes of knowledge, awareness, intent, emotion, action, habit, and Other



Note : Number of studies with outcomes of knowledge, awareness, intent, emotion, action, habit, and Other disentangled by positive ("Yes"), unclear ("Unclear"), or negative ("No") impacts of climate change education strategies.

We take cognitions about climate change to be either awareness of climate change (i.e., knowing climate change exists and is presently happening) or knowledge about climate change (i.e., knowing the factual mechanisms that explain climate change and its consequences). Importantly, cognitions about climate change should reflect that students' beliefs about how climate change works and its consequences match the available scientific evidence, regardless of their emotional investment in the matter or subsequent behaviors. Cognitions include knowing the most important causes and consequences of anthropogenic climate change or correctly identifying which actions have a larger impact on climate change, among others.

Attitudes towards climate change include both emotional reactions about climate change and intentions to act about climate change. In this sense, attitudes towards climate change could be linked with climate anxiety, climate helplessness, confidence in international collaboration about climate change, and claiming to be willing to implement several actions to fight climate change. Crucially, attitudes do not amount to actual behavior.

Finally, behaviors about climate change include actions that participants carried out to fight climate change or habits, that is, actions that have been repeated consistently over time. In this sense, interventions that observed behavioral change observed actions taken or reported by participants to fight climate change or adapt to it. For example, consuming less meat or participating in a public event aiming at convincing decision-makers to pass laws to protect the environment can be taken as behaviors.

Mitigation of and adaptation to climate change are not possible without human behavior change, be it on the individual, collective, or policy level. However, understanding a problem does not necessarily mean that we know how to solve it or that we can agree on how to implement measures to address it: this is the well-documented "knowledge-behavior" gap in the environment field. To narrow the divide between knowledge and action regarding climate issues, climate educators were urged to develop content that focuses on local environmental changes or local places, cultures, and activities (Rousell & Cutter-Mackenzie-Knowles, 2020). Additionally, framing the message to establish a shared understanding with their target audiences has been documented (Knutti, 2019). A recent systematic review aimed at identifying successful strategies for climate change education highlighted the importance of presenting personally relevant and meaningful information, as emphasized by (Monroe et al., 2016).

Thus, it is crucial to attempt to close the knowledge-behavior gap, particularly for the interest of this systematic review, using the most effective climate change education strategies. From the documents we reviewed, three main results helped us precise the nature of the knowledge-action gaps:

The number of documents addressing the knowledge as an outcome was higher (87.7%) than those addressing the awareness (43.8%) and, more importantly, is much higher than those addressing the attitude factors (emotion 19.2% and intent 22.6%) and the behavior factors (action 12.3% and habits 6.2%) (**Figure 6**).

The percentages of studies that declared a positive effect of the intervention are higher for knowledge and awareness (88%) than emotion and intent (76%) or action and habits (77%) (**Figure 6**). The indicators of cognition changes (especially knowledge) were more constant and easily defined than attitudes and behaviors. Regarding knowledge, we can separate a majority of studies that measure knowledge by evaluating the correctness of answers in questionnaires (e.g.(Kolenaty et al., 2022; Lester et al., 2006) and the ones that study the complexity of the cognitive structure in the explanation of climate change processes (e.g. (Chin et al., 2016; Jacobson et al., 2017). Concerning awareness, the indicators were more varied, as they measured, for example, a change in the beliefs of participants concerning anthropogenic climate change (e.g,(Walsh & Tsurusaki, 2018) the awareness of the impact one's everyday activities on climate change (e.g., (Karpudewan & Mohd Ali Khan, 2017), or the awareness that climate change is more important for society than previously thought, among others. In terms of intent, we found many specific outcomes, such as the willingness to speak more about climate change, and the willingness to change consumption habits, transport, waste disposal, or what some authors call "action-knowledge". In the behavioral outcomes, we found an extensive range of actions (e.g., communicating about climate change, organizing community meetings, participating in protests, reaching out to political personnel, fighting against an environmentally detrimental project and habits (e.g., consumption, transport, diet, energy saving at home or school). Finally, the emotional outcomes go from concern to fear and hope, passing through a broad range of personal feelings or more specific emotions such as empathy toward nature or climatic refugees.

However, we found that the increase in climate change knowledge had a positive effect on diminishing climate denial and possible scientific misconceptions. For teachers (entourage), curriculum and instruction appear to be important factors in increasing climate change knowledge and perceptions more aligned to those of climate scientists (Lambert & Bleicher, 2013), consistent with (S. Liu et al., 2015; Schubatzky & Haagen-Schutzenhofer, 2022; White et al., 2022) studies for teachers and (Tasquier, 2015) for students.

Depending on the types of knowledge, these can have different impacts on people's concern about climate change, their willingness to act, or even the social acceptance of climate change policies. Causal knowledge significantly increased climate change concern and willingness to support climate-friendly policies (Shi et al., 2015) while (Light et al., 2022) showed that knowledge overconfidence through a large subjective-objective knowledge gap —the difference between the individuals' assessments of their knowledge and their actual knowledge— may track climate change denial attitudes. Finally, schoolchildren were more likely to report support for adaptation, mitigation, and individual climate-friendly behaviors if they think global warming is happening (K. T. Stevenson, Peterson, et al., 2018).

3.4.2 Emotions

The effectiveness of climate change education partly depends on how some emotions are strategically harnessed and managed in educational programs and communication efforts. Striking a balance between raising awareness of the urgency of the issue and providing individuals with the tools and motivation to take meaningful action is key to reaching optimal results. Our review showed

that learning climate change causes tends to cause negative emotions in schoolchildren ("negative" fear, anger, sadness, helplessness) while some other additional topics and approaches have the potential to moderate this effect: lessons on climate change solutions(Jones & Whitehouse, 2021), positioning students as capable problem solvers able to affect change in their families and communities (Herrick et al., 2022; Trott, 2022).

Highlighting the positive aspects of sustainable living, such as a sense of fulfillment or connection to nature, can create positive emotions that encourage sustainable behaviors(Cebesoy & Karisan, 2022; Cibik & Boz-Yaman, 2022; Korfgen et al., 2017; Nakamura et al., 2019; Pruneau, Doyon, Langis, Vasseur, Martin, et al., 2006; Pruneau, Doyon, Langis, Vasseur, Ouellet, et al., 2006; Sellmann & Bogner, 2013; Trott, 2022; Veijalainen & Clayton, 2013). Building empathy towards nature through interventions (e.g., everyday nature experiences, environmental program on global climate change, 'Head, Hands, and Heart' model of Transformative Sustainability Learning, naming species initiative) could create social norms or intent to climate-friendly behaviors, although positive long-lasting effects are subject to caution.

Positive emotions (hope in particular) tend to be associated with more action against climate change but not systematically: (Wang & Chen, 2022) show that hope per se has no significant effect on knowledge and self-reported mitigation behavior while (Jones & Whitehouse, 2021; K. T. Stevenson, Peterson, et al., 2018) (Khadka et al., 2021) show a positive association.(Oberauer et al., 2023) shows that negative (respectively, positive) emotions are associated with more (respectively, less) complex thinking competence. Findings based on lectures and movies eliciting different emotions in 1730 students, (Wang & Chen, 2022) warn that fear emotion can be counterproductive and suggest an interesting potential complexity based on the interventions' foci: general knowledge and causes of climate change can cause negative emotions (anger, sadness, and helplessness) while lessons on solutions cause positive emotion (such as hope and happiness). Consistently, one important aspect that should be taken into consideration regarding interventions that are emotion-based is the emotional maturity of the participants in conjunction with students' questions, concerns, and misconceptions.

3.4.3. Self-efficacy

In at least 20 papers, self-efficacy is mentioned as an important feature in the fight against climate change, serving as a fundamental psychological driver that can shape individuals' and communities' responses to this global crisis. Self-efficacy is the perception an individual has of their ability to control whether they emit or not a specific behavior and to enact it correctly and consistently if they choose to do so (Bandura, 1997) A strong sense of self-efficacy is important because it instills confidence and belief in one's capacity to take meaningful action to limit climate change. In the face of climate change, this belief can become a catalyst for proactive steps, such as reducing personal carbon footprints, advocating for sustainable policies, and embracing eco-friendly lifestyles. Fostering self-efficacy through education, awareness campaigns, and empowerment initiatives, allows people to overcome the overwhelming nature of climate change and to envision themselves as capable change-makers. This, in turn, fuels the collective effort needed to address the complex and

interconnected challenges posed by climate change, creating a more sustainable and resilient future for our planet.

Nineteen articles in our review targeted and evaluated self-efficacy toward pro-environmental behaviors. These are mostly effective in fostering a strong sense of self-efficacy, perceptions of control over mitigation/ adaptation behaviors or personal responsibility towards climate change via a number of educational strategies including active learning (DeWaters et al., 2014), realistic role-playing (Meya & Eisenack, 2018) outdoor activities (Khadka et al., 2021) and inter-generational contact (S. Hu & Chen, 2016b)directed at students and as well as interventions directed at teachers such as content expert lessons (Siegner, 2018)or teaching materials and activities (Xie et al., 2014). However, the limited attention afforded to this determinant of behavior instead of arguably equally important ones such as attitudes towards them or social coordination over CC mitigation/adaptation is not compatible with the Theory of Planned Behavior (Ajzen, 1991) suggesting that consistent adoption of behaviors is heavily facilitated by perceiving that the behaviors are easily implemented and does not entail heavy material or social costs. In this sense, failing to effectively complement self-efficacy interventions with social coordination or attitudes towards mitigation/adaptation of pro-environmental behaviors may limit or even completely annul otherwise effective, knowledge-aimed, interventions in their goal of changing behavior.

3.4.4. Attitudes

Attitudes towards a behavior are defined as what people think about the behavior, specifically, whether it is perceived as positive, pleasurable, and beneficial for the self or, on the contrary, is perceived as costly, painful, or uncomfortable. Crucially, attitudes do not deal with the considered behavior's known consequences but rather with whether it is a behavior that is associated with valued social groups or is aesthetically pleasing. As for self-efficacy, research suggests that bad attitudes toward specific behaviors can preclude their effective implementation even knowing the potentially harmful consequences of the considered behaviors. For example, one can know the negative health consequences of alcohol or tobacco consumption even while having positive attitudes towards smoking because it is pleasurable or characteristic of a valued social group. As for pro-environmental behavior and education, our review also shows few interventions directly aimed at changing attitudes towards behaviors. These include video (Flora et al., 2014)and in-class lessons (Harker-Schuch et al., 2020), active hands-on interventions (Trott, 2022), and inter-generational contact (S. Hu & Chen, 2016b) All interventions are effective in fostering more positive attitudes towards pro-environmental behaviors independently of the actual knowledge content students acquired. However, as above, the comparatively limited attention given to attitudes (as opposed to knowledge) about pro-environmental behaviors may prove that educational interventions are ineffective as behavior change mechanisms since possible effects of knowledge on behavior can be weakened by ultimately negative attitudes towards certain pro-environmental behaviors (Ajzen, 1991).

3.4.5 Local and personally relevant climate issues

Locally relevant interventions are of prime importance, as highlighted in the reviewed studies (Monroe et al., 2016) One consistent finding is that programs focusing on local, personally relevant climate change issues effectively engage schoolchildren. These programs inspire agentic action, fostering a keen sense of personal responsibility. (Trott, 2022). These initiatives have a transformative impact, reshaping students' beliefs, attitudes, and behaviors concerning climate change. This is rooted in the local context, rendering the subject personally significant. (Holthuis et al., 2014; Littrell et al., 2022). The projects excel in promoting competence for mitigation, particularly among future generations. They achieve this by nurturing a new form of citizenship, where individuals feel a profound connection to and responsibility for their local environment (Park & Kim, 2020). Students' deep attachment to their natural environment, often stemming from their local identity, serves as a potent motivator. Their desire to protect the Earth, driven by a clear understanding of how climate change impacts their immediate surroundings, fuels their active engagement (Nussbaum et al., 2015; Pruneau et al., 2003). The success of these locally grounded interventions transcends the specific cases examined, finding relevance in broader environmental education contexts. The transferability of this approach to diverse settings underscores its effectiveness in cultivating climate change cognitions, attitudes, and behaviors (Schrot et al., 2021; Shea et al., 2016).

These studies underscore the vital role of personally relevant, locally relevant interventions in connecting with students. These programs foster engagement and induce transformative change, enhance competency for mitigation, harness motivational forces, and hold promise for wider adoption in environmental education.

3.5. CCE Interventions

3.5.1. Theoretical Education Frameworks

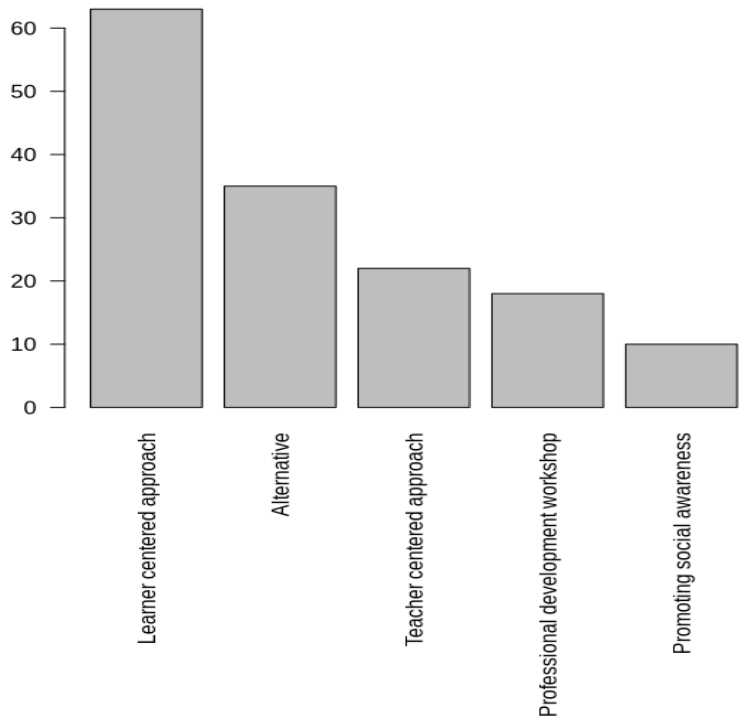
We analyzed whether the educational interventions were embedded in the schools' curriculum or not. More than half of the educational strategies implemented in the studies reviewed were curricular (53.6%), whereas about a third (33.1%) were extracurricular. This finding shows that schools and/or the agencies responsible for generating guidelines and strategies for education management in the analyzed countries appear to be including climate change education in their curricula. Eleven of the educational interventions (7.3%) were targeted exclusively to teachers or pre-service teachers. The rest of the educational

strategies found in our review were both curricular and extracurricular (2.6%) or unclear regarding this aspect (about 3.3%).

Most of the educational strategies on climate change were implemented indoors (69.5%) with just 4.6% of the interventions taking place exclusively outdoors, while the remaining 25.2% of the studies report combining both an indoor and outdoor strategy (one study did not report the setting). Educational strategies were administered mainly in a face-to-face format (82.9%). Only a few of the interventions were fully administered virtually (6.6%) or remotely (2.0%). Almost 9% of the educational strategies included mixed formats (face-to-face and remote or face-to-face and virtual or face-to-face, remote and virtual).

We performed an analysis of the theoretical frameworks that guided the intervention's pedagogical designs based on the authors' explicit declaration (when available, see Figure 7). On the basis of this information categorized interventions into those whose main distinctive aspect was to be (1) learner centered (characterized by the design of learning experiences that support learners in constructing new and more complex understandings of the problem on the basis of their own prior knowledge and experiences, 41%) (Duffy & Jonassen, 2013) (2) promoting social awareness aiming at contextualizing science education and moving away from mere content-based instruction to incorporate relevant aspects of socio-cultural life, 6%) (Sadler et al., 2007, 2011) (3) alternative (i.e. using less traditional resources like intergenerational contact, technology enhanced, art-based, visual arts, gaming/gamification) to attain their goals, 23%; (4) teacher-centered (where the instructional structure entails, first, information transmission by means of some form of direct instruction (Jacobson et al., 2017) independent of the learner´s prior knowledge, and only then (if at all) allowing learners to engage in more active learning, 14%). In addition to this, there were (n=18) professional development workshops that included a diversity of pedagogical strategies.

Figure 7. Number of studies per theoretical educational framework



Source: Authors.

3.5.2 Pedagogical techniques

This review included various types of interventions, each assessing many possible impacts of climate change education. This diversity in intervention types allowed for a comprehensive exploration of the effects of climate change education across various educational modalities. These interventions spanned a wide spectrum of pedagogical techniques, including, but not limited to, virtual reality (VR) experiences, comprehensive teaching and learning modules, dedicated climate change curricula, workshops, engaging summer camps, and educational video games. Therefore, it is possible to classify interventions into broader categories (Figure 8):

- Lessons based [n=60]: participants are involved in traditional and non-traditional classes where they receive lectures, presentations from experts, or educational videos with some important and relevant information about climate change. Additionally, it is very common to use discussions and/or focus groups or activities through workshops. Brainstorming, conceptual maps, and drawings emerge as pedagogical strategies used.

- Combined strategies [n=41]: some of the articles are not focused on specific types of intervention, instead, a wide array of strategies is used as a mechanism to inform, provide, or increase knowledge, change attitudes, or modify behaviors of participants in climate change. For this instance, a combination of lessons, workshops, art, and project-based learning is seen as a way to deliver intervention to participants.

- Project-based learning [n=19]: some articles report different types of intervention in which participants are involved in indoor, outdoor, laboratory experiments or action research experiences. It is quite common that reported experiences include observations, taking different measures, and participating in activities such as summer camp or clubs in which students learn concepts, discuss, and report their personal experiences. There are reports of the creation of gardens in school settings.

- Curriculum-based [n=11]: the implementation of curriculums is a frequent strategy of intervention, and it tends to be a mechanism to introduce a wide range of topics of climate change in classes. Most often, these curriculums are based on more general policies or educational normative frameworks, both global and local.

- Technology/Virtual scenarios-based [n=9]: participants received different information in virtual settings, e.g., VR or Web Apps. The use of VR is an innovative way of learning and makes it possible for students to interact with various scenarios, real and simulated. These articles consider that the use of technology/virtual strategies facilitates the engagement and enjoyment of learners.

- Culturally based [n=6]: In these interventions participants were trained in different types of activities such as music composing, photovoice projects, and audiovisual projects (e.g., filmmaking). Not all of these interventions imply the creation of something towards climate change themes, other activities let participants interact with different exhibitions linked to the topics learned, e.g., visiting a museum or a factory.

- Game-based interventions [n=6]: the use of games and video games in climate change education is a promising tool according to different articles. Students benefit from these types of interventions in which the main purpose is to engage and provide some interactive content about climate change education.

The settings across the included studies in this systematic review exhibited a wide array of geographical and environmental contexts. The primary setting for many of these investigations was educational institutions, predominantly schools. However, observed

settings extended beyond traditional classrooms to encompass diverse settings, including museums and natural outdoor settings. In approximately 20 % of the studies, at least a part of the pedagogical activities was outdoor. These varied settings offered a comprehensive exploration of climate change education, capturing the richness of real-world contexts. Interestingly, non-traditional settings were included in both curricular and co-curricular interventions. Suggesting that schools are already open to the possibility of non-traditional settings to present content and develop skills required for their curricula.

The interventions within these settings demonstrated a high degree of adaptability and innovation. While the majority of interventions were conducted in person, mirroring conventional classroom experiences, several studies included technology-mediated interventions. These remote or technology-mediated interventions, in some cases, were integrated into extracurricular activities, fostering an extended and dynamic learning landscape. Additionally, a portion of the interventions was seamlessly integrated into daily curricular activities, highlighting the relatively easy integration of climate change education into existing educational structures. This approach to setting and mode of delivery within the reviewed studies underscores the multifaceted nature of climate change education, adaptable to a variety of learning environments and delivery methods.

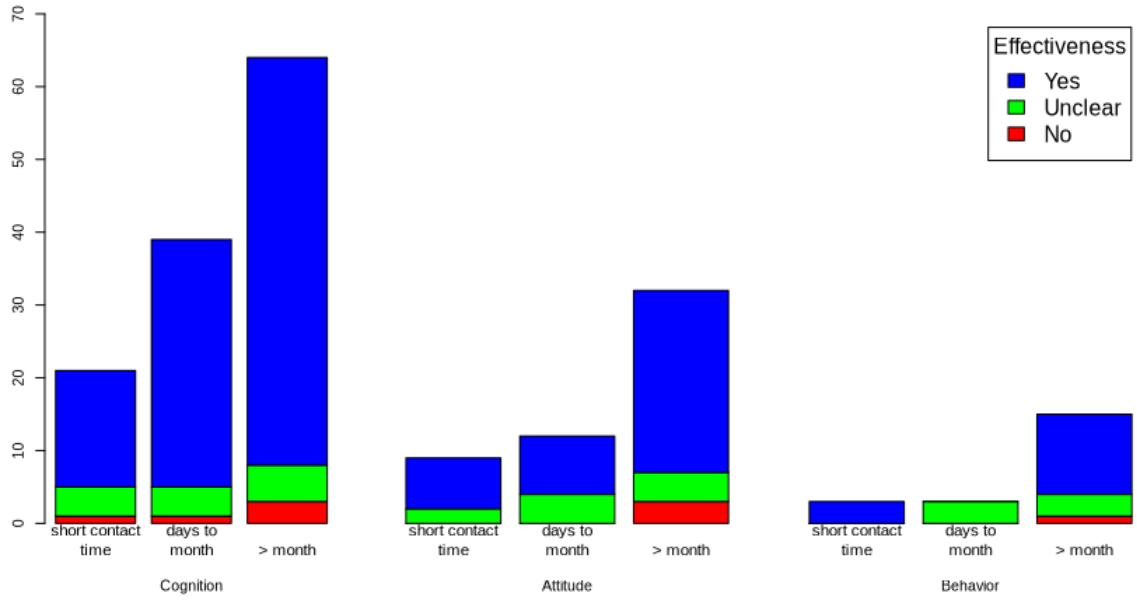
3.5.3. Duration of the interventions

It is difficult to establish a specific duration of the interventions reported in the studies included in this systematic review. The differences across studies permit us to consider that interventions can vary from one day to two years, with different approaches in their presentation (**Figure 8**). As an example, some of the reported interventions are divided into activities through 1-15 weeks (about three and a half months) with sessions of 45-90 minutes each day or included in the regular classes or curriculum. An overwhelming majority of the interventions do not last more than a year, which strongly hampers the effectiveness assessment of behaviors or habits.

As suggested in **Figure 8**, the longer the intervention the more there are non-effective interventions across all outcomes. While counterintuitive, this finding may reflect a methodological gap in implemented interventions that limits their interpretation. Indeed, most studies implemented relatively short pre-post interventions with no further follow-up observations. These research designs can only observe whether the intervention had the intended effect immediately after implementation but not whether this effect is maintained over time. Therefore, several very short interventions may have observable effects immediately after implementation, but these disappear sometime after implementation. In the absence of follow-up observations, it is not possible to determine which of the short

interventions, if any, maintains its effects over time. On the other hand, extended interventions have the possibility of longer and more numerous follow-up observations and therefore can offer direct evidence on whether they caused the intended effect on the outcome whether this effect was maintained over time, and to what extent it diminished over time. We believe that longer interventions provide better evidence of effectiveness, and therefore reveal an overestimation of instruction effectiveness in short-term studies.

Figure 8. Number of studies by the duration of intervention in the function of the type of outcome (Cognition, Attitude, and Behavior)



Note: Effectiveness is indicated by the colors; blue for "Yes", green for "Unclear" and red for "No".

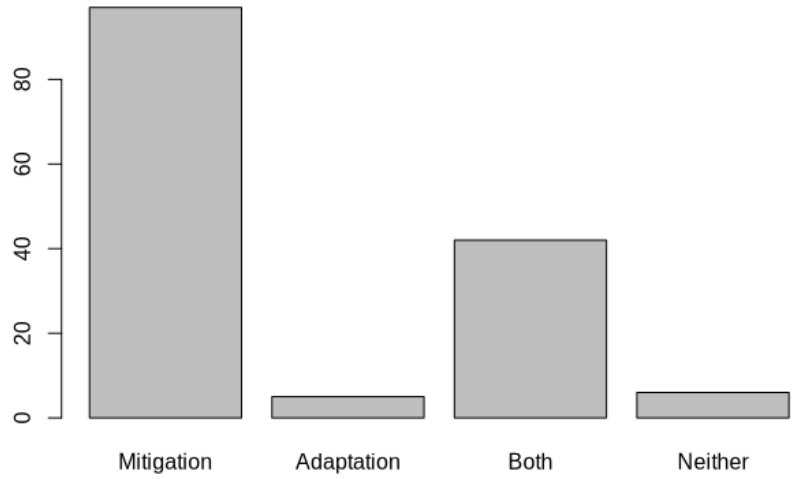
Source: Authors.

3.5.4. Mitigation vs. Adaptation focus

Given the large variability of aspects of climate change that were subject to intervention (e.g., greenhouse gas emissions, social causes and impacts of climate change, loss of biodiversity, wildfires, and climate migration, among many others), we divided all considered intervention outcomes into two broad categories: climate change mitigation or climate change adaptation. We take as climate change mitigation all interventions aiming at diminishing anthropogenic climate change, typically, by reducing its causes. These include, for example, reducing greenhouse gas emissions, reducing electricity consumption, or recycling, among many others.

On the other hand, we take climate change adaptation as all actions aiming to limit the negative human and social consequences of an already existing climate change. These include, for instance, educating people on the proper reactions to catastrophic climate events such as forest fires or floods, teaching water conservation techniques, or local crop plantation, among others.

Figure 9. Number of studies focusing on Mitigation, Adaptation, Both or Neither (see Methods)



Source: Authors.

Sixty-two percent of the studies focused on mitigation, while only 3% focused specifically on the adaptation aspect, 27% concerned both aspects, and 7% concerned interventions that were too theoretical (e.g., description of the physical processes of greenhouse mechanisms) to be linked to either mitigation or adaptation (**Figure 9**).

The few studies on adaptation focused on natural disasters (earthquakes potentially modulated by climate, floods, and heatwaves, (Williams et al., 2017; Zhong et al., 2021)), islands, coastal or hot vulnerable places allow educators to make climate change education personally relevant choosing extreme weather to which the local community is facing. Adaptation-mitigation city planning (e.g., Nature-based strategies, building design) can lead to many co-benefits while adaptation-based climate change education can act as a potential magnifier of the effectiveness of these city plans (Boyd et al., 2022).

In general, we find a knowledge- and an intent-behavior gap: the link between what we know about climate change, what we want to do, and what we do is by no means straightforward, a fortiori one year after climate change interventions. If climate change education can reach positive outcomes in knowledge, attitudes, and behaviors while helping to meet climate targets, there is no current scientific ground to translate all the intentions to act into actions or habits (Cordero et al., 2020).

3.5.5. Analysis of methodologies

Forty-seven percent of the studies included in this systematic review used a quantitative methodology, 26% used a qualitative methodology, and 26% used mixed methods or associated quantitative and qualitative methods. 79% of the studies employed a pre-post comparison to conclude their research (95% of the quantitative studies, 88% of the mixed method studies, and 45% of the qualitative studies). While the classical design of pre-post comparisons of survey results analyzed simple classical T-tests was preponderant, we found a very high diversity of methodologies, theoretical approaches, and designs to measure the effect of climate change education. Some researchers preferred the use of qualitative case studies which allowed them to dive into the complexities of individual responses to climate change education (e.g. (Gladwin et al., 2022; Goulah, 2017) while others collected and evaluated the effects of the interventions on thousands of students (e.g., (Xie et al., 2014)). Amongst the studies, some used an ethnographic methodology (e.g. (Jones & Whitehouse, 2021; McGowan & Bell, 2022)), others were based on the psychological theory of planned behavior (S. Hu & Chen, 2016b), the social judgment theory (White et al., 2022) or used conceptual maps to evaluate the conceptual changes in the climate change concepts of the students (Eggert et al., 2017; Ratinen et al., 2013). These examples illustrate the dynamism of the multidisciplinary research arena of climate change education.

While getting information from various scientific perspectives is important to get a full picture of the challenges, successes, and failures of climate change education, a small effort of standardization in the evaluation of interventions might allow us to compare research findings globally. In the current panorama, it would be impossible to conduct a meta-analysis and to provide an evidence-based evaluation of best practices in CCE, backed up by numerical figures. We urge the researchers from the field to propose standardized surveys and to define the best tools to analyze them. The objective is not to reduce the diversity of methodological approaches, it is merely to provide a complementary impartial way to compare studies across continents and pedagogical methodologies.

3.5.6. Climate change education participatory initiatives

In our review, two CCE participatory and citizen initiatives are evaluated across the papers (n=4). First, K.i.d.Z.21 is built on a transdisciplinary and constructivist approach of linking scientific reasoning and teenagers' real-life concerns in both in-school and out-of-school settings aimed at transforming attitudes and behaviors related to climate change. (Deisenrieder et al., 2020; Keller et al., 2019b) found a positive effect of the k.i.d.Z.21 one-year program on students through various outcomes concerning CC behavior and awareness. Second, (Deisenrieder et al., 2020; Keller et al., 2019b) show how additional participation in the teenager's climate protests of "Fridays for Future (FFF)" - a global climate strike movement

started in 2018, launched by young climate activist Greta Thunberg - could foster self-efficacy, perceived collective effectiveness and intent and action outcomes. However, based on a sample of several thousand students, (Oberauer et al., n.d.) revealed that the k.i.d.Z. 21 modules did not influence students' levels of complexity thinking competence in their explanations of climate change for themselves and humanity in general. Those aspects need further research, in particular how climate change education can nurture the knowledge for action.

3.6. Socio-economic factors and interventions

It is worth noting that most studies targeted urban populations living in high-income countries. 68 out of the 114 documents for which we could extract both the income group and the Urban/Rural variable, were exclusively targeting urban zones in high-income countries. Rural interventions in middle and low-income countries are extremely rare: only one document concerned exclusively rural areas of the intermediate-income group of countries (Pekel, 2019) and only one in the lower-income group.

Concerning the targeted populations, the proportion of studies aimed at students was higher in the high-income countries (82%) than in the intermediate-income country group (56%), where a larger proportion focused on teachers (40% compared to 11%). All four studies from the lowest-income group targeted students, and the two studies concerning parents specifically were both conducted in high-income countries. "Classical" teacher-centered interventions were more predominant in the lower-income countries (11% in the high-income countries, 23% in the intermediate group, and one study out of four in the lowest group). Similarly, all interventions classified as "alternative" (see section 3.5.1) were from high-income countries, except (S. Hu & Chen, 2016b) from China. Concerning the contents of the interventions, all interventions focusing on the anthropogenic climate change controversies were conducted in high-income countries. In contrast, the intermediate group of income had a higher proportion of intervention including adaptation to climate change (44%). Local issues of climate change were more regularly presented to students from intermediate and lower-income countries (50% of the studies). Finally, comparatively more studies from intermediate-income countries measured behavior effects (34% compared to 12% in high-income countries), while all studies from lower-income countries measured exclusively cognition factors. Altogether, we found that while the diversity of intervention types was less clear in the intermediate and lowest-income countries, they seem to focus more on concrete local issues and solutions to those. That said, 40% of the interventions from the intermediate income group took place in Turkey, and 17% in China. Therefore, we are unable to separate the influence of the economic national income factors from the cultural specificities of the countries.

Regarding the context-dependent interventions in rural or urban environments, it is interesting to note that three studies out of the seven which were conducted in exclusively rural contexts, were extracurricular, and only one was directed to teachers. While 31% of the studies conducted in urban contexts and of the studies in mixed rural/urban environments included adaptation issues, 50% of the studies in a rural context included it. Similarly, five interventions out of seven presented local examples of climate change, while the proportion in the urban context was only 40%. The theoretical approaches in rural contexts were equitably distributed among alternative (two studies), learner-centered, teacher-centered approaches, and promoting social awareness (one study each). Significantly more studies were based on learner-centered approaches in urban contexts. None of the studies from rural contexts measured the effects of the interventions on behavioral changes. Amongst the papers from both rural and urban contexts, we found no comparisons regarding which approach was more effective in urban vs rural contexts. Altogether, presenting local examples and focusing on adaptation strategies might be easier and more meaningful in a rural context. However, there is a research gap in the development of specific strategies for climate change education in rural contexts, particularly in low-income countries where the differences in lifestyle between rural and urban areas might be more sensible.

3.7. Effectiveness of intervention strategies

3.7.1 Main effectiveness results and high diversity of approaches

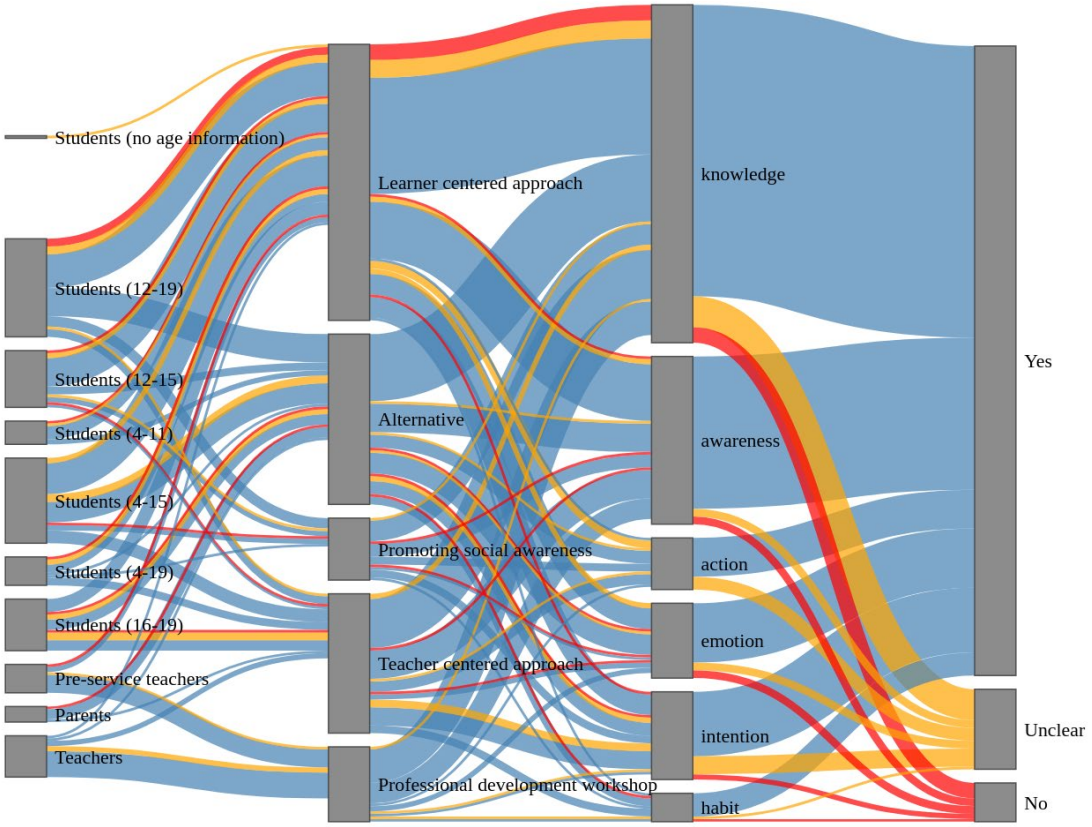
In the 146 analyzed documents, we found a high diversity of pedagogical approaches to climate change education. Research in this area is exploring various educational theoretical frameworks, pedagogical strategies, and tools, as well as both curricular and extracurricular solutions to address the climate crisis. The number of "classical" interventions (curricular, teacher-centered approaches with only indoor activities) corresponds to less than 5% of the studies. This is complemented by a wide range of scientific methodologies to assess the effectiveness of the intervention ranging from observational and ethnographic methodologies e.g., (McGowan & Bell, 2022) to highly specialized quantitative data analysis with specific scales e.g.,(Kolenaty et al., 2022) The creativity reflected in climate change education efforts, together with a high diversity of analytical methodologies and the complexity of the relationships between cognition, attitudes, and behaviors, makes it difficult to make comparisons or draw general conclusions about their effectiveness.

Authors from the analyzed studies reported 290 outcomes from our analysis framework (knowledge, awareness, emotions, intent, actions, or habits). Out of these 290 outcomes, the majority reported having positive effects on participants (n=244), some reported effects that were not positive (n=31), and a small group reported no positive effects of the intervention (n=16) (see **Figure 6**). This overwhelmingly high number of positive effects together with the small number of "classical" interventions, may suggest a potentially high publication bias, i.e., researchers and journals in the field tend to publish studies with pedagogical innovations and positive results, not studies assessing classic methodologies or those that failed to show positive results. In addition to this, it points toward the importance of building common ground, including evaluation standards across all scientific or disciplinary fields from which the intervention comes. However, it also suggests that many pedagogical interventions can improve the cognition, attitudes, and behaviors of students and their entourage. This result should also be read as an incentive to develop as much as possible the initiatives of climate education, regardless of the chosen approach. Indeed, while most analyzed studies suggested positive outcomes, the lack of unified methods to assess the effectiveness of the intervention impedes comparing the effectiveness of interventions or building up more multi-faceted ones by coordinating several smaller interventions into a larger, theoretically-driven intervention program. It is also a call for both researchers and journals to the dangers of publication bias since non-effective interventions can be just as informative as effective ones and not reporting ineffective interventions can distort published literature and hamper scientific advances.

3.7.2 General patterns of effectiveness

We compared general patterns of effectiveness for the different populations, intervention types (indoor/outdoor, curricular/extracurricular, pedagogical framework and tools), and outcomes using data representation tools (see **Figure 10**) to identify patterns of effectiveness for different populations. While considering the effectiveness reported by the authors against the high dimensionality of the categories extracted in our systematic review, no clear patterns emerged from these data representation tools. Hence, we are not able to provide general conclusions for the most efficient pedagogical strategies to apply to our separated populations by accounting for all documents. The high diversity of pedagogical methodologies, analysis frameworks, and outcomes (see section 3.7.1) made it difficult to analyze all the aspects of climate change education. Moreover, this absence of clear patterns might be reinforced by the publication bias toward positive results. We encourage researchers from the field to publish more systematically negative outcome results in climate change education research. These results could help define which strategies to avoid and give more significance to the positive outcomes.

Figure 10. Example of multifactorial representation of the effectiveness of climate change intervention



Note: From left to right in grey bars: population category, theoretical pedagogical framework, outcome, and effectiveness). In such Sankey Diagrams, the width of the links between categories represents the number of studies. All links are colored depending on the final effectiveness reported in the papers (red: no, yellow: unclear, blue: yes).

Source: Authors.

3.7.3 Comparative designs and effectiveness in individual studies

Twenty-four documents included a comparison of different pedagogical elements in their studies, which allows us to report some best practices for climate change education. The elements compared in these studies range from details in the implementations of pedagogical methods (e.g. (Leitao et al., 2022; Stevenson, King, et al., 2018) to completely different theoretical approaches (Karpudewan & Mohd Ali Khan, 2017; Littrell et al., 2022).

Concerning the theoretical approaches, the literature shows that student-centered pedagogies perform better than traditional education, in terms of both knowledge and awareness. Particularly, constructivist approaches provide better results than traditional teacher-centered pedagogies for students ranging from 11-15 years old (Karpudewan & Mohd Ali Khan, 2017), to 16-18 years old (Karpudewan et al., 2015; Karpudewan & Mohd Ali Khan, 2017). Also, pedagogies allow students to engage emotionally with the issue of climate change: students experience connection to nature through outdoor pedagogical settings (Korfgen et al., 2017), discussion with local seniors, or creative expression through short films (Littrell et al., 2022) also appear to improve their knowledge, awareness or intent concerning climate change better than the comparable control groups receiving traditional interventions. Finally, the pedagogical activities that allow students to grasp the complexity of climate change issues appear more efficient, students participating in argumentative activities through argument-driven inquiry (Salsabila et al., 2019): 13-14 years old), using concept cartoons in argumentation-based activities (Pekel, 2019): 15-16 years old), or activities promoting critical evaluation of two competing climate change models (Lombardi et al., 2013)) gain climate change knowledge more efficiently than their comparable counterpart control group. (Bhattacharya et al., 2021)showed comparable results on 14-18-year-old students by comparing students in a model-based instruction, allowing students to discover complex modeling practices and a non-model-based instruction.

All previous educational methodological comparisons are strongly grounded in educational theoretical developments and participate in the debates engaged in climate change education concerning the most efficient theoretical frameworks. However, their conclusions may be simple to apply practically. For instance, compare the “productive failure” and “direct instruction” pedagogical design in two groups receiving the same instruction contents but changing the order of activities. The group that engages first in the instruction with a complex system problem to resolve before receiving the lecture tends to gain more knowledge than the group receiving the lecture first. This example shows that, beyond complex theoretical development in education science, the literature contains practical solutions that may help educators enhance the efficiency of their climate change interventions.

By using comparative research designs, various authors show that details concerning their interventions might have strong consequences on their final pedagogical effects. Presenting articles with the same contents but with framing close to students' interests affects their emotive reception and attitude toward climate change (R. B. Stevenson et al., 2017). Similarly, the induction of hope in an intervention can enhance knowledge gains compared to fear (Wang & Chen, 2022), and elements of game design which cause competitive behavior between students have deleterious effects compared to the other designs (Leitao et al., 2022). Comparative methods can also be used to show that specific activities can enhance the general effectiveness of a complete climate change education module (e.g., museum exhibition (Saribaş et al., 2016), virtual reality marine exploration (Markowitz et al., 2018), naming a species (Veijalainen & Clayton, 2013), using visual material in addition to traditional instruction methods (Bozdogan, 2011).

Finally, it is important to note that the effects of climate change education are not independent of the external environment. (Deisenrieder et al., 2020) shows the k.i.d.Z.21 educational program has a more positive effect on the knowledge, awareness, and behavioral changes of the students participating in political climate protests. It is also possible to externally influence the effectiveness of climate change education. (Kabir et al., 2015) show using comparative methods that providing schools with a complete manual concerning climate change and health protection was useful in increasing the knowledge of students.

3.8. Limitations

This systematic review has several inherent limitations that should be acknowledged. Firstly, our review considers a priori grey and peer-reviewed published literature on climate change education, however, a large and growing number of teachers throughout the world teach climate change in their classrooms but do not publish their interventions and associated measured outcomes. According to a global survey (UNESCO, 2021), 67% of teachers, principals, and other education stakeholders declare that climate change is well or partially integrated into environmental themes in schools of teachers and 40% are confident in teaching the cognitive aspects of climate change. As it is not their main job, it is understandable that the teachers are very unlikely to publish in peer-reviewed journals the large amount of theoretical or practical activities on climate change education they teach worldwide.

Second, the field of education boasts a vast body of literature, while our specific focus on recent developments in climate change education was constrained to a pool of 146 articles

(albeit the largest systematic review on climate change education up to date). This disproportion in the volume of available literature may have introduced a bias towards more extensively studied educational topics. Geographical considerations must be considered. The selected studies in this review disproportionately represent high-income per capita Northern America and Western Europe countries, which could impact the generalizability of the findings.

Third, the publishability of negative or null results can introduce bias. Studies that did not yield significant findings may be less likely to be published, potentially skewing the overall picture of climate change education in the literature found that articles in which the authors explicitly concluded to have found support for their hypothesis were cited two to three times more than the ones that did not. This limitation should be kept in mind when assessing the comprehensiveness of the review. We tried to address this issue by including many databases and grey literature. The quality of the analyses in the articles included is a potential limitation. The review relied on the methodologies, rigor, and reporting quality of the selected studies. Variability in the quality of research and analysis across the articles included may have influenced the overall findings and conclusions of this review. It is crucial to be mindful of the methodological diversity when concluding the synthesized literature.

Fourth, our review looks at the climate change education impacts on schoolchildren and their entourage but, by construction, we do not look at impacts on the general population or impacts of sustainable environmental education which are complementary topics but beyond the scope of our research. However, those latter studies could help to give a broader view of what can and cannot work in terms of climate change (i.e., a specific case of an environmental problem) education interventions. For instance, results are less clear concerning the knowledge-behavior gap when looking at the most effective mechanisms to promote household action on climate change. A recent meta-analysis (Nisa et al., 2019) showed that behavioral interventions on their own have very small average effects on household behaviors, in particular climate change mitigation. On the other hand, increasing the educational achievement of the youth is a sustainable development objective but (O'Neill et al., 2022) (found that improved educational attainment is even associated with a slight increase in emissions. It is important to stress that environmental-friendly behavioral interventions could have stronger effects when used in combination with alternative strategies. Our review is thus limited to the scope and state-of-the-art conclusions about schoolchildren and climate change education.

These limitations, while acknowledged, should not diminish the value of this review but rather underscore the need for further research and a nuanced understanding of the complexities inherent in the field of climate change education.

3.9. Implications for climate change education practitioners

Although this review has focused on research that disposes of measurable findings, showing also that traditional education strategies, null or negative results are less likely to be published, we report below some implications for CCE practitioners on the main take-homes from the systematic review outputs and from our considerations of promising avenues and missing factors to account in the design of CCE interventions, as well as desired actions for CCE practitioners from policy and the international arena to take forward.

3.9.1. Summary for policymakers

This summary is presented below in **Box 1** and **Scheme 1**.

Box 1. Summary of the effectiveness of and implications for climate change education

- **Result 1**
  Many innovative pedagogies have been introduced in Climate Change Education (CCE), in terms of approaches (e.g. constructivist, inquiry-based, or project-based learning), tools (e.g. games, web platforms), pedagogical framework (e.g. global - UNESCO- and local education program as NGSS or k.i.d.Z.21) and settings (e.g. outdoor, museums, photovoice, art elicitation, etc.) {see sections 3.5.1, 3.5.2, 3.5.5, 3.5.6 and 3.7}
- **Result 2**
  Alternative CCE practical activities (Gaming, art-based, entertainment-based: technology-enhanced; intergenerational or place-based as museums and parks) allow more positive emotional outcomes, knowledge, and intent to act {see sections 3.5.1 and 3.5.2}
- **Result 3**
  By decreasing the order of use in CCE interventions, we find: lessons-based (27%), combined strategies (26%), project-based learning (13%), curriculum-based (10%), Technology/virtual-based (6%), cultural-based (5%) and game-based (3%) {see sections 3.5.1, 3.5.2 and 3.5.5}
- **Result 4**
  83% of the CCE studies show positive outcomes: higher-than-average positive outcomes for Cognitions (88%), lower-than-average positive outcomes for Attitudes (76%) and Behaviors (77%). All initiatives concerning CCE should be encouraged, even though the intervention is traditional {see section 3.4}
- **Result 5**
  Knowledge in CC is the most studied outcome (41%) but not a sufficient condition to change long-term behavior. However, CC knowledge decreases misconceptions, climate denial and opposition to individual climate-friendly behaviors {see section 3.4}
- **Result 6**
  Local & personally relevant CC examples strengthen knowledge and intent {see sections 3.4.5}
- **Result 7**
  Transversality improves awareness and intent, for instance in history (e.g., climate history), economy (e.g., CC impacts, negative externalities), mathematics (e.g., data, charts, activities about CC), language (e.g., image analysis, stories) or chemistry (e.g., greenhouse effect) {see section 3.1.2}

- **Result 8**
  Strong empathy towards nature and engaging students in meaningful action and problem-solving likely increases CC-related long-term behavior {see section 3.4.2}

  Result 9
  Competition (vs. collaboration) & fear/anger (vs. hope) emotion dampen positive outcomes for climate change behaviors {see sections 3.4.1 and 3.4.2}

- **Result 10**
  Evidence exists on positive multiplier effect through intergenerational learning. Not enough research, evidence or consensus exists on significant differential outcomes depending on gender, culture, student's ages, socio-economic status, rurality, or ethnicity {see sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4 and 3.6}

- **Result 11**
  More CCE research and practices are needed on the integral effects (cognitions, attitude, behaviors), qualitative and quantitative, indicating all authorized socio-demographic data, and/or with control randomized groups of students and entourage (teachers and parents) on a long-term basis (> one year and/or with sustainability tests on time) and with multiple local mitigation and adaptation activities in several disciplines {see sections 3.5 and 3.7}

- **Result 12**
  Debunking controversies and misconceptions gives positive outcomes on climate change awareness and intent to act of students and parents, particularly in the United States (with predominant body of associated literature, where CCE-social controversy is high). Particular attention should be paid to not present climate change as "controversial" by nature {see sections 3.1 and 3.2}

- **Result 13**
  The diversity of evaluation/analysis methodologies is too high to be comparable i.e., difficult to evaluate what works best based on the number of publications in the literature {see sections 3.7.1 and 3.7.2}

- **Result 14**
  24 papers use comparative study designs to compare different methodologies, and usually innovative pedagogies (constructivism, multidisciplinary, collaborative etc.) perform better in terms of cognition, attitude, and behavior outcomes {see sections 3.7.3}

- **Result 15**
  International framework and governance to promote climate change education implementation in countries, collaborations between national ministries of Environment and Education to build national trainings of educational and environmental experts, teachers and policy-makers, making CCE a core and holistic curriculum component, provide high-quality national materials and promote community of practices between researchers and educational practitioners are among the most urgent recommendations in the literature {see sections 3.8 and 3.9}

Scheme 1. Schematic representation of current promising interventions, research gaps, and recommendation for main actions

3.9.2. In the educational community

While more than half of the educational strategies are integrated into school curricula, non-traditional interventions are mostly reported: 95% of the climate change education interventions studied here are extra-curricular or not teacher-centered approaches or outdoor activities. Stimulating the creativity of teachers and students to build and implement locally relevant integral climate change education projects in their schools but especially beyond: in their homes or their communities is key.

Strong gaps can exist between current society claims and school implementation of climate change learning. For instance, in the United States, according to the results of a national poll (Kamenetz, 2019), more than 80% of parents or teachers support the teaching of climate change but most teachers (58%) do not teach climate change in schools. Interestingly, the

main reason (65% of teachers) put forward is because "it's not related to the subject I teach". This could indicate that there is a lack of adequate, high-quality, and national materials and training targeting teachers where transversality of the climate change topic is taught. As shown by the UNESCO survey in 2021 "Learn for our Planet: A Global Review of How Environmental Issues are Integrated into Education" (UNESCO, 2021) courses most likely to include climate-related content were biology, science, and geography but very few in Mathematics, History or Language which highlights a key opportunity to improve the climate change education materials and training for teachers in those latter areas.

Moreover, 30% of teachers reported that they were not familiar with suitable pedagogies on climate change education, and approx. 20% were unable to choose "their subjects or the time to teach the topic or felt they didn't have the necessary knowledge and skills" (UNESCO, 2021) Thus, there is a crucial need for pre-service and in-service teacher training on climate change education based on scientific evidence. Engaging teachers in implementing integral activities (i.e., combining class interventions about "minds, heart, and hands" (Siegner, 2018; Trott, 2022; UNESCO, 2019)) is also key.

In only 53% of the countries (n=100) the national curriculum frameworks included climate change at least once with a very limited depth of inclusion (i.e., less than 300 words per million words) (UNESCO, 2021a). When climate change is included in the national or school curriculum, teachers are incentivized to spend time teaching climate change, they are more likely to feel convinced and prepared and can have support to access CCE resources.

About the content analyzed through country submissions under the United Nations Framework Convention on Climate Change, social and emotional or behavioral learning was less commonly discussed than cognitive learning about climate change education (UNESCO, 2019) Thus, as well as for research, plans of CCE should include more attitudinal and behavioral learning approaches.

Finally, only 40% of national education laws and 45% of educational strategies explicitly refer to CCE (UNESCO, 2021) which indicates that countries should build legal frameworks to incentivize and strengthen the CCE's core curriculum component at the national level.

3.9.3. In the research community

More CCE research and practices are needed on the integral effects (cognitions, attitude, behaviors), qualitative and quantitative, indicating all authorized socio-demographic data of the samples, ideally with control randomized groups of students and entourage (teachers and parents) on a long-term basis (>1 year and/or with sustainability tests on time) and with multiple local mitigation and adaptation activities in several disciplines. As indicated in our

Methods (see section 3.1.3), the screenings of our systematic review did not include several studies from NGOs or other languages than English, because they mainly discuss the intervention contents without measurable outcomes. This indicates a need for researchers, NGOs and international organizations to adopt methods and measurements that can effectively measure and capture the effectiveness CCE interventions.

Knowing that the consequences of climate change will be particularly acute for the rural population of developing countries (Barbier and Hochard, 2018), it appears crucial to increase our research efforts in these contexts because studies are far too scarce (n=2). Similar recommendations exist about the differential outcomes depending on gender, culture, student's age, socio-economic status, or ethnicity: more research, evidence, or consensus is needed to improve and frame CCE interventions.

Negative or null results are also crucial for the progress of science and its self-adjusting nature, but it is much harder to convince reviewers and editors to publish them (Bespalov et al., 2019). Researchers themselves tend to reduce the submission of such results when it happens, as well. Our systematic review encourages the researchers to publish both positive, null, and negative results given the relatively unexplored nature of all characteristics of climate change education impacts at the research level. As pointed out by (Cordero et al., 2020) this can: i) provide quality checks for past research, ii) reduce time and resources needed for researchers to avoid doing several times the same tests, iii) help give the correct big picture of a topic and increase reproducibility and iv) help prioritize correctly some national interventions in several domains (e.g. if an educational approach is shown to provide negative results, it helps society to adapt the decisions).

Finally, there is a need for standardized methods for evaluating pedagogical effects. We do not believe that using exclusively standardized tools would be better for climate change education research, however, in addition to the high variety of methods and theoretical approaches, the use of standardized tools (e.g., surveys adapted to global climate change knowledge and the keys to analyzing its results in terms of cognition, attitudes, and behaviors) could allow us to make proper comparisons at the global level.

Conclusions

In conclusion, our systematic review has provided valuable insights into the worldwide effects of climate change education on the cognitions, attitudes, and behaviors of schoolchildren and their entourage. Through the analysis of a diverse range of studies, we have addressed the key research questions posed in this paper:

(1) Curricular and Extracurricular Activities: We have found that climate change education takes place within both curricular and extracurricular settings, with more than half of the educational strategies being integrated into school curricula. This inclusion of climate change education within formal education systems signifies a growing recognition of its importance. Moreover, we have identified a wide range of intervention types, from traditional classroom-based lessons to innovative approaches like virtual reality experiences, workshops, and educational games. These diverse strategies aim to provide students with the knowledge and skills needed to comprehend and respond to the complex issue of climate change.

(2) Intervention Strategies: Our review highlights the multifaceted nature of climate change education interventions. These strategies encompass not only knowledge acquisition but also the cultivation of attitudes and emotions toward climate change. Lessons and combined strategies appear to be the most common approaches, emphasizing the importance of providing students with information and opportunities for discussion. Additionally, we have seen the emergence of innovative interventions that harness emotions strategically to engage students and motivate action. Fostering a sense of hope and self-efficacy is crucial in inspiring individuals to take pro-environmental actions. The use of technology, games, and VR settings is encouraged; future education strategies may consider these options to engage learners in climate change education.

(3) Effectiveness of Intervention Strategies: Our analysis indicates that the knowledge-behavior gap is a persistent challenge in climate change education. While knowledge-focused interventions tend to have a positive impact, there is room for improvement in addressing attitudes, emotions, and behaviors. A key finding is the importance of bridging the gap between knowledge and behavior by addressing attitudes and emotions effectively. The role of self-efficacy is particularly noteworthy, as it instills confidence in individuals, empowering them to take action in mitigating and adapting to climate change. Future climate change education interventions should emphasize not only knowledge but also attitudes and self-efficacy to enhance their effectiveness.

(4) Diverse Responses Across Populations: Our review also considers the diverse demographic characteristics of the participants in these studies, including age, gender, socio-economic status, and cultural backgrounds. Importantly, the interventions have demonstrated flexibility and adaptability in accommodating different age groups and addressing a wide range of cultural contexts. This adaptability is crucial in ensuring that climate change education reaches and resonates with a broad and diverse audience. Overall, climate change education has made

significant strides in raising awareness and knowledge among schoolchildren and their broader communities. However, there is still work to be done in closing the knowledge-behavior gap and fostering the necessary attitudes and emotions that drive action. Our findings underscore the importance of ongoing innovation in educational strategies, such as leveraging technology, harnessing emotions, and promoting self-efficacy. Building updated curriculums, national CCE training for teachers, and creating a community of practices and climate education policy in Global South and North are urgent to meet climate targets (see for instance current international ALEC project: https://www.alec.oce.global/en/projects/alec). This is a crucial issue, as UNESCO recently warned that "53% of the world's national education curricula make any reference to climate change and when the subject is mentioned, it is almost always given very low priority." Worse: less than 40% of teachers are confident in teaching about climate change severity and feel able to explain the climate change impacts on their region (UNESCO, 2021).

The results of this systematic review have profound implications for the future of climate change education, emphasizing the need for a holistic approach that addresses both cognitive and emotional dimensions. By tailoring interventions to the diverse needs and characteristics of learners, we can inspire meaningful action and contribute to a more sustainable and resilient future for our planet. Climate change education, grounded in critical innovative pedagogies, has the potential to empower the next generation to become informed and proactive stewards of the environment, ultimately bridging the knowledge-behavior gap that persists in addressing climate change.

Appendix 1. Search

Scopus

Search: (TITLE-ABS-KEY (adolescent OR child* OR teen* OR *school* OR juvenil* OR parent* OR famil* OR young* OR youth OR student* OR pupil* OR relatives OR teacher* OR household OR sibling*) AND (TITLE-ABS-KEY (educat* W/3 climat*) OR TITLE-ABS-KEY (educat* W/3 "global warming") OR TITLE-ABS-KEY (educat* W/3 "global heating") OR TITLE-ABS-KEY (class* W/3 climat*) OR TITLE-ABS-KEY (class* W/3 "global warming") OR TITLE-ABS-KEY (class* W/3 "global heating") OR TITLE-ABS-KEY (course* W/3 climat*) OR TITLE-ABS-KEY (course* W/3 "global warming") OR TITLE-ABS-KEY (course* W/3 "global heating") OR TITLE-ABS-KEY (teach* W/3 climat*) OR TITLE-ABS-KEY (teach* W/3 "global warming") OR TITLE-ABS-KEY (teach* W/3 "global heating") OR TITLE-ABS-KEY (learn* W/3 climat*) OR TITLE-ABS-KEY (learn* W/3 "global warming") OR TITLE-ABS-KEY (learn* W/3 "global heating") OR TITLE-ABS-KEY (qualificat* W/3 climat*) OR TITLE-ABS-KEY (qualificat* W/3 "global warming") OR TITLE-ABS-KEY (qualificat* W/3 "global heating") OR TITLE-ABS-KEY (pedagog* W/3 climat*) OR TITLE-ABS-KEY (pedagog* W/3 "global warming") OR TITLE-ABS-KEY (pedagog* W/3 "global heating") OR TITLE-ABS-KEY (*curricul* W/3 climat*) OR TITLE-ABS-KEY (*curricul* W/3 "global warming") OR TITLE-ABS-KEY (*curricul* W/3 "global heating") OR TITLE-ABS-KEY (train* W/3 climat*) OR TITLE-ABS-KEY (train* W/3 "global warming") OR TITLE-ABS-KEY (train* W/3 "global heating"))) AND NOT (TITLE ("university" OR "higher education")) AND NOT (TITLE-ABS-KEY ("class* climate")) AND (EXCLUDE (DOCTYPE , "cr") OR EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "Undefined")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish") OR LIMIT-TO (LANGUAGE , "German") OR LIMIT-TO (LANGUAGE , "Portuguese") OR LIMIT-TO (LANGUAGE , "French"))

Database: Scopus

Searched in: All

Language: en, ge, es, fr, po

Document type: All except (books and conference reviews)

Web of Science Core Collection

Search: TS= (child* OR teen* OR adolescent OR *school* OR parent* OR famil* OR youth OR young OR juven* OR student* OR pupil* OR household OR sibling* OR relatives OR teacher*) AND TS=((climat* OR ”global warming” OR “global heating”) NEAR/3 (educat* OR teach* OR learn* OR class* OR train* OR qualif* OR course* OR pedagog* OR *curricul*)) NOT TI=("university" OR "higher education") NOT TS=("class* climate")

Database: Web of Science

Searched in: Web of Science Core Collection

Language: en, es, ge, fr, po

Document type: All except(Book review or Meeting abstract)

Web of Science Scielo

Search: TS= (child* OR teen* OR adolescent OR *school* OR parent* OR famil* OR youth OR young OR juven* OR student* OR pupil* OR household OR sibling* OR relatives OR teacher*) AND TS=((climat* OR ”global warming” OR “global heating”) NEAR/3 (educat* OR teach* OR learn* OR class* OR train* OR qualif* OR course* OR pedagog* OR *curricul*)) NOT TI=("university" OR "higher education") NOT TS=("class* climate")

Database: Web of Science

Searched in: SciELO

Language: All

Document type: All

Informit

Search: [All Fields:("adolescent" OR All Fields:"child" OR All Fields:"children" OR All Fields:"teenager" OR All Fields:"teens" OR All Fields:"teen" OR All Fields:"teenage" OR All Fields:"school" OR All Fields:"schools" OR All Fields:"preschool" OR All Fields:"preschools" OR All Fields:"juvenile" OR All Fields:"juveniles" OR All Fields:"parent" OR All Fields:"parents" OR All Fields:"family" OR All Fields:"families" OR All Fields:"young" OR All Fields:"youngster" OR All Fields:"youngsters" OR All Fields:"youth" OR All Fields:"student" OR All Fields:"students" OR All Fields:"pupil" OR All Fields:"pupils" OR All Fields:"relatives" OR All Fields:"teacher" OR All Fields:"teachers" OR All Fields:"household" OR All Fields:"sibling" OR All Fields:"siblings")] AND [All Fields:("climate education" OR All Fields:"climate change education" OR All Fields:"education for climate" OR All Fields:"global warming education" OR All Fields:"education on global warming" OR All Fields:"education for global warming" OR All Fields:"global heating education" OR All Fields:"education on global heating" OR All Fields:"education for global heating" OR All Fields:"climate class" OR All Fields:"climate change class" OR All Fields:"class on climate" OR All Fields:"class for climate" OR All Fields:"global warming class" OR All Fields:"global warming class" OR All Fields:"class on global warming" OR All Fields:"class for global warming" OR All Fields:"global heating class" OR All Fields:"global heating class" OR All Fields:"class on global heating" OR All Fields:"class for global heating" OR All Fields:"climate course" OR All Fields:"climate change course" OR All Fields:"course on climate" OR All Fields:"course for climate" OR All Fields:"global warming course" OR All Fields:"global warming course" OR All Fields:"course on global warming" OR All Fields:"course for global warming" OR All Fields:"global heating course" OR All Fields:"global heating course" OR All Fields:"course on global heating" OR All Fields:"course for global heating" OR All Fields:"teachings on climate" OR All Fields:"teachings for climate" OR All Fields:"teaches climate" OR All Fields:"teach climate" OR All Fields:"teachings on global warming" OR All Fields:"teachings for global warming" OR All Fields:"teaches global warming" OR All Fields:"teach global warming" OR All Fields:"teachings on global heating" OR All Fields:"teachings for global heating" OR All Fields:"teaches global heating" OR All Fields:"teach global heating" OR All Fields:"learn climate" OR All Fields:"learns climate" OR All Fields:"learn global warming" OR All Fields:"learns global warming" OR All Fields:"learn global heating" OR All Fields:"learns global heating" OR All Fields:"climate qualifications" OR All Fields:"climate change qualifications" OR All Fields:"qualifications on climate" OR All Fields:"global warming qualifications" OR All Fields:"qualifications on global warming" OR All Fields:"global heating qualifications" OR All Fields:"qualifications on global heating" OR All Fields:"climate pedagogy" OR All Fields:"climate change pedagogy" OR All

Fields:"pedagogical program on climate" OR All Fields:"pedagogical intervention on climate" OR All Fields:"climate change pedagogical" OR All Fields:"global warming pedagogy" OR All Fields:"pedagogical program on global warming" OR All Fields:"pedagogical intervention on global warming" OR All Fields:"global warming pedagogical" OR All Fields:"global heating pedagogy" OR All Fields:"pedagogical program on global heating" OR All Fields:"pedagogical intervention on global heating" OR All Fields:"global heating pedagogical" OR All Fields:"climate curriculum" OR All Fields:"climate change curriculum" OR All Fields:"curricular activities on climate" OR All Fields:"curricular activities for climate" OR All Fields:"extracurricular activities on climate" OR All Fields:"extracurricular activities for climate" OR All Fields:"global warming curriculum" OR All Fields:"curricular activities on global warming" OR All Fields:"curricular activities for global warming" OR All Fields:"extracurricular activities on global warming" OR All Fields:"extracurricular activities for global warming" OR All Fields:"global heating curriculum" OR All Fields:"curricular activities on global heating" OR All Fields:"curricular activities for global heating" OR All Fields:"extracurricular activities on global heating" OR All Fields:"extracurricular activities for global heating" OR All Fields:"climate training" OR All Fields:"climate trainings" OR All Fields:"climate change training" OR All Fields:"climate change trainings" OR All Fields:"training on climate" OR All Fields:"trainings on climate" OR All Fields:"global warming training" OR All Fields:"global warming trainings" OR All Fields:"training on global warming" OR All Fields:"trainings on global warming" OR All Fields:"global heating training" OR All Fields:"global heating trainings" OR All Fields:"training on global heating" OR All Fields:"trainings on global heating" OR All Fields:(educat* climat*)~3 OR All Fields:(class* climat*)~3 OR All Fields:(course* climat*)~3 OR All Fields:(teach* climat*)~3 OR All Fields:(learn* climat*)~3 OR All Fields:(qualif* climat*)~3 OR All Fields:curricul* climat*)] AND All Fields:("university" AND NOT [All Fields:"higher education") OR All Fields:("class climate"] AND NOT [All Fields:"classroom climate") OR All Fields: 'classroom climate'] AND Resource Type: Conference OR Report OR Journal

Database: Informit

Search in: Humanities & Social Sciences Collection, Health Collection

Language: All

Document type: Conferences, Journal, Report

Embase

Search: (TITLE-ABS-KEY (adolescent OR child* OR teen* OR *school* OR juvenil* OR parent* OR famil* OR young* OR youth OR student* OR pupil* OR relatives OR teacher* OR household OR sibling*) AND (TITLE-ABS-KEY (educat* W/3 climat*) OR TITLE-ABS-KEY (educat* W/3 "global warming") OR TITLE-ABS-KEY (educat* W/3 "global heating") OR TITLE-ABS-KEY (class* W/3 climat*) OR TITLE-ABS-KEY (class* W/3 "global warming") OR TITLE-ABS-KEY (class* W/3 "global heating") OR TITLE-ABS-KEY (course* W/3 climat*) OR TITLE-ABS-KEY (course* W/3 "global warming") OR TITLE-ABS-KEY (course* W/3 "global heating") OR TITLE-ABS-KEY (teach* W/3 climat*) OR TITLE-ABS-KEY (teach* W/3 "global warming") OR TITLE-ABS-KEY (teach* W/3 "global heating") OR TITLE-ABS-KEY (learn* W/3 climat*) OR TITLE-ABS-KEY (learn* W/3 "global warming") OR TITLE-ABS-KEY (learn* W/3 "global heating") OR TITLE-ABS-KEY (qualificat* W/3 climat*) OR TITLE-ABS-KEY (qualificat* W/3 "global warming") OR TITLE-ABS-KEY (qualificat* W/3 "global heating") OR TITLE-ABS-KEY (pedagog* W/3 climat*) OR TITLE-

ABS-KEY (pedagog* W/3 "global warming") OR TITLE-ABS-KEY (pedagog* W/3 "global heating") OR TITLE-ABS-KEY (*curricul* W/3 climat*) OR TITLE-ABS-KEY (*curricul* W/3 "global warming") OR TITLE-ABS-KEY (*curricul* W/3 "global heating"))) AND NOT (TITLE ("university" OR "higher education")) AND NOT (TITLE-ABS-KEY ("class* climate")) AND (EXCLUDE (DOCTYPE , "cr") OR EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "Undefined")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish") OR LIMIT-TO (LANGUAGE , "German") OR LIMIT-TO (LANGUAGE , "Portuguese") OR LIMIT-TO (LANGUAGE , "French"))

Database: Scopus

Searched in: All

Language: en, ge, es, fr, po

Document type: All except (books and conference reviews)

Proquest

Search: ((adolescent OR child* OR teen* OR school* OR preschool* OR juvenil* OR parent* OR famil* OR young* OR youth OR student* OR pupil* OR relatives OR teacher* OR household OR sibling*) AND ((educat* NEAR/3 climat*) OR (educat* NEAR/3 "global warming") OR (educat* NEAR/3 "global heating") OR (class* NEAR/3 climat*) OR (class* NEAR/3 "global warming") OR (class* NEAR/3 "global heating") OR (course* NEAR/3 climat*) OR (course* NEAR/3 "global warming") OR (course* NEAR/3 "global heating") OR (teach* NEAR/3 climat*) OR (teach* NEAR/3 "global warming") OR (teach* NEAR/3 "global heating") OR (learn* NEAR/3 climat*) OR (learn* NEAR/3 "global warming") OR (learn* NEAR/3 "global heating") OR (qualificat* NEAR/3 climat*) OR (qualificat* NEAR/3 "global warming") OR (qualificat* NEAR/3 "global heating") OR (pedagog* NEAR/3 climat*) OR (pedagog* NEAR/3 "global warming") OR (pedagog* NEAR/3 "global heating") OR (curricul* NEAR/3 climat*) OR (curricul* NEAR/3 "global warming") OR (curricul* NEAR/3 "global heating") OR (train* NEAR/3 climat*) OR (train* NEAR/3 "global warming") OR (train* NEAR/3 "global heating"))) NOT (("class climate" OR “classroom climate” OR “school climate”) OR ("university" OR "higher education"))

Database: Proquest

Searched in: Environmental science collection, Natural science collection, Language: en, ge, es, fr, po

EBSCO-host

Search: (adolescent OR child* OR teen* OR *school* OR juvenil* OR parent* OR famil* OR young* OR youth OR student* OR pupil* OR relatives OR teacher* OR household OR sibling*) AND ((educat* N3 climat*) OR (educat* N3 "global warming") OR (educat* N3 "global heating") OR (class* N3 climat*) OR (class* N3 "global warming") OR (class* N3 "global heating") OR (course* N3 climat*) OR (course* N3 "global warming") OR (course* N3 "global heating") OR (teach* N3 climat*) OR (teach* N3 "global warming") OR (teach* N3 "global heating") OR (learn* N3 climat*) OR (learn* N3 "global warming") OR (learn* N3 "global heating") OR (qualificat* N3 climat*) OR (qualificat* N3 "global warming") OR (qualificat* N3 "global heating") OR (pedagog* N3 climat*) OR (pedagog* N3 "global warming") OR (pedagog* N3 "global heating") OR (*curricul* N3 climat*) OR (*curricul* N3 "global warming") OR (*curricul* N3 "global heating") OR (train* N3 climat*) OR (train*

N3 "global warming") OR (train* N3 "global heating")) NOT ("university" OR "higher education") NOT ("class* climate")

Database: Proquest

Searched in: Educational Resource Information Center (ERIC), APA PsycINFO

Language: en, ge, es, fr, po

Other databases

- Various websites without structured query systems were browsed and documents were directly downloaded if relevant:
- Regional Development Bank:
- World Bank (https://documents.worldbank.org/en/publication/documents-reports/docadvancesearch)
- Asian Development Bank (https://www.adb.org/publications)
- Inter-American Development Bank (https://publications.iadb.org/en)
- African Development Bank (https://www.afdb.org/en/documents/publications)
- UNESDOC https://unesdoc.unesco.org/advancedSearch/:new
- 3ie: https://developmentevidence.3ieimpact.org/
- Academic Network on Global Education and Learning (ANGEL: https://angel-network.net/)

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