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Review

Climate Change Education in Primary and Lower Secondary Education: Systematic Review Results

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Abstract: Global climate change is rightly receiving increasing attention, including in the field of education. Climate change education (CCE) is becoming one of the key areas of education in general and it is therefore not surprising that more attention is also being paid to climate education research. This review study presents an analysis of papers focusing on climate education for ISCED (International Standard Classification of Education) 1 and 2 students. The selection of the analyzed sources follows the PRISMA 2020 statement; out of 850 identified records, 43 made it into the analysis. Articles that met each of the following criteria were included in the analysis: (i) the impact of the article meets the inclusion in the Web of Science Core Collection service, (ii) the article was published in the period 2001–2020, (iii) the central theme of the article is CCE, (iv) the target audience is ISCED 1, ISCED 2 students or their teachers, (v) the article has a research character with the presentation of methodology and results, or it is a review study that includes an analysis of the records meeting the criteria described above. The quantitative description of the results shows the diversity in journals publishing studies, the exponential increase in their number in recent years, and the hegemony of the United States in this field of research. The qualitative content analysis shows that the most frequently addressed topics focus on knowledge, behavior, actions, experiences, and attitudes. The results show that as the urgency of climate change increases, so do the number and diversity of research studies on climate education for the target group. Most of these studies focus on the mitigation behaviors and willingness to act of students.

Keywords: climate change education; climate literacy; primary education; lower secondary education; review

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Citation: Nepraš, K.; Strejčková, T.; Kroufek, R. Climate Change Education in Primary and Lower Secondary Education: Systematic Review Results. *Sustainability* **2022**, *14*, 14913. https://doi.org/10.3390/su142214913

Academic Editor: Julie Ernst

Received: 10 October 2022
Accepted: 9 November 2022
Published: 11 November 2022

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1. Introduction

Climate change represents a unique challenge of our time. The history of human civilization has shown in many examples the power of humans to fundamentally change the landscape and the environment. Collapses of ecosystems, agricultural systems or local climates have led to the weakening or destruction of entire empires. At the same time, and as a consequence of the changes, war conflicts, population declines, and a general regression of cultural and social development emerged. Human-induced climate change is another in a long line of consequences that the development of human civilization has brought about to date. The impact of past environmental crises has mostly been local or regional. Climate change, by contrast, is occurring on a planetary scale. It is therefore a current threat to the entire civilization with a high risk of adverse developments not only in a limited region, but worldwide. One of the necessary pathways for dealing with, and preventing, such global problems is education [1–3]. Thus, in the case of problems arising from man-made climate change, we speak of climate change education (CCE) [4,5]. This is a relatively new discipline of education that has quickly established itself given the urgency of the climate crisis. Climate change education is a relatively new branch of education that finds its roots primarily in environmental and sustainability education

and science education [6]. However, it differs from them in its object, where it targets one particular challenge of the present. Climate change education is designed to equip students with the knowledge, skills and competencies that will make them the agents of change much needed to deal with the climate change crisis. Thus, properly implemented CCE can be one of the most effective mitigation measures with long-term effects [7]. As complex as climate change is, so are the educational strategies employed in CCE [8]. They vary significantly depending on the level of education, with older students being able to take a fully holistic approach and abstraction, while younger children need to view climate issues through place-based learning approaches. In addition, there is an associated need to cover CCE holistically, not limiting it to the school setting but fully engaging with non-formal education [9].

In the past, a number of CCE research studies have addressed climate change knowledge. The results of these studies have repeatedly highlighted the limitations of scientific knowledge approaches in their ability to influence the attitudes and behaviors of children and young people [10,11]. Despite this unclear relationship between knowledge and behavior, the role of knowledge must not be completely neglected. Sufficient knowledge has an impact on climate change concerns, which further influences children's willingness to act in favor of the climate [12]. Children's engagement and eventual action is also influenced by their perceptions of their ability to achieve change at the individual, local and governmental levels [13]. In addition to increasing pro-environmental attitudes, CCE programs should also address the mitigation of negative emotions such as fear or anger about climate change [14]. These emotions are often seen in the growing movement of young people around the world who are concerned about the inaction of governments and corporations. Climate change thus becomes an educational issue that should be seen primarily as a social issue in which students themselves are implicated [15,16]. CCE is thus the way to activate children's political agency in schools, universities, and the public domain [17]. The problematic implementation of CCE in formal education and its partial rejection by teachers necessitate a search for new educational approaches [5]. Current research on CCE has led Finnish researchers to develop a viable comprehensive model, the bicycle model [18]. This is useful in developing CCE policy, research and practice, and presents a holistic view of CCE. The bicycle model consists of the following aspects, represented by the different parts of the bicycle: knowledge and thinking skills—wheels; values, identity, and worldview—bicycle frame; motivation and participation—saddle; future orientation—handlebars; hope and other emotions—light; action—chain and pedals; operational barriers—breaks. operational barriers. Climate education, like the bicycle in the model, needs all the listed components to function smoothly. The model thus helps CCE program designers not to leave out any of the important aspects needed for a successful program. The model is also used by environmental education researchers, teachers and practitioners in other countries, such as Portugal [19], Australia [20] and the Czech Republic [21].

The increasing amount of research in the field of CCE has also led to the implementation of review studies that provide an overview of the development and key topics in the field. Rousell and Cutter-Mackenzie-Knowles [22] set out to identify key areas for future CCE research and illustrate two unfortunate realities. Firstly, that students' understanding of climate change is limited, error-laden and heavily influenced by the media, and secondly, that we lack appropriate didactic approaches to effectively influence students' attitudes and behaviors. Monroe et al. [8] tracked various CCE interventions in the EBSCOhost database and identified four specific topics appropriate for CCE: engaging in deliberative discussions, interacting with scientists, addressing misconceptions, and implementing school or community projects, among others. Over and above these themes, they then named two areas that are common to broader environmental education, namely a focus on meaningful information relevant to students' personal lives and the use of activating educational strategies. It is not without interest that 26 of the 49 articles analyzed came from the USA. A review by Puttick and Talks [23] focused on the sources of information that

teachers work with in CCE. They mention the low number of research papers that address the topic and identify four dimensions of climate change information sources: the Internet, government sources, mass media and professional development courses. They also point to the "superabundance" of information about climate change and the need to work with high-quality sources when teaching students. The two review studies on CCE focus on the context of the developing world. Mbah et al. [24] looked at the involvement of Indigenous Knowledge Systems in CCE and identified three levels of adaptation: social, structural and institutional. They highlight the need to decolonize CCE through place-based, participatory and holistic approaches. Apollo and Mbah [25] then point out that although CCE is being implemented in country curricula in East African countries, there is a lack of coherent approaches to leverage CCE as a tool in their adaptation and mitigation strategies. In their review study, Kranz et al. [26] describe how public-sphere actions on mitigation and adaptation are discussed in CCE in schools. They point out that CCE does not correspond with the discourse of climate research and there is a lack of discussion of public-sphere actions in schools. They conclude that CCE should incorporate political literacy to educate climate-literate citizens. The key to the further development of CCE research is a commentary by Busch et al. [27], who describe epistemologically distinct forms of knowledge in CCE research, introduce research strategies that are used in this context, and make recommendations for future research. They point out that research opportunity lies within both the sociocultural and critical perspectives, and the necessity of development, validation and utilization of common research instrumentation. McKenzie [28] undertook a content analysis of 377 submissions to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat. These included National Communications reporting on recent activities, Nationally Determined Contributions and National Adaptation Plans. The analysis revealed, among other things, a strong emphasis on cognitive knowledge over affective and action-oriented approaches. Regional differences have also been taken into account, with European countries on average including more content in relation to both Action for Climate Empowerment elements and Sustainable Development Goal indicator components. Radzi et al. [29], in their systematic review of 35 articles, examined the elements relevant to creating climate change awareness, the acquisition of sustainable skills and the actions taken to develop global competencies in climate change among secondary school students. They defined three themes used to create climate change awareness: effects of climate change, factors affecting climate change, and mitigation plans in handling climate change issues.

In the following text, we use the International Standard Classification of Education: ISCED 2011 to refer to the levels of education observed [30].

For any educational approach to be successful, it must begin at an early age. It becomes natural for pupils, who see it as an integral part of the curriculum and respect its importance. This also applies to climate change education. Most of the articles cited in the previous text focused on older students, and younger ones tend to be neglected in this respect. The reason is simple: the complexity of climate change is better addressed with older students, with an adequate knowledge base and a sufficient level of abstraction. We believe that CCE needs to be implemented from primary school or even kindergarten. Since there is no review study yet devoted to this peripheral area of CCE, we decided to fill this gap. Thus, we seek to answer the question: What are the current state and trends of educational research in the CCE area at the ISCED 1 and ISCED 2 levels?

The sub-objectives are then to find answers to the following questions:

In which journals are studies on CCE published?
What is the chronological evolution of publications on CCE?
What is the representation of the nationalities of the respondents and their age in the studies reviewed?
What research design do the studies have, and what research methods were used?
What are the specific topics addressed in the CCE studies for ISCED 1 and 2?

The aim of the study is therefore to provide an overview of existing pedagogical research in the field of climate change education at ISCED 1 and 2 levels.

2. Materials and Methods

The selection of the analyzed sources follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [31], used for systematic reviews.

2.1. Selection Process

The basic inclusion criteria were (i) the impact of the article meeting the inclusion in the Web of Science Core Collection service, (ii) topicality in terms of the year of publication, (iii) the central theme is CCE, (iv) the target audience is ISCED 1, ISCED 2 students or their teachers, (v) the article has a research character with the presentation of methodology and results, or it is a review study with an analysis of the records meeting the above criteria. The Web of Science Core Collection database (www) was chosen for the analysis. The research time period was determined by the years 2001–2020. In the initial phase, all records (document types: article) corresponding to keywords close to the CCE domain of interest (climate change, climate change education, climate education, climate attitudes, climate change attitudes, climate change literacy, climate literacy, pro-climate behavior, climate change perception, climate change knowledge, environmental sensitivity, pro-environmental behavior) combined with keywords focused on general education (school, primary school, secondary school, elementary school, teacher) were retrieved. This search identified 850 records as of 18 February 2021.

In the first phase, duplicate search results were reduced using the appropriate Microsoft Excel tools, followed by exclusion of records based on abstract checking. In this way, articles that dealt with other areas of research were excluded, especially those that were not related to CCE and studies that no longer clearly met any of the eligibility criteria in terms of abstract. In the follow-up phase, all non-compliant records were eliminated on the basis of full-text checking with respect to all defined eligibility criteria. Each record was retrieved by two independently working reviewers (Karel Nepraš—KN, Tereza Strejčková—TS). In case of ambiguity about the inclusion of a study in the research, a third reviewer (Roman Kroufek—RK) was invited to make the final decision about the inclusion or exclusion of a record. Thus, 43 articles were finally included in the analysis (see Appendix A). The process of elimination of non-compliant records based on abstract checking and then full-text checking can be seen in Figure 1.

2.2. Data Collection

For the purpose of analyzing information from the selected studies, a form was created for entering the observed characteristics of individual articles. Using five randomly selected articles, the form was pilot tested and modified based on the input received. The final version of the form was subsequently used for data collection. Data extraction was performed on an evenly distributed set of articles by two reviewers (KN, TS). A third reviewer (RK) was responsible for checking the completeness and factual accuracy of the data extraction and making decisions in case of ambiguity.

The analysis looked at sub-categories that provide a more detailed insight into the current state of CCE at the primary level. In the data collection, we extracted background information about the article, research design and key findings.

Specifically, the following categories were recorded: title of the article, author(s), year of publication, the journal in which the article was published, year of publication, the nationality of the respondents, the age of the respondents, number of respondents, the research design, including the research methods used, and the content of key findings that were achieved in the study set. Following the procedure developed by Ardoin and Bowers [32], coding was conducted in each of the above categories, examples of which can be found in Table 1. The monitored categories were found for all articles included in the analysis.

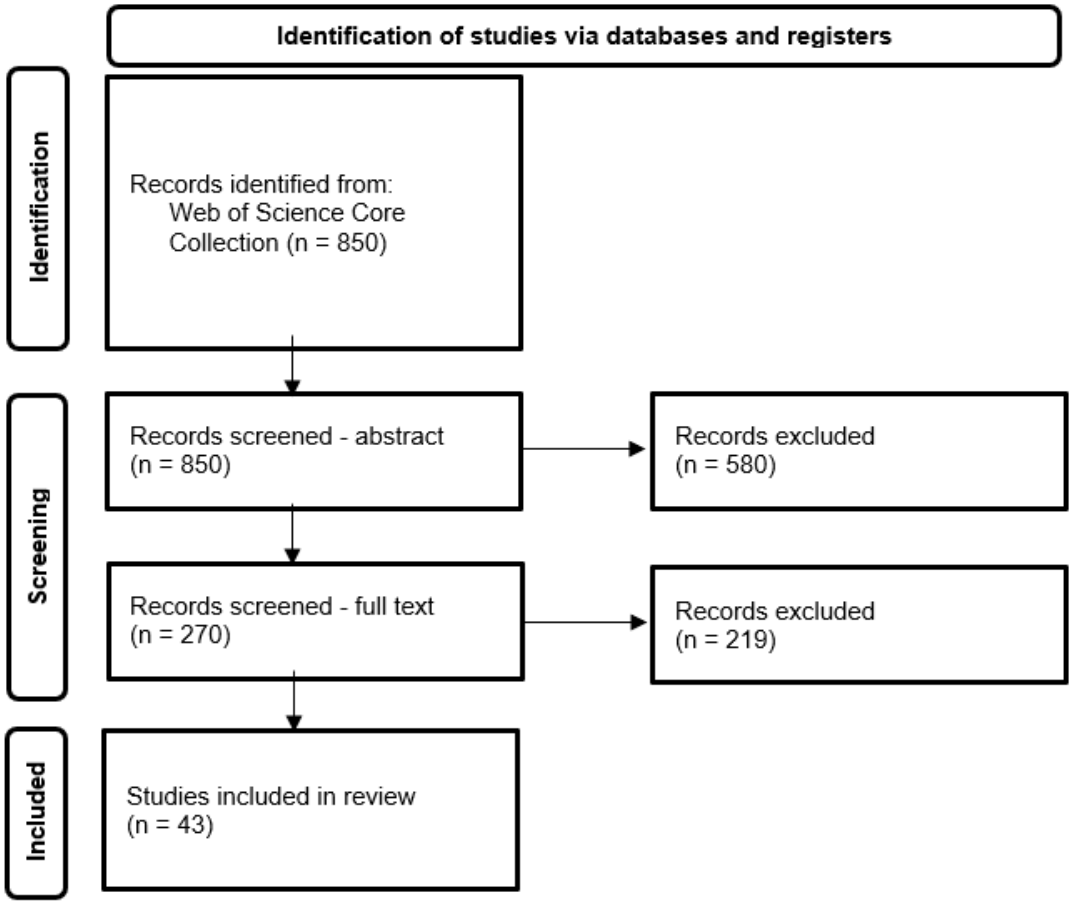


Figure 1. PRISMA 2020 flow diagram describing the selection of studies for analysis.

Table 1. Categories monitored and examples of codes.

Category	Explanation	Examples of Codes
Journal	The journal in which the article was published	Sustainability, Environmental Education Research
Year of publication	Year in which the article was published	2017, 2021
Nationality of respondents	Nationality of survey respondents	USA, Czech Republic
Age	Age of respondents	8 years, 13 years
Research design	Type of research carried out	quantitative, qualitative, mixed
Research methods	Methods of data acquisition used	questionnaire, focus group, observation
Content of articles	Key elements of articles, processed by separate content analysis.	knowledge, behavior, attitudes

In cases where the data could be easily quantified (e.g., journal, year of publication, nationality of respondents...), the data were quantitatively assessed. The content of the articles was analyzed using a qualitative approach through a conceptual content analysis of the topics covered in the articles included in our work. The aim of the content analysis was to capture the breadth and frequency of topics covered within the articles reviewed. The analysis was treated as a conventional content analysis [33] without the use of preconceived categories [34] with specific categories added during the coding process [35]. Within the content analysis, specific codes were recorded and then grouped into superordinate categories based on semantic similarity. The individual categories were defined as relatively narrowly defined topics, which the analyzed articles addressed to some extent. The definition of categories is determined by the set of codes they associate with. If codes with a meaning that did not correspond to the meaning of the category were present in the

text of the analyzed articles, they were ignored. The analysis then determined how many articles each category was represented in. Investigator triangulation [36] was used to ensure higher validity of the analysis, with two team members (KN, TS) working independently on the procedure described above. The resulting selection includes the categories and codes arrived at by the two independent compilers of the analysis. In case of unclear situations, another team member (RK) was invited to make decisions, while also ensuring control and possible correction within the analysis.

In the last segment of the results, the key findings of the research articles included in the analysis are presented, with the arrangement based on the results of the content analysis.

3. Results

This chapter will present the main results obtained from the analysis of the selected articles. First, an overview of the results from the descriptive quantitative analysis is presented. In the following sections, the results of the qualitative analysis focusing on the content and key findings of the analyzed articles are presented.

3.1. Quantitative Analysis

The analyzed studies were published in a total of 20 different journals. Their diversity is quite high, corresponding to the breadth of the topic. They are dominated by journals focusing on education, psychology and specifically on climate change. Figure 2 shows those journals that published at least two studies. Traditional journals focused on environmental and sustainability education lead the way.

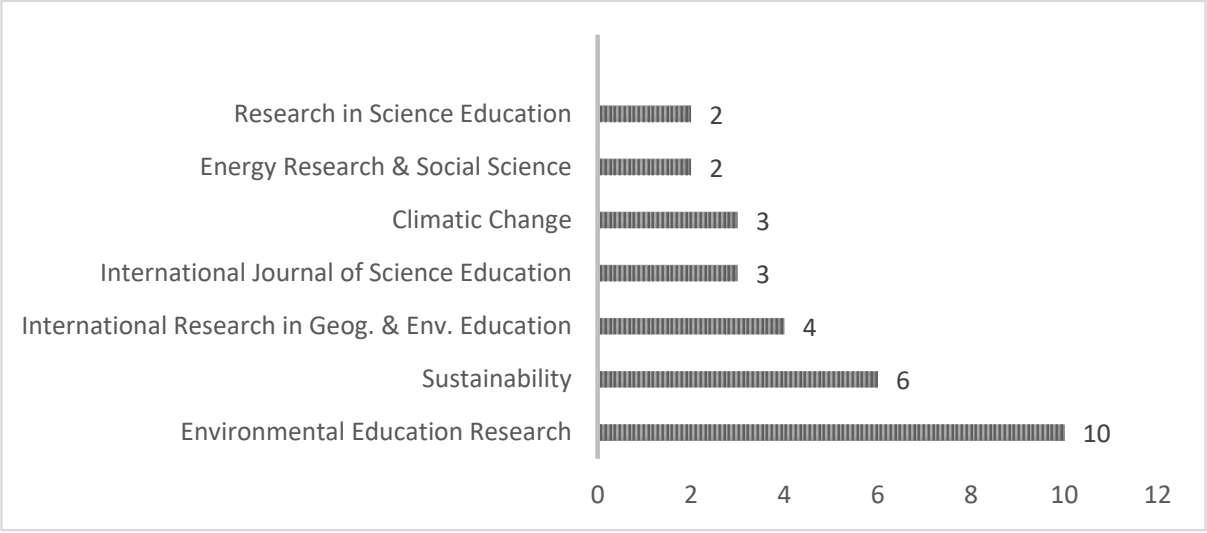


Figure 2. Number of studies in journals with at least two studies.

Although the period between 2001 and 2020 was monitored, only studies from 2009 onwards were included in the final selection. No identified studies from 2001 to 2008 were included in the analysis because they did not meet at least one of the inclusion criteria. The number of included studies has been increasing over time, with the largest number published in the last three years under review (Figure 3).

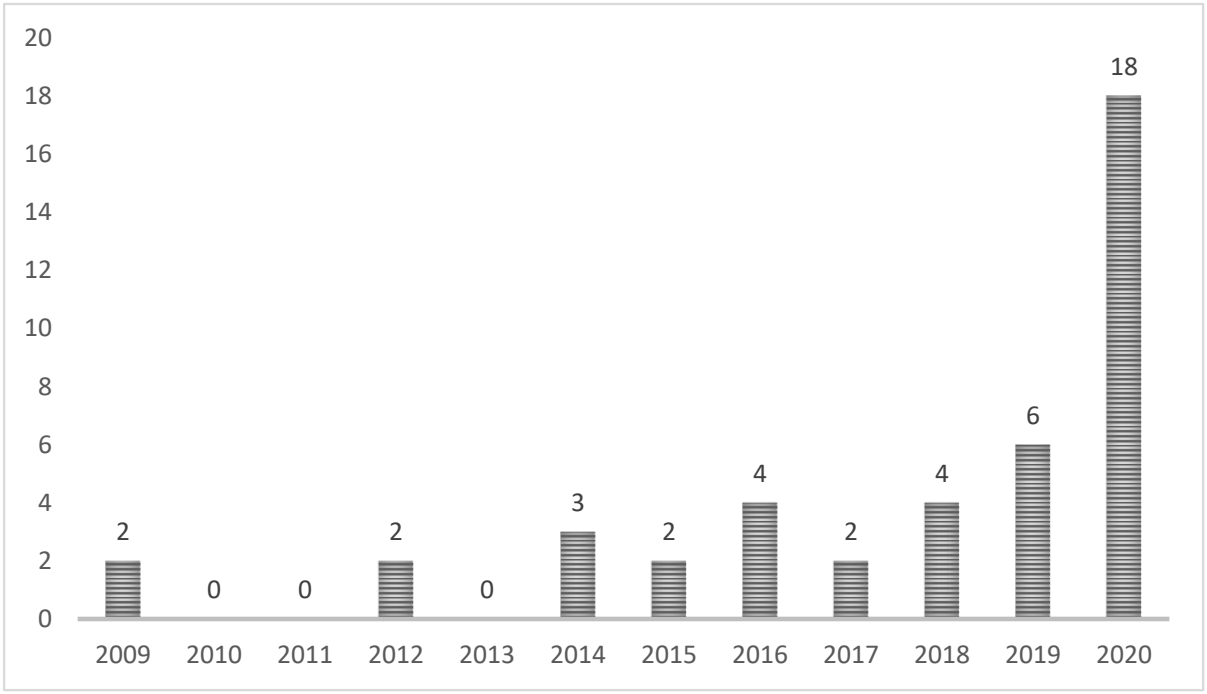


Figure 3. Number of studies per year.

In terms of the nationality of respondents, the United States of America (16 studies) and the European Union (17 studies) dominate the analyzed studies. Six of the studies are from Australia, with three each from Malaysia and the United Kingdom. Figure 4 provides an overview.

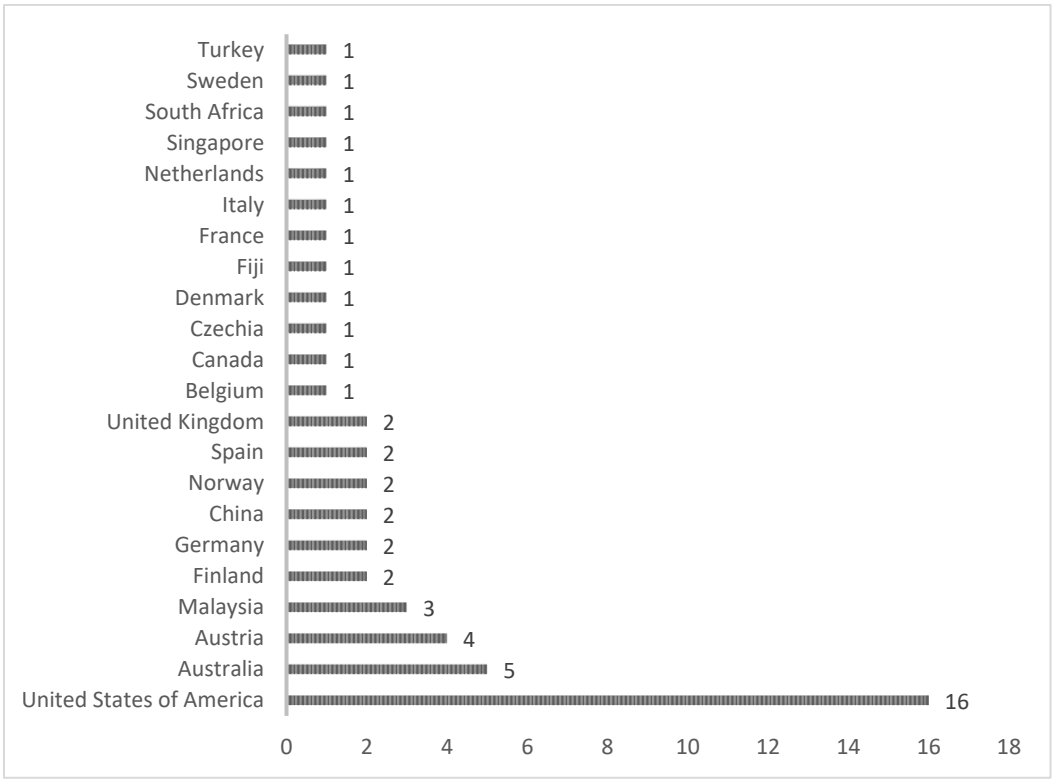


Figure 4. Number of studies by nationality of respondents.

The age of the respondents, in relation to the ISCED 1 and 2 education categories, ranged from 6 to 15 years. As the chart shows, some of the studies analyzed also worked with older respondents who already fall into the ISCED 3 category. The age of the respondents represented in the analyzed studies can be seen in Figure 5; there is a noticeable under-representation of research in the ISCED 1 area, especially in the 6–9 age group, probably stemming from the more complicated data collection from younger pupils. On the other hand, children aged 11–14 are the most frequently processed group.

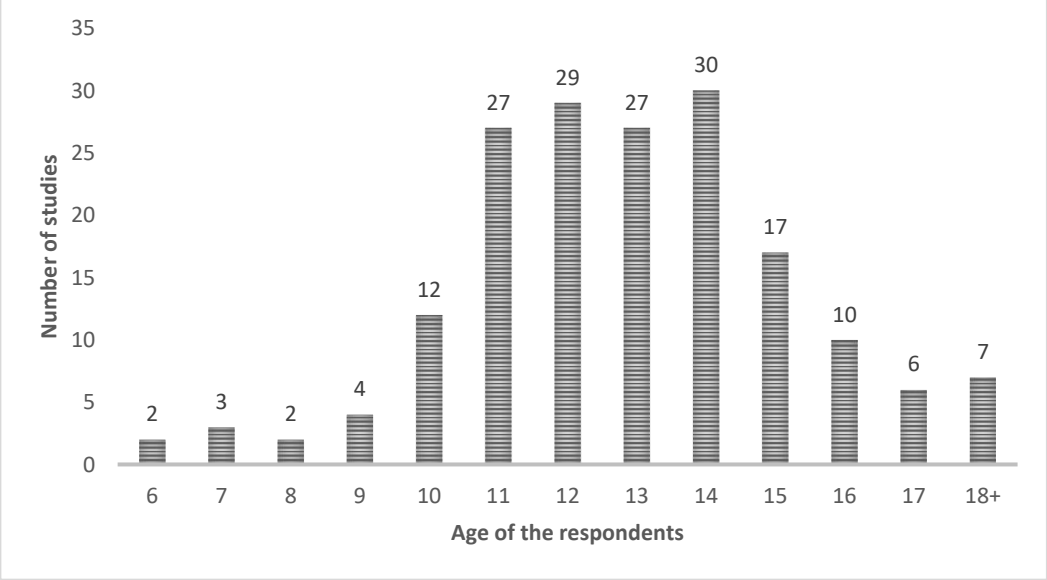


Figure 5. Age of respondents in the analyzed studies.

Three studies focus purely on ISCED 1 age category respondents, while the other eight studies include respondents from ISCED 1 and 2 categories. Most of the studies (22) work with respondents in the ISCED 2 category and the remaining 10 studies already have a range across the ISCED 2 and ISCED 3 age categories.

The vast majority of the studies analyzed have a quantitative research design (23). The size of the research sample in quantitatively designed studies is most often in the order of hundreds of respondents, with five studies working with more than a thousand respondents and four with fewer than a hundred. More than two-thirds of the quantitatively designed studies were concerned with describing the status of a particular segment of the CCE, five studies documented an experiment and two studies documented an evaluation. Approximately one-fifth of the studies (9) worked with a qualitative design. Qualitatively designed studies were characterized by lower numbers of respondents in the tens or at most the first hundreds. Qualitatively designed studies are typically concerned with the description of the condition, whereas only one study each from the analysis set is devoted to the documentation of the experiment and evaluation. About a quarter of the studies (11) worked with a mixed design; in contrast to the previous two types of design, studies following experiments predominated, while condition documentation and evaluation were each devoted to two studies. Most studies with mixed design worked with a pool of respondents in the hundreds.

Questionnaire surveys dominate the research methods used in more than three-quarters of the analyzed studies (34). This is largely to be expected in the context of a predominantly quantitative and mixed research design. Other research methods used in less than a quarter of the studies were interviews (10), and to a lesser extent focus groups (5), observations (2), and individual testing, material analysis and post-qualitative methods.

3.2. Content Analysis

The results of the content analysis show the breadth and frequency of the topics covered in the analyzed set of articles. The papers usually deal to varying degrees with a group of multiple categories. Capturing the proportion of sub-categories, and therefore the proportion of topics covered within each article, was not part of the analysis. The results therefore show the frequency of presence of each category in the set of analyzed articles. As can be seen from the table (Table 2), the largest number of articles deal in various forms with knowledge (47%) and behavior (42%), with a larger number of articles also dealing with action-related areas (30%) and experiences (23%). On a more general level, it is possible to trace more frequent work with topics related to the cognitive and conative areas compared to the somewhat less represented affective area.

With a more specific insight into the code set, it is also possible to classify the most frequently processed topics directly related to CCE. The most represented topics in this context are climate change knowledge and variations of codes related to climate change behavior and climate conservation behavior. Another more frequently represented one is climate change action, which is linked in research to the concepts of mitigation and adaptation. Other topics addressed in at least a tenth of the analyzed articles include climate change-related attitudes, awareness, concerns, mitigations, views, adaptations and perceptions.

Table 2. Content analysis. An overview of the categories, codes and number of articles in which the categories occur.

Category	Codes	Number of Articles
Knowledge	knowledge, climate change knowledge, action knowledge, declarative knowledge, self-reported knowledge	20
Behaviors	behavior, environmental behavior, pro-environmental behavior, climate conserving behavior, climate friendly behavior, consumption behavior, climate change-related behavior, climate change behavior, perceived behavior control, curtailment behavior, climate conservation behavior, similarly also in the "behavior" variant	18
Actions	act, action, willing to take action, environmental action, willing to act, pro-environmental action, climate change action, climate action, action to mitigate climate change, climate change adaptation activities, act in climate mitigation, action knowledge	13
Experiences	experiences of educating, educational experiences, experiences regarding climate change, experiential climate change curriculum, life experiences	10
Attitudes	environmental attitudes, climate change related attitudes, attitudes towards climate change, attitudes to energy saving, attitudes towards science, attitudes related to reducing energy save	8
Literacies	literacy, climate literacy, energy literacy, energy curtailment literacy	8
Mitigations	climate change mitigation, climate mitigation, mitigation to climate change, mitigation behaviors	7
Awareness	climate change awareness, environmental awareness, awareness of climate change risks	6
Beliefs	beliefs, environmental beliefs, self-efficacy beliefs, climate change beliefs, student beliefs, teacher beliefs	6
Concerns	concern, climate change concern, environmental concern	6
Views	views about . . . , views of science, climate change related views, views on climate change mitigation, worldview	6

Table 2. *Cont.*

Category	Codes	Number of Articles
Adaptations	climate change adaptation, adaptation to climate change, adaptive responses to climate change	5
Interventions	intervention, climate change intervention, climate change education intervention, climate science intervention, psychological intervention	5
Perceptions	perception of climate change risks, risk perception, climate change perception, perception of science learning environment	5
Skills	argumentation skill, basic skill	4
Hopes	hope, climate change hope	3
Motivations	motivation	3
Emotions	emotions	1
Intentions	intentions	1
Moral reflections	moral reflection	1
Values	values	1

3.3. Key Results

Of the 43 articles analyzed, more than half (25) are devoted to describing the status of a particular segment of CCE and possibly other related topics under consideration. Thirteen studies document pedagogical experiments related to CCE and five studies are devoted to the evaluation of different forms of intervention in CCE.

3.3.1. Description of Status

The most common areas addressed in the research articles analyzed are knowledge, willingness to act and behavior to mitigate climate change.

According to Chang and Pascua [37], students' background knowledge of climate change consists of incomplete and incorrect elements that are embedded in coherent and structurally correct mental models. Therefore, the transformation of the mental models that students have formed about climate change should be at the forefront of the pedagogical approach. Harker-Schuch et al. [38] define four knowledge domains of climatology in a given age group: Earth in the Solar System; gravity and its effect on the atmosphere; albedo and solar radiation; greenhouse gases and their warming potential. In constructing climate change knowledge models, studies suggest the necessity of understanding the concept of the greenhouse effect to understand global warming and its link to climate change [39]. Pearce et al. [40] showed that older children have some basic knowledge about climate change and energy, while the impacts of energy use on the environment remain unclear. Further, despite many aspects of CCE already mastered, the messages of international organizations are not being received or understood at the local level, suggesting the need for easier translation of scientific knowledge into society [41].

Some of the studies are concerned with building relationships and attitudes towards climate change and anthropogenic global warming. Pearce et al. point to the fact that children experience negative emotions when talking about the consequences of climate change and that energy is often wasted [40]. More generally, there are weak but significant relationships between science-related attitudes and attitudes towards climate change and the environment [11]. There are significant positive relationships between values and belief, values and personal norms, and belief and personal norms [42]. Increased climate change knowledge is positively related to anthropogenic global warming acceptance, with a stronger relationship for individualists, who are also 16.1% less likely to accept anthropogenic global warming than communitarian respondents. Non-white individuals and women demonstrate higher levels of anthropogenic global warming acceptance and climate change risk perception [43]. The importance and status of teachers is underscored

by the results of the study [44], which found that teachers' belief that climate change occurs and students' knowledge of climate change were the strongest predictors of students' belief that climate change occurs and anthropogenic global warming. Byrne et al. [45] identified six main interpretive repertoires used to legitimize or challenge everyday lifestyles in relation to climate change: everyday life, self-interest, environment, science and technology, society, and justice. According to the study [46], acceptance of anthropogenic global warming had the strongest association with climate change concern, and the frequency of discussions with friends and family was the second strongest predictor; therefore, the authors emphasize the importance of building acceptance of anthropogenic global warming within CCE.

A larger number of the studies addressed predictors of climate change mitigation behavior. Social norms [47], more detailed discussion with family and friends and higher socioeconomic status [48,49] emerge as significant predictors, with a willingness to conform to the norm rather than react to environmental influences [40] dominating the study results. Other documented predictors of behavior are personal norms [42], climate change knowledge [47,50,51], values [42], beliefs [42,50], motivation [50], climate change concern [48,49], and hope [49,51]. It has been shown that climate change hope and climate change concern are independent of climate change behavior [49]. There was also evidence of a positive relationship between climate change knowledge and climate change concern and hope [52]. The results of the study [53] further indicated that students currently associate climate change mitigation strategies with unrelated environmental problems significantly less than in previous surveys, but at the same time, the understanding of adaptive responses to climate change is limited.

According to the results of the analyzed studies, willingness to act depends on gender, social norms, interest in environmental topics and perceived barriers. Women show a higher willingness to act in favor of climate change mitigation measures [51,54,55]. Furthermore, students' greater willingness to act is related to activities that bring minimal inconvenience or that are rooted in social practice [56] or directly bring personal benefit [54]. In this context, it has also been documented that students are more concerned and perceive short-term climate change risks as a higher priority than long-term risks [57]. Greater willingness to act is further conditioned by a higher interest in general environmental topics and the perceived importance of climate change mitigation measures [55].

The level of environmental awareness affects the perception of current and future climate change risks [57]. According to the level of climate change awareness, teenagers can be divided into four groups differing in cognitive, affective and conative aspects of climate change awareness [58]. In this context, the authors point out the need to take into account the heterogeneity of young people in terms of climate change awareness within CCE.

In terms of learning strategies, the importance of democratic learning [59], exploratory and experiential approaches [60,61], participatory approaches [17,62], and more generally, long-term interactive learning compared to short-term interventions [41] is confirmed. Some of these approaches can be described as traditional. In contrast, Keller et al. [63] further demonstrate in their longitudinal study that effective approaches, and especially combinations of them, are those based on transdisciplinary and moderate constructivist theories.

In addition, the importance of participation in days for climate change actions (such as Fridays For Future) was confirmed to significantly enhance personal interest in climate change, enhanced feelings of self-efficacy, climate-friendly behavior and enhanced multiplicative action [59].

Among young people, it is also possible to trace the influence of the wider social context from which they emerge. Czech students are more skeptical about the usefulness of proposed measures to mitigate climate change in an international context [54], and students from international schools in Hong Kong are more active and organized in fighting climate change compared to students from local schools [60]. Students in Fiji do not distinguish between changes in the climate and normal weather events [64]. The aforementioned critical

importance of teachers' beliefs in climate change on students in North Carolina, USA, is underscored by results showing that 92.1% of teachers believe global warming, but only 12% acknowledge anthropogenic global warming [44].

The main documented relationships resulting from the analyzed studies are shown in Table 3.

Table 3. Positive relationships between predictors and dependent variables documented by the analyzed studies.

Predictor	Dependent Variable	References
climate change (CC) knowledge	anthropogenic global warming (AGW) acceptance	[43]
values	beliefs	[42]
science-related attitudes	CC attitudes and the environment	[11]
acceptance of AGW	CC concern	[46]
discussions with friends and family	CC concern	[46]
social norms	CC mitigation behavior	[47]
discussions with friends and family	CC mitigation behavior	[48,49]
higher socioeconomic status	CC mitigation behavior	[48,49]
personal values	CC mitigation behavior	[42]
CC knowledge	CC mitigation behavior	[47,50,51]
values	CC mitigation behavior	[42]
beliefs	CC mitigation behavior	[42,50]
motivation	CC mitigation behavior	[50]
CC concern	CC mitigation behavior	[48,49]
CC hope	CC mitigation behavior	[49,51]
gender	CC mitigation behavior	[51,54,55]
environmental awareness	perception of CC risks	[57]
values	personal norms	[42]
beliefs	personal norms	[42]
students' knowledge of CC	students' belief in CC and AGW	[44]
teachers' beliefs in CC	students' belief in CC and AGW	[44]
gender	willingness to act	[51,54,55]
social norms	willingness to act	[51,54,55]
interest in environmental topics	willingness to act	[51,54,55]
perceived barriers	willingness to act	[51,54,55]
social practice	willingness to act	[56]
personal benefits	willingness to act	[54]
perceived importance of CC mitigation measures	willingness to act	[55]

3.3.2. Experiments and Evaluations

The experimentally focused research in the analyzed studies shows the effectiveness and impact of different teaching approaches as well as some other aspects that complete the picture of the current state of CCE. Various innovative approaches are being tested within the CCE. Although these are diverse methods, a common indicator is the success in meeting the objectives related to increasing knowledge, literacy, awareness and understanding in relation to climate change.

The use of the geospatial curriculum has led to a significant increase in climate change knowledge [65]. The argumentation intervention on the socio-scientific issue of climate change significantly increased students' understanding of climate change [66]. The use of the "Sustainable City" project based on the use of robotics in education has led to increased skills and motivation in relation to climate change [67]. The application of the 5E learning cycle resulted in a significant difference in global warming knowledge and environmental attitudes compared to the application of standard teacher-centered teaching methods [68]. Teaching about climate change using computer models has led to significant advances in learning [69]. Immersive Virtual Reality learning in climate change instruction showed significant increases in declarative knowledge, self-efficacy, STEM intentions, outcome expectations and intentions to change behavior [70]. Yearly implementation of climate change curriculum integrated with social studies and language

arts increased climate literacy, reading comprehension, and overall engagement with the topic [71]. An extracurricular program based on participatory methods increased climate change awareness and led to a substantial increase in the scientific and social dimensions of climate change knowledge [62]. In the Climate Change + Me project, children participated as co-researchers [17]. Intergenerational discussion of the local consequences of climate change led to a greater willingness to support climate change mitigation [72]. The implementation of cross-curricular experiential climate change curriculum in school garden classrooms led to an improvement in student learning and engagement as well as teacher professional development [73]. Climate literacy can also be improved via digital games [38] and with a climate change curriculum implemented via an integrated social studies and language arts framework [71].

The issue of climate change is identified within CCE as the content of pedagogical interventions, but in some cases, it is also used as a means to achieve other related goals. The urgency of addressing climate change and understanding the scientific and social dimensions of climate change increased children's interest in science [74].

The research of Porter et al. [75] points to the important role of the teacher, who with the appropriate background information is more effective at conveying the science of climate change, particularly when it is taught through an understanding of the carbon cycle and its human impacts, compared to external climate change specialists. In the context of these results, Porter et al. call for NGOs active in CCE to invest in the development of teaching materials and subsequent professional development for teachers rather than focusing on in-school presentations.

4. Discussion

As the results of our analysis show, research on CCE in primary schools is currently in a dynamic phase of development. The increase in the number of published articles in recent years has been exponential, which is consistent with the rapid increase in the number of publications in a number of other climate change-related research areas [76–78]. It is worth noting, however, that while many aspects of global climate change have been addressed by the scientific community for a considerably longer period of time [79–81], the work related to CCE in primary school is, for the most part, still very young.

Rousell and Cutter-Mackenzie-Knowles [22] identified a significant geographical disparity in the distribution of CCE research for the period 1993–2014, with North America, particularly the USA, and European Union countries dominating. The results of our review study show the persistence of a similar geographic distribution of the CCE research segment we studied in the following period. The majority of CCE research (84%) takes place in high-income economies. It is a minority (16%) in upper-middle-income economies and absent in lower-middle and low-income economies [82]. At the same time, the production of CO_2 as a key greenhouse gas of human-induced climate change has been declining in high-income countries in recent years, while it has been increasing significantly in middle-income countries [83]. In this respect, it seems desirable to focus future research on CCE in the geographical context mentioned above, where it is currently lacking. At the same time, however, the geographical distribution of publications is partly different in some other climate change-related research areas [84].

The disproportionality of the focus of the analyzed articles is interesting. Less than half of them presented the results of experimental or evaluation research. Yet, these are the ways through which to identify appropriate educational approaches in schools or functional programs leading to the development of mitigating behaviors [12]. As the content analysis shows, these should be approaches and programs that focus on the affective components of personality, i.e., attitudes, beliefs, values or motivation. These qualities have been repeatedly shown in research to be strong predictors of appropriate mitigation behavior [47–51]. Community connectedness is also important for the success of educational interventions and programs. Children often perceive climate change as something distant and abstract and it is therefore appropriate to bring it down to the level

of their community. Whether it is an intergenerational discussion of the local consequences of climate change [72] or the use of citizen science [17], the principles of place-based education [85] work for CCE.

Similar to general pro-environmental behavior, girls show a higher willingness to act when it comes to climate change mitigation behavior [54,55]. As in the case of environmental education, the question of empowerment arises [86]. How can we prepare lessons and programs with the aim of making boys more confident and motivated to behave in this way?

In the context of the other results, it can be concluded that there is room for further research within the CCE segment under study at the lower primary school (ISCED 1) level, especially in the 6–10 age group. In terms of content, the least researched topics are those related to the affective domain, such as motivations, emotions, and hopes. Environmental education research has repeatedly demonstrated the importance of younger ages for building emotional connections that are prerequisites for the subsequent development of values, attitudes and ultimately behavior and willingness to act. From this perspective, it is therefore desirable to focus future research on the outlined research gaps, the coverage of which would help us to better understand the shaping of thinking in relation to climate change threats and thus ultimately contribute to a better chance of better coping with the serious challenges of the future.

Limitations of the Review

Despite our best efforts to conduct a high-quality review study, we are aware of certain limitations, which we summarize here. Review study risk of bias is associated with the factors of setting partial eligibility criteria and with limitations based on the subjective form of selection and processing of records and partial information. The use of a single database (Web of Science Core Collection) for the review study was motivated by the desire to capture publications with the strongest impact in the scientific community. It is likely that if records from other databases were included, a larger number of studies would be accepted into the analysis and some of the categories examined might have partially different results. The keyword combinations used were tested, modified and supplemented in the pilot analysis, but it cannot be excluded that the number of accepted articles and partial results could have been different to some extent with different keyword combinations. The subjectivity of the output was further minimized in the criteria assessment process and data extraction by a methodology associated with independent work by multiple reviewers. Nevertheless, the omission of a small number of relevant publications cannot be completely ruled out.

5. Conclusions

Pedagogical research in climate change education is undergoing a tumultuous development. This also applies to research on the target group of ISCED 1 and 2 pupils and their teachers. Within the world, this research is disproportionate and is mainly concentrated in countries with high-income economies. Support for educational research should also be directed to developing countries, not only in the field of climate change. For CCE to succeed, it is important to focus less on merely describing the situation and even more on research to evaluate training programs and identify effective practices. Such practices should be community-embedded, transdisciplinary, value-developing and lead to climate change mitigation behavior. These practices can then serve as models for successful CCE. Future review studies could thus focus specifically on a detailed meta-analysis of the effectiveness of educational approaches in CCE. Our study provides a systematic review of articles specifically related to CCE in primary schools. The results can be used to establish a more specific initial theoretical base in follow-up research that will address CCE at a given educational level.

Author Contributions: Conceptualization, R.K. and K.N.; methodology, K.N. and R.K.; validation, K.N. and T.S.; formal analysis, K.N. and T.S.; investigation, K.N. and T.S.; resources, K.N. and T.S.; data curation, K.N., T.S. and R.K.; writing—original draft preparation, K.N., R.K. and T.S.; writing—review and editing, K.N. and R.K.; visualization, K.N.; supervision, K.N. and R.K.; project administration, T.S., K.N. and R.K.; funding acquisition, K.N. and R.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by European Structural and Investment Fund, Operational Programme Research Development and Education and Ministry of Education, Youth and Sports grant number CZ.02.2.69/0.0/0.0/19_073/0016947, U21–Improving the Quality of the Grant Competition and Teaching in Doctoral Study Programmes at the UJEP.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Overview of articles included in the analysis.

Authors	Title	Year	Journal	Location	ISCED	Research Design *	Type of Research **	Methods ***	Reference
Akaygun, S., Adadan, E.	Fostering senior primary school students' understanding of climate change in an inquiry-based learning environment	2020	Education 3–13	Turkey	2	QUANT	EXP	QUES	[61]
Baker, C., Clayton, S., Bragg, E.	Educating for resilience: parent and teacher perceptions of children's emotional needs in response to climate change	2020	Environmental Education Research	Australia	1,2	QUANT	STAT	QUES	[87]
Bodzin, A.M., Fu, Q.	The Effectiveness of the Geospatial Curriculum Approach on Urban Middle-Level Students' Climate Change Understandings	2014	Journal of Science and Educational Technology	USA	2	QUANT	EXP	QUES	[65]
Bofferding, L., Kloser, M.	Middle and high school students' conceptions of climate change mitigation and adaptation strategies	2015	Environmental Education Research	USA	2,3	QUANT	EXP	QUES	[53]
Boyes, E., Skamp, K., Stainsstreet, M.	Australian Secondary Students' Views About Global Warming: Beliefs About Actions, and Willingness to Act	2009	Research in Science Education	Australia	1	QUANT	STAT	QUES	[56]
Busch, K.C., Ardoin, N., Gruehn, D., Stevenson, K.	Exploring a theoretical model of climate change action for youth	2019	International Journal of Science Education	USA	2,3	QUANT	STAT	QUES	[47]
Byrne, J., Ideland, M, Malmberg, C., Grace, M.	Climate Change and Everyday Life: Repertoires children use to negotiate a socio-scientific issue	2014	International Journal of Science Education	United Kingdom, Sweden	1	QUALIT	STAT	FOC	[45]
Cutter-Mackenzie, A., Rousell, D.	Education for what? Shaping the field of climate change education with children and young people as co-researchers	2019	Children Geographies	Australia	1,2	QUALIT	STAT	other, postqualitative	[17]
Dawson, V., Carson, K.	Introducing Argumentation About Climate Change Socioscientific Issues in a Disadvantaged School	2020	Research in Science Education	Australia	2,3	QUANT	EXP	QUES	[66]
Deisenrieder, V., Kubisch, S., Keller, L., Stötter, J.	Bridging the Action Gap by Democratizing Climate Change Education-The Case of k.i.d.Z.21 in the Context of Fridays for Future	2020	Sustainability	Germany, Austria	2,3	MIXED	STAT	QUES, INT	[59]
Dijkstra, E.M., Goedhart, M.J.	Development and validation of the ACSI: measuring students' science attitudes, pro-environmental behavior, climate change attitudes and knowledge	2012	Environmental Education Research	France, Italy, Nether-lands, Norway, Spain	2,3	QUANT	STAT	QUES	[11]
Harker-Schuch, I., Mills, F., Lade, S., Colvin, R.	CO2peration-Structuring a 3D interactive digital game to improve climate literacy in the 12–13-year-old age group	2020	Computers and Education	Australia, Austria	2	QUANT	EVAL	QUES	[38]
Hermans, M., Korhonen, J.	Ninth graders and climate change: Attitudes towards consequences, views on mitigation, and predictors of willingness to act	2017	International Research in Geographical and Environmental Education	Finland	2	QUANT	STAT	QUES	[55]

Table A1. *Cont.*

Authors	Title	Year	Journal	Location	ISCED	Research Design *	Type of Research **	Methods ***	Reference
Hu, S., Chen, J.	Place-based inter-generational communication on local climate improves adolescents' perceptions and willingness to mitigate climate change	2016	Climatic Change	China	1,2	MIXED	EXP	QUES, INT, FOC	[72]
Chang, C.-H., Pascua, L.	Singapore students' misconceptions of climate change	2016	International Research in Geographical and Environmental Education	Singapore	2	QUALIT	STAT	INT	[37]
Jackson, L., Pang, M.-F.	Secondary school students' views of climate change in Hong Kong	2017	International Research in Geographical and Environmental Education	Hongkong	2,3	QUANT	STAT	QUES	[60]
Jacobson, M.J., Goldwater, M., Markauskaite, L., Lai, P.K., Kapur, M., Roberts, G., Hilton, C.	Schema abstraction with productive failure and analogical comparison: Learning designs for far across domain transfer	2020	Learning and Instruction	Australia	2	QUANT	EXP	test	[69]
Karpudewan, M.	The relationships between values, belief, personal norms, and climate conserving behaviors of Malaysian primary school students	2019	Journal of Cleaner Production	Malaysia	1,2	QUANT	STAT	QUES	[42]
Karpudewan, M., Roth, W.-M., Bin Abdullah, M.N.S.	Enhancing Primary School Students' Knowledge about Global Warming and Environmental Attitude Using Climate Change Activities	2015	International Journal of Science Education	Malaysia	1	MIXED	EXP	QUES, INT	[68]
Keller, L., Stötter, J., Oberrrauch, A., Kuthe, A., Körfgen, A., Hüfner, K.	Changing Climate Change Education Exploring moderate constructivist and transdisciplinary approaches through the research-education co-operation k.i.d.Z.21	2019	GAIA-Ecological Perspectives for Science and Society	Austria	2	MIXED	EXP	QUES	[63]
Kuthe, A., Keller, L., Koerfgen, A., Stötter, H., Oberrauch, A., Höferl, K.-M.	How many young generations are there?—A typology of teenagers' climate change awareness in Germany and Austria	2019	Journal of Environmental Education	Germany, Austria	2	QUANT	STAT	QUES	[58]
Lehnert, M., Fiedor, D., Frajer, J., Hercik, J., Jurek, M.	Czech students and mitigation of global warming: beliefs and willingness to take action	2020	Environmental Education Research	Czech Republic	2,3	QUANT	STAT	QUES	[54]
Mohamed Ali Khan, N.S., Karpudewan, M., Annamalai, N.	Moving Beyond the One-Size-Fits-All Model in Describing the Climate Conserving Behaviors of Malaysian Secondary Students	2020	Sustainability	Malaysia	2	QUANT	STAT	QUES	[50]
Nkoana, E.M.	Exploring the effects of an environmental education course on the awareness and perceptions of climate change risks among seventh and eighth grade learners in South Africa	2020	International Research in Geographical and Environmental Education	South Africa	2	QUALIT	STAT	QUES	[57]
Pearce, H., Hudders, L., Van de Sompel, D.	Young energy savers: Exploring the role of parents, peers, media and schools in saving energy among children in Belgium	2020	Energy Research and Social Science	Belgium	1,2	QUALIT	STAT	INT	[40]
Petersen, G.B., Klingenberg, S., Mayer, R.E., Makransky, G.	The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education	2020	British Journal of Educational Technology	Denmark	2	QUALIT	EXP	QUES	[70]
Porter, D., Weaver, A.J., Raptis, H.	Assessing students' learning about fundamental concepts of climate change under two different conditions	2012	Environmental Education Research	Canada	2	MIXED	EXP	QUES	[75]
Ratinen, I., Uusiautti, S.	Finnish Students' Knowledge of Climate Change Mitigation and Its Connection to Hope	2020	Sustainability	Finland	2	QUANT	STAT	QUES	[51]
Reis, J., Ballinger, R.C.	Creating a climate for learning-experiences of educating existing and future decision-makers about climate change	2020	Marine Policy	United Kingdom	2,3	MIXED	STAT	analysis of materials	[41]
Ruiz Vicente, F., Zapatera Llinares, A., Montes Sanchez, N.	"Sustainable City": A Steam Project Using Robotics to Bring the City of the Future to Primary Education Students	2020	Sustainability	Spain	1	QUANT	EVAL	QUES	[67]
Scott-Parker, B., Kumar, R.	Fijian adolescents' understanding and evaluation of climate change: Implications for enabling effective future adaptation	2018	Asia Pacific Viewpoint	Fiji	2,3	QUALIT	STAT	FOC	[64]
Sezen-Barrie, A., Miller-Rushing, A., Hufnagel, E.	It's a gassy world': starting with students' wondering questions to inform climate change education	2020	Environmental Education Research	USA	2	QUALIT	EVAL	INT	[88]
Shepardson, D.P., Niyogi, D., Choi, S., Charusombat, U.	Seventh grade students' conceptions of global warming and climate change	2009	Environmental Education Research	USA	2	QUALIT	STAT	INT	[39]

Table A1. *Cont.*

Authors	Title	Year	Journal	Location	ISCED	Research Design *	Type of Research **	Methods ***	Reference
Siegner, A.B.	Experiential climate change education: Challenges of conducting mixed-methods, interdisciplinary research in San Juan Islands, WA and Oakland, CA	2018	Energy Research and Social Science	USA	2,3	MIXED	EXP	QUES, INT, observation	[73]
Siegner, A., Stapert, N.	Climate change education in the humanities classroom: a case study of the Lowell school curriculum pilot	2020	Environmental Education Research	USA	1,2	MIXED	EVAL	QUES, INT	[71]
Stevenson, K., Peterson, N.	Motivating Action through Fostering Climate Change Hope and Concern and Avoiding Despair among Adolescents	2016	Sustainability	USA	2	QUANT	STAT	QUES	[49]
Stevenson, K.T., Peterson, M.N., Bondell, H.D.,	Developing a model of climate change behavior among adolescents	2018	Climatic Change	USA	2	QUANT	STAT	QUES	[52]
Stevenson, K.T., Peterson, M.N., Bondell, H.D.	The influence of personal beliefs, friends, and family in building climate change concern among adolescents	2019	Environmental Education Research	USA	2	QUANT	STAT	QUES	[46]
Stevenson, K.T., Peterson, M.N., Bondell, H.D., Moore, S.E., Carrier, S.J.	Overcoming skepticism with education: interacting influences of worldview and climate change knowledge on perceived climate change risk among adolescents	2014	Climatic Change	USA	2	QUANT	STAT	QUES	[43]
Stevenson, K.T., Peterson, M.N., Bradshaw, A.	How Climate Change Beliefs among US Teachers Do and Do Not Translate to Students	2016	PLOS ONE	USA	2	QUANT	STAT	QUES	[44]
Trot, C.D.	Children's constructive climate change engagement: Empowering awareness, agency, and action	2020	Environmental Education Research	USA	1,2	MIXED	EVAL	QUES, FOC	[62]
Trott, C.D., Weinberg, A.E.	Science Education for Sustainability: Strengthening Children's Science Engagement through Climate Change Learning and Action	2020	Sustainability	USA	1,2	MIXED	EXP	QUES, FOC	[74]
Valdez, R.X., Peterson, M.N., Stevenson, K.T.	How communication with teachers, family and friends contributes to predicting climate change behavior among adolescents	2018	Environmental Conservation	USA	2	QUANT	STAT	QUES	[48]

* Research design: QUANT—quantitative, QUALIT—qualitative, MIXED—mixed. ** Type of research: EVAL—evaluation, EXP—experiment, STAT—description of status. *** Methods: FOC—focus groups, INT—interview, QUES—questionnaire.

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