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Systematic Review

The (Un)political Perspective on Climate Change in Education—A Systematic Review

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Abstract: Mitigating and adapting to climate change requires foundational changes in societies, politics, and economies. Greater effectiveness has been attributed to actions in the public sphere than to the actions of individuals. However, little is known about how climate literacy programs address the political aspects of mitigation and adaptation. The aim of this systematic literature review is to fill this gap and analyze how public-sphere actions on mitigation and adaptation are discussed in climate literacy programs in schools. Based on database searches following PRISMA guidelines we identified 75 empirical studies that met our inclusion criteria. We found that central aspects of climate policy such as the 1.5-degree limit, the IPCC reports, or climate justice are rarely addressed. Whilst responsibility for emissions is attributed to the public sphere, the debate about mitigation usually focuses on the private sphere. Climate change education does not, therefore, correspond to the climate research discourse. We show that effective mitigation and adaptation are based on public-sphere actions and thus conclude that effective climate education should discuss those public actions if it is to be effective. Hence, we propose that climate education should incorporate political literacy to educate climate-literate citizens.

Keywords: climate change education; climate literacy; climate change; sustainability education; political education; literature review; private and public-sphere action; mitigation; adaptation; climate justice

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1. Introduction

The global climate crisis is probably the greatest social challenge of the 21st century and dealing with it is the most important task for our societies and economies. An essential step towards mastering this global challenge is meeting the agreements of the 2015 Paris Climate Conference to limit global warming to 1.5 °C [1]. This requires prompt and extensive efforts to reduce greenhouse gas emissions to mitigate climate change. Besides mitigation measures, actions to adapt to climate change are crucial to make societies and infrastructure as resilient as possible to both the existing and foreseeable consequences of climate change. In this regard, the Intergovernmental Panel on Climate Change (IPCC) provides regular scientific assessments on climate change and its implications as well as mitigation and adaptation options. These overviews represent the state of knowledge concerning climate change and are the key basis for international negotiations.

In IPCC reports (e.g., [2–5]) and political documents [6–8] on climate change, education is considered to be of great importance for making societies and economies carbon-neutral and resilient to the consequences of climate change. Education is seen as a key for changing individual behaviors and for generating public support for—or at least an understanding

of—political measures taken to mitigate and adapt to climate change. However, little is known about the extent to which climate education incorporates current debates around the adaptation and mitigation strategies discussed, for example, by the IPCC, or whether the role of international agreements (e.g., limiting global warming at 1.5 °C) are covered. In this review, we fill this gap and analyze how climate change is taught as a "socioscientific issue" [9–12] in different educational interventions for elementary and secondary school students. Our goal is to find out how the "socio" and the "scientific" are connected in current programs. To this end, we use a coding frame based on research findings on environmental policy and political education to investigate how the political perspective of climate mitigation and adaptation is currently addressed in climate change education.

2. Theoretical Background

2.1. Current State of the Climate Change Debate

The Earth's climate was first physically modeled in the 1970s. This groundbreaking scientific achievement allowed scientists to quantify variability in the climate and predict the influence of human-induced greenhouse emissions on global warming (among [13]). Despite over fifty years of evidence of anthropogenic climate change and its effects, the global mean temperature has so far risen by 1.1 °C (±0.1 °C) compared to the pre-industrial era [14]. An important step towards mastering this global crisis, set at the Paris Climate Conference 2015, is to limit global warming to 1.5 °C until the end of the century in comparison to the pre-industrial era. However, the recently published IPCC Report demonstrates that to achieve this goal, climate neutrality, in terms of reaching net zero carbon emissions, would have to be reached between 2030 and 2050 [4]. Despite these ambitious goals, climate change research predicts that further increases in global temperatures are highly likely until 2050, regardless of all the climate protection scenarios that have been considered [4,5]. This finding reflects the urgency in developing further measures to cope with and stop global warming.

2.2. Mitigating Climate Change

Nevertheless, according to current scientific knowledge, drastic and irreversible climate changes can be prevented if we succeed in limiting the temperature rise to 1.5 °C through mitigation measures designed to reduce greenhouse gas emissions [4,8]. These mitigation measures must be implemented in all sectors of the economy (e.g., energy supply, transportation, buildings, industry, agriculture, forestry, and waste management). One of the greatest ways to reduce greenhouse gas emissions is by reducing energy-related carbon dioxide emissions, mainly caused by burning fossil fuels. To do so, it is necessary to switch to renewable energy sources instead of using coal and oil [15].

2.3. Adapting to Climate Change

As stated before, climate change is not just a challenge for the future. Due to the global warming that already has taken place, the effects of climate change (such as the retreat of glaciers and loss of ice, warming of the oceans, sea level rise, climate zones migrating poleward, and increasing weather and climate extremes) are already tangible, with different manifestations depending on the geographic location, infrastructure, demographics, and numerous other factors, and will become even more apparent in the future [5]. Climate scientists are increasingly able to attribute events such as heavy rain, heat waves, and droughts to human caused climate change (e.g., [16–18]). These events have an enormous impact on our ecosystems and their respective interactions and, hence, on humankind. In a recent study Callaghan et al. report that almost 85% of the global population has already experienced weather events enhanced by climate change. These weather extremes lead, for example, to low ground water, flooding, erosion, agricultural damage, forest loss, insufficient water supply, biodiversity loss, and human health issues including breathing problems, mental illness, insect-borne diseases, and heatstrokes [19]. In particular, the

findings of a study by Vicedo-Cabrera et al. revealed that 37% of all heat deaths in the last three decades would not have occurred without anthropogenic climate change [20].

Measures to adapt to the unavoidable consequences of climate change are necessary to maintain our quality of life and to ensure sustainable risk management and provision for the public. If adaptation measures are not taken in time there may be considerable negative social, ecological, and economic consequences [4,21]. Adaptation strategies can take place in many different domains (such as human health, soil, finances, industry and commerce, transport, agriculture, and biodiversity). Some examples of adaptation measures are forest rejuvenation, unsealing of surfaces, heat action plans, development of urban greenery, cradle-to-cradle economy approaches, and disaster mitigation plans (e.g., [22]).

2.4. Climate Justice

The global climate crisis is not only a scientific issue but is also an issue of equity and justice as it affects different social groups on different magnitudes [23]. Climate justice is a normative concept that views anthropogenic climate change as an ethical and political problem, rather than merely an environmental and technical challenge [24–26]. For the purpose of this review, we describe climate justice along two central normative perspectives (for a general review see Newell et al. [23]): (1) *Intersectional inequity*. Climate justice aims to ensure that today's unequal distribution of the consequences of global warming is balanced, taking, for example, into account the "polluter pays" principle [4,27], since populations that contribute least to climate change often suffer its consequences most severely and are least prepared [7,28]. This is also described with the term MAPA, meaning "Most Affected People and Areas", which describes areas and regions that are the least responsible for the climate crisis, but are the ones who suffer the most from its consequences. Furthermore, climate justice includes not only allocating the greenhouse gas emissions, leading to global warming proportionately among all people worldwide, but also taking historical emissions as well as recent emissions per capita into account [29]. (2) *Intergenerational inequality*. If the planet continues to warm on its current trajectory, the average 6-year old will live through roughly three times as many climate disasters as their grandparents. They will see twice as many wildfires, 1.7 times as many tropical cyclones, 3.4 times more river floods, 2.5 times more crop failures, and 2.3 times as many droughts as someone born in 1960. Today's children will be exposed to an average of five times more disasters than if they lived 150 years ago [30].

Members of this young generation took action regarding these future prospects in the "Fridays For Future" grassroots movement over the last three years and contributed to the climate change discourse [31–34]. Within this climate movement climate justice is a central concept, evidenced by claims such as "What do we want? Climate Justice!" in official documents and in the global demonstrations of the Fridays for Future movement [35]. In the light of the debate about climate justice, the German Federal Constitutional Court [36] has demanded substantial emission-reduction measures until 2030, because the climate protection act irreversibly postpones high burdens for reducing emissions until after 2030. In order to still achieve the climate targets limiting global warming to 2 °C as planned, and, if possible, to 1.5 °C, the reductions that would then still be necessary would have to be made even more urgently and at shorter notice. Practically every freedom would be potentially affected by these obligations and this would be at the expense of the younger generation and would violate their freedom rights. Therefore, the climate protection act was determined to be unconstitutional and thus in need of revision.

2.5. Climate Change Education

As children, adolescents, and young adults are those who are the most affected by climate change, they must be encouraged at an early stage to recognize climate-related risks and possible actions. This results in an urgency for learners at all school levels to deal with this significant challenge to both their present and future living environment [6,37,38]. Against this backdrop, the competencies of this young target group to assess, act, and shape

the future is a necessary and crucial element of climate literacy [39–41]. In many—often political—documents, education is described as a key factor in promoting these competencies by creating an awareness of climate-relevant problems, teaching knowledge about these problems, and promoting the competencies to mitigate and adapt to them [42]. In recent years, many programs and studies have been conducted with the aim of enhancing the climate literacy of citizens and students. The findings of these programs and studies have been summarized by three recent reviews with distinct foci of analysis. In a systematic review, Monroe et al. summarized the findings of 49 intervention studies on identifying effective climate change education. They report that successful interventions commonly focus on personally relevant information and the use of active and engaging teaching methods [43]. Jorgenson et al. analyzed 70 papers on environmental and energy education in order to find out how climate change and necessary innovations in energy systems are related in climate education. They found that most interventions focus on personal or local energy efficiency to mitigate climate change but that only three studies promoted public actions such as community wind parks [44]. The most recent and extensive review by Bhattacharya et al. describes students' and teachers' conceptions and beliefs as well as teaching practices in the context of climate education by summarizing 178 empirical studies. A main finding of their review is that research on climate education focuses primarily on core concepts, such as the greenhouse effect, the carbon cycle, and resource availability, but that they avoid explicitly addressing the political aspects of climate change [45].

2.6. Pro-Environmental Attitudes

As well as conceptions about climate change, attitudes to, and perceptions of, climate change are often discussed as relevant to the initiation of mitigation and adaptation actions. Studies on students' environmental attitudes show that awareness of climate issues is meanwhile widespread among young people. Their climate awareness is very clearly characterized by a global and long-term perspective [46]. Many young people in the early industrialized countries consider fundamental changes in the economy and society to be necessary and place the onus here on the state. They expect targeted legal measures from the state to protect the environment and adapt to climate change impacts. With regard to their own behavior, they are contradictory: on one hand, they want to act ecologically and be socially responsible; on the other hand, they often do not want to cut back on consumption of, for example, electrical and entertainment technology [47]. Behavioral changes toward a more sustainable lifestyle are processes that have been extensively studied in the social sciences (e.g., [48–51]). Attitudes towards, and knowledge of, the respective topics are elaborated as essential characteristics for climate and environmental action. With regard to climate issues, however, a complex picture emerges: 94% of Europeans consider protecting the environment important to them personally, and 56% consider it very important [52]. There is also high public support for sustainable action: 93% of German citizens agree that nature should only be used in a way that safeguards biodiversity and preserves nature for future generations [53]. A survey conducted by UNDP [54] that covers 50 countries with 56% of the world's population showed that independently from the region, people see the planet in a climate emergency, demanding for more ambitions politics to fight global warming (Western Europe and North America: 72%; Eastern Europe and Central Asia: 65%; Arab States: 64%; Latin America and Caribbean: 63%; Asia and Pacific: 63%; sub-Saharan Africa: 61%). Moreover, in countries with high emissions from land-use change, there is strong support for conserving forests and land. In high emitting countries, people demand renewable energy policies in eight of ten countries.

These results indicate that there is already a high level of environmental awareness. People are aware of environmental challenges, they have pro-environment and pro-sustainability attitudes, and they support political action for a sustainable future. The central challenge, however, seems different: How can climate awareness lead to stringent climate action? Taken together, the literature shows that the majority of intervention studies on climate change education promote students' conceptual understanding of the causes

and consequences of climate change and individual strategies to mitigate climate change. Additionally, we see that in countries around the world, awareness of environmental issues and pro-environmental attitudes can be found.

2.7. From Climate Change to Climate Policies

All governments in the industrialized world face the demand for a rapid transformation of their societies into a carbon-neutral world, where no more greenhouse gasses are emitted than are captured and adaptation measures are taking place. The central means by which governments respond to such demands are through the adoption of effective climate policies [55]. Common policy approaches range from regulation (e.g., how much CO_2 is a car allowed to emit) via subsidies (e.g., programs to promote renewable energies or the insulation of buildings) to market-based mechanisms (e.g., emissions trading). Moreover, no major document on climate change gets by without mentioning the central role of education in creating a more sustainable future (for example [56], but also [2]). A key question, therefore, is: What is the impact of policy instruments and education programs in particular on greenhouse-gas emissions?

Many educational programs aim to change students' individual behavior by promoting awareness of the consequences of climate change. However, findings from a study [57], in which people's resource consumption and environmental awareness were examined, challenge this view. The respondents were grouped according to income, lifestyle, and values. One would expect that a high level of environmental awareness would be followed by a lower consumption of resources. The data show a negative correlation between environmental consciousness and environmentally sensible behavior. People with a high in environmental consciousness had a bigger carbon footprint than those indicating less environmental awareness. The study revealed that environmental impacts are best predicted by people's income level and not by their attitudes. From the results it can be deduced that strategies to reduce resource consumption should start in the well-educated middle and upper classes, as the reduction potentials are particularly high there. However, the data also show that to reduce resource consumption and greenhouse gas emissions, appealing to responsibility towards the environment is not an effective strategy [58]. There is little to no evidence that pro-environmental attitudes, awareness, or perceptions lead to climate-friendly behaviors. Gatersleben et al. [59] come to similar results in the UK when showing that people with high environmental concerns often also hold high materialistic values. These findings are also reflected in a study conducted by Stern who classified behaviors that had a positive impact on the environment and assessed different theories of environmentalism [60]. When summarizing evidence on the factors that determine environmentally significant behavior Stern found that the more important a behavior is in terms of its environmental impact, the less it depends on attitudinal variables, including environmental concern [60]. If behavior change is not driven by knowledge we must ask: What, then, should be the goal of climate literacy education?

With a look into the history of environmental policy by the examples of stopping the depletion of stratospheric ozone, the abandonment of nuclear power, and the improvement of air quality in Europe, Niebert [61] argues that all major ecological challenges have not been solved by individual behavioral changes or by "ecologically responsible" consumption, but by political regulations. Further evidence for this claim comes from an analysis of the air pollutant emissions of 14 OECD countries over a period of 25 years (1990 to 2014; [62]). Steinenbach analyzed the effectiveness of different policies in improving the quality of the environment. The study revealed that only command-and-control regulations or technical standards are associated with reductions in air pollutant emissions. Softer instruments such as market- and information-based policies or educational programs were found to have no significant influence on reducing emissions of air pollutants [62]. A similar conclusion was reached by the IPCC in 2007, which found little evidence that information-based policies have achieved significant reductions in emissions beyond business as usual [2]. Chawla and Cushing, thus, argue that the most effective action is political

engagement: People cannot purchase energy efficient cars, use public transportation, or travel on bikeways, for example, unless businesses and governments make these choices available in the first place [63]. With this argument in mind, it is obviously not enough for climate change education to support climate-friendly actions: It needs to emphasize the most strategic actions. This issue has also been raised by Stern who distinguishes between 'private-sphere actions' and 'public-sphere actions' [60]:

Private-sphere actions consist of a personal awareness to the purchase, use, and disposal of personal and household products that impact the environment. Behavior in the private sphere differs from environmental behavior in the public sphere in that it has a direct impact on the environment. However, the environmental impact of each individual's personal behavior is small.

Public-sphere actions range from different kinds of environmental citizenship (e.g., petitioning on environmental issues, donating to environmental organizations, discussions with politicians, support or acceptance of environmental regulations, and willingness to pay higher environmental taxes) to activistic action such as active participation in environmental organizations and organizing demonstrations (e.g., climate strikes).

Some behaviors, such as saving energy at home or traveling by bike—which are often targeted in educational programs—directly cause a reduction in the overuse of natural resources [64]. Other environmental actions have a more indirect impact by shaping the context in which choices are made that directly cause environmental change. For example, behaviors that promote environmental and taxation policies usually have greater environmental impact in comparison to behaviors that directly change the environment. As a consequence, Gardner and Stern [65] argue that although private actions for the environment are important, the most effective actions are public actions, when people organize to pressure government and industry. The role of public-sphere actions in climate policy is underpinned in a study by Nash and Steurer [66], who analyzed the emergence of climate change acts as a key legislative tool to mitigate climate change. They found that governments are more likely to adopt strong climate change acts when heightened attention at the discursive level politicize public climate debates. The overarching climate discourse had an even greater influence on the ambition of climate change legislation in the form of climate acts than the political orientation of governments. Based on these findings we argue that the development of political socialization and civic action regarding climate change is highly relevant to effective climate literacy. Therefore, we need to identify which conditions should be promoted to foster students' interest and engagement in public issues regarding climate change.

2.8. Climate Literacy as Political Literacy

In terms of tackling climate change, climate literacy could make an essential contribution, as political decisions for climate actions need citizens' support in democratic societies, but what is the appropriate grain size for education? How much do citizens need to know in order to make informed decisions or to support political measures in a democratic society? Do we need to understand the radiation budget, the electron transport chain in photosynthesis, transpiration coefficients, or even the absorption spectrum of CO_2 in order to meet the planetary load limits? Bord et al. [67] have shown that misunderstanding environmental changes and their causes leads to a decline in public support for a committed environmental policy. If, for example, climate change is attributed to the *ozone hole*, and this hole is closing, why should climate protection still be pursued? Thus, a basic understanding of sustainability-related issues is probably less important in terms of personal choices, but more important in terms of enabling political participation [68].

Empirical findings from both educational research and climate research show that people in the developed regions such as Europe [69] and the US [70] already have a high level of climate consciousness, but that the opportunities for, and influence of, personal behavior changes are limited. For the improvement of effective climate action, political measures on local as well as global levels, such as emission caps and the removal of

subsidies for fossil fuels, are more important. Moreover, Dalelo [71] points out that—especially for countries in the Global South—professionals with political climate skills are needed to negotiate effective measures for climate protection and adaptation. In that sense, climate literacy education can contribute by strengthening the ability of students to engage in political participation and enable them to question the mechanisms that have led to the climate crisis. Overall, democracy is enhanced when people are able to evaluate and address issues such as the climate crisis in an informed manner and a solution-oriented way [72,73].

Waldron et al. show in their exploratory study that most of the teachers and trainee teachers they interviewed conceptualize climate change as a physical–geographical process and focus on individual private actions [74]. In contrast, environmental specialists focus on a transdisciplinary conceptualization of climate change, requiring an understanding of ecological, ethical, social, economic, and political factors [74,75]. Effective climate change education not only needs the integration of the ethical, social, and economic perspectives of climate change, but the political perspective as well.

There are many factors in fostering students' democratic competences that lie outside the influence of schools and science educators, such as the sociodemographic status of their parents [76], parents' political engagement [77,78], or an authoritative (democratic) parenting style [79]. Nevertheless, education in both formal and informal settings plays a central role in the development of political competences as young people need opportunities to practice collaborative decision making in everyday life, such as in school or after-school activities, youth organizations, etc. [80,81]. Research has shown that teachers who use the following approaches have a high potential to foster an active citizenship:

- Connecting curricular content with current events, such as social, economic, and justice issues, is a primary factor associated with students' political interest, activity and sense of political efficacy [82–86].
- Engaging with public issues at the local level, where students can see democratic processes in action and observe the effects of their contributions [83,87,88].
- Creating opportunities for a discussion of public issues in the classroom. In particular, fostering deliberative discussions with a change in perspectives helps discussants better understand their own and others' viewpoints [43,89].
- Fostering a political understanding, which means knowledge about political institutions as well as knowledge of current political events (for example climate conferences, legislative reforms on energy issues, etc.) [84,90–95].

3. Objectives

Recent research on climate literacy and environmental education has shown that many programs focus on conveying factual information about climate science and related scientific competences. To meet the potential of educational interventions to mitigate climate change, adapt to its impacts, and address climate justice matters, it is essential to provide students with knowledge about the political perspective of climate change and empower them to participate in politics. Therefore, we investigated the following research question:

How do current educational intervention studies on climate literacy incorporate the political perspective of mitigation and adaptation on climate change?

We analyze how greenhouse gas emissions are connected to different sectors in the educational materials, which private- and public-sphere mitigation and adaptation strategies are mentioned, and what policy regulation options are referred to. Furthermore, we analyze which actions in the public sphere (i.e., active discussion, reflection on one's own and others perspectives, discussions about climate justice, etc.) can be found.

4. Materials and Methods

As the previous reviews by Bhattacharya et al. [45], Jorgenson et al. [44], and Monroe et al. [43] focus on climate change education (albeit without explicitly investigating the political perspective of climate change), their analyzed literature built the initial

base of our data set. To extend and update the data set, we also conducted a new database search. We used the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) checklist, which provides guidelines for reporting systematic reviews in order to comply with standards and enhance transparency and replicability [96]. All publications included in the analysis were read several times by the authors and were reviewed with respect to the inclusion criteria. Next, the coding scheme we developed, which specifically focuses on the political perspective of climate change education, was applied to analyze the original studies in accordance with the research question.

4.1. Search Procedure

Initially, all publications analyzed by Bhattacharya et al. [45] (n = 178), Jorgenson et al. [44] (n = 70), and Monroe et al. [43] (n = 49) were included in our sample of potentially relevant publications. The 297 references were added to a dataset in Zotero.

To avoid overlooking relevant articles, especially as there has been increased attention on the topic in the last few years, an additional database search was conducted to detect recently published articles that were not part of the previous reviews.

For the database search we selected databases that represent different disciplines that address climate change education, science education, and psychology: Education Resource Center (ERIC) by the US Department of Education (educational science), PsychINFO by the American Psychological Association (psychology), and Web of Science by Thomson Reuters (social and natural sciences, humanities). All databases were searched on the 21 December 2021. To obtain relevant articles, the following search criteria were used: (1) relevant search terms were used; (2) the publications were peer reviewed; (3) the publications were articles; (4) the articles were written in English; and (5) the articles were published after 2017 (with the goal to extend the data set originating from the prior reviews [43–45] and to include articles published most recently).

Keywords for the database search were selected to include all potential articles relevant to the objectives of the literature review and also to target the same relevant samples as the prior reviews [43–45]. Therefore, the selection of keywords was based on the keywords used in the previous reviews and only expanded by three additional terms. First, the search term "climate literacy" was added, as this construct refers to people's specific knowledge about climate change, as well as their abilities and attitudes relevant to taking action regarding climate change [39–41]. The search terms "political participation" and "participation" were also used, as we set a specific focus on the political perspective of, and action towards, climate change. Accordingly, the keywords chosen for the literature search were:

Climate change OR global warming OR climate literacy AND environmental education OR education for sustainability OR education for sustainable development OR conservation education OR climate change education OR climate education OR sustainability education OR ecology education OR energy education OR non-formal education OR climate change education OR climate education OR climate change science education OR climate change STEM education OR climate change education research OR participation OR political participation.

The database search yielded 1245 records (ERIC: 301; PsychINFO: 586; WebofScience: 358), plus 297 records from the previous reviews, which we collated and de-duplicated in Zotero. After de-duplication, 1441 unique records remained. For the analysis we conducted a two-step approach: First, all articles retrieved for inclusion in the review were screened based on their title and abstract to exclude articles not related to the study objectives. Next, we assessed the full-text articles to select eligible articles based on the following inclusion criteria:

1. Topic. Studies were included if the topic was climate change. Studies were excluded if the topic did not relate to the objectives of the literature review (e.g., self-determination in the health domain).
2. Population. Studies were included if participants were elementary and/or secondary school students and the study took place in formal education (e.g., school, excursion

or field trips out of school). If the information about the educational setting was not given in the article, the criteria of school age (6 to 20 years) was applied. All other populations were excluded.

3. Type of study. We included articles that presented empirical data. Theoretical papers, descriptions of activities, or curriculum analyses were excluded. We included studies with a pre- and post-test, only a post-test, randomized trials (experimental studies) and cluster-randomized trials (quasi-experimental studies). We would have also included cross-over trials, but we found none. We only included studies in English.
4. Type of intervention. We included studies consisting of defined intervention conditions that explicitly aimed to provide students with knowledge about climate change, knowledge about mitigation and adaptation strategies, or to encourage students to actively take action in the public or private sphere related to climate change. These interventions could be, for example, energy conservation projects or the application of climate kits with experiments, as long as they targeted climate change education. Additionally, we only included studies in which it was possible to determine whether changes in the students' knowledge or behavior were due to the intervention. Therefore, solely longitudinal studies (for example, studies investigating the development of attitudes and behaviors towards climate change) that did not describe a specific intervention measure were excluded. Project studies were included because they took place in a formal education.

In cases of discrepancies for any of these criteria, consensus was reached by discussion. The included articles were then read several times, analyzed, and documented.

4.2. Data Analysis

The data analysis was based on an already existing analysis grid by Adamina et al. [97], which was developed specially for the analysis of journal articles and teaching materials on climate change education and therefore seemed like an appropriate foundation for our project. To address our research question, we adapted the analysis grid, with a specific focus on the political perspective of climate change education (see Table 1 for the coding scheme). To do so, we operationalized climate change mitigation and adaptation measures using Stern's [53] conceptual framework of environmentally significant behavior, which distinguishes between "private sphere actions" and "public-sphere actions." The authors and two trained research assistants have experience in climate change education (both as practitioners and researchers). The category system was constructed based on literature (e.g., [4,5]), as demonstrated in other reviews [43,98] and on the adaption of Stern's terminology [53]. Overall, the categories were built deductively and were complemented inductively with specific anchor examples using methods for qualitative data analysis [99] and qualitative content analysis [100,101]. Additionally, the data analysis was guided by the results section of the checklist used for reporting systematic reviews [96], which included the reporting of study characteristics, sample characteristics, and study results. We developed a standardized data extraction form (using an Excel spreadsheet) to extract study characteristics and to document the categorizations of the analysis, which allowed a semi-quantitative content analysis (e.g., frequency of intervention characteristics). The standardized form, including the coding scheme, was pilot tested by all study team members using nine randomly selected studies. Team members worked independently to analyze the intervention details. Throughout the coding process the team members discussed a sample of studies representative of the evidence base. The decisions made with respect to this sample were then applied across the reviewed literature. Coded data were compared and categories were refined, with any discrepancies being resolved through discussion.

Table 1. Coding scheme for the data analysis based on Adamina et al. [97].

Coding Category	Description
Study Characteristics	
Educational level	Samples were grouped into three categories: primary education (grade 1–4), lower secondary education (grades 5–9), upper secondary education (grades 10–13). If no grade levels are reported, we used students' ages or school descriptions to group the samples.
Subject	The school subject or discipline in which the intervention took place. If the intervention took place in more than one school subject, the code interdisciplinary was used. If the study is not related to a specific subject this was coded as curriculum-independent.
Learning goals	Which of the following goals in relation to climate change are addressed in the intervention? The students . . . . . . understand climate change. . . . discuss and evaluate mitigation and/or adaptation strategies . . . reflect ethical aspects of climate change . . . take action in mitigation and/or adaptation.
Relation of knowledge and action	Does the intervention focus on knowledge about and/or action on mitigation and adaptation strategies?
Which emission sectors are addressed?	Energy, transportation, agriculture and land use change, waste, industry
At which level and how are reasons for greenhouse gas emissions addressed?	private sphere (individual), public sphere (society, economy)
On which level and how are mitigation strategies addressed?	Private sphere (individual), public sphere (society, economy), technical sphere (scientific/technical concept but no actor is mentioned)
On which level and how are adaptation strategies addressed?	Private sphere (individual), public sphere (society, economy), technical sphere (scientific/technical concept but no actor is mentioned)
Which level of the political system is addressed?	Individual, local, national, global
Which interest groups of the climate debate are addressed?	Economy, politics, society, scientific community
Which public-sphere regulation strategies are addressed?	Regulations, taxation, caps (emission trading), voluntary agreements
Which climate justice matters are addressed?	Intergenerational/intersectional justice

5. Results

In the Results Section, we first describe the included studies, presenting a flowchart of the search procedure and data analysis. Next, we give an overview of how the political aspect of climate change was addressed in the interventions by describing findings regarding the learning goals, interest groups, emission sectors, and policy instruments. We then present results of in-depth analyses related to the sources of emissions and mitigation strategies, and the consequences of emission and adaptation measures, as well as matters of climate justice in the analyzed intervention studies. This section is followed by the results focusing on public-sphere action on climate change. We end the Results Section by presenting a typology that describes six types of interventions that differ regarding their learning goals, teaching methods, and the assumed effects on students' mitigation and adaptation actions.

5.1. Description of Included Intervention Studies

The literature searches resulted in 1441 records. First, we screened titles and abstracts and excluded records that did not portray the objectives of our review (n = 1151). In a second step, we performed an in-depth analysis of the remaining records and their full text. Based on the inclusion criteria we excluded papers that were (1) not related to the topic of climate change education (n = 6; e.g., school class climate, physical activity participation), (2) related to climate change education but not at school level (n = 145; e.g., university education, science teacher education), (3) did not present empirical data (n = 9; e.g., curriculum analysis, position papers), and (4) were not intervention studies (n = 55; e.g., longitudinal studies). Our final data set comprised n = 75 articles that were obtained for further analysis (see Figure 1). The 75 articles we retained for analysis were published between the adoption of the Kyoto Protocol [8] in 1997 and 2021 (see Appendices A and B for the coding of the individual studies and their references).

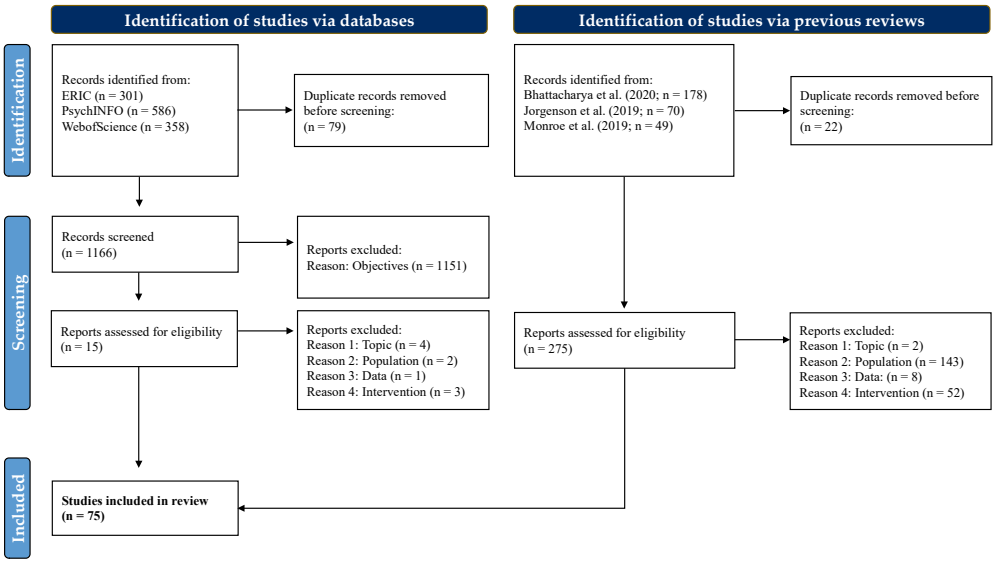

Figure 1. Flowchart of the search procedure and data analysis used for the systematic literature review, following PRISMA guidelines [96].

5.2. Overview of Intervention Characteristics

The 75 analyzed intervention studies are from 17 countries, with USA (n = 36), Germany (n = 6), Australia (n = 5), Canada and Malaysia (both n = 4), Sweden and UK (both n = 3), India, Israel, Italy, and Switzerland (each n = 2), and Columbia, Denmark, Greece, Portugal, Taiwan, and Turkey (each n = 1) (see Figure 2).

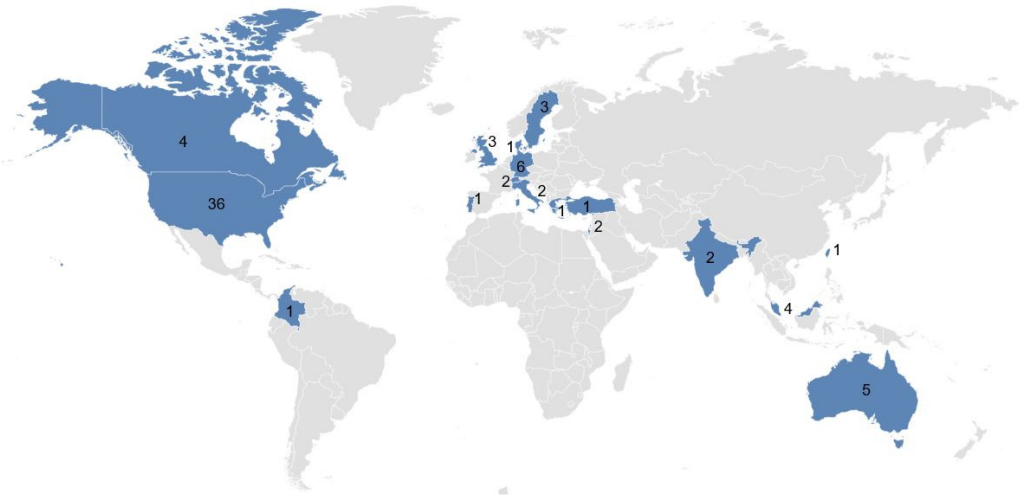

Figure 2. World map showing the geographic distribution of the analyzed studies in the literature review.

The majority of the climate education interventions took place at secondary school level (n = 46) with 30 at lower secondary schools. Thirteen studies took place at elementary school level (some studies incorporate students from multiple educational levels; see Figure 3a). Most of the interventions (n = 57) took place in science classes with only six interventions taking place in cross-curricular settings. Twelve were curriculum-independent or whole school approaches (see Figure 3b). A focus on understanding was the most common learning goal (n = 47), followed by discussing adaptation and mitigation strategies (n = 14) and the promotion of actions on mitigating and adapting to climate change (n = 16). The discussion of moral or ethical aspects of climate change is a central goal in three of the analyzed interventions (see Figure 3c).

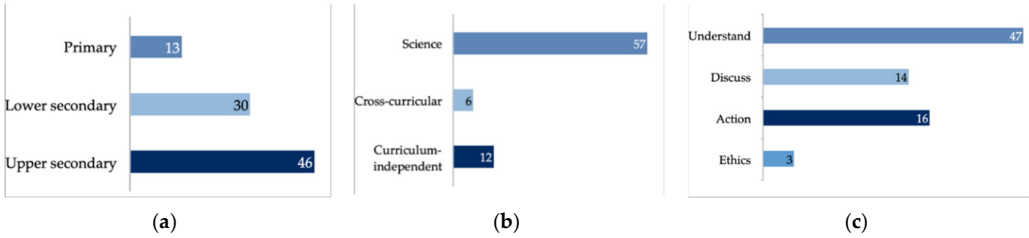

Figure 3. Intervention characteristics of the analyzed studies, including the educational level of the sample, the subject the intervention was based on and its learning goals: (**a**) Educational level; (**b**) Subject; (**c**) Learning goals. *Note*. The educational level does not add up to 75 because some studies incorporate students from multiple educational levels.

The interest groups addressed within the interventions were society (n = 29), science (n = 6), politics (n = 8), and economy (n = 4) (see Figure 4a). The level of action to mitigate climate change (Figure 4b) is focused equally on the individual (n = 10), national (n = 9), and international (n = 10) level, while the local level is comparatively underrepresented (n = 5). When it comes to policy instruments discussed to mitigate climate change, nearly all strategies focus on voluntary agreements (n = 21), while regulatory instruments are only mentioned three times, while environmental taxes or emission trading are not mentioned at all (Figure 4c). Responsibility for the emissions (Figure 4d) is, if mentioned at all, mainly attributed to actors in the public sphere (n = 25), whereas individuals (private sphere; n = 8) are mentioned infrequently. Scientific or technical concepts are addressed just twice. Mitigation strategies (Figure 4e) are most often addressed in the private sphere (n = 29), followed by the technical sphere (n = 9), whereas the public sphere (e.g., political or societal actors) is mentioned rarely (n = 5). The same pattern arises in interventions on adaptation strategies, which, if addressed at all, load into the private sphere (n = 9) and technical sphere (n = 4), while the public sphere is only mentioned in one study (Figure 4f).

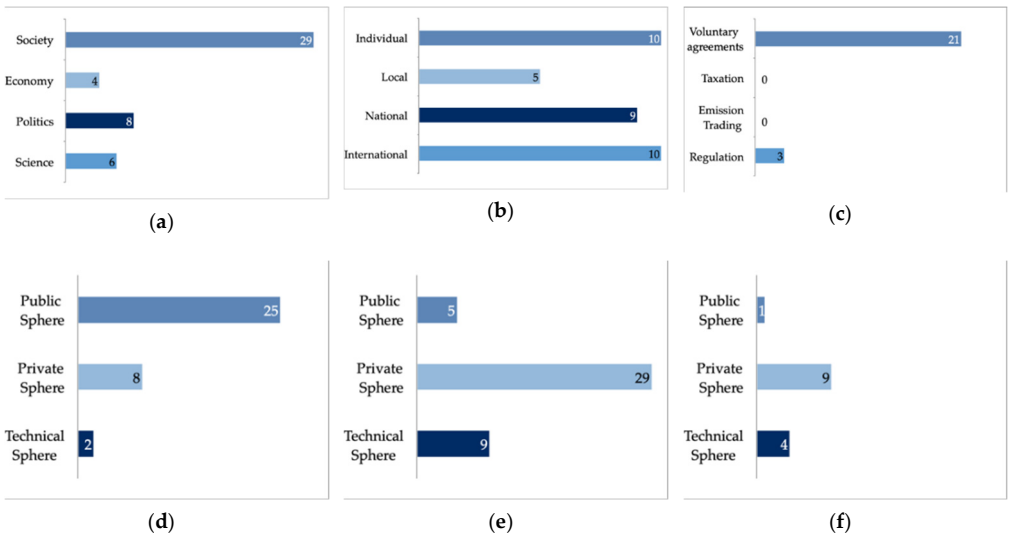

Figure 4. Analysis of the educational interventions for different characteristics of the political perspective: (**a**) Interest groups (n = 47); (**b**) Level of action (n = 34); (**c**) Responsibility (n = 35); (**d**) Policy Instruments (n = 24); (**e**) Mitigation (n = 43); (**f**) Adaptation (n = 14). *Note*. The characteristics do not add up to 75 because they apply not to all studies.

5.3. Addressing Sources of Emissions and Mitigation Strategies

As an indicator of how the analyzed studies reflect debates within climate science and climate politics on mitigating climate change, we evaluated how the sources of greenhouse gas emissions were connected to different sectors in the interventions. We examined how

the emission sectors addressed in the studies' interventions corresponded to the sectoral emissions identified by the IPCC [4] (Figure 5). Our analysis shows that only 47 of the 75 studies analyzed mention concrete emission sources such as electricity, heat, transport, agriculture, etc. In the majority of the studies, "CO_2 emissions" are only mentioned abstractly without assigning them to a concrete source. This does not necessarily mean that emission sources were not addressed in the interventions, but they were not reported, which at least may indicate the relevance attributed by the study authors to these aspects.

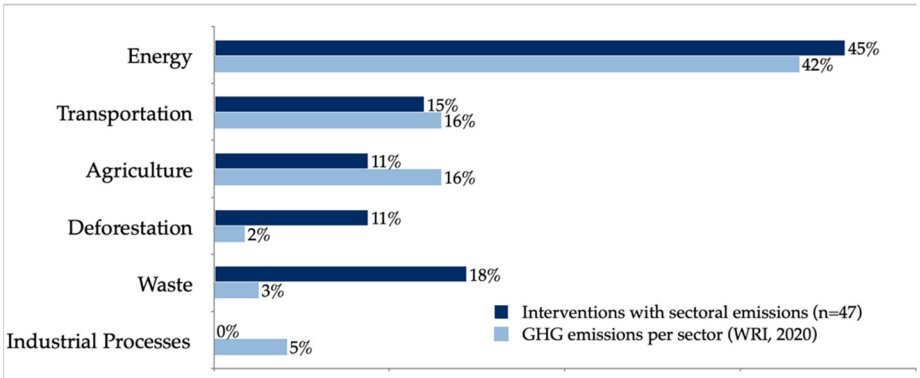

Figure 5. Comparison of emission sectors in interventions and IPCC emission data [102].

Energy. A more detailed analysis of emission sources in the 47 studies that mention specific sources reveals that energy-related emissions are named in all of them, mostly in connection with fossil fuels. There is no further differentiation within the sectors (e.g., whether energy is used for electricity or heat generation, or whether the emissions come from buildings or industry). The emphasis on the energy sector is consistent with its identification as central by the IPCC [4]. In only a few of the studies [103–106] are consistency measures (expansion of renewable energies) discussed in addition to sufficiency measures (energy savings). Efficiency measures (energy efficiency) are not mentioned. There is no differentiated consideration of renewable energies (e.g., wind, hydroelectric, or solar power) in any of the interventions, or of any political, social, or economic strategies for promoting the transformation of the energy sector (support programs, carbon pricing, bans, etc.). Four studies discuss nuclear power as a green energy technology [107–110], but do not discuss the lifespan of CO_2 emissions in comparison to nuclear energy (when extracting uranium) or other environmental consequences (e.g., nuclear waste disposal).

Transportation. The second most frequently cited source of emissions is the transportation sector. This is hardly surprising as transport offers great potential for individual behavioral changes. Here, too, the number of interventions (15%; e.g., [111–113] roughly corresponds to the relative magnitude of emissions identified by the IPCC (16%). In addition to sufficiency measures (e.g., traveling by bicycle instead of car, by train instead of plane), consistency measures (e-mobility) are mentioned in only a few studies [114]. Efficiency measures (more fuel-efficient cars) are not discussed.

Waste. The waste sector is clearly disproportionately represented in the interventions in terms of its relevance to climate politics. Waste is mentioned in about 18% of the sector-differentiating studies, mostly in connection with individual recycling strategies [114–116] or waste collection. According to the IPCC, only 3% of emissions are attributable to waste, which is not negligible but may be lower in priority than other sectors.

Agriculture and land use change. Deforestation as a form of land-use change also plays a role in nearly 11% of interventions, which is significantly overrepresented compared to 2% of the emissions from deforestation. Other agricultural emissions (livestock, meat production) are mentioned in a minority of studies [109,117,118]. Other agricultural emissions (e.g., land-use change, peatlands) are not mentioned in any study.

Industrial emissions. Nearly 30% of the global CO_2 is emitted by industry, 24% thereof by energy-intensive processes (e.g., steel production or the production of fertilizers) and

more than 5% as a byproduct of chemical conversion processes (e.g., production of cement or ammonia) [4]. None of these emissions are referred to in the interventions we analyzed. Usually only generic phrases, such as emissions from "industry", are used in the interventions.

5.4. Addressing Consequences of Emission and Adaptation Measures

Both mitigation and adaptation are essential responses to climate change. Here, we evaluate how the adaptation of societies and individuals to the consequences of climate change are addressed in the publications we analyzed.

Bofferding and Kloser [111] report that secondary school students often confuse mitigation with adaptation behaviors and do not recognize measures to reduce the vulnerability to the effects of climate change. The authors propose not only to give explicit instruction about adaptation measures in class, but also recommend discussing the relationships between sufficient adaptation measures and the amount of emitted greenhouse gasses. We did not find any interventions that explicitly took up these recommendations. Our analysis shows that of the 75 publications, only 18 mention adaptation measures (in contrast to the 47 studies that address emission sources). Although most studies focus on private-sphere adaptation measures (n = 9), such as the preparation of the household for extreme events or collecting rainwater, technical concepts of adaptation, such as efficient irrigation, are mentioned only four times, and public-sphere adaptation measures (i.e., regional adaptation plans) are mentioned only once. Adaptation measures for key risks are described with respect to the following sectors: ecosystems [119–123], agriculture [123], drinking water [124], public health [123], communities [111,123,125], security/poverty [126], and extreme weather events [121,127].

One impressive study focusing on anticipatory adaptation responses that are based on future climate change projections for South Australia is presented by Bardsley and Bardsley [119]. Their approach provides students with the challenge of generating ideas for the hypothetical development of a caravan park in response to projected impacts of climate change, including increased hot spells, sea-level rise, reduced water availability, increasing bushfire, and floods. An example of such a planning decision is to build barriers to stop the floods and so to reduce damage to the caravan park and reduce erosion as a consequence of the predicted higher frequency of storm surges and flooding events. In another interesting study, Nussbaum et al. [121] take reactive adaptation options to already existing consequences into account. The authors present an educational game in which students explore various household or community options in the light of the effects of climate change on the water level of Lake Mead in the southwestern U.S. These options are, for instance, what local or state policymakers could do to conserve water (e.g., raise water prices), or household conservation options (e.g., fix leaky toilets). Likewise, Alexandar and Pyyamoli [124], trained students in India to create awareness among the local community about climate change adaptations (i.e., planting trees, collecting rainwater) to conserve local water resources through service-learning. Stapleton [126] reports on American youths who participated in an educational program in Bangladesh and who helped locals move a school to higher grounds to avoid flooding and interacted with climate refugees.

5.5. Addressing Climate Justice

Overall, six of the 75 interventions addressed climate justice issues and, therefore, a normative side of the climate change debate. In cases in which climate justice was part of the intervention, intersectional inequity played a role, especially local and global justice issues. Although global justice issues are often intertwined with social inequities, only three interventions seemed to tackle these issues together [125,126,128]. Surprisingly, as all of the analyzed studies had children or young adolescents as their participants, no study explicitly addressed intergenerational inequality. Half of the studies addressing climate justice issues included only brief statements regarding the incorporation of these issues (e.g., [111,120,129]). This does not necessarily mean that climate justice was not addressed

more extensively in their interventions, rather it was not reported in more detail, which may indicate the importance placed on climate justice by the authors. However, some made it one of their central learning goals, or even the theoretical framework of their climate change intervention [125,126,128]. We describe these studies in more detail below.

Siegner and Stapert [125] addressed intersectional inequality using a global perspective on the climate crisis. The aim of their intervention was to develop, implement, and evaluate a climate change curriculum in middle school, with a specific focus on climate change from a global and holistic point of view. The global perspective consisted of three themes: (1) Energy (e.g., mapping carbon production and carbon use; history and industrialization), (2) movements (e.g., climate change agents and their biographies), and (3) collective action (e.g., environmental law). In the latter two themes intersectional inequality played a role, illustrated by addressing global justice issues such as climate migrants and indigenous peoples. The authors describe the purpose of their choosing a global perspective on a global crisis as a springboard for students to feel empowered taking (local) action on global issues.

In Öhman and Öhman's [128] study, the students took part in a role-playing activity in which they represented different countries in a UN negotiation about a climate change agreement. In the intervention, climate change was portrayed as a problem that involves conflicts between different interests and value perspectives resulting in justice issues. In the study, the topic of global economy was the central point of connection between interest and values in the climate crisis. It was used as a backdrop to reflect on political power relations, whilst students discussed challenges and potential solutions on a global and local level. Politicians were introduced as the key people in power and voters as the central stakeholders. Furthermore, difficult aspects of international climate change agreements were discussed, such as being hampered by political difficulties in enforcing changes that would lead to a redistribution of the economy or affect a country's economic competitiveness, both of which would affect the voters' economic standards and, ultimately, the politicians' own power positions. Moreover, it was mentioned that the wealth of the Global North is mainly based on the resources of the Global South. Thus, a dilemma without any self-evident or obvious solution was described whilst the political perspective of climate change was directly addressed.

In Stapleton's [126] intervention climate justice was contextualized through a detailed examination of climate change impacts on populations in Bangladesh, with the aim of educating youth in industrialized, wealthy nations to become mobilized, climate-engaged individuals. American students participated in a global climate change education program in Bangladesh, a country severely affected by climate change. They experienced climate change impacts through excursions into mangrove forests and interactions with affected people. The program revolved around the concept of solidarity, working with those who lack power and privilege and are impacted by systemic oppression. Although the concept of MAPA was not explicitly named it became the backdrop of climate change in the study. Key issues on a social and global level arose, not only with respect to Bangladesh, but also generalized to the Global North and South. These issues included imbalances of power and wealth, social injustice, and power disparities within climate change impacts. Thus, the students implicated themselves as part of the problem and had to acknowledge their own obligations in mitigation. This is the only intervention that uses multi-perspective approaches to not only address socioeconomic factors but also global differences with regard to the consequences of climate change and mitigation and adaptation requirements.

Two of the studies discussed above [126,128] seemed to focus solely on climate justice and therefore did not emphasize scientific concepts about climate change. Although all of the three studies discussed above [125,126,128] go into detail about climate justice issues whilst setting different foci, they seem to share commonalities. They all promote knowledge about climate justice and they all involve students actively through public-sphere actions (collective actions), discussions, or a real-life experience on site. The topics of these interventions are closely linked to the political perspective of the climate crisis (e.g., regulation of the global economy, climate migrants, or climate justice in the context

of MAPA). None of these three studies made any mention of concrete contributions to a solution, related, for example, to different emission sectors, emission amounts, policy instruments, or concrete political regulations such as taxation, emission trading, voluntary agreements, or financial aid given by richer industrialized countries to poorer countries [5].

5.6. Addressing Public-Sphere Actions on Climate Change

The data in Figure 4c–f show that the relative majority of the studies see responsibility for the causes of climate change in the public sphere while measures for mitigating or adapting to climate change is in most cases discussed in the private sphere. The same holds for instruments to mitigate global warming: While different authors [60–63] have shown that it is regulation policies that is most effective to handle global warming, the vast majority of the instruments—if any—discussed in the studies are voluntary agreements. These findings lead to the impression that most educators collectivize the responsibility for the causes for global warming while privatizing the responsibility to handle global warming.

However, those studies discussing public sphere actions show very interesting approaches: With regard to public-sphere knowledge, we found that only 21 of the 75 papers referred to climate policies, legal requirements, or the IPCC. More specifically, 4 studies referred to the Kyoto Protocol, 2 to the 2 °C goal, and 18 to the IPCC. However, the IPCC is typically not addressed in these studies as a political framework. Rather, it is used in reference to scientific knowledge about climate change and to the scientific and societal relevance of mitigation and adaptation. Likewise, climate policy reference frameworks (i.e., 1.5 °C limit) are addressed seldomly [111,119,125,130,131]. Taking a closer look at what was taught in the educational interventions, just five of them refer to national or international climate policies, global treaties on emission caps, or the IPCC reports [123,125,132–134]. Most studies refer to climate policy (e.g., [135], who mention the IPCC report in the introduction and in the discussion of their publication) but do not go further than using the reports to justify why understanding climate change and its impacts are imperative. Tasquier et al. [133] make explicit reference to the IPCC reports in their intervention to introduce the students to scientific research. Covitt et al. [132] focused their analysis on the conceptual use of the quantitative carbon cycling model representation from the IPCC as a reasoning tool. The IPCC is not referred to in any of the interventions addressing climate justice issues. Interventions that allowed a more in-depth analysis are described below.

Buchanan et al. [136] and Jensen [137] both describe participatory, problem- and project-oriented learning activities at different school levels in which possibilities for collective action are addressed and local political actors are involved. An Australian program evaluated by Buchanan et al. [136] takes on the demand formulated by several authors from the political sciences that public-sphere action is promoted by connecting climate change in a cross-curricular way by making links between climate change education and subjects such as English, mathematics, science, design and technology, or geography.

Bardsley and Bardsley [119] and Kapudewan and Mohd Ali Khan [138] focus on the local to national level, but without addressing options for public-sphere actions. Bardsley and Bardsley [119] describe the development of planning opportunities for sustainable management of the coastal system under a climate change scenario for 2030. In this study, possible personal behavioral and broader societal responses based on climate change scenarios for South Australia were evaluated by students. The aim was to reduce the impacts of climate change within the context of a hypothetical development of a caravan park near the coastline. Kapudewan and Mohd Ali Khan [138] describe a group discussion in which students present what they could do to reduce emissions from the viewpoint of different stakeholders (e.g., minister, town planner, or farmer). The change in perspective is an important way to promote the development of public-sphere action [43,89,139].

One of the very few studies that addressed the political perspective of climate change at the primary school level, and political regulations other than voluntary agreement options, is Wang [140], in which the development of argumentation skills took place in an online learning environment. Through the analysis of the question of whether a new

naphtha cracking plant should be built, students also discussed political regulation options at national levels such as bans.

Stevenson et al. [123] used agricultural and environmental message framing when working with agriculture students. The students were asked to read one of four short articles addressing either the farming community, public health, environment, or agriculture. The authors found this approach to be an effective teaching practice in promoting public-sphere action. The articles referred to national policies and described how these policies help limit threats to communities (i.e., improving the energy efficiency of homes to reduce energy costs and the impacts of climate change threatening communities worldwide). One feature of the short articles was that all ended with a positive message frame: efforts to limit global warming are a "win-win" situation as they will reduce the risks of global warming as well as improve national agriculture and health.

Focusing on the international level, Öhman and Öhman [128] describe a role play in which students represent different countries in a simulated UN negotiation about a climate change agreement. This intervention is embedded into a 10-week thematic project on climate change in the subjects of Swedish, geography, and civics with the goal of preparing students to participate in international civic debates. The analysis focused on students' interactions; changes in their knowledge are not described. Similarly, Siegner and Stapert [125] present and evaluate a climate change curriculum implemented in an integrated social studies and language framework, incorporating not only action competence, but also knowledge learning goals. Aspects of civic education were simulated into a "World Climate Summit". In this UN climate negotiations activity, students observed through their negotiations how their intended emission reduction plans affected global temperatures by explicitly taking reference to the 2 °C limit specified at the COP 21. Further service-learning projects at the local community level will be added to the curriculum to link the local to the international as well as the individual to the collective/political level.

Tasquier et al. [133] explore students' epistemological knowledge of models and modeling in science through a climate change learning environment. Their lesson on political and economic scenarios is of special interest in terms of the political perspective. Their core message is that individuals as well as policy makers have the power to contribute to climate change mitigation through the behaviors of the individuals in their daily activities. They also discuss collective political and economic aspects and institutional choices (e.g., the role of global treaties on emission caps).

5.7. Intervention Typology

The following typology describes six types of interventions that differ regarding their main learning goals and how and which mitigation and adaptation actions they explicitly or implicitly promote. The categories are not exclusive as some studies combine elements of multiple types (e.g., they promote mitigation and adaptation strategies, or they address preconceptions and complex system knowledge). However, most studies can be assigned clearly to one type. For every category the supposed effect of the interventions on students' mitigation and adaptation actions are summarized.

Overcoming preconceptions about climate change. Numerous intervention studies aim at enhancing students' understanding of crucial concepts such as the greenhouse effect [141,142]. Typically, they address only one concept but describe this concept as well as the related student preconceptions in detail. Some of these studies argue that a foundational understanding of climate change is necessary for contributing to climate protection. These teaching approaches are based on constructivist theories of learning and directly address preconceptions that students should overcome. To induce conceptual change, they use inquiry activities and/or argumentation, often in combination with scaffolding (e.g., [143]), concept cartoons (e.g., [144]), conceptual metaphors (e.g., [142]), or teacher explanations (e.g., [141]). Subsequently, they initiate negotiation and reflection of the new concepts by group or class discussions [145]. The effects of these interventions are investigated in pre–post study designs that are sometimes combined with a treatment group and control

group comparison. All of these studies report that their interventions led to a substantial change in students' understanding of the targeted concept. Interestingly, if any mention is made of mitigation strategies, it is only in the introduction and discussion of the manuscript; they are not taught to the students. In addition, the focus of all studies in this area remains narrowly on teaching the physical science basis of climate change. We did not find inter- or transdisciplinary approaches, in which knowledge about the greenhouse effect is taught alongside knowledge about its economic, social, or political interrelationships, in the interventions. It seems that these studies follow an implicit heuristic of "understanding climate change leads to action against climate change".

Teaching complex knowledge about climate change and its consequences. Climate change and its consequences is a complex topic as it involves interacting processes in different earth spheres (i.e., atmosphere, hydrosphere, and biosphere) that are each in themselves complex and affected by human activities. In contrast to studies aiming to overcome students' preconceptions, these interventions are not limited to one concept but rather focus on the interaction of different subsystems related to climate change (e.g., the impact of carbon cycling on the climate system). They promote students' systems thinking so that the students can understand the complexity of climate change and reason about it. To do so, they utilize representations of complex and interrelated systems [118,130,146,147], computational models that enable students to explore the impact of different variables on the climate system [148–150], or scaffolding to support students' scientific argumentation [140]. They include anthropogenic factors affecting global warming or the potential effects of changes in human behavior on global warming [147–149]. However, they seldom address how to initiate mitigation strategies that students can adopt in the public or private sphere. Their implicit heuristic of climate education seems to be "if students understand how the complex earth system is influenced by human activities, they will take action".

Knowing and discussing mitigation strategies. Unlike the first two intervention types, there are interventions that explicitly teach or discuss strategies to mitigate climate change. In these interventions, students learn how humans influence the climate system and, additionally, what they, their families, and their peers can do to slow down global warming. These interventions focus on strategies on the personal or local level, such as saving energy and electricity [122,125,131,151,152], using environmentally friendly transportation [111–113,152], or using regenerative energy sources [111,113,152]. However, some interventions also inform students about climate policy, such as national and international strategies to reduce greenhouse gas emission [122,133], or economic regulation of greenhouse emissions [125]. One finding of these studies is that just acknowledging anthropogenic climate change is not sufficient to initiate public-sphere action. Instead, conceptual understanding of climate change and knowledge about mitigation strategies can lead to individual efforts to reduce personal impact on climate change and thus limit such action-value gaps [111,153]. Furthermore, knowledge about climate change and mitigation strategies also has a positive impact on students' self-efficacy regarding their private-sphere mitigation actions [152]. Besides knowledge, credible role models who have successfully adopted mitigation actions can help to induce private-sphere actions [151]. However, all these effects have only been observed in a short period after the intervention. It is an open question how enduring the mitigation behavior of students is. The supposed effect of these interventions can be described by the heuristic "if students understand climate change and why and how to change their behavior they will do so".

Changing beliefs regarding climate change and facilitating positive attitudes towards the environment. Whereas the first three intervention types address students' conceptions and knowledge about climate change or mitigation strategies, this category consists of interventions that explicitly aim to facilitate positive attitudes towards the environment or to change students' beliefs regarding climate change. These studies are often motivated by models of environmental education that include affective variables such as students' connectedness with nature as moderators between knowledge about the environment and pro-environmental behavior [154]. Dunkley [155] reports that field trips to places

where students can experience human dependency upon the non-human world can help students to establish affective connections with the natural world and to perceive how climate change might affect their lives. In the intervention of Semmens et al. [156], students created art illustrating complex processes related to climate change, which induced a feeling of personal connectedness to nature. In more traditional science classes, framing climate change within community-relevant problem scenarios can elicit feelings of worry in students [123]. Presenting facts about climate change through an entertaining, multi-sensory, captivating presentation has a positive influence on students' beliefs, involvement, and conservation behaviors [157]. The heuristic of these interventions can be described as "students must feel their connectedness with nature and acknowledge climate change in order to take action".

Take action on climate change. In this type of intervention, students not only learn facts and concepts about climate change and mitigation strategies, but also take public-sphere actions against climate change during the intervention. These actions include the identification of ways to reduce their energy consumption [103,136,158,159], writing service announcements to teach the public about global warming [160], sending written petitions to private companies and local village boards [137], discuss with politicians [161] or signing a public commitment to reduce personal energy consumption [162]. The focus of these interventions is to do something in the public sphere that directly mitigates climate change at the school or local level. In an extreme form of these interventions, students do not even receive specific knowledge about climate change or mitigation strategies (or at least this is not mentioned in the intervention description). Instead, they choose to initiate something in the local community based on their own perspectives. The students decide which problem they want to work on and how teachers and experts from the local community will support them to achieve their goals [137]. "Take action" studies typically describe the students' actions and their impact on the local community in detail. An impressive example is the decision of a community council to build a new bike lane in consequence of a petition and the political activism of students from a regional school [137]. All studies report that students' actions are successful. Students' willingness to take action depends on the simplicity of the actions, encouragement from family members, and support from the school and teachers. The heuristic of these interventions seems to be "if students want to take action, let them act".

Teaching strategies to adapt to the consequences of climate change. In climate science there is a consensus that climate change is caused by human emission of greenhouse gasses, that these emissions already have a profound influence on our climate system, and that the consequences already harm humans by increases in extreme weather events such as storms, floods, and more and longer arid periods [163]. Consequently, some interventions teach students how to adapt to these events by conserving local water resources [121,124], preparing families to survive floods [127], or discussing strategies to adapt to increasing bushfire risk and the rise of sea levels [111,119]. All adaptation strategies are based on the most likely local risk scenarios. The teaching approaches include simulation games [121], preparation projects (preparing flood surviving boxes with parents), and planning community adaptation strategies in response to local risk scenarios [119]. One finding of these studies is that students who understand and acknowledge that climate change is happening are more likely to support adaptation strategies [123]. Generally, the impact of these interventions on personal and local adaptation to the risk scenarios are substantial as they carry over into families and local communities [124,127]. The local and personal relevance of the adaptation strategies seem to be the reason why these interventions are effective [123]. Interventions on adaptation strategies seem to follow the heuristic: "climate change is happening and harming us, so we have to adapt if we want to live securely".

The frequency of the six intervention types differs. While only 7% of the interventions belong to the "take action" type, over 80% belong to the three categories that focus on promoting knowledge to induce action (preconception 27%, mitigation 29%, and complex

knowledge 34%), and 19% of the studies address adaptation strategies. The frequencies do not add up to 100% because a few studies belong to two intervention types.

6. Discussion

The aim of this review was to investigate how current educational intervention studies on climate literacy incorporate the political perspective of mitigation and adaptation on climate change. We analyzed 75 empirical studies to find out how their interventions connect greenhouse gas emissions to different sectors, how different interventions mention private- and public-sphere strategies for mitigation and adaptation, and—if at all—what policy regulation options are referred to. Furthermore, we analyzed which methods (e.g., active discussions, reflection on perspectives, and discussions about climate justice) are referred to in the interventions to discuss or promote actions in the public sphere.

This is the fourth review in the last three years to summarize empirical findings about climate change education. In contrast to the previous three reviews, we included only intervention studies conducted in regular school contexts. We excluded any interventions that took place in higher education, and excluded correlational studies without any intervention and purely theoretical papers. We applied this focus on regular classroom settings because primary and secondary education reaches every student and thus has the potential to promote the extensive mitigation and adaptation actions that are required as a consequence of climate change. For the same reason we focus on the political aspects of climate change in our analysis. The reviews by Bhattacharya et al. [45], Jorgenson et al. [44], and Monroe et al. [43] found that political aspects of climate change are hardly addressed in climate change interventions, and that climate change education focuses mainly on delivering scientific concepts about climate change but seldom promotes public-sphere mitigation or adaptation actions. By utilizing a framework based on scientific knowledge about actions necessary to mitigate and adapt to the forecasted consequences of climate change, we were able to evaluate why an education that avoids the political aspects of climate change is ineffective. The specific focus on political aspects of climate change allows us to highlight the few interventions that already incorporate elements of political literacy in the context of climate change. These elements include climate justice, the promotion of adaptation to climate change, and the initiation of public-sphere actions.

We found that the majority of intervention studies focus on private-sphere actions, while only a minority of the studies include public-sphere actions. The current climate education seems to align with the motto of early environmental education, "think global act local". The dominant effect heuristics of interventions seems to be that education can contribute to mitigate climate change by informing students about climate change and what they personally can do to mitigate it. This fits our finding that the responsibility for the emissions is often attributed to large-scale societal actions while mitigation actions focus on private and technical/scientific strategies and voluntary agreements. An explanation for this finding might be the vision of environmental education and reform pedagogy to empower young people with individual possibilities for action and to link content to the students' lives. However, this view confuses private-sphere action with personal action as individuals, whereas students can support or initiate public-sphere actions. Limiting actions to the private sphere is not only problematic with regard to the empirically established low effectiveness of such actions on political developments and real greenhouse gas emissions [60,63]. It is also problematic as it assumes that promoting basic knowledge and addressing attitudes will save the climate. Empirical data [57] show that the correlation between attitudes and greenhouse-gas emissions varies from non-existent to negative and, even if a connection could be established, Kaiser et al. [164] have shown how difficult it is to initiate long-lasting changes in individual behavior.

As a consequence, climate education should address public-sphere actions instead of private-sphere actions in order to effectively mitigate climate change and to initiate adaptation actions. To obtain an impression of how current interventions promote students' actions, we first discuss which emission sources and mitigation strategies are addressed in

climate education. Next, we discuss how public-sphere actions on climate change have been addressed so far, and whether we can expect an implicit effect of interventions focusing on teaching knowledge about climate change on students' actions. Finally, we discuss how adaptation is taught currently and why including issues of climate justice is important for climate education.

6.1. Addressing Sources of Emissions and Mitigation Strategies

To take effective public-sphere mitigation actions, students need to have a realistic picture of the sources of greenhouse gas emissions and who is responsible for them. In this regard, informing students about sources of greenhouse gasses can be seen as grounding political action. We found that current climate education has a strong focus on energy-related issues, which is congruent with the importance of emissions from this sector. However, it is interesting to note that almost all studies focus exclusively on electricity production as the main source of emissions. Heat supply is not addressed in any of the studies; although, this is currently one of the most pressing political challenges in the early developed countries, ranging from heat supply for domestic heating to heat demand in industry. Furthermore, it is interesting that only sufficiency-oriented—and in nearly all cases exclusively private sphere—actions are addressed. The switch to renewable energy sources, which are currently the most important political element in the debate in the industrialized countries, as well as strategies for increasing energy efficiency, are hardly addressed at all. This lack of attention to renewable energy means that the potential for educating students about one of the most important factors in the debate about climate change is wasted.

With regard to the disproportionate focus on the waste sector compared to the emissions from waste, it shows a (con)fusion of climate education with general environmental education. In this regard, the transition to a circular economy is undoubtedly a significant policy strategy for a sustainable society, but the argument in the analyzed studies is not one that is reflected in terms of climate issues, but often falls through either human rights issues or chemical pollution issues. At this point, the strong focus of climate literacy studies on the waste sector seems to replicate a phenomenon found particularly in everyday conceptions of climate change, namely that climate change is caused by pollution [165]. The—also—disproportionate focus of climate literacy studies on deforestation as a cause of climate change relative to real emissions can be explained by the curricular importance of photosynthesis as the central reaction for carbon sequestration in school science. Unfortunately, this focus comes at the expense of real carbon fixation potentials and current carbon sources in peatlands, among others. There could be interesting curricular links here, including the draining of peatlands for livestock.

It is interesting that neither specific energy-based emissions nor process-based emissions from industry play a role in the studies—not even in the studies that are categorized as science education, in which technical processes such as those used in steel production often play a role, especially in chemistry classes. Here, anchoring points for climate education in science education could be formed. Climate education concepts [97] illustrate that addressing the emission sector is already possible in elementary and middle school when appropriate teaching materials are applied, for example by using emission sketches.

In sum, we found that current climate education interventions give students only a partially realistic picture of greenhouse gas emissions, for example, the energy sector is not discussed in detail and other sectors are either missing (e.g., industry) or overrepresented (e.g., waste) compared to their impact on global emissions. In consequence, it is not surprising that the mitigation actions proposed in these studies are also limited to these sources. It seems that climate education focuses only on those sources that can be addressed by private-sphere actions, no matter if they are relevant with regard to their impact on global greenhouse gas emissions. The over-emphasis on cutting private energy consumption (particularly electricity consumption) has not only a limited mitigation effect because of its small magnitude, but its effect can further vanish if the saved energy is used elsewhere

(e.g., by industry). Such rebound effects appear when improvements in resource efficiency actually lead to more rather than less energy consumption because of a reduction in energy prices. To avoid such effects, private-sphere actions need to be accompanied by political measures such as caps, which can hardly be taken if they are not demanded by the public [166]. Thus public-sphere actions are actually a prerequisite for private-sphere actions to be effective.

6.2. How Are Public-Sphere Actions on Climate Change Addressed So Far?

When looking at knowledge about public-sphere actions and how such actions are promoted, it is striking that very few interventions introduce students to actions described in official political documents or the IPCC reports. This is surprising as these documents describe the scientific and political consensus on mitigation actions and are thus a relatively solid knowledge base for educational interventions. The findings on mitigation measures are at least as reliable as the scientific findings on climate change, which are directly discussed with students in some intervention studies (e.g., [133]). The minimum requirement for promoting students' public-sphere actions would be to inform students about common policy instruments such as regulation, subsidies, or market-based mechanisms [55]. Based on this knowledge, they can build up their own opinion about political mitigation strategies and, if old enough, make informed decisions in public elections. Furthermore, this knowledge can serve as a starting point for some students to take further actions such as becoming involved in climate activism because they know which instruments and actions they can demand from decision makers. However, informing students about relevant political discourses is only one strategy, and is not the most effective strategy for engaging students in public-sphere actions. Further teaching approaches include opportunities for students to discuss public issues in the classroom [43,89,128] or engaging students with public issues at the local level, so that they can observe the effects of their activism [83,167,168]. The studies in our review that use these methods are aimed at changing policies on a local level [136,137]. At first glance this seems to be a straightforward approach as students can easily initiate concrete actions within their personal environment. However, the "Fridays for future" protests, a global grassroots initiative based on local groups, which demands extensive political actions on climate change, demonstrate that students can dominate and shift public debates even on an international level [31–34]. Given the multiple methods for promoting public-sphere actions ranging from informing students about climate policies to taking part in activism, the question remains, why current education about such a highly political topic such as climate change seldom addresses the political perspective.

Three explanations are at hand. The first is that climate change interventions are conducted in the context of science education and that science educators are not able or willing to teach the societal and political perspective of climate change. However, solely focusing on science concepts when doing science in schools misses the demands of science curricula, as Osborne and Dillon [169] have shown in an analysis of science education curricula in the early industrialized countries, who demand a science education not as an end in itself, but rather to provide students with skills for active citizenship.

However, the question remains, why there are not more political education or interdisciplinary research teams developing and investigating climate education programs. It is possible that there are additional reasons for the dearth of research into the political aspects of climate change education. It may be that researchers and teachers are unwilling to inform students about the political aspect of the topic, or even to promote students public-sphere actions because it is a controversial topic and they are afraid to publicly support a specific political ideology [128,170]. Science educators may believe that if a genuine science topic becomes political, it is too close to advocacy to address it in the classroom. However, this applies for many other controversial topics in history or politics, and there are teaching methods used to inform students about controversial issues and to help students find their own position on these topics without overwhelming them [43]. The first two statements highlight the importance of promoting teacher education that

meets these requirements [171,172]. In order to supply teachers with knowledge about the political aspects of climate change, the corresponding pedagogical content knowledge as well as teaching methods must be taught [173]. The third explanation is that even if socioscientific issues have become a major strand in science education research, the choice of which specific topics are taught at the intersection of science and society—such as climate change— is motivated by more general educational concerns. That is, climate change is taught not only to prepare students to deal with climate change but because it motivates students to learn scientific concepts. Thus, this socioscientific issue is boiled down to teaching the scientific but not the societal perspective. While social change is at the core of environmental education's mission [174] and sustainability education [175], it seems challenging for K–12 educators, program developers, and science education researchers to shift the goals from scientific facts to political literacy.

6.3. Indirect Effect of Current Climate Education on Students' Public-Sphere Actions?

We found that current climate change interventions predominantly deliver knowledge about climate change but seldom directly promote public-sphere actions. However, they might have an indirect effect on students' actions including their public-sphere actions if understanding the causes and consequences of climate change initiates effective actions. For each of the identified intervention types, we next discuss whether and how interventions belonging to a specific type can contribute to student actions, in particular their public-sphere actions.

Studies aiming at overcoming students' preconceptions about climate change report enthusiastic results with respect to understanding the science behind global warming. From a science education point of view, this is a motivating result as the strategies are obviously successful. With regard to the findings of Bord et al. [67], that a basic understanding of environmental changes is necessary to develop public support for a committed environmental policy, teaching the principles of climate change can indeed contribute to effective mitigation strategies [68,176]. However, the central question of how deep an understanding of the physical science basis of climate change is needed for lay people and students to support mitigation strategies stays open. A wide range of authors ([83,86], among others) have shown that it is crucial for curricular content to incorporate current events from public, social economic issues in order to increase students' political interest and activity. It could therefore be an appropriate strategy for climate educators to broaden their perspective from a narrow science perspective to a more trans- and interdisciplinary perspective.

Teaching complex knowledge about climate change and its consequences reflects the demand from sustainability sciences to foster students' systems thinking competences as a major factor for initiating environmentally friendly actions [177]. Moreover, from the perspective of political education interventions, systems thinking could promote actions within the public sphere, as multiperspectivity and acquiring cross-domain knowledge are important promoters of political socialization.

Intervention studies that aim at creating an understanding of climate change and a knowledge of mitigation and adaptation strategies can lead to private-sphere actions and have a positive impact on students' self-efficacy regarding their personal mitigation and adaptation actions. However, this limitation to private-sphere actions is problematic because it suggests that individual students are responsible for mitigating and adapting to climate change and that their private-sphere actions will have a substantial effect on climate change. These interventions, thus, counteract the promotion of public-sphere actions, which are the most effective actions with respect to mitigating and adapting to climate change [60,63,66]. Studies aiming at promoting positive attitudes towards the environment are effective in changing students' attitudes but not in triggering climate friendly behavior and, thus, are the least effective interventions in terms of mitigating and adapting to climate change if they only address attitude change. Promoting positive attitudes might be effective as an additive to other interventions that are focused on taking action. However, cooperative learning environments in which students discuss controversial issues can lead

to higher levels of personal awareness and perceived self-efficacy in relation to global warming [89]. Thus, addressing the political aspect of climate change might have side-effects on students' attitudes. These effects can be explained by cognitive dissonance theory, which proposes that people adapt their attitudes to their behavior in order to eliminate conflict between attitudes and behavior [178,179]. Rather than changing attitudes in order to change behaviors, the implication of cognitive dissonance theory is that attitude change follows behavior change. This is a further argument for focusing on action in climate education and not limiting it to delivering knowledge and trying to change attitudes.

Interestingly, many studies in which students take action on climate change focus on public-sphere actions such as writing service announcements to teach the public about global warming or sending written petitions to private companies and local village boards. In the intervention described by Jensen [137], the students achieved impressive success when putting public pressure on the local boards by demonstrating and communicating their demands via newspapers. This demonstrates the potential of educational interventions that address public-sphere actions. However, public actions can also be promoted by less direct approaches such as teaching students about possible political regulation strategies to mitigate climate change [93–95] or reflecting on historic social movements [180].

Our findings show that current interventions in climate education do not correspond to the current state of climate research that rapid, extensive, and coordinated actions are required to mitigate and adapt to climate change. As effective mitigation and adaptation actions are public-sphere actions, effective climate education needs to prepare students to understand, participate in, and initiate such actions. That is, climate education needs to incorporate political literacy in the context of climate change. Moreover, initiating students' actions seems to have positive side-effects on their attitudes towards nature and mitigating climate change. Claiming that the participatory perspective is crucial for effective climate education is not a totally new approach to sustainability education. Many authors have claimed that aspects such as action competence and independent opinion making should be a significant feature of environmental and sustainability education (see [181–187]). We consider it to be surprising and important finding that, to date, a focus on action has not played a dominant role in climate education research.

6.4. Addressing Consequences of Emissions and Adaptation Measures

Both mitigation and adaptation are crucial in tackling climate change and are increasingly integrated into policy processes [3,5]. Interventions that teach adaptation strategies tend to address the most likely local risk scenarios and mainly take up measures in the private sphere. This seems a promising approach to motivate students and to illustrate the relevance of the issue of climate change. Stevenson et al. [123] showed that support for adaptation strategies is higher if students understand and acknowledge climate change as a current issue. Therefore, it seems important to explicitly address local adaptation measures in class (e.g., [188]), both in terms of adaptation to what is already happening and to future changes in the climate system (i.e., extreme events) and their consequences. However, educational interventions often do not address student confusion about mitigation and adaptation measures, nor do they relate the impact of adaptation measures to CO_2 emissions. Focusing solely on private-sphere actions at the local level is missing opportunities for greater impacts. It is necessary to integratively consider, discuss, and evaluate actions in terms of conflicting problems, goals, and solutions [97]. The adaptation responses reported in the interventions we analyzed did not tend to relate public-sphere actions to the findings from the IPCC reports nor to climate policy goals from local to international levels. Students need to understand how local adaptation measures in response to climate change risks are linked to societal activities and political climate change frameworks at national and international levels (e.g., the protection of particularly vulnerable ecosystems), such as in the study by Bardsley and Bardsley [119]. Moreover, the local focus overlooks issues of justice with regard to adaptation options for populations that contribute least to climate change but often suffer its consequences the most. Even though the consequences of climate

change affect regions differently, adaptation strategies need to be based on international solidarity and cooperation [189] (p. 13). This cooperation is also crucial for industrialized countries as the fatal consequences of extreme weather events can cause damage that local or even national governments can hardly handle [190]. Thus, climate change education has to include issues of justice to lay a foundation for international solidarity.

6.5. Why Is Addressing Climate Justice Necessary?

Talking about climate change mitigation and adaptation illuminates that the global climate crisis is indeed an issue of inequity, as it impacts different social groups on different scales [191], and the most harm is caused to those who are least responsible for causing it [4,5]. This emphasizes the social perspective of this socioscientific issue [9–12]. Although justice issues underpinned the climate change discourse since before the United Nations Framework Convention on Climate Change [37] in 1992, and gained reasonable attention since then, this prominent role in the climate change debate is not reflected in our findings. Our results show a disproportionately low implementation of climate justice in climate education in relation to its importance in scientific and political debates. Furthermore, except for one study by Siegner and Stapert [125], no intervention addresses the "polluter pays" principle or emissions per capita [27]. This is striking because it would be easy to implement by working, for example, with actual CO2-emission data (e.g., [192]), or by illustrating challenges based on histories of social oppression, geographical position, or group membership (e.g., class, race, age, and country of origin). These inequalities both produce climate change and profoundly shape responses to it [23].

Furthermore, our finding that few interventions address climate justice conflicts with the fact that climate justice is the central motive of the "Friday For Future" movement. This connects to results from a Swiss interview study with participants of the climate strikes, who stated that they acquired their climate science knowledge in school, while their political and economic concepts on climate change were often inspired by their peer group and social media [193]. A representative study by Wahlström et al. [194] came to a similar conclusion that social media (44.7%) and friends or acquaintances (24.1%) were the top primary sources for protest information among youths in 19 cities around the world.

The fact that the climate education studies we examined make little reference to climate justice indicates that there are many missed opportunities, and perhaps even dangers, considering that the information shared on social media is uncurated, the sources of this information are usually not transparent, and that social media is also the source of fake news [195] and a venue for the promotion of misconceptions [196]. Arguably, more integration of climate justice issues into formal and informal climate education could lead to more sound, holistic, and transparent messaging of climate justice issues. There is currently great untapped potential here that could—and should—be addressed in the future. In this sense, the topic of climate justice could act as a kind of door-opener for addressing the political perspective of climate change in education contexts, since both the causes and consequences of climate change lie in a historically constituted global economic system, and can thus be understood as an intersecting set of social inequalities [23]. In this regard, Ho and Seow [197] identified the advantage of interdisciplinary curricula, where teachers are able to contextualize the climate crisis in its historical, social, and economic perspectives. At the same time, a crisis that has arisen at the political and overall socio-economical level can also point to possibilities for action at that very level to facilitate a sustainable and climate-just transition.

6.6. Limitations

Our analysis is based on the notion of effective climate education as an education that leads to actions sufficient to limit and handle the consequences of climate change. Against this background, current climate education focuses almost entirely on private-sphere actions that are insufficient to limit global warming to 1.5 °C or to adapt to the fatal consequences of climate change. This instrumentalist notion of education seems legitimate

because of the urgency and scope of the problem. However, there are three alternative notions of effective education in the context of climate change. The first sees education not as an instrument but as an intentless process of empowering one's individual nature in order to secure one's value and continuance (Humboldt, 1974 cited in [198]). In this regard, understanding climate change and private-sphere actions can be seen as effective as they empower students to form their own opinions about climate change and to take actions in a self-determined way. The second notion can be described as achieving effective (science) education through the means of climate change. On this view, climate change is seen as an interesting context in which scientific concepts can be promoted and, thus, make science education more effective. The third view only emerged recently and portrays successful education and learning as more than just acquiring facts and knowledge about climate change and transferring it into actions. Successful education in this sense can be described as resilience-promoting, where the psychological perspective of climate change is addressed [199]. In this context, responses to the climate crisis, its potential impacts on mental health and well-being, and its consequences for climate action are addressed to strengthen students' psychosocial resilience mechanisms [200]. Examples include the promotion of reflective abilities, and addressing psychosocial aspects of climate change such as climate anxiety (e.g., [201–203]), climate grief (e.g., [204,205]), or climate despair [206]. All three notions of effective education in the context of climate change are legitimate and important. However, researchers and teachers should be aware of which goals they want to reach and should tailor their interventions in accordance with those goals and be aware that interventions that are limited to science concepts and private-sphere actions will not mitigate climate change or lead to the adaptation of its impacts. Thus, teaching scientific concepts and knowledge should go along with promoting public-sphere actions.

Our search for relevant literature included three prior reviews on climate change education [43–45]. We also searched three databases (ERIC, PsychInfo, and Web of Science) that index the most relevant journals in order to include the most recent publications. As we only wanted to analyze peer-reviewed intervention studies on climate change, we excluded several potential sources of information on the political perspective of climate change education. However, relying on the peer-review policies of the journals as a quality criterion for the included studies and keeping the objectives of this review in mind, we believe our findings are based on a diverse enough sample to offer meaningful insights and draw out relevant implications. We acknowledge that our findings might not translate to the climate change education landscape in general because we included only peer-reviewed intervention studies and, e.g., no materials that have not been tested empirically. However, we are confident that our results are representative in terms of the general findings. For instance, Adamina et al. [97] conducted an extensive analysis of teaching materials and journals relevant to climate change education from primary to upper secondary school levels in German-speaking countries. Their findings mirrored our results in that they noted few contributions in terms of the political perspective and that measures to reduce emissions mostly address the private sphere. Moreover, most of the studies analyzed in our review were conducted in Europe, North America, and Australia. Only very few studies came from other regions. As we did not apply any regional exclusion criteria, our findings represent the international visible research on climate education. However, even when research from other regions is invisible it seems plausible that it exists, but we cannot analyze whether and how climate education from these countries might differ from climate education in western countries.

In our analysis we relied on the authors to describe the content of their interventions. These descriptions are presumably not always comprehensive, but rather reflect the focus of the authors. We have to assume that the central content of the interventions is described even if less central contents are not all covered. To ensure that we did not miss any details regarding content, we analyzed further materials describing the interventions in more detail (e.g., external curriculum descriptions, appendices with detailed design descriptions) to extend the information about the interventions analyzed.

6.7. Implications for Researchers and Educators

The findings of this systematic literature review on the political perspective in current climate change education reveals a strong focus on the communication of the physical science basis of climate change. If a focus on mitigation and adaptation of climate change is to be emphasized more strongly—something we definitely encourage—interventions to strengthen citizens' climate literacy should use broader approaches. To put it more pointedly, any study that is claimed to have an impact on saving the climate, but then exclusively uses measures that have neither a direct nor an indirect effect on the climate, does not meet its own goals. Research shows that young people already have very positive environmental attitudes [54], that private actions do not have a significant impact on the climate [55], and that there is a set of measures known to increase young people's ability to participate politically [82–95]. It is therefore necessary to shift the focus of climate education in line with the empirical findings from research in environmental economics and political education in order to achieve a greater impact. In this regard, education can offer a potential to activate contagious change processes that lead to mitigation and adaptation strategies with a significant effect [207–209]. Based on our findings, we encourage the climate education community to experiment with the following recommendations to make climate literacy education more effective—for students and for the climate:

1. *Transform socioscientific issues to social and scientific issues* Climate science debates (IPCC, 1.5 °C limit, renewable energy strategies, etc.) should not only be implemented in the rationale of climate literacy studies, but in climate education programs themselves. We should avoid framing climate change as a socioscientific issue, and then only teach the physical science basis of climate change. Climate science discusses climate issues at the interface of science and society—and so should we.
2. *Teach about all sources of emissions* For a comprehensive climate education, all emission sectors should be addressed. For prioritization, a focus on the actual emissions identified by the IPCC or in national greenhouse gas reports seems reasonable. Interesting curricular links could be made, especially in science education, to carbon flows [210,211] in agriculture, renewable energy [212,213] and energy efficiency [214], emissions from industry [215], etc., without any problems. This could help students connect science knowledge to real life problems.
3. *Teach about mitigation and adaptation* Much of climate education concentrates on the physical science basis. However, this only represents one of three parts of the IPCC assessments. The majority of the assessment reports concentrate on mitigation and adaptation strategies; this ratio could be a good starting point for climate education as well. As it is often not the physical science basis that is discussed controversially in the media and in economic and political discourse, but rather strategies to adapt to climate change and to mitigate global warming, educating climate literate citizens should place a focus on mitigation and adaptation.
4. *Take the responsibility to the public sphere* Research from various disciplines shows that it is not the private actions or the attitudes of individuals that make a difference, but rather our collective actions in the public sphere. Therefore a one-sided focus on private-sphere action should be avoided in climate education. It places an excessive responsibility on learners' shoulders, which, firstly, they cannot meet, and, secondly, is not empirically justified. The large emission savings and adaptation mechanisms require social, political, and economic responsibility. Based on the evidence, we should set the priorities right and equip learners with the competence to act as responsible citizens.
5. *Climate education should strengthen learners' political literacy* To strengthen the ability of learners to participate in public debates about climate change, findings from policy education research should be considered in terms of how to educate politically literate citizens at different school levels to build up competencies for independant and reflective political thinking and action [97,216]. In particular, methods focussing on a change in perspective, role play, cross-curricular discussions or debates, or involving

encounters with real actors (e.g., politicians, companies, and affected people) are underrepresented in current intervention studies. Experimenting with such methods and implementing them into the curriculum could contribute to an evidence-based climate change education.

6. *Make climate justice not only a social media but a school issue* Climate justice plays a central role for students and their public engagement to mitigate and adapt to climate change. Since climate justice plays only a peripheral role in climate education interventions and students obtain their knowledge from social media and peer interactions, we encourage the climate education community not to let this opportunity pass by and to integrate a foundational knowledge about the perspectives and challenges of climate justice into the programs.
7. *Train (science) teachers to become effective teachers of climate literacy* Teachers draw on their knowledge and beliefs and, thus, impact the climate literacy of their students. To enable sustainable learning, teachers need to be educated on how to teach climate change effectively. Thus, the academic education of teachers as well as professional development programs for practicing teachers should also implement the political perspective of climate change (i.e., political CK and PCK on climate change policies). Here, also more research is needed on what scientific and socioeconomic knowledge students and teachers need, as well as what materials have to be provided.
8. *Report more details about interventions* Further research on climate education should present more details about the content taught (e.g., which sources of emissions are addressed) and teaching methods utilized in the interventions. This is not only important for research and reproducibility but also for teaching in order to adapt materials and methods. We suggest, for example, using online appendices to share details and materials.

We advocate for an implementation of the political perspective in climate change education, as it is a powerful concept that contributes to understanding the climate crisis and the most effective actions against it. However, as only a small number of studies incorporate the most effective ways of mitigating and adapting to climate change, we see here great potential for future research. Relevant research questions that should be addressed are: How can students' political literacy regarding climate change be promoted effectively? What knowledge of climate policies do students need to support or take public-sphere action? How is scientific knowledge about climate change related to political knowledge about climate change?

7. Conclusions

Scientific findings from climate change research show that increasingly rapid and profound change is needed to stabilize the Earth's climate and preserve humanity's existence. Science also shows that effective solutions already exist to address the climate crisis and thus limit global warming and its impacts. In this context, education is an essential element in implementing a climate-just transformation. However, education can only live up to this expectation and unfold its transformative potential if effective opportunities, such as public-sphere action in contrast to individual action, and mitigating and adapting to climate change, are addressed. Therefore, to shed light on the role of the political perspective in climate change education, we conducted this systematic literature review. We found that there is still great potential for implementing public-sphere action in educational programs at school levels. Our analysis further shows that key aspects of climate policy such as the 1.5 °C limit, IPCC reports, or climate justice are rarely addressed in interventions. While the responsibility for emissions is attributed to the public sphere, the debate on climate change mitigation mostly focuses on the private sphere. Thus, our results show that climate education is currently not in line with the current climate research discourse. As effective mitigation and adaptation rely on public-sphere actions, we conclude that effective climate education should discuss these public actions if it is to be effective. With the current need for transitional processes and the great potential of education in mind,

we recommend a shift in teaching and learning about climate change towards political education in order to educate climate literate citizens. Such education moves away from a focus on the individual, and towards collective and meaningful measures that empower students to develop political knowledge and action about climate change as an expression of a more holistic understanding of the climate crisis, human nature, the natural world, and the interconnectedness of it all.

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Appendix A

Table A1. Overview of 75 intervention studies selected for final inclusion in the systematic literature review.

Study	Education Level	Subject	Sectoral Emissions	Responsibility	Action: Mitigation	Action: Adaption	Interest Groups	Policy Instruments	Main Learning Goal
Alexandar and Poyyamoli, 2012	Lower	Science			Private sphere, technical sphere	Private sphere, technical sphere	Society	Voluntary agreements	understand climate change.
Arya, and Maul, 2016	Upper	Curriculum-independent	Waste				Society	Voluntary agreements	discuss and evaluate mitigation and/or adaptation strategies
Assarf and Orion, 2008	Upper	Science	Deforestation						understand climate change.
Assarf and Orpaz, 2009	Upper	Science							understand climate change.
Baker, et al., 2013	Primary	Cross-curricular		Public sphere (society, economy)	Private sphere				understand climate change.
Barata, et al., 2017	Lower	Curriculum-independent	Waste						take action in mitigation and/or adaptation.
Bardsley and Bardsley, 2007	Upper	Science	Agriculture	Private sphere (individual)	Private sphere	Private sphere	Society	Voluntary agreements	take action in mitigation and/or adaptation.
Bofferding and Kloser, 2015 *	Lower, Upper	Science	Energy	Public sphere (society)	Private sphere	Private sphere	Science	Voluntary agreements	discuss and evaluate mitigation and/or adaptation strategies
Breslyn, et al., 2017	Lower	Science	Energy, Transport, Agriculture	Public sphere (society)			Society	Voluntary agreements	take action in mitigation and/or adaptation.
Buchanan, et al., 2016	Primary, Lower	Cross-curricular	Energy						take action in mitigation and/or adaptation.
Christensen and Knezek, 2018	Lower	Science	Energy	Private sphere (individual)	Private sphere		Society	Voluntary agreements	understand climate change.
Covitt, et al., 2021	Lower, Upper	Science							understand climate change.
Dunkley, 2016 *	Upper	Curriculum-independent	Waste		Private sphere	Public sphere			discuss and evaluate mitigation and/or adaptation strategies
Edsand and Broich, 2019	Upper	Science			Private sphere		Society	Voluntary agreements	understand climate change.
Eggert, et al., 2017	Upper	Science	Energy, Transport, Deforestation		Technical sphere		Society, Politics, Economy		understand climate change.
Fisher, 2016	Upper	Curriculum-independent	Deforestation, Agriculture, Waste	Public sphere (society)	Private sphere	Private sphere	Society		take action in mitigation and/or adaptation.
Flora, et al., 2014	Upper	Science	Energy, Waste	Public sphere (society)	Private sphere	Private sphere	Society	Voluntary agreements	take action in mitigation and/or adaptation.
Gold, et al., 2015	Lower, Upper	Science					Society, Economy		understand climate change.
Hallar, et al., 2011	Lower	Science							understand climate change.
Holley and Park, 2020	Upper	Science	Energy, Waste						understand climate change.
Holthuis, et al., 2014	Lower, Upper	Science	Energy, Transport	Public sphere (society)	Private sphere	Private sphere			understand climate change.
Jakobsson, et al., 2009	Upper	Science	Agriculture						discuss and evaluate mitigation and/or adaptation strategies
Jensen, 2004	Primary, Lower	Curriculum-independent							take action in mitigation and/or adaptation.
Jin, et al., 2013	Primary, Lower, Upper	Science	Energy	Public sphere (society)			Society		understand climate change.
Karpudewan, et al., 2017	Upper	Science	Energy, Transport	Public sphere (society)	Private sphere		Society, Politics, Economy	Voluntary agreements	understand climate change.
Karpudewan, et al., 2015a	Primary	Science	Energy, Transport	Public sphere (society)	Private sphere, technical sphere		Politics		understand climate change.

Table A1. *Cont.*

Study	Education Level	Subject	Sectoral Emissions	Responsibility	Action: Mitigation	Action: Adaption	Interest Groups	Policy Instruments	Main Learning Goal
Karpudewan, et al., 2015b	Upper	Science	Energy, Agriculture						understand climate change.
Klosterman and Sadler, 2010	Lower	Science							discuss and evaluate mitigation and/or adaptation strategies.
Leigh, 2009	Lower, Upper	Curriculum-independent	Energy	Private sphere (individual)	Private sphere		Society	Voluntary agreements	take action in mitigation and/or adaptation.
Lester, et al., 2006 *	Primary	Science	Energy, Transport		Private sphere	Technical sphere	Society		take action in mitigation and/or adaptation.
Lombardi, et al., 2015	Lower	Science		Public sphere (society)					understand climate change.
Markauskaite, et al., 2020	Upper	Science					Society	Voluntary agreements	understand climate change.
Mason and Santi, 1998	Primary	Science	Energy, Waste						discuss and evaluate mitigation and/or adaptation strategies
Mastura and Rohaida, 2017	Lower	Science	Energy, Deforestation		Private sphere		Society	Voluntary agreements	understand climate change.
McNeal, et al., 2014	Upper	Science			Private sphere		Society	Voluntary agreements	understand climate change.
McNeill and Pimentel, 2009	Upper	Science	Energy, Transport, Waste		Private sphere		Society	Voluntary agreements	discuss and evaluate mitigation and/or adaptation strategies
McNeill and Vaughn, 2010	Upper	Science	Deforestation, Waste	Public sphere (society)	Private sphere		Society	Voluntary agreements	take action in mitigation and/or adaptation.
Niebert and Gropengießer, 2015	Upper	Science	Energy, Deforestation						
Niebert and Gropengießer, 2014	Upper	Science		Public sphere (economy)	Technical sphere				understand climate change.
Niebert and Gropengießer, 2012	Upper	Science	Energy	Public sphere (economy)	Technical sphere				understand climate change.
Nussbaum, et al., 2015	Lower	Science	Energy, Agriculture	Public sphere (society)	Private sphere	Private sphere			understand climate change.
Öhman and Öhman, 2013	Upper	Cross-curricular							reflect ethical aspects of climate change
Oluk and Özalp, 2007	Lower	Science	Energy, Agriculture	Public sphere (society)			Society		understand climate change.
Österlind, 2005	Lower	Science	Energy, Waste	Public sphere (society)			Society	Voluntary agreements	understand climate change.
Pallant and Lee, 2015	Lower, Upper	Science							understand climate change.
Porter, et al., 2012	Lower	Science	Energy, Deforestation	Public sphere (society)					understand climate change.
Pruneau, et al., 2006	Lower, Upper	Curriculum-independent							take action in mitigation and/or adaptation.
Pruneau, et al., 2003	Lower	Science	Energy, Waste						understand climate change.
Reinfried, et al., 2012	Lower	Science	Energy	Public sphere (society, economy)					understand climate change.
Reinfried and Tempelmann, 2014	Upper	Science		Public sphere (society)					understand climate change.
Rousell, et al., 2017	Upper	Cross-curricular				Technical sphere			discuss and evaluate mitigation and/or adaptation strategies
Rule and Meyer, 2009	Upper	Science	Energy, Transport, Deforestation, Waste	Public sphere (society)	Private sphere	Private sphere	Society		discuss and evaluate mitigation and/or adaptation strategies
Rye, et al., 1997	Primary	Science	Energy, Waste						understand climate change.

Table A1. *Cont.*

Study	Education Level	Subject	Sectoral Emissions	Responsibility	Action: Mitigation	Action: Adaption	Interest Groups	Policy Instruments	Main Learning Goal
Schelly, 2012	Upper	Cross-curricular	Energy	Public sphere (society), private sphere (individual)	Technical sphere		Society		take action in mitigation and/or adaptation.
Schramm, et al., 2018	Upper	Science	Energy, Deforestation				Science		understand climate change.
Schuster, et al., 2008	Upper	Science							understand climate change.
Sellmann and Bogner, 2013a	Upper	Curriculum-independent	Energy, Transport	Public sphere (society)	Technical sphere			Voluntary agreements	understand climate change.
Sellmann and Bogner, 2013b	Upper	Science	Energy, Transport	Public sphere (society), private sphere (individual)	Private sphere, public sphere	Private sphere	Society, Politics	Voluntary agreements	understand climate change.
Semmens, et al., 2021	Lower	Science	Energy, Deforestation	Public sphere (society, economy)	Private sphere				understand climate change.
Siegner and Stapert, 2020 *	Lower	Cross-curricular	Energy, Transport	Public sphere (society)	Private sphere, public sphere		Society, Politics, Science	Regulation	reflect ethical aspects of climate change
Stapleton, 2019 *	Upper	Curriculum-independent							reflect ethical aspects of climate change
Stevenson, et al., 2017	Upper	Science	Energy, Agriculture, Waste		Private sphere, technical sphere, public sphere	Technical sphere	Politics, Economy		understand climate change.
Svihla and Linn, 2012	Lower	Science	Energy, Transport, Agriculture, Waste	Private sphere (individual)	Private sphere		Society	Voluntary agreements	understand climate change.
Taber and Neil, 2009	Primary	Science	Energy, Transport	Public sphere (society), private sphere (individual)	Private sphere				discuss and evaluate mitigation and/or adaptation strategies
Tasquier, et al., 2016	Upper	Science	Energy, Transport	Public sphere (society)	Private sphere, public sphere		Society, Politics, Science	Regulation	discuss and evaluate mitigation and/or adaptation strategies
Varma and Linn, 2012	Lower	Science	Energy	Public sphere (society), private sphere (individual)	Private sphere		Society	Voluntary agreements	take action in mitigation and/or adaptation.
Vethayagam and Hemalatha, 2010	Primary	Curriculum-independent							take action in mitigation and/or adaptation.
Visintainer and Linn, 2015	Lower, Upper	Science							understand climate change.
Vitale, et al., 2016	Upper	Science							understand climate change.
Walsh and Blakely, 2018	Upper	Science	Energy				Science		discuss and evaluate mitigation and/or adaptation strategies
Walsh and McGowan, 2017	Upper	Science					Science		discuss and evaluate mitigation and/or adaptation strategies
Wang, 2014	Primary	Science	Energy, Waste	Public sphere (society)	Public sphere		Society	Regulation	discuss and evaluate mitigation and/or adaptation strategies
Williams, et al., 2017	Primary	Curriculum-independent				Private sphere			take action in mitigation and/or adaptation.
Zangori, et al., 2017	Upper	Science							understand climate change.
Zografakis, et al., 2008	Primary, Lower, Upper	Curriculum-independent	Energy		Private sphere				take action in mitigation and/or adaptation.

* Studies who address justice in the intervention.

Appendix B

References of 75 intervention studies selected for final inclusion in the systematic review.

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