sustainability

MDPI

Article

Bridging the Knowledge–Practice Gap: Assessing Climate Change Literacy Among Science Teachers

Hiya Almazroa

Teaching and Learning Department, College of Education and Human Development, Princess Nourah bint Abdurrahman University (PNU), Riyadh 11564, Saudi Arabia; hmalmazroa@pnu.edu.sa

Abstract: This research aimed to investigate the knowledge levels and teaching practices of Saudi science teachers regarding climate change, focusing on exploring the correlation between these aspects. The cross-sectional descriptive survey included teachers at middle and high school levels in public schools. The questionnaire study comprised three sections: collecting demographic data, assessing teachers' understanding of climate change through factual inquiries, and evaluating teaching practices related to climate change. The findings reveal a promising degree of awareness among teachers, with a majority correctly identifying crucial elements of climate change while also exposing misconceptions and knowledge gaps. While a notable portion of teachers reported teaching climate change-related aspects, some indicated minimal involvement in extracurricular activities linked to climate change. The correlation analysis between science teachers' climate change knowledge and practices indicates a weak connection between the two variables, suggesting that teachers' knowledge might not substantially impact their actual teaching practices regarding climate change concepts. Limitations included reliance on self-reported data and a sample size that could impact result generalizability. Future research recommendations include combining quantitative data with qualitative methods, comparing knowledge and practices across regions or demographics, and conducting longitudinal studies. This study's implications stress the importance of targeted professional development, advocating for climate change education integration into formal curricula, and policy adjustments mandating climate change education.

Keywords: climate change; science teacher; in-service teachers; teacher's knowledge; teaching practices; environmental education; survey; Saudi Arabia

Citation: Almazroa, H. Bridging the Knowledge–Practice Gap: Assessing Climate Change Literacy Among Science Teachers. *Sustainability* **2024**, *16*, 9088. https://doi.org/10.3390/su16209088

Academic Editor: Mohammad Aslam Khan Khalil

Received: 22 August 2024
Revised: 14 October 2024
Accepted: 18 October 2024
Published: 20 October 2024

1. Introduction

Over the years, the global impact of the climate crisis has grown increasingly and become more evident given the regular occurrences of severe weather incidents, the melting of glaciers, and heatwaves impacting human populations. Education about climate change is a crucial response to mitigate its effects [1], and following the Tbilisi Declaration of 1977 [2], the significance of shifting human behavior towards a problem-solving orientation through environmental education has become evident. Climate change presents a multifaceted challenge on a worldwide level that requires joint action.

Despite the lack of reported incidents involving fossil fuels and climate justice, Saudi Arabia's substantial portion of the world's proven petroleum reserves, emphasized by the Organization of the Petroleum Exporting Countries (OPEC, 2024 [3]), underscores its importance in international climate dialogues. Bentahar et al. [4] underscore the role of education in transitioning the nation from an oil-dependent to a service-driven economy. Education stands pivotal in aligning Saudi Arabia's educational system with broader societal visions, as articulated by Alnahdi [5] and Al-Zaharni and Rajab [6].

The scientific methodology should be coupled with public education and awareness campaigns to tackle and alleviate the phenomenon [7]. Climate change signifies a complex issue that underscores the necessity of educating future generations to critically engage

with the vast array of knowledge and perspectives in this field [8]. The importance of education in increasing climate change awareness, enhancing adaptation capabilities, and reducing vulnerabilities to climate disasters has been underscored by the Global Education Monitoring (GEM) reports [1]. Environmental education, as a global initiative addressing climate change, fosters awareness to facilitate informed decision-making, climate change adaptation, and the adoption of sustainable lifestyles [9].

In a UNESCO report [10], the significance of teacher education in aligning academic functions with sustainability for the successful implementation of the Sustainable Development Goals (SDGs) in higher education institutions was emphasized. However, Systematic Literature Reviews (SLRs) show a research gap concerning teachers' training related to SDGs [11], which underscores the need for increased research contributions to enhance teacher training programs effectively and emphasizes the crucial role of teachers and teacher education in advancing sustainability in education. Teachers play a pivotal role within the educational system as they are responsible for selecting and adapting learning resources, experiences, and pacing to facilitate effective learning progression for students [12,13]. Climate change ranks among the crucial socio-scientific topics that teachers ought to discuss with their students [14]. According to Ekpo and Aiyedun [9], environmental education is portrayed as a worldwide initiative addressing climate change, fostering awareness to facilitate informed choices, climate change adaptation, and the adoption of sustainable lifestyles. Eneji et al. [15] suggest that environmental education enhances awareness, facilitates informed decision-making, contributes significantly to climate change adaptation and community resilience, and empowers individuals—both women and men—to embrace sustainable ways of living.

The nature of this study and the context of previous research have centered on science teachers in the domain of climate change education, such as Eze et al. [16], Zaini, et al. [17] and Dal et al. [18]. This study will continue to build upon existing knowledge and provide a more in-depth exploration within this specific area. Multidisciplinary perspectives are pertinent in addressing climate change education; therefore, focusing on science teachers aligns with the existing literature and allows a deeper investigation into the unique challenges and opportunities faced by educators in this particular field.

This study seeks to evaluate the climate science knowledge levels of teachers and scrutinize their teaching practices concerning various aspects of climate change. The research outcomes aim to provide insights into the climate science literacy levels and teaching practices of Saudi teachers regarding climate change. By identifying deficiencies in teachers' understanding of climate change in Saudi Arabia, this study addresses a gap in academic research that likely extends to regions that have received limited scholarly attention. As such, this needs assessment study serves as the initial phase of capacity building for educators [19]. The primary objective of this research is to enhance existing knowledge by investigating science teachers' comprehension of climate change and its potential impact on teaching practices. Through this exploration, valuable insights can be gained to guide policy-making, curriculum development, and teacher training efforts aimed at addressing climate change within the realm of science education. This study delves into teachers' perspectives on climate change, drawing upon insights from prior research conducted in developing nations facing significant climate risks to deepen understandings of climate change causes, effects, and potential mitigation strategies, building upon the groundwork laid by Ullah et al. [20].

While prior research has primarily concentrated on bolstering teachers' content knowledge related to climate change, underscoring the belief that a comprehensive understanding of the scientific facets of climate change would naturally lead to proactive measures, this study aims to bridge the gap between knowledge and action. Recognizing that attitudes or awareness alone may not automatically translate into environmentally responsible behaviors, this research contributes to the discourse on how knowledge influence practices, particularly in addressing the implications of climate change [21]. With a focus on eval-

uating the level of knowledge and practices of Saudi science teachers regarding climate change, this study aims to address the following key questions:

1. What are the levels of teachers' climate change knowledge?
2. What pedagogical approaches and educational methods do science teachers utilize to teach climate change concepts?
3. What is the relationship between science teachers' understanding of climate change and their implementation of climate change concepts in classroom teaching?

While the focus of this research is predominantly on Saudi Arabia, its implications resonate on a much broader scale. Climate change knows no boundaries, and its effects are felt universally, albeit with regional variations [22]. As such, understanding climate change education in one region can offer invaluable insights for others. The lessons derived from Saudi Arabia's unique geographical, socio-cultural, and educational contexts can serve other nations in their journey to integrate climate change education into the education system.

Literature Review

In response to the pressing need for climate change education in classrooms, educators are increasingly recognizing its pivotal role as a core subject [14]. Moshou and Drinia [23] delve into the attitudes and knowledge of primary school teachers towards climate change, revealing potential gaps in preparing future educators to effectively address this critical issue. Their study underscores the imperative for concrete actions to bridge these gaps and enhance teachers' readiness in teaching about climate change. Zaini et al. [17] focus on the coverage of climate change and environmental education within the current curriculum, particularly examining the perspectives of science teachers. Their findings underscore the necessity for a student-centered approach and improvements in the curriculum to better tackle climate change and foster proactive student engagement. Opuni-Frimpong et al. [24] explore the perspectives of senior high school teachers in Ghana's Bono region regarding climate change and their readiness to integrate it into their teaching. The study uncovers variations in teachers' preparedness based on the subjects they teach, emphasizing the significance of an interdisciplinary teaching approach and continuous professional development to enhance climate change education. Eze et al. [16] highlight gaps in climate science literacy and training needs among Nigerian teachers, pointing towards potential challenges in effectively conveying accurate information about climate change to students. Their study underscores the importance of addressing these gaps through targeted teacher education initiatives. Chowdhury et al. [25] investigate Bangladeshi teachers' perceptions of climate change, shedding light on the factors influencing their understanding of this global issue. The study provides insights into how sociodemographic and academic-related factors shape teachers' perceptions of climate change. Gaye and Mugaloglu [26] delve into pre-service teachers' beliefs regarding global climate change, emphasizing the influence of cognitive, behavioral, and personal factors on their perceptions. The study suggests that teacher training programs should consider these factors to strengthen pre-service teachers' beliefs in climate change. Karami et al. [27] assess Iranian secondary school teachers' knowledge and practices related to climate change education, highlighting the need for improved attitudes and practices through enhanced educational programs and curriculum reforms. Dal et al. [18] investigate social studies and science teachers' awareness of climate change, noting the impact of professional development workshops on their understanding of this critical issue. The research studies collectively highlight concern about the readiness of teachers to teach climate change and suggest that future teachers may lack adequate preparation and comprehensive understanding of CC. The studies indicate variations in teachers' awareness and understanding of climate change. While some teachers demonstrate a good understanding, others have moderate or weak levels of knowledge. Enhancing teachers' practices can facilitate effective implementation of climate change education in schools. By attending to these facets, educators can play a

pivotal role in promoting environmental awareness, sustainable practices, and informed decision-making among students.

2. Methodology

The research process diagram presented in Figure 1 visually encapsulates the sequential steps involved in conducting the research study. From the initial phase of research initiation to the subsequent data collection, analysis, findings, conclusions, and recommendations, the diagram delineates a structured approach to the research process.

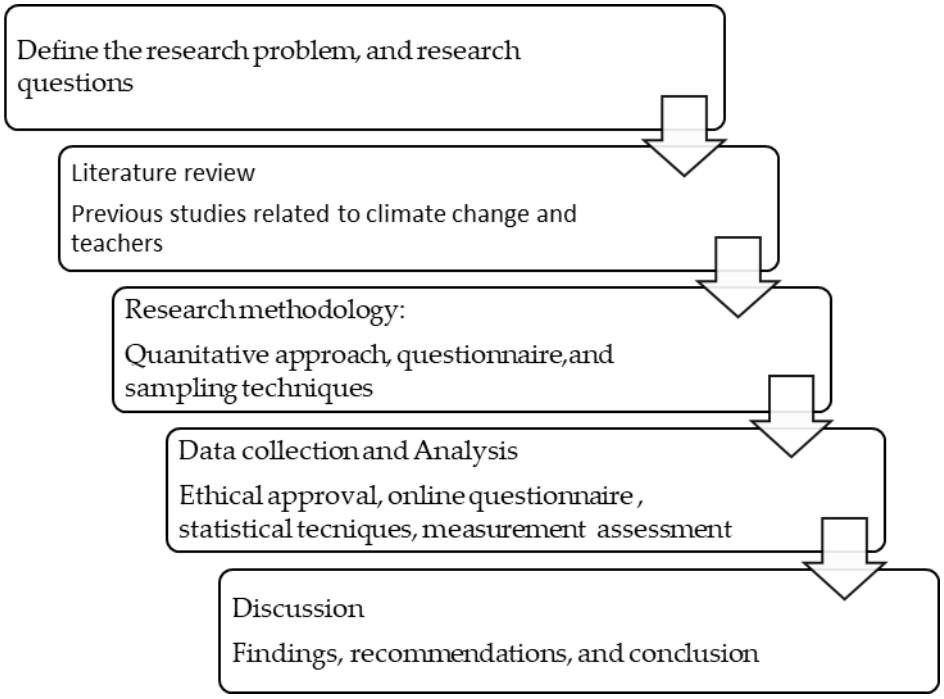

Figure 1. Process diagram to illustrate the research flow.

2.1. Context of the Study

As a member of the G20 and BRICS, Saudi Arabia stands ready to lead climate discussions in the Gulf and Middle East and collaborate with global stakeholders. Saudi Arabia has committed to UNFCCC initiatives, diversifying its energy mix through investments in renewable sources like solar and wind power, and enhancing climate resilience with water conservation projects, afforestation programs, and coastal safeguarding measures [28]. Understanding and addressing climate change are imperative for sustainable development and the welfare of Saudi Arabia's populace. With this multifaceted climate change challenge, the urgency to strengthen educational practices becomes apparent. Saudi Arabia's unique circumstances necessitate a comprehensive approach to align teacher training with the current evolutions in environmental education and sustainability practices. Under the current state of professional development for teachers, content usually focuses on pedagogical knowledge, such as peer learning or mentoring/coaching techniques [29]; however, the fast-paced changes in the climate sector [30] necessitate a need for professional development on content to ensure students are prepared and equipped with relevant knowledge to pursue careers in these fields.

In Saudi Arabia's education system, more than 500,000 teachers cater to six million students [31]. Governed by a centralized structure with top-down management, the Ministry of Education (MOE) dictates educational policies, curricula, budget allocations, staffing decisions, and textbook approvals [28]. Teacher candidates are required to pass a licensing exam, and are expected to engage in continuous professional development, often facilitated by Educational Supervision Offices, where educational supervisors conduct workshops and lectures [32]. Teacher supervisors identify training needs through evaluations and

coordinate with training centers to communicate these requirements. TALIS 2018 [29] highlights the structured approach of professional development courses in Saudi Arabia, focusing on enhancing design and pedagogical delivery. The report indicates that 73% of teachers in Saudi Arabia participate in courses and seminars, while only 54% engage in training programs centered on peer learning or mentoring/coaching.

2.2. Participants

This cross-sectional descriptive survey research aimed to investigate science teachers' understanding and practices concerning climate change in Riyadh, Saudi Arabia. The study involved 197 science teachers from 12 educational districts in Riyadh, encompassing both middle and high school levels in public schools, teaching subjects such as biology, natural science, chemistry, and physics.

This study concentrated on middle and high school science educators in public schools within Riyadh, Saudi Arabia. To guarantee a diverse sample, a three-phase sampling technique was employed at the beginning of the 2023 academic year. This method, as emphasized by Greenfield and Greener [33], enhances the efficiency and accuracy of the study. The selection process commenced by picking schools from the Ministry of Education's database. Riyadh was segmented into five geographical regions, with a random selection of schools from each region for survey deployment. Subsequently, a random group of teachers within each chosen school participated in the survey.

To maintain ethical standards, the study emphasized the informed consent process and the absence of right or wrong answers. The sampling methodology utilized in this study seems suitable for achieving the research objectives. Data collection was conducted through an online survey. Web-based surveys are recognized as effective tools that leverage internet connectivity to reach individuals and organizations that may be challenging to engage through conventional methods [34]. By utilizing web-based surveys, this study aimed to efficiently gather a substantial sample size while addressing potential challenges related to participant engagement and geographical constraints.

Data collection was conducted following the approval of Princess Nourah bint Abdulrahman University. IRB Registration Number with KACST, KSA: HAP-01-R-059. IRB Log Number: 23-0259.

2.3. Questionnaire

The questionnaire utilized in this study consisted of three sections. The first section focused on gathering demographic information from the participants. The second and third sections delved into assessing the science teachers' knowledge of climate change and their teaching practices related to the subject. Section 1, Demographic Information, aimed to collect data regarding the background of the participants, such as their age, gender, educational qualifications, teaching experience, and school affiliation. Section 2, Science Teachers' Knowledge of Climate Change, included fifteen true or false queries on topics like climate change effects, global warming, specific phenomena, personal engagement, and attitudes. In Section 3, Teaching Practices Related to Climate Change, participants were asked about their teaching practices concerning climate change. Each question was evaluated based on the number of responses indicating "Yes" and "No. The questionnaire presented seven statements regarding aspects such as the inclusion of climate change in the curriculum, teaching activities related to climate change, and readiness to incorporate climate change topics into their courses. The questionnaire was adopted from previous research by the author in [34]. The items of the questionnaire were derived from previous studies and include scholarly articles focusing on topics such as perceptions about climate change and public perceptions of climate change among school teachers [24,25,35–38].

2.4. Validation and Reliability

The designed instrument underwent face validation and a trial test to ensure the study's results were valid and reliable, confirming the relevance, appropriateness, and

clarity of its items. To validate the content of the test items, a panel of experts, consisting of two education doctorates with expertise in environmental education, one in geography, and four in science education, reviewed the questionnaire. The experts were provided with the questionnaire and invited to provide feedback based on the following criteria: (1) alignment of question items with the instrument's dimensions, (2) phrasing of the items, (3) response format, and (4) suggestions for additional items to enhance the test. Prior to expert validation, initial adjustments were implemented to refine the questionnaire items, as detailed below.

A pilot study of the questionnaire was carried out to assess the internal statistical reliability of the various measures. Table 1 presents Cronbach's Alpha values for assessing the internal consistency or reliability of the factors related to knowledge and teaching climate change. Cronbach's Alpha values for the climate change knowledge factor vary from 0.484 to 0.837, showing a moderate to high degree of internal consistency. Cronbach's Alpha values for the teaching factor range from 0.497 to 0.839, indicating a moderate to high level of internal consistency. Both factors show relatively similar levels of internal consistency, with most phrases having Cronbach's Alpha values above 0.6, indicating acceptable reliability.

Table 1. Cronbach's Alpha for the reliability of the factors of the survey.

Knowledge and Climate Change				Teaching and Climate Change	
Phrase	**R**	**Phrase**	**R**	**Phrase**	**R**
1	0.837 **	9	0.837 **	1	0.839 **
2	0.623 **	10	0.623 **	2	0.627 **
3	0.783 **	11	0.783 *	3	0.766 **
4	0.811 **	12	0.811 **	4	0.81 **
5	0.755 **	13	0.755 **	5	0.757 **
6	0.484 *	14	0.484 **	6	0.497 **
7	0.657 **	15	0.657 **	7	0.669 **
8	0.829 **				

* indicates significance at the 0.05 level (two-tailed). ** indicates significance at the 0.01 level (two-tailed).

Table 2 provides Kuder–Richardson (KR) coefficients for assessing the internal consistency or reliability of knowledge related to climate change as a whole and its two dimensions. The KR coefficient for the Knowledge and Climate Change dimension is 0.93, indicating a high level of internal consistency among the 15 items related to this aspect. The KR coefficient for the Teaching and Climate Change dimension is 0.84, pointing to a good level of internal consistency among the items specific to teaching aspects related to climate change. Combining both dimensions, the total KR coefficient for the entire set of 22 items related to climate change knowledge is 0.95. This high coefficient signifies a strong internal consistency across all items, reflecting the reliability of the instrument in assessing participants' knowledge of climate change comprehensively.

Table 2. Kuder–Richardson equation for knowledge of climate change as a whole and in its two dimensions.

Dimensions	N	Alpha Cronbach
Knowledge and Climate Change	15	0.93
Teaching and Climate Change	7	0.84
Total	22	0.95

3. Results

This study analyzed Saudi science teachers' knowledge and teaching practices on climate change, focusing on their inter-relation. It involved 197 teachers instructing various science subjects at middle and high school levels. The survey comprised sections for demographic data, climate change concept evaluation, and teaching practice assessment. SPSS (version 26.0) was utilized to analyze the data.

3.1. Demographic Characteristics of Respondents

Table 3 summarizes the survey results from 197 teachers across various variables. Table 3 presents distribution of the teachers by gender, age, stage, major, and years of teaching experience. The findings indicate that 63.96% of the teachers were female, while 36.04% were male. In terms of age, the majority of respondents fell into the 41–50 age range (49.75%), followed by the 31–40 age range (30.96%). Regarding teaching level, 38.58% of the teachers taught in middle school, while 61.42% taught in high school. The most common major among the teachers was biology (39.59%), followed by physics (32.99%) and chemistry (22.84%). In terms of teaching experience, the largest group (36.55%) had 21–30 years of experience, followed by 11–20 years (35.03%). These results provide a snapshot of the demographics and characteristics of the surveyed teachers.

Table 3. Research sample demographics.

Variable		N	%
Gender	Female	126	63.96%
	Male	71	36.04%
Total		197	100%
Age	20–30	15	7.61%
	31–40	61	30.96%
	41–50	98	49.75%
	51–60	23	11.68%
Total		197	100%
Teaching level	Middle School	76	38.58%
	High School	121	61.42%
Total		197	100%
Major	Biology	78	39.59%
	Physics	65	32.99%
	Chemistry	45	22.84%
	Other	9	4.57%
Total		197	100%
Teaching experience	1–5-Y	26	13.20%
	6–10 Y	30	15.23%
	11–20 Y	69	35.03%
	21–30 Y	72	36.55%
Total		197	100%

3.2. Science Teachers' Knowledge About Climate Change

Table 4 presents the results of a survey measuring the knowledge level of participants regarding various climate change-related issues. On average, the respondents demonstrated a knowledge degree of 0.80, indicating a relatively high level of knowledge regarding climate change concepts. The participants demonstrated varying levels of understanding

across different statements related to climate change. While some concepts received high correct response rates, others indicated areas of confusion and lower comprehension levels.

Table 4. Science teachers' knowledge of climate change.

N		True		False		Mean	STD	Rank	Knowledge Degree
		F.	%	F.	%				
1	Earth's climate has changed little in the past	22	75.9%	7	24.1%	0.76	0.44	6	middle
2	Global warming is a reality	28	96.6%	1	3.4%	0.97	0.19	2	too high
3	Climate change is a local problem:	20	69%	9	31%	0.70	0.47	7	middle
4	Climate change and extreme weather are linked.	28	96.6%	1	3.4%	0.97	0.19	2	too high
5	Climate change impacts food security and food production	27	93.1%	2	6.9%	0.93	0.26	3	too high
6	Climate change and global warming are different phenomena	12	41.4%	17	58.6%	0.41	0.50	9	too low
7	Deforestation is linked to climate change	25	86.2%	4	13.8%	0.86	0.35	4	high
8	An increase in rainfall phenomenon is associated with climate change	28	96.6%	1	3.4%	0.97	0.19	2	too high
9	Tropical cyclones phenomena are associated with climate change	27	93.1%	2	6.9%	0.93	0.26	3	too high
10	Heatwaves and wildfires phenomena are associated with climate change	29	100%	0	0	1.00	0.00	1	too high
11	Warming of the atmosphere, land and oceans could be limited by zero out emissions	29	100%	0	0	1.00	0.00	1	too high
12	Climate change is heating the world evenly	17	58.6%	12	41.4%	0.59	0.50	8	low
13	The Earth's oceans are becoming more acidic due to increased CO2 emissions	23	79.3%	6	20.7%	0.80	0.41	5	high
14	The hole in the Ozone Layer contributes the most to current global warming	5	17.2%	24	82.8%	0.17	0.38	10	too low
15	My country is vulnerable to climate change	29	100%	0	0	1.00	0.00	1	too high
	Average					0.80	0.39		high

Key concepts like the reality of global warming (96.6%), the link between climate change and extreme weather (96.6%), and the vulnerability of their countries to climate change (100%) were well understood by the majority of participants. Phenomena such as heatwaves and wildfires (100%) were correctly associated with climate change, indicating a strong grasp of these relationships.

The concepts necessitating additional clarification encompass the distinction between climate change and global warming (41.4% correct), the idea that climate change uniformly heats the world (58.6% correct), the function of the ozone layer in global warming (17.2% correct), and misconceptions.

Table 5 offers insights into the status of climate change education, teachers' involvement, and their readiness to address climate change topics. All participants (100%) confirmed the presence of a specific subject in the curriculum designed to educate about climate change. The majority of respondents (86.2%) agreed that the science curriculum's syllabus provides significant information about climate change. While a considerable proportion (65.5%) of teachers reported that they are currently teaching aspects related to climate change, a significant number (34.5%) indicated that they are not. The majority of respondents (93.1%) reported promoting activities that help mitigate global warming. A significant portion (79.3%) of teachers expressed readiness to teach climate change topics in their courses, even if they are not included in the science curriculum. However, 20.7% indicated their lack of readiness.

Table 5. Teaching practices related to climate change.

N		Yes		No		M	SD	Rank	
		frequencies	%	F.	%				
1	Is climate change mandated as a cross-cutting component in the curriculum by law?	0	0	29	100%	0.00	0.00	7	too low
2	Is there a specific subject in the curriculum designed to educate about climate change?	29	100%	0	0	1.00	0.00	1	too high
3	Does the science curriculum syllabus contain substantial information about climate change?	25	86.2%	4	13.8%	0.86	0.35	3	high
4	Are you currently teaching any aspects related to climate change?	19	65.5%	10	34.5%	0.66	0.48	5	middle
5	Do you have self-initiative to carry out extracurricular climate change activities?	14	48.3%	15	51.7%	0.48	0.51	6	too low
6	Do you promote activities that help mitigate global warming?	27	93.1%	2	6.9%	0.93	0.26	2	too high
7	Are you ready to teach or include climate change (CC) topics into your courses even if they are not included in the science curriculum?	23	79.3%	6	20.7%	0.79	0.41	4	middle

None of the respondents indicated that climate change is mandated as a cross-cutting component in the curriculum by law. Less than half of the participants (48.3%) expressed self-initiative to carry out extracurricular climate change activities.

3.3. Correlation Between Science Teachers Knowledge and Practices Related to Climate Change

The correlation coefficient value indicates the relationship between science teachers' understanding of climate change and their practices related to it. In this case, the correlation coefficient value is 0.05, suggesting a weak correlation between the two variables.

This result implies that there is little association between science teachers' knowledge about climate change, specifically related to the curriculum, and their practices in addressing climate change. It suggests that teachers' knowledge about climate change may not be a significant factor influencing their actual practices or implementation of climate change education in the classroom.

4. Discussion

4.1. Science Teachers' Knowledge About Climate Change

The results shed light on the comprehension levels of science teachers regarding various facets of climate change. The survey results show a high level of awareness among participants, with an average knowledge degree of 0.80, indicating a strong understanding of climate change concepts. The author believes that factors contributing to the depth of climate change knowledge among Saudi science educators could be explained by their prerequisite bachelor's degrees in scientific fields, which enhance their comprehension due to extensive study. Additionally, effective curriculum integration in Saudi schools guides teachers on teaching climate change topics, while access to up-to-date resources like textbooks and online tools supports educators in expanding their knowledge base on climate change. In Saudi Arabia, a new "Mathematics and Natural Science Curriculum Project" has been implemented, and is seen as a catalyst to improve the quality of science education. Also, the media in Saudi Arabia and recent major conferences in the region play essential roles in enriching teachers' understanding of climate change. These platforms empower educators to remain updated, incorporate innovative approaches, and enhance their students' readiness to tackle climate change issues.

Comparative studies by Chowdhury et al. [25] in Bangladesh and Ikoro and Ezeanyim [39] in Nigeria also highlight substantial levels of climate change knowledge among teachers in different regions. Likewise, following a study involving teachers engaged in a professional development program aimed at enhancing their scientific understanding of global climate change, Liu et al. [40] observed heightened recognition of the critical nature of global climate change and the necessity of integrating it into their science instruction. This observation aligns with the notion proposed by Milér et al. [41], suggesting advancements in climate science that have the potential to extend to educators. However, Eze et al. [16] revealed that over 60% express low proficiency across all climate science topics.

Despite some positive aspects, the research results reveal areas of confusion among teachers, with many exhibiting low to moderate levels of literacy in climate change concepts. This study identified three specific areas where teachers showed the lowest average literacy scores: distinguishing climate change from global warming, understanding that climate change does not uniformly heat the world, and misconceptions regarding the ozone layer. Understanding these nuances is vital for a comprehensive grasp of climate dynamics, indicating room for improvement.

Misunderstandings related to the ozone layer can indeed hinder a clear understanding of the primary drivers of climate change, potentially impeding effective efforts to address these crucial factors. The confusion often arises from the conflation of evidence concerning the greenhouse effect and the ozone layer. When educators themselves lack a firm grasp of these concepts, they are prone to misinterpretation, leading to inadvertent transmission of misconceptions to their students [42].

One of the common misconceptions prevalent among teachers is the incorrect association between the greenhouse effect and the ozone hole, a fallacy that has been observed in various studies [43]. For instance, a study conducted in Finland uncovered that pre-service teachers exhibited incomplete and inaccurate factual knowledge and conceptual understanding of the greenhouse effect [44]. These findings underscore the critical need to address these misconceptions and enhance teachers' understanding to ensure accurate and effective climate change education within educational settings.

The implications of teachers' misconceptions regarding climate concepts are indeed extensive, impacting not just their teaching but also student understanding. These misunderstandings can impede effective efforts to address climate change drivers, potentially leading to misguided actions and inadequate preparedness for climate impacts. To tackle these challenges, targeted professional development programs are necessary to enhance teachers' understanding and ensure accurate communication of climate change in education. Emphasizing emotional aspects alongside scientific facts is crucial for comprehensive climate change education, as focusing solely on data may lead to climate anxiety among

teachers, [45,46]. Effective education on climate change demands proficient and skilled educators who can elevate students' comprehension and empower them as agents for change. In the United States, teachers are increasingly recognizing the significance of integrating climate change education into their teaching practices to counter skepticism [47].

4.2. Science Teachers' Practices Related to Climate Change

The results provide valuable insights into science teachers' involvement in addressing climate change. Teachers' practices regarding climate change have several potential implications:

1. Presence of a specific subject: All participants (100%) confirmed the presence of a specific subject in the curriculum designed to educate about climate change. This indicates a positive step towards integrating climate change into Saudi education. Numerous nations have included climate change and environmental education in their educational programs through the establishment of a framework prepared to impart knowledge and cultivate competencies [48].
2. The study underscores the recognition by a significant majority (86.2%) of teachers regarding the inclusion of climate change in the science curriculum, emphasizing the pivotal role of science education in educating on this critical issue. Integrating climate change topics into the curriculum is vital for cultivating a robust scientific understanding among students. The research aligns with previous work [49], demonstrating a growing inclination among secondary school educators to incorporate climate change themes. While individual efforts are valuable, enhancing climate change education requires more than curriculum adjustments; teacher education is crucial for equipping future educators to effectively integrate climate change education and drive meaningful changes in educational settings [49].
3. Current teaching practices: A significant portion of teachers (65.5%) currently include elements of climate change in their instruction, while 34.5% do not, indicating variations in teaching approaches. Past research [50,51] has highlighted the obstacles teachers face in integrating climate change education, notably curricular restrictions. Further examination from teachers' perspectives is necessary. Suggestions to integrate climate change education into teacher training programs are vital to adequately equip educators for addressing this crucial 21st-century challenge. Ongoing research should delve into specifics like topics covered, teaching impacts, and extracurricular involvement for a comprehensive understanding.
4. Promotion of climate change activities: The majority of respondents (93.1%) reported promoting climate change activities, which highlights the positive role teachers play in fostering environmental consciousness and encouraging actions that contribute to addressing climate change. By promoting such activities, teachers can inspire students to actively participate in mitigating the impacts of climate change and adopting sustainable practices.
5. Readiness to teach climate change topics: A notable proportion of teachers (79.3%) have demonstrated a readiness to teach climate change topics, even if they are not formally included in the science curriculum. In Winter's [51] study, prospective science teachers unanimously expressed their eagerness to include climate change education in their future instructional endeavors. This commitment aligns with a prior investigation that investigated the perceived advantages of teaching climate change among Turkish teachers [52].
6. This study highlights that only less than half of the participants (48.3%) took the initiative to organize extracurricular activities related to climate change, revealing a potential gap in teachers' motivation or awareness of involving students beyond the regular curriculum. Dillon [53] noted teachers' recognition of the educational value of utilizing school facilities and outdoor spaces, aligning with the integration of education into students' physical environments. This comprehensive approach is crucial as extracurricular learning, including nature exposure, significantly influences

environmental attitudes, with lasting impacts [54]. Recognizing the pivotal role of educational institutions could enhance a more holistic climate change education strategy [51].

7. Mandate for climate change education: The absence of a mandate for climate change education in the curriculum, as indicated by all respondents answering "No", is concerning. Mandating climate change as a cross-cutting component in the curriculum by law can ensure consistent and comprehensive education across schools. Without such a mandate, the integration and prioritization of climate change education may vary, leading to inconsistencies in students' knowledge and awareness.

In general, UNESCO showed evidence from various sources that indicates a lack of strong integration of environmental topics in both pre-service and in-service teacher training programs. The majority of teachers have received limited or no preparation in these subject areas. A lack of specific treatment of climate change as a specialized topic was evident in most of the international studies [1]. There is significant potential for countries to enhance the scope and quality of training provided to teachers, both before and during their service, focusing particularly on Environmental and Sustainable Development (ESD) education, including topics like climate change.

In summary, while there are positive aspects to the findings, such as the presence of a specific subject and efforts by teachers to promote climate change activities, there are areas that require attention. These include the absence of a mandate for climate change education, inconsistencies in teaching practices, limited extracurricular engagement, and the need for further support and readiness among teachers. Addressing these areas can contribute to more comprehensive and effective climate change education, empowering students to become informed and active participants in tackling this global challenge.

4.3. Correlation Between Science Teachers' Knowledge and Practices Related to Climate Change

The correlation coefficient of 0.05 between science teachers' climate change knowledge and their teaching practices suggests a weak relationship. This finding indicates a limited association between teachers' understanding of climate change and their actions in addressing this topic within the curriculum. It implies that knowledge alone may not significantly impact how teachers incorporate climate change education in their classrooms.

Although unexpected, this weak correlation underscores the necessity of investigating additional influencers on teachers' practices concerning climate change. Variables like available resources, training opportunities, institutional support, and personal beliefs likely exert more substantial influences on educators' engagement with and implementation of climate change education. Further exploration is crucial to uncover the underlying reasons for this weak correlation and to identify the key determinants of teachers' approaches to climate change education. These investigations underscore the necessity of considering additional factors beyond factual teachings, such as the influence of political contexts [55].

The prevailing focus in current research has primarily centered on enhancing teachers' content knowledge regarding climate change. Previous studies have emphasized the significance of bolstering content knowledge [56,57], operating under the assumption that a comprehensive understanding of the scientific facets of climate change would naturally prompt proactive actions [57]. While interventions have demonstrated success in augmenting climate change knowledge [56,58], Winter et al. [51] contend that attitudes or awareness alone do not inherently lead to environmentally responsible behaviors. This discrepancy between knowledge and action is commonly known as the "knowledge–behavior gap" [59].

Studies suggest that simply enhancing knowledge about climate change may not directly result in behavioral changes [60]. To effectively bridge this gap, it is imperative to transcend mere knowledge enhancement and delve into practical applications. Given similar disparities seen in environmental contexts beyond climate change [61], a comprehensive approach to climate change education becomes crucial, one that integrates values, societal norms, emotions, and forward-thinking skills among pre-service teachers. This aligns with the holistic model of climate change education [62].

Increased awareness stemming from improved knowledge has the potential to drive behavioral transformations, while inadequate comprehension of climate change can yield adverse consequences. Exploring the impact of sustainability-focused education on teachers' capacity to deliver instruction aligned with the Sustainable Development Goals (SDGs) is vital. Training educators to recognize the interconnectedness of social, environmental, and economic challenges with the SDGs can equip them with the necessary sustainability skills to effectively educate future generations [11]. Further exploration in this realm is essential for devising effective strategies to enhance climate change education and aid educators in seamlessly integrating this critical subject into their teaching methodologies.

An implication of the results is that it is recommended to offer targeted professional development programs for science teachers to enhance their understanding of climate change concepts and best practices for teaching them effectively. Moreover, advocacy for the integration of climate change education into formal curricula is necessary, providing teachers with clear guidelines and resources to ensure consistent and comprehensive coverage. In addition, advocacy is needed for policy changes that mandate climate change education, provide necessary resources, and support teachers in delivering high-quality climate change education. Also, fostering partnerships with local communities, and experts is necessary to provide science teachers with practical tools, resources, and real-world examples to enrich their teaching of climate change.

4.4. Limitation and Future Research Agenda

This study has provided valuable insights into climate change knowledge and practices among Saudi science teachers. However, it is important to acknowledge the limitations of this research, which focused solely on science teachers in Riyadh city using survey methods. To address these limitations and further enhance understanding of climate change knowledge and practices among science teachers, several avenues for future research can be explored.

Firstly, this study relies on self-reported data, susceptible to biases such as social desirability bias and inaccuracies in respondents' perceptions of their knowledge and practices. Using Likert-based instruments may not fully assess teachers' climate science proficiency, warranting caution in drawing conclusions from results. It is suggested to supplement these results with in-depth interviews and qualitative methods to gain a nuanced insight into teachers' climate science knowledge and literacy.

Furthermore, acknowledging this study's focus on science teachers in climate change education and the limitation of this narrow scope, future research should involve teachers from diverse disciplines for a holistic view. The methodology's similarity to previous studies may constrain the depth of certain analyses.

Moreover, a limitation of this study is its narrow focus on science teachers in Riyadh city. Future research could benefit from broadening the scope by comparing the relationship of science teachers' climate change knowledge and practices across different regions or demographics to reveal potential variations and best practices. This comparative approach may illuminate key contributing factors, facilitating the development of tailored strategies and interventions that are effective across various contexts.

Finally, it is essential to acknowledge that the correlation between teachers' knowledge and practices related to climate change may be shaped by a multitude of factors, including cultural, social, educational, and political influences. Future research should delve into these factors to pinpoint effective strategies for promoting climate change education through targeted interventions and mentorship programs.

5. Conclusions

This research provides a comprehensive analysis of science teachers' knowledge and practices regarding climate change in Riyadh, Saudi Arabia. The study's findings shed light on the levels of teachers' understanding, their teaching practices, and the correlation between knowledge and practices. The study involved 197 science teachers at middle

and high school levels in public schools. The questionnaire used in this study had three sections: one for demographic information, another for assessing teachers' knowledge of climate change using true or false queries, and a third section focusing on their teaching practices related to the subject. The study reveals that science teachers in Riyadh, Saudi Arabia, exhibit a strong understanding of climate change concepts, with a high average knowledge degree of 0.80. While most teachers include climate change in their curriculum and teaching practices, there is a weak correlation (0.05) between their knowledge and actions in addressing climate change topics. This suggests that factors beyond understanding influence their teaching practices, such as available resources, training opportunities, institutional support, and personal beliefs. This study's limitations include relying on self-reported data, which may be subject to biases, and the narrow focus on science teachers in Riyadh. Future research should consider using qualitative methods, involving teachers from diverse disciplines, and exploring factors influencing climate change education beyond teachers' knowledge levels. Additionally, comparative studies across regions or demographics could provide insights into variations and best practices in climate change education. Understanding these complexities can inform the development of effective strategies and interventions for promoting climate change education. Overall, this study contributes significantly to the discourse on climate change education and underscores the importance of addressing teachers' knowledge and practices to effectively educate students on this critical issue.

Funding: This work was supported by the Princess Nourah bint Abdulrahman University Researchers Supporting Project (number PNURSP2024R430), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

Institutional Review Board Statement: The studies involving humans were approved by the IRB at Princess Nourah bint Abdulrahman University with KACST, KSA: (HAP-01-059).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. UNESCO. Learn for Our Planet a Global Review of How Environmental Issues are Integrated into Education. 2021. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000377362 (accessed on 12 May 2022).
2. Gillett, M. THE TBILISI DECLARATION. *McGill J. Educ./Rev. Des Sci. L'éducation McGill* **1977**, *12*, 243–245. Available online: https://mje.mcgill.ca/article/view/7156 (accessed on 12 October 2024).
3. Organization of the Petroleum Exporting Countries. OPEC Annual Statistical Bulletin. OPEC. 2024. Available online: https://publications.opec.org/asb (accessed on 1 September 2024).
4. Bentahar, A.; Copeland, K.; Stevens, S.; Vukelich, C. Educational Change in Saudi Arabia: Insights from One USA/KSA Teacher Professional Development Collaborative. *Int. Educ. Stud.* **2021**, *14*, 77. [CrossRef]
5. Alnahdi, G.H. Educational Change in Saudi Arabia. *J. Int. Educ. Res.* **2014**, *10*, 1–6. [CrossRef]
6. Al-Zaharni, N.O.A.; Rajab, H. Attitudes and perceptions of Saudi EFL teachers in implementing Kindong of Saudi Arabia's vision 2030. *Int. J. Engl. Lang. Educ.* **2017**, *5*, 83–99. [CrossRef]
7. Rahimi, M. Public Awareness: What Climate Change Scientists Should Consider. *Sustainability* **2020**, *12*, 8369. [CrossRef]
8. Hung, C.C. *Climate Change Education: Knowing, Doing and Being*; Routledge: London, UK, 2014.
9. Ekpo, C.G.; Aiyedun, T.G. Environmental Education: A Tool for Creation of Awareness on Adaptation to climate change in Nigeria. *IOSR J. Res. Method Educ.* **2019**, *9*, 12–21. [CrossRef]
10. United Nations Educational, Scientific and Cultural Organization (UNESCO). Education for Sustainable Development GoalsLearning Objectives. 2017. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000247444 (accessed on 12 June 2024).
11. Almazroa, H.; Alotaibi, W.; Alrwaythi, E. Sustainable Development Goals and Future-Oriented Teacher Education Programs. *IEEE Trans. Eng. Manag.* **2022**, *71*, 13517–13530. [CrossRef]
12. Favier, T.; van Gorp, B.; Cyvin, J.B.; Cyvin, J. Learning to Teach Climate Change: Students in Teacher Training and their progression in pedagogical content knowledge. *J. Geogr. High. Educ* **2021**, *45*, 594–620. [CrossRef]
13. Stabback, P. *What Makes a Quality Curriculum? In-Progress Reflection No. 2 "on Current and Critical Issues in Curriculum and Learning"*; UNESCO International Bureau of Education: Paris, France, 2016.

14. Dawson, V. Western Australian High School Students' Understandings About the Socioscientific Issue of Climate Change. *Int. J. Sci. Educ.* **2015**, *37*, 1024–1043. [CrossRef]
15. Eneji, C.-V.O.; Onnoghen, N.U.; Acha, J.O.; Diwa, J.B. Climate Change Awareness, Environmental Education and Gender Role Burdens Among Rural Farmers of Northern Cross River State, Nigeria. *Int. J. Clim. Change Strateg. Manag.* **2021**, *13*, 397–415. [CrossRef]
16. Eze, E.; Nwagu, E.; Onuoha, J. Nigerian Teachers' Self-Reported Climate Science Literacy and Expressed Training Needs on Climate Change Concepts: Prospects of Job-Embedded Situative Professional Development. *Sci. Teach. Educ.* **2022**, *6*, 1535–1567. [CrossRef]
17. Karim, N.; Othman, H.; Zaini, Z.-I.; Rosli, Y.; Wahab, M.I.A.; Al Kanta, A.M.; Omar, S.; Sahani, M. Climate Change and Environmental Education: Stance from Science Teachers. *Sustainability* **2022**, *14*, 16618. [CrossRef]
18. Dal, B.; Ozturk, N.; Alper, U.; Sonmez, D.; Cokelez, A. An Analysis of the Teachers' Climate Change Awareness. *Athens J. Educ.* **2015**, *2*, 111–122. [CrossRef]
19. Eze, E.; Nwagu, E.K.N. Dimensions of Teachers' Expressed Capacity Building Needs on Climate Change Education Strategies. *Interdiscip. J. Environ. Sci. Educ.* **2021**, *17*, e2251. [CrossRef]
20. Ullah, W.; Nafees, M.; Khurshid, M.; Nihei, T. Assessing farmers' perspectives on climate change for effective farm-level adaptation measures in Khyber. *Environ. Monit. Assess.* **2019**, *191*, 547. [CrossRef] [PubMed]
21. Rimm-Kaufman, S.E.; Storm, M.D.; Sawyer, B.E.; Pianta, R.C.; LaParo, K.M. The Teacher Belief Q-Sort: A measure of teachers' priorities in relation to disciplinary practices, teaching practices, and beliefs about children. *J. Sch. Psychol.* **2006**, *44*, 141–165. [CrossRef]
22. IPCC. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Möller, V., Okem, A., Rama, B., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022.
23. Moshou, H.; Drinia, H. Climate Change Education and Preparedness of Future Teachers—A Review: The Case of Greece. *Sustainability* **2023**, *15*, 1177. [CrossRef]
24. Opuni-Frimpong, N.Y.; Essel, H.B.; Opuni-Frimpong, E.; Obeng, E.A. Sustainable Development Goal for Education: Teachers' Perspectives on Climate Change Education in Senior High Schools (SHS). *Sustainability* **2022**, *14*, 8086. [CrossRef]
25. Chowdhury, M.T.A.; Ahmed, K.J.; Ahmed, M.N.Q.; Haq, S.M.A. How Do Teachers' Perceptions of Climate Change Vary in Terms Of Importance, Causes, Impacts and Mitigation? A Comparative Study in Bangladesh. *SN Soc. Sci.* **2021**, *1*, 174. [CrossRef]
26. Ceyhan, G.D.; Mugaloglu, E.Z. The Role of Cognitive, Behavioral and Personal Variables of Pre-Service Teachers' Plausibility Perceptions about Global Climate Change. *Res. Sci. Technol. Educ.* **2019**, *38*, 131–145. [CrossRef]
27. Karami, S.; Shobeiri, S.M.; Jafari, H.R. Assessment of Knowledge, Attitudes, and Practices (KAP) Towards Climate Change Education (CCE) Among Lower Secondary Teachers in Tehran, Iran. *Int. J. Clim. Change Strateg. Manag.* **2017**, *9*, 402–415. [CrossRef]
28. Meemar, S.S.; Poppink, S.; Bierlein Palmer, L. Educational Decentralization Efforts in a Centralized Country: Saudi Tatweer Principal Perceptions of New Authorities Granted. *Int. J. Educ. Policy Leadersh.* **2018**, *13*, 1–15. [CrossRef]
29. OECD. *TALIS 2018 Results (Volume I): Teachers and School Leaders as Lifelong Learners*; OECD Publishing: Paris, France, 2018. [CrossRef]
30. Islam, M.T.; Ali, A. Sustainable green energy transition in Saudi Arabia: Characterizing policy framework, interrelations and future research directions. *Next Energy* **2024**, *5*, 100161. [CrossRef]
31. Ministry of Education. *Request for Proposals: Building Leadership for Change Through School Immersion*; Ministry of Education: Riyadh, Saudi Arabia, 2018.
32. Algarni, F.; Male, T. Leadership in Saudi Arabian public schools: Time for devolution? *Int. Stud. Educ. Adm.* **2014**, *24*, 45–59.
33. Greenfield, T.; Greener, S. (Eds.) *Research Methods for Postgraduates*; John Wiley & Sons: Hoboken, NJ, USA, 2016.
34. María, A.; Almazroa, H.; Eng, T.O. South-South Dialogues: Perceptions of Latin American, Arabian and Asians Teachers on Climate Change. Unpublished Data.
35. Wright, K.B. Researching Internet-Based Populations: Advantages and Disadvantages of Online Survey Research, Online Questionnaire Authoring Software Packages, and Web Survey Services. *J. Comput.-Mediat. Commun.* **2005**, *10*, JCMC1034. [CrossRef]
36. Gerson, F.; Carla, J.; Sousa, G.; Guilherme, S.; Isabela, S. Public Perceptions of Climate Change: A Case Study with School Teachers and undergraduate students in Brazil. *Weather* **2019**, *74*, 320–325.
37. The Washington Post. Climate Change Quiz. 2022. Available online: https://www.washingtonpost.com/climate-solutions/interactive/2022/climate-change-quiz/ (accessed on 3 May 2023).
38. Pihkala, P. Toward a Taxonomy of Climate Emotions. *Front. Clim.* **2022**, *3*, 738154. [CrossRef]
39. Victor, M.; Luciana, R. Looking to Future Perceptions About Climate Change in Brazil: What Children's Teachers Think, Learn and Teach About? *Nat. Hazards* **2020**, *104*, 2325–2337. [CrossRef]
40. Ikoro, I.S.; Ezeanyim, U.E. Assessment of Secondary School Science Teachers' Knowledge of Climate Change in the South East Nigeria, For Inclusion in the Secondary School Curriculum. *Int. J. Weather Clim. Change Conserv. Res.* **2016**, *2*, 9–19.

41. Liu, S.; Roehrig, G.; Bhattacharya, D.; Varma, K. In-Service Teachers' Attitudes, Knowledge and Classroom Teaching of Global Climate Change. *Sci. Educ.* **2015**, *24*, 12–22. Available online: https://digitalcommons.unl.edu/natrespapers/1000 (accessed on 7 February 2024).
42. Milér, T.; Hollan, J.; Válek, J.; Sládek, P. Teachers' Understanding of Climate Change. *Procedia-Soc. Behav. Sci.* **2012**, *69*, 1437–1442. [CrossRef]
43. Groves, F.; Pugh, A. Elementary pre-Service Teacher Perceptions of the Greenhouse Effect. *J. Sci. Educ. Technol* **1999**, *8*, 75–81. [CrossRef]
44. Ikonomidis, S.; Papanastasiou, D.; Melas, D.; Avgoloupis, S. The Anthropogenic 'Greenhouse Effect': Greek Prospective Primary Teachers' Ideas About Causes, Consequences And Cures. *J. Sci. Educ. Technol* **2012**, *21*, 768–779. [CrossRef]
45. Ratinen. Primary Student-Teachers' Conceptual Understanding of the Greenhouse Effect: A Mixed Method Study. *Int. J. Sci. Educ.* **2013**, *35*, 929–955. [CrossRef]
46. Galway, L.P.; Field, E. Climate Emotions and Anxiety Among Young People in Canada: A National Survey and Call to Action. *J. Clim. Change Health* **2023**, *9*, 100204. [CrossRef]
47. Ojala, M. Hope in the Face of Climate Change: Associations with Environmental Engagement and Student Perceptions of Teachers Emotion Communication Style and Future Orientation. *J. Environ. Educ.* **2015**, *46*, 133–148. [CrossRef]
48. Johnson, L.C. Climate Change Education and Environmental Education: Perceptions and Knowledge Among Environmental Educators in the Southeastern United States. Ph.D. Thesis, Columbus State University, Columbus, GA, USA, 2019. Available online: https://csuepress.columbusstate.edu/theses_dissertations/317 (accessed on 3 September 2023).
49. Læssøe, J.; Mochizuki, Y. Recent Trends In National Policy on Education for Sustainable Development and Climate Change Education. *J. Educ. Sustain. Dev* **2015**, *9*, 27–43. [CrossRef]
50. Dawson, V.; Eilam, E.; Tolppanen, S.; Assaraf, O.B.Z.; Gokpinar, T.; Goldman, D.; Putri, G.A.P.E.; Subiantoro, A.W.; White, P.; Widdop Quinton, H. A Cross-Country Comparison of Climate Change in Middle School Science And Geography Curricula. *Int. J. Sci. Educ.* **2022**, *44*, 1379–1398. [CrossRef]
51. Ho, L.-C.; Seow, T. Disciplinary Boundaries and Climate Change Education: Teachers' Conceptions of Climate Change Education in the Philippines and Singapore. *Res. Geogr. Environ. Educ* **2017**, *26*, 240–252. [CrossRef]
52. Winter, V.; Kranz, J.; Möller, A. Climate Change Education Challenges from Two Different Perspectives of Change Agents: Perceptions of School Students and Pre-Service Teachers. *Sustainability* **2022**, *14*, 6081. [CrossRef]
53. Namdar, B. Teaching Global Climate Change to Pre-Service Middle School Teachers Through Inquiry Activities. *Res. Sci. Technol. Educ* **2018**, *36*, 440–462. [CrossRef]
54. Dillon, J. Science, the Environment and Education Beyond the Classroom. In *Second International Handbook of Science Education*; Springer: Berlin/Heidelberg, Germany, 2012; pp. 1081–1095.
55. Harris, F. Developing a Relationship with Nature and Place: The Potential Role of Forest School. *Environ. Educ. Res.* **2021**, *27*, 1214–1228. [CrossRef]
56. Kranz, J.; Schwichow, M.; Breitenmoser, P.; Niebert, K. The (Un)Political Perspective on Climate Change in Education—A Systematic Review. *Sustainability* **2022**, *14*, 4194. [CrossRef]
57. Monroe, M.C.; Plate, R.R.; Oxarart, A.; Bowers, A.; Chaves, W.A. Identifying Effective Climate Change Education Strategies: A Systematic Review of the Research. *Environ. Educ. Res* **2019**, *25*, 791–812. [CrossRef]
58. Rousell, D.; Cutter-Mackenzie-Knowles, A. A Systematic Review of Climate Change Education: Giving Children and Young People a 'Voice' and a 'Hand' in Redressing Climate Change. *Child. Geogr* **2020**, *18*, 191–208. [CrossRef]
59. Jorgenson, S.N.; Stephens, J.C.; White, B. Environmental Education in Transition: A Critical Review of Recent Research on Climate Change and Energy Education. *J. Environ. Educ* **2019**, *50*, 160–171. [CrossRef]
60. Wibeck, V. Enhancing Learning, Communication and Public Engagement About Climate Change—Some Lessons from Recent Literature. *Environ. Educ. Res* **2014**, *20*, 387–411. [CrossRef]
61. Boyes, E.; Stanisstreet, M. Environmental Education for Behaviour Change: Which Actions Should be Targeted? *Int. J. Sci. Educ* **2012**, *34*, 1591–1614. [CrossRef]
62. Kollmuss, A.; Agyeman, J. Mind the Gap: Why do People Act Environmentally and What are the Barriers to Pro-Environmental Behavior? *Environ. Educ. Res.* **2002**, *8*, 239–260. [CrossRef]