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Climate Change Education and Secondary School Students: A Meta-Synthesis (1993-2017)

La educación para el cambio climático y los estudiantes de educación secundaria: metasíntesis (1993-2017)

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ABSTRACT

Interest in climate change education has grown increasingly in educational research over the last two decades, during which there have been numerous studies and reviews. This paper synthesizes knowledge focusing on secondary school students and climate change education. A meta-synthesis was conducted over 76 papers, identified by a systematic literature review approach, involving students from 26 nationalities. The multiple methodologies used and the variety of sociocultural student profiles made it challenging to generalize the findings. This meta-synthesis allows us to establish the background for this population concerning the following areas: general knowledge, levels of awareness and responsibility ratings related to the phenomenon, concern and perception of risk, pro-environmental attitudes, and perceived self-efficacy. Generally, secondary school students demonstrate similar knowledge about the issue and share common misconceptions. The dimension of perceptions and attitudes is more diverse.

RESUMEN

En las últimas dos décadas, se ha constatado un creciente interés en torno a la educación para el cambio climático. Muestra de ello son los numerosos estudios y las diversas revisiones publicadas sobre este tópico educativo. En este artículo, presentamos una síntesis de conocimiento con el objetivo de analizar y valorar el alcance que han tenido los esfuerzos educativos en torno al cambio climático y relacionados con el estudiantado de educación secundaria. Se realizó revisión bibliográfica desde un enfoque sistemático junto a la técnica de metasíntesis, identificando 76 artículos publicados en revistas de alto impacto en el periodo 1993-2017 en el que participaron estudiantes de educación secundaria de 26 nacionalidades. La diversidad de metodologías empleadas y la variedad de perfiles socioculturales de la población participante dificulta generalizar los resultados obtenidos. Sin embargo, este estudio permite establecer el estado del arte sobre esta población estudiantil en lo que respecta a dimensiones como: el conocimiento general; la conciencia climática; los grados de responsabilidad atribuida al fenómeno antrópico; la preocupación y la percepción de riesgo; las actitudes proclimáticas; y la percepción de autoeficacia en la resolución del problema. En líneas generales, el alumnado de educación secundaria demuestra una dimensión conceptual homogénea con similares niveles de conocimiento ay compartiendo concepciones alternativas, mientras que las dimensiones de las actitudes y las percepciones son más heterogéneas.

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1. Introduction

The urgency of climate change (CC) risks emphasizes the need for education to prioritize objectives to create a decarbonized and equitable society. This entails advancing educational research and developing new concepts to understand and address CC effectively. International bodies recognize education's crucial role in transitioning toward sustainable development models (Intergovernmental Panel on Climate Change, 2018). UNESCO (2015) highlights education's pivotal role in raising awareness and fostering behavioral change for CC mitigation and adaptation.

In this sense, exploring how secondary school students perceive the climate crisis provides insights into the effectiveness of international educational guidelines. This paper aims to answer the following questions: What does the scientific literature reveal about secondary school students' perceptions of the climate crisis?

The research employs a meta-synthesis approach (Timulak, 2014) to address this question, analyzing cognitive elements related to CC representation among secondary school students. The analysis includes 76 studies published between 1993 and 2017, identified through a systematic literature review across various databases.

The paper discusses why meta-synthesis is recommended for Climate Change Education (CCE) research, followed by an introduction to the research methodology. Findings are presented in subsections covering students' understanding of CC occurrence, causes, consequences, and potential solutions. Additionally, it delves into students' awareness levels, responsibility ratings, concerns, perceptions of CC risks, pro-environmental attitudes, and perceived self-efficacy.

2. Background

Interest in CCE research has increased over the last two decades, as evidenced by recent international journal monographs published on the topic, for example, Environmental Education Research (Reid, 2019), International Research in Geographical and Environmental Education (Chang & Pascua, 2017) or Revista Mexicana de Investigación Educativa (Gutiérrez Pérez et al., 2020). This growing interest is also reflected in review studies that focus on the topic and address various topics as the comprehension of CC, including knowledge, attitudes, perceptions, or behaviors (Anderson, 2012; Bozdogan, 2011), educational interventions (Anderson, 2012; Monroe et al., 2017) or teachers' professional development (Hestness et al., 2014).

Findings suggest superficial knowledge and the presence of misconceptions among primary school students. These results are also confirmed among secondary school students, university students, and pre-service teachers, who share common misconceptions (Bozdogan, 2011). Both girls and boys exhibit comparable levels of knowledge, even prior to enrolling in specialized courses such as Science and Technologies or Humanities and Social Sciences. However, misconceptions persist despite this. However, these misunderstandings could be addressed with specific activities targeting these issues (Anderson, 2012; Bozdogan, 2011; Monroe et al., 2017).

Concerning educational activities, there are connections between educational activities, local problem-solving, individual behavior, and their impacts which underscore the importance of individual capacity to achieve sustainable goals, a shift towards solution-focused motivational framing, values that enhance students' engagement with the topic, and the promotion of a sense of self-efficacy and empowerment (Anderson, 2012; Monroe et al., 2017). Narrative techniques, images, and persuasive texts have been identified as effective educational tools. Correspondingly, Monroe et al. (2017) emphasize that deliberative discussion, interaction with scientists, activities addressing misconceptions, and community projects are all effective CCE strategies.

This body of reviewed literature highlights the growing interest in CCE research and the potential for enrichment in this field. Research within CCE covers diverse topics, including cognitive elements, teaching practices, and communication strategies. However, these reviews target various audiences, including students and teachers at different educational levels. Therefore, this paper specifically focuses on secondary school students for two reasons: firstly, these students are in a stage of cognitive development crucial to shaping their representation of the CC and their attitudes, and secondly, they are part of the population in mandatory education likely to continue to higher education, potentially occupying stakeholder positions in the future.
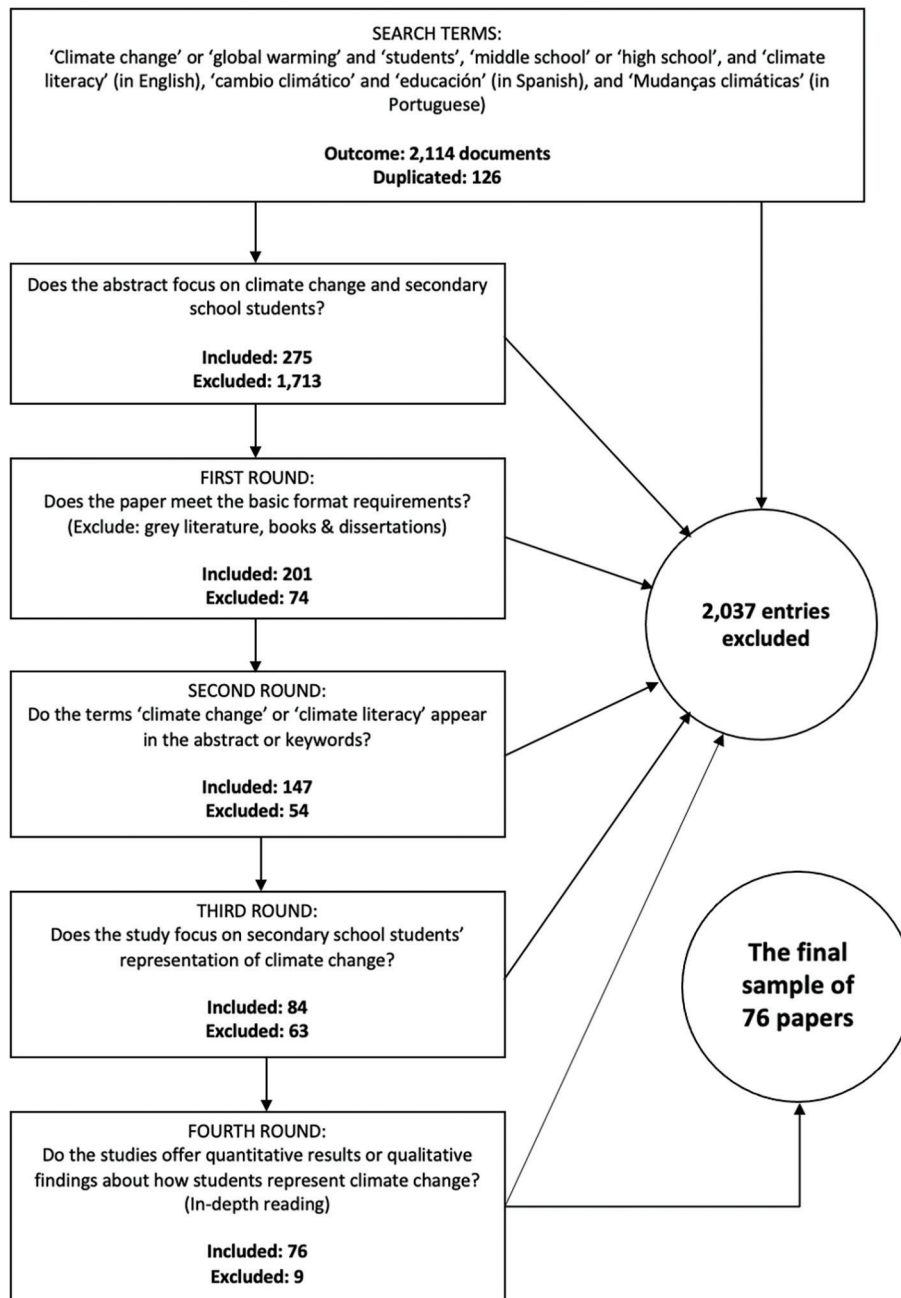
3. Methods

The systematic literature review (SLR) was conducted from October 17, 2017, to December 20, 2017. The search engines Web of Science, Scopus, Redalyc, Scielo, and Dialnet were utilized to identify studies in English, Spanish,

and Portuguese. The sample selection was comprehensive, considering the countries where the studies were conducted. A total of 76 articles were identified through an SLR of works published between 1993 and 2017. The vetting process and results can be consulted in Figure 1.

To answer the research question, a systematic approach was employed to compile studies, which were then analyzed using a meta-synthesis approach guided by a descriptive focus (Timulak, 2014). This comprehensiveness necessitates assessing how these studies coexist and complement one another, evaluating their contributions to understanding the current educational reality.

The term meta-synthesis is most frequently used in the field of knowledge synthesis, representing a meta-analytical procedure that is more interpretative than aggregative (Timulak, 2014). It is particularly suitable when findings are collected from studies with different methodological approaches without statistical analysis.

Figure 1. Vetting process and results.

The opportunities of qualitative meta-synthesis emerge when the focus is on a study of secondary data from various pieces of research on the same topic, even if different methodological designs have been used. The essential contributions involve identifying, selecting, and analyzing preliminary studies to generate new knowledge (American Psychological Association, 2019).

3.1. Data analysis

Social Representation Theory (SRT) is employed as an interpretative framework, recognizing it as an appropriate and flexible theoretical and conceptual framework to investigate how individuals and groups perceive, transform, and communicate aspects of both close and distant social reality. Its epistemological and methodological potential is complemented by its interdisciplinary nature, which is increasingly utilized in social and behavioral sciences research. This approach has provided SRT with a substantial range of research methods, including qualitative meta-synthesis (De Rosa, 2013).

To create analytical categories, the theoretical framework follows Moscovici's hypothesis on the three-dimensional nature of a social representation:

1. Information "relates to the way a group's knowledge of a social object […] is organized" (Moscovici, 2008, p. 23).
2. The field of representation includes beliefs, opinions, or judgements and (Moscovici, 2008).
3. The attitude "allows the global orientation in relation to the object of the social representation to be drawn out" (Moscovici, 2008, p. 25), i.e., its subjective assessment.

4. Findings

Figure 2 provides the geographical distribution of the students. The final number does not match the 76 articles because some research involved students from different countries (https://doi.org/10.5281/zenodo.10623944).

4.1. Students' information about the climate change

In concept maps created by students from the United States, redundant concepts were identified, including fossil fuels, melting glaciers, sea level, weather, temperature, greenhouse effect, atmosphere, or biosphere (Schuster et al., 2008). Similarly, students in Germany included the same concepts (Sellmann et al., 2015). Students

Figure 2. Distribution of students' nationalities.
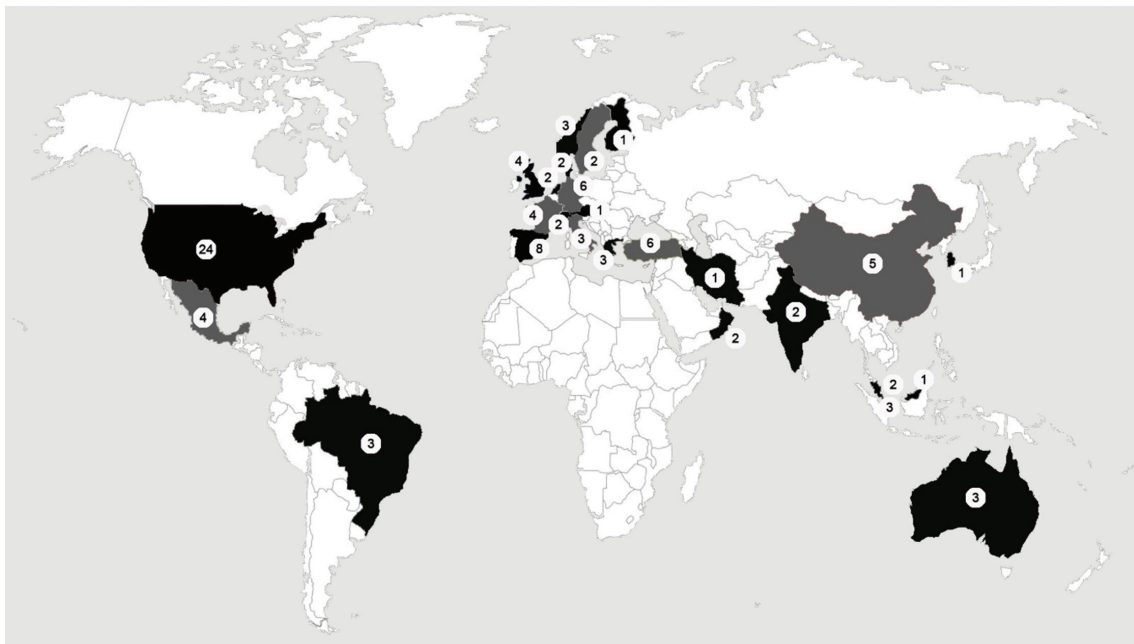
from Turkey associated CC with the rise in the planet's average temperature, connecting this with the melting of polar ice caps, rising sea levels, or desertification. They also link CC to other damage to nature caused by human beings, mentioning the destruction of the ozone layer, the irresponsibility of society, or the intensive use of fossil fuels (Aydin, 2010). Using the free association technique, Fløttum et al. (2016) concluded that most words employed by Norwegian students belong to similar areas of knowledge as those confirmed previously.

These findings align with those obtained in research utilizing quantitative techniques, where students also tend to demonstrate a limited grasp of information (Chang & Pascua, 2014; Dijkstra & Goedhart, 2011; Parant et al., 2017; Rule & Meyer, 2007; Tasquier & Pongiglione, 2017). Their understanding predominantly focuses on the consequences and impacts of CC, and its general causes and only occasionally delves into possible solutions (Boyes et al., 1993; Boyes & Stanisstreet, 2012; Holmqvist & Olander, 2017; Kılınç et al., 2009; Liarakou et al., 2011; Lin, 2016; McNeill & Vaughn, 2012).

Concerning the causes, some Spanish students identified transport, air pollution, and industrial activity (40–60%); waste management, water pollution, household energy consumption, chlorofluorocarbon emissions, and deforestation (10–20%); and the misuse of water, the use of fossil fuels, the destruction of the ozone layer, and the rise in GHG (10%) (Punter et al., 2011). Even though these students are responding to an open-ended question, the major trends identified so far are still present, as in the case of Italian students (Tasquier & Pongiglione, 2017).

On the other hand, students from Mexico City attribute the main cause of CC to the air pollution generated by cars and factories (61.2%), which may be associated with the traffic density and the high levels of air pollution in their city (Calixto-Flores, 2015a).

Regarding consequences, students from Spain, identify impacts on the physical and natural environment (melting of the polar ice caps, rising temperatures, extinction of species, desertification, etc.) without recognizing the effects they may have socially and economically. A very low percentage identified effects on health, problems resulting from food shortages, or environmental migration (Punter et al., 2011). These tendencies were confirmed by checking against open-ended questions, whose answers highlight the physical impacts of the climate system, in contrast to the limited importance given to impacts related to socioeconomic factors by one of the studies carried out in Mexico (Calixto-Flores 2015a) and Italy (Tasquier & Pongiglione, 2017).

In terms of solutions, students recognize the effectiveness of mitigation actions, such as modifying industrial processes, using less fossil fuel, reducing vehicle emissions, planting more trees, or improving education, compared to other solutions whose usefulness the students did not note, such as reducing the use of artificial fertilizers, producing fewer livestock products, or purchasing fewer goods and products (Ambusaidi et al., 2012; Boyes et al., 2009; Boyes & Stanisstreet, 2012; Calixto-Flores, 2015a; Chhokar et al., 2011; Kılınç et al., 2011; Malandrakis et al., 2011; Rodríguez et al., 2010; Tasquier & Pongiglione, 2017).

Secondary school students tend to regard international treaties as more useful than local and national legislation to mitigate CC, while few students express trust in the effectiveness of environmental taxation while recycling tends to be the most repeated solution in their daily lives, even though it is very far from being a real option (McNeill & Vaughn, 2012; Malandrakis et al., 2011).

Finally, many studies mention the maintenance of misconceptions (Daniel, 2004; Karpudewan et al., 2015; Shepardson, Choi, et al., 2011; Shepardson, Niyogi, et al., 2011). Their persistence and universality are largely due to the difficulty of understanding such a complex and abstract phenomenon (Adams, 1999; Peters & Songer, 2013). Most of these misconceptions are identified and described in the analytical approaches of the studies mentioned above (Schuster et al., 2008; Sellmann et al., 2015).

There are misconceptions that link CC and seismic activity (Chang & Pascua, 2016; Espejel & Flores, 2015; Yazdanparast et al., 2013). Also it is related to different types of pollution, associations with air pollution are dominant in this case as the erroneous connection between acid rain and CC (Boyes et al., 1993; Punter et al., 2011; Yazdanparast et al., 2013). But there is also a tendency to link CC to other types of pollution, such as marine and inland water pollution (Boyes et al., 2008), solid waste landfills, or dumping of radioactive waste (Boyes et al., 1993; Chang & Pascua 2016; Oztas et al., 2014).

The confusion between climate and weather is also widespread (McNeill & Vaughn, 2012; Bodzin et al., 2014; Dawson, 2015) without appreciating the space-time coordinates involved in both concepts. Although some studies report improvements in the differentiation of the two concepts after playing a simulation game (Nussbaum et al., 2015), the trend suggests that changes are only recognized for short periods of time and at a local level. This means that the space-time dimension of CC is difficult to grasp. Another exception is observed in a study carried out with a group of students from Sweden (Holmqvist & Olander, 2017). Nonetheless, its findings are not considered to be generalized since the sample was relatively small (N = 51), and all the participants were from the same school in their final years of secondary education and were taking a subject that focused on

university studies in Natural Sciences. These special features may indicate that the results might be affected by the academic profile or increased intrinsic motivation, as Tasquier (2015) suggests.

Lastly, two alternative conceptions have remained for over three decades, linked to the understanding of climate change since it first started to emerge: the metaphor of the hole in the ozone layer as a cause and/or consequence of CC and the confusion between the natural greenhouse effect and its anthropic alteration. On the one hand, the confusion between the ozone layer and CC is partly due to incomplete knowledge of CC based on logic that seems simple and coherent: CC is brought about by a hole through which allows a larger amount of solar radiation in, and this causes the atmospheric temperature to rise. The apparent simplicity of this argument has the capacity to substitute or replace causal concepts and theories that are scientifically sound (Arto-Blanco, 2009; Boon, 2010; Boyes et al., 1993, 2008; Chang & Pascua, 2014, 2016; DeWaters et al., 2014; García-Rodeja & Lima, 2012; Holmqvist & Olander 2017; Lin, 2016; Niebert & Gropengiesser, 2013, 2014; Stevenson, Peterson & Bradshaw, 2016; Tasquier & Pongiglione 2017).

On the other hand, some authors state that confusion around the greenhouse effect is due to a conceptual error (Chang & Pascua, 2014; Lin, 2016). In their opinion, this results from the terminology used by the scientific community in the first communications that reached society regarding the climate crisis in the 1980s (Chang & Pascua, 2014). Other studies allude to the shortcomings hidden by the non-existence of complex systemic thought, which is required to understand both phenomena and differentiate between them (Shepardson et al., 2014). From this, it can be deduced that, whether due to the use of vague terminology in curricula, the teaching and learning processes, the way this terminology is dealt with in textbooks (Reinfried et al., 2012), or how information is displayed in the media, the 'greenhouse effect' concept is very important when it comes to understanding CC: not as a natural phenomenon that is being altered due to human interference, but as a synonym for the process by which it is altered (Boon, 2010; Chang et al., 2017; Espejel & Flores, 2015; García-Rodeja & Lima, 2012; Reinfried & Tempelmann, 2014; Rye et al., 1997).

4.2. Beliefs and perceptions about climate change

Most secondary school students tend to accept the existence of CC and its anthropic causes (Barbosa et al., 2012; Boyes et al., 2009; Chhokar et al., 2011; Kılınç et al., 2011; McNeill & Vaughn, 2012; Öhman & Öhman, 2013; Rodríguez et al., 2010). Nonetheless, in socio-political contexts where there is a higher percentage of denial, such as the United States, there are studies that show that less than 70% of the students believe that CC exists (DeWaters et al., 2014; Stevenson et al., 2014). Other studies suggest that this percentage falls between 75% and 90%. However, it's worth noting that these studies only included students with high academic achievement or those interested in science (Monroe et al., 2016; Rule & Meyer, 2009; Shea et al., 2016). Other research suggests that a higher percentage of students from the United States think that CC is not real (20–30%). Notwithstanding, when these students are given rigorous scientific information, they accept the existence and human causality of CC (Stevenson, Peterson & Bradshaw, 2016), while the acceptance of CC by family and friends also seems to be a predictor of higher acceptance among students (Stevenson, Peterson & Bondell, 2016).

It is worth to mentioning that beliefs and perceptions vary in relation to the background of the students. This is the case, for instance, with some students from China who, despite recognizing the responsibility of governmental institutions, accept some responsibility for the problem, in contrast to groups of students in Western contexts (Boyes et al., 2008). However, differences are also observed in the West, as in the case of Norway where 60% of students accept that acting against the climate crisis is a moral imperative for individuals, with 80% recognizing the different responsibility of wealthier countries in contrast to poorer countries (Fløttum et al., 2016).

In Latin America, statements about CC from students in Brazil show that only 28.6% recognize some type of responsibility for the problem. Within this group, 46% indicate that it is their own responsibility, putting part of the blame on their actions; another 46% generically attributed the responsibility to humanity, and the remaining 8% hold those in government responsible (Barros & Pinheiro, 2013). In the case of Mexico (Bello-Benavides et al., 2017; Calixto-Flores, 2015b), students tend to associate CC with the natural environment, as something that is relatively distant or disconnected from social life. This psychological distance makes it difficult for students to accept responsibilities for the causes and actions for the consequences of CC.

With regards to concern and risk perception, generally, adolescents from Western societies (the United Kingdom, United States, Greece, New Zealand, and Finland, among others) tend to consider their concern about the risks of CC to be moderate, while the level of concern of students from other sociocultural contexts such as India, Turkey, China, Brunei, or Hong Kong is higher (Boyes et al., 2014; Hermans & Korhonen, 2017; Jackson & Pang, 2017). Nevertheless, in a study with 1,370 students from Europe, Dijkstra and Goedhart (2011) conclude

that, after the activity, an authentic science project, more than 80% realized that people can be affected by CC. Stevenson, Peterson, and Bondell (2016) also concluded that the view of family and friends regarding CC predicted concern. Furthermore, in general terms, students tend to channel possible threats towards a distant future, between 25 and 100 years away, identifying CC as an issue with little relevance to their personal lives (Barros & Pinheiro, 2013; Shea et al., 2016; Stevenson & Peterson, 2016).

In contrast, exposure to adverse climate experiences seems to influence on risk perception and the need for self-protection. This is the case with students in Turkey, who identified air pollution (71.1%) as the main environmental problem that concerns them the most, while fewer students are concerned about climate change (18%) (Özdem et al., 2014). Researchers note that 69% of participants have been affected by health problems because of air pollution, either personally or through their relatives, which is a determining variable in increased concern. In the case of ethnic minority students (excluding white minorities) from the USA, they disproportionately suffer the effects of CC. This is attributed to the fact that the areas where they generally live are more likely to be found inside cities, meaning they are directly affected by air pollution or by the urban heat island effect, leading to a higher impact and concern of CC (Stevenson et al., 2014).

Gender differences in risk perception levels should not be overlooked. Generally, women express greater concern about CC than men (Stevenson & Peterson, 2016). They often perceive a higher potential threat and show more urgency in addressing its possible impacts. Additionally, a larger percentage of females support the notion that CC science is crucial for the future of humanity (Dijkstra & Goedhart, 2011).

The difficulty of associating risks and everyday experiences with CC, in addition to the view that nothing can be done about it or the opinion that it is now too late to do anything, explains the low percentage of students who included CC among their main environmental concerns.

4.3. Attitudes related to climate change

The works by Edward Boyes and Martin Stanisstreet, which include samples of students from different backgrounds — Oman, Australia, the United Kingdom, India, Turkey, Greece, and Spain — are very useful for analyzing how socioeconomic and cultural backgrounds influence attitudes and practical orientations. Two main aspects are of particular interest in these studies: a) the tendency of students to take pro-environmental actions against CC; and b) their level of confidence in the efficacy attributed to performing these actions.

The authors set out a series of actions:
- Level 1. Actions that do not bring about major changes to personal lives, or which are socially recognized and accepted.
- Level 2. Actions that are beyond the students' control, and so performing them does not result in their comfort, lifestyles or future expectations being sacrificed.
- Level 3. Actions that entail substantial changes.

The results suggest that students from Oman, India, and Turkey have a higher tendency to take pro-environmental actions (13, 15, and 12 actions out of 17, respectively) than students from Greece (8 actions out of 16) and students from Australia, Spain, and the United Kingdom (4, 5 and 4 actions out of 17, respectively). Among the direct actions, it is stated that in level 1 (for example, unplugging unused electronic devices, recycling, or planting trees), a majority in all groups are inclined to take these actions, except for the ones from the United Kingdom.

In level 2, responses are more varied. All students agree to buy more efficient electrical appliances and improve home insulation, except in Australia, where similar percentages are willing or unwilling to make these changes. Most students are willing to buy products processed with artificial fertilizers, except in Australia and Spain, where no majority stance exists. The United Kingdom is the only sample where most students reject this action. The authors suggest this rejection may stem from students' lack of awareness of the links between fertilizer use and nitrogen oxide emissions and their failure to recognize these as greenhouse gases (GHG) (Boyes & Stanisstreet, 2012).

Most groups tend to agree on activities related to using smaller and more efficient cars and renewable energy, with varying degrees of support or rejection. Notably, students from Oman and India are most willing to support these actions, while those from the United Kingdom are most opposed, despite recognizing their effectiveness against CC.

Nuclear power is rejected by a majority of groups except India and Greece. The authors suggest India's support may stem from active government promotion, contrasting with European reluctance (Chhokar et al., 2011).

Level 3 actions include buying fewer trendy products, reducing meat consumption, using public transport more, and minimizing private car usage. Students from Western countries (Australia, Spain, and the UK) show similar reluctance toward purchasing new products, eating less meat, and reducing private car usage. In contrast, more students from Oman, India, and Greece are willing to reduce consumption. These differences may stem from factors such as a lack of understanding of GHG emissions' impact, differing social and cultural norms, biased assessments of action effectiveness, or limited attention to consumer lifestyles and climate change in certain countries' environmental education. (Boyes et al., 2009).

This trend is seen again in eating less meat: students from Western countries are not as willing to change their diets as students from Oman, India, and Turkey. Hermans and Korhonen (2017) found results that align with the aforementioned works using a similar questionnaire with Finnish students.

When exploring the moral considerations in the arguments of Chinese students and focusing on accepting or rejecting certain actions to combat CC, Sternäng and Lundholm (2011) identified two perspectives: the individual as 'myself' and the individual as 'someone else'. The authors conclude that the environmental solutions to specific problems vary depending on the perspective of each student:

> A student is likely somewhat anthropocentric when the individual is 'me'. Only her/his own personal needs are stressed and the aspect of nature is not considered and thus excluded in her/his reasoning. When the individual is 'someone else', the students seem to advocate a keen concern for the environment, and thus the relation to and the aspect of nature itself is addressed. (Sternäng & Lundholm, 2011, p. 1144).

Students *often prioritize cultural context over knowledge w*hen assessing decisions to reduce environmental impact. For example, in Flora et al. (2014) study, respondents reported making short-term changes like recycling or taking shorter showers but overlooked more impactful actions like using a reusable water bottle, possibly due to the short survey duration or social stigma associated with such behavior, seen as a sign of poverty.

In Fløttum et al. (2016) study, most Norwegian students expressed trust in addressing climate change, but three trends emerged regarding their self-efficacy perception: some doubted individual actions' global impact, others hesitated due to lifestyle sacrifices, and a third group denied climate change's reality. Despite high concern and belief in crisis resolution, only 10% held an ecocentric view, 60% favored a techno-optimistic future relying on technology, and 30% anticipated a catastrophic outcome.

Students from North Carolina also showed intermediate levels of confidence in their actions (Stevenson et al., 2018). These confidence levels are low regarding whether people can solve the problem, although they are hopeful that some will continue to seek solutions to the climate crisis (Stevenson & Peterson, 2016). In the case of Mexico, almost 50% of the students from Mexico City agree that their actions can help minimize CC. However, only 20% uphold this belief when the magnitude of the climate crisis is considered (Calixto-Flores, 2015b).

When solutions are located in their daily lives, students outsource the effective solutions to institutional and industrial spheres; they also perceive that the responsibilities they could assume do not concern them and that they are far from being able to have an influence (Stevenson & Peterson, 2016; Calixto-Flores, 2015b). Nonetheless, students place far greater trust in the power of the school to effect changes than the power of families, thus recognizing the significant transformative potential they attribute to the school educational experience.

5. Conclusions

The analysis of 76 articles underscores the diverse methodological designs employed in research on CCE within secondary education. Predominantly, these studies concentrate on students' comprehension of the climate change. It becomes evident that, despite geographical and cultural disparities among participants, the multifaceted and complex nature of the phenomenon poses a challenge to its understanding. This complexity limits knowledge, primarily focusing on atmospheric aspects and exhibiting biases in correctness and coherence. Notably, cognitive barriers persist, evident in the prevalence of alternative conceptions hindering a profound grasp of the issue.

Regarding this cognitive dimension, the meta-synthesis results suggest that formal education needs to foster systematic, critical, and multidimensional thinking essential for comprehending the climate crisis. Embracing a transdisciplinary scientific culture, intertwining natural sciences and social sciences and humanities, becomes crucial. Pedagogical strategies must extend beyond concept transmission, encouraging activities that facilitate deeper levels of knowledge through deliberation and discussion. Addressing pre-existing ideas collectively and individually, while constructing alternative conceptions about CC, emerges as vital.

In the realm of CCE research, the consistent focus on exploring knowledge about CC suggests a need to broaden study subjects to encompass variables influencing CC representation. Exploring the roles of gender, socioeconomic status, prior experiences, or worldviews of a personal or sociocultural nature is advisable.

Furthermore, a gap exists between research, educational policies, and practices within the education system. Despite research outcomes, the transmission of knowledge lacks significant influence on expected outcomes. Effective dissemination of foundational findings is necessary for educational responses addressing climate crisis challenges. Teacher training, for both new and experienced educators, emerges as crucial.

From our perspective, the main challenge in CCE is its exclusive confinement to Natural Sciences. This bias marginalizes essential knowledge from other epistemologies and areas, such as Social Sciences, Humanities, or the Arts, which are pivotal for integrating cultural, axiological, economic, and ethical aspects in social transformation (Caride & Meira-Cartea, 2020; González-Gaudiano & Meira-Cartea, 2019). Neglecting these aspects hampers the creation of a post-carbon society aligned with social and environmental justice principles. CCE must incorporate imperatives of climate justice and equity. It should remain attuned to local and global signs of the climate crisis, fostering learning processes that connect individuals and society to a phenomenon inducing uncertainties in their daily lives.

6. Limitations

There are inherent limitations to this type of study. We consider that there is a geographical bias due to the over-representation of students from Western countries which could be due to a linguistic bias due to the authors' language skills. However, a considerable body of work has been published in recent years (https://doi.org/10.5281/zenodo.10623944). Moreover, there are distinctive geographical, social, cultural, and educational characteristics that play a fundamental role in educating citizens, involving great variations in teaching, and learning processes and the socialization of pupils, so the results and conclusions must be assessed with all these limitations in mind.

We also recognize that the time span covered by this review may introduce a temporal bias, given the six-year gap between our study (1993-2017) and its potential publication. Despite this, beyond questioning its timeliness, this gap enables us to trace back to the origins of what, 30 years ago after the Earth Summit in Rio de Janeiro, was not yet acknowledged as a significant climate emergency, with the devastating and enduring impacts we now associate with it. Notably, no literature review similar to ours has been discovered to date, which offers the possibility for further upgrades in this field of study.

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Authors' contributions

Antonio García-Vinuesa: Conceptualization, Data curation, Formal analysis, Research, Methodology, Software, Visualization, Writing-draft, Writing-review and editing.
Pablo Á. Meira-Cartea: Formal analysis, Research, Methodology, Supervision, Validation, Writing-review and editing.
José A. Caride-Gómez: Research, Methodology, Supervision, Validation, Writing-review and editing.

References

Adams, S. T. (1999). Critiquing claims about global warming from the World Wide Web: A comparison of high school students and specialists. *Bulletin of Science, Technology & Society, 19*(6), 539–543. https://doi.org/10.1177/027046769901900610

Ambusaidi, A., Boyes, E., Stanisstreet, M., & Taylor, N. (2012). Omani students' views about global warming: Beliefs about actions and willingness to act. *International Research in Geographical and Environmental Education, 21*(1), 21–39. https://doi.org/10.1080/10382046.2012.639154

American Psychological Association. (2019). *Publication manual of the American Psychological Association.* American Psychological Association.

Anderson, A. (2012). Climate change education for mitigation and adaptation. *Journal of Education for Sustainable Development, 6*(2), 191–206. https://doi.org/10.1177/0973408212475199

Arto-Blanco, M. (2009). Climate change narrated by secondary school students: analysis of icons and metaphors. *AmbientalMente Sustentable: Revista Científica Galego-Lusófona de Educación Ambiental*, 7, 115–125.

Aydin, F. (2010). Secondary school students' perceptions towards global warming: a phenomenographic analysis. *Scientific Research and Essays 5*(12), 1566–1570. https://doi.org/10.5897/SRE.9000825

Barbosa, L., Lima, M., & Machado, A. (2012). Disputes over global warming: movement of voices and meanings produced in the classroom. *Ensaio Pesquisa em Educação em Ciências (Belo Horizonte),* 14(1), 113–130. https://doi.org/10.1590/1983-21172012140108

Barros, H., & Pinheiro, J. (2013). Psychological dimensions of global warming according to the view of Brazilian teenagers. *Estudos de Psicologia (Natal), 18*(2), 173–182. https://doi.org/10.1590/S1413-294X2013000200002

Bello-Benavides, L. O., Meira-Cartea, P. Á., & González-Gaudiano É. J. (2017). [Social Representations of Climate Change in a Group of Secondary School Students in Spain and a Group of High School Students in Mexico. *Revista Mexicana de Investigación Educativa, 22*(73), 505–532.

Bodzin, A. M., Anastasio, D., Sahagian, D., Peffer, T., Dempsey, C., & Steelman, R. (2014). Investigating climate change understandings of urban middle-level students. *Journal of Geoscience Education, 62*(3), 417–430. https://doi.org/10.5408/13-042.1

Boon, H. J. (2010). Climate change? Who knows? A comparison of secondary students and pre-service teachers. *Australian Journal of Teacher Education*, 35, 104–120. https://doi.org/10.14221/ajte.2010v35n1.9

Boyes, E., Chuckran, D., & Stanisstreet, M. (1993). How do high school students perceive global climatic change: What are its manifestations? What are its origins? What corrective action can be taken. *Journal of Science Education and Technology, 2*(4), 541–557. https://doi.org/10.1007/BF00695323

Boyes, E., Skamp, K., & Stanisstreet, M. (2009). Australian secondary students' views about global warming: Beliefs about actions, and willingness to act. *Research in Science Education, 39*(5), 661–680. https://doi.org/10.1007/s11165-008-9098-5

Boyes, E., & Stanisstreet, M. (2012). Environmental education for behaviour change: Which actions should be targeted?. *International Journal of Science Education, 34*(10), 1591–1614. https://doi.org/10.1080/09500693.2011.584079

Boyes, E., Stanisstreet, M., Skamp, K., Rodriguez, M., Malandrakis, G., Fortner, R. W., Kilinç, A., Taylor, N., Chhokar, K., Dua, S., Ambusaidi, A., Cheong, I., Kim, M., & Yoon, H. G. (2014). An international study of the propensity of students to limit their use of private transport in light of their understanding of the causes of global warming. *International Research in Geographical and Environmental Education, 23*(2), 142–165. https://doi.org/10.1080/10382046.2014.891425

Boyes, E., Stanisstreet, M., & Yongling, Z. (2008). Combating global warming: the ideas of high school students in the growing economy of South East China. *International Journal of Environmental Studies, 6*5(2), 233–245. https://doi.org/10.1080/00207230701284543

Bozdogan, A. E. (2011). A Collection of Studies Conducted in Education about 'Global Warming' Problem. *Educational Sciences: Theory and Practice, 11*(3), 1618–1624.

Calixto-Flores, R. C. (2015a). Social representations of climate change on students of secondary education. *REXE-Revista de estudios y experiencias en educación, 14*(27), 15–32.

Calixto-Flores, R. C. (2015b). A proposal of environmental education for the teaching of climate change. *Diálogos Educativos*, 29, 54–68.

Caride, J.A., & Meira-Cartea, P.Á. (2020). Environmental education at the limits, or the civic and pedagogical need for responses to a civilization that collapses. *Pedagogía Social Revista Interuniversitaria*, 36, 21-34. https://doi.org/10.7179/PSRI_2020.36.01

Chang, C. H., & Pascua, L. (2014). Uncovering the nexus between scientific discourse and school geography in Singapore students' understanding of climate change. *Research in Geographic Education*, 16, 41–56.

Chang, C. H., & Pascua, L. (2016). Singapore students' misconceptions of climate change. *International Research in Geographical and Environmental Education, 25*(1), 84–96. https://doi.org/10.1080/10382046.2015.1106206

Chang, C. H., & Pascua, L. (2017). The state of climate change education – reflections from a selection of studies around the world. *International Research in Geographical and Environmental Education*, *26*(3), 177–179. https://doi.org/10.1080/10382046.2017.1331569

Chang, C. H., Pascua, L., & Ess, F. (2017). Closing the 'Hole in the Sky': The Use of Refutation-Oriented Instruction to Correct Students' Climate Change Misconceptions. *Journal of Geography, 117*(1), 3–16. https://doi.org/10.1080/00221341.2017.1287768

Chhokar, K., Dua, S., Taylor, N., Boyes, E., & Stanisstreet, M. (2011). Indian secondary students' views about global warming: beliefs about the usefulness of actions and willingness to act. *International Journal of Science and Mathematics Education, 9*(5), 1167–1188. https://doi.org/10.1007/s10763-010-9254-z

Daniel, B., M. Stanisstreet, & Boyes, E. (2004). How can we best reduce global warming? School students' ideas and misconceptions. *International Journal of Environmental Studies 61*(2), 211–222. https://doi.org/10.1080/0020723032000087907

Dawson, V. (2015). Western Australian high school students' understandings about the socioscientific issue of climate change. *International Journal of Science Education, 37*(7), 1024–1043. https://doi.org/10.1080/09500693.2015.1015181

De Rosa, A. S. (Ed.). (2013). Social representations in the 'Social Arena'. Routledge. https://doi.org/10.4324/9780203102138

DeWaters, J. E., Andersen, C., Calderwood, A., & Powers, S. E. (2014). Improving climate literacy with project-based modules rich in educational rigor and relevance. *Journal of Geoscience Education, 62*(3), 469–484. https://doi.org/10.5408/13-056.1

Dijkstra, E. M., & Goedhart, M. J. (2011). Evaluation of authentic science projects on climate change in secondary schools: A focus on gender differences. *Research in Science & Technological Education, 29*(2), 131-146. https://doi.org/10.1080/02635143.2011.58163

Espejel, A., & Flores, A. (2015). Knowledge and perception of global warming on high school youths, Tlaxcala. *Revista mexicana de ciencias agrícolas, 6*(6), 1277–1290.

Flora, J. A., Saphir, M., Lappé, M., Roser-Renouf, C., Maibach, E. W., & Leiserowitz, A. A. (2014). Evaluation of a national high school entertainment education program: The Alliance for Climate Education. *Climatic Change, 127*(3), 419–434. https://doi.org/10.1007/s10584-014-1274-1

Fløttum, K., Dahl, T., & Rivenes, V. (2016). Young Norwegians and their views on climate change and the future: findings from a climate concerned and oil-rich nation. *Journal of Youth Studies, 19*(8), 1128–1143. https://doi.org/10.1080/13676261.2016.1145633

García-Rodeja, I., & Lima, G. (2012). Climate change and the change of models of students' thinking. *Enseñanza de las Ciencias, 30*(3), 0195-218.

González-Gaudiano, E. J., & Meira-Cartea, P. Á. (2019). Environmental education under siege: Climate radicality. *The Journal of Environmental Education, 50*(4-6), 386-402. https://doi.org/10.1080/00958964.2019.1687406

Gutiérrez Pérez, J., Meira Cartea, P. Á., & González Gaudiano, É. J. (2020). Education and Communication for Climate Change. *Revista Mexicana de Investigación Educativa*, *25*(87), 819-842.

Hermans, M., & Korhonen, J. (2017). Ninth graders and climate change: Attitudes towards consequences, views on mitigation, and predictors of willingness to act. *International Research in Geographical and Environmental Education, 26*(3), 223–239. https://doi.org/10.1080/10382046.2017.1330035

Hestness, E., McDonald, R. C., Breslyn, W., McGinnis, J. R., & Mouza, C. (2014). Science teacher professional development in climate change education informed by the Next Generation Science Standards. *Journal of Geoscience Education, 62*(3), 319–329. https://doi.org/10.5408/13-049.1

Holmqvist, M., & Olander, C. (2017). Understandings of climate change articulated by Swedish secondary school students. *Journal of Biological Education, 51*(4), 349–357. https://doi.org/10.1080/00219266.2016.123`3130

Intergovernmental Panel on Climate Change. (2018). *Summary for Policymakers. In Global Warming of 1.5°C*. IPCC. https://d66z.short.gy/qFUnLY

Jackson, L., & Pang, M. F. (2017). Secondary school students' views of climate change in Hong Kong. *International Research in Geographical and Environmental Education, 26*(3), 180–192. https://doi.org/10.1080/10382046.2017.1330036

Karpudewan, M., Roth, W. M., & Chandrakesan, K. (2015). Remediating misconception on climate change among secondary school students in Malaysia. *Environmental Education Research, 21*(4), 631–648. https://doi.org/10.1080/13504622.2014.891004

Kılınç, A., Boyes, E., & Stanisstreet, M. (2011). Turkish school students and global warming: beliefs and willingness to act. *Eurasia Journal of Mathematics, Science and Technology Education, 7*(2), 121–134. https://doi.org/10.12973/ejmste/75187

Kılınç, A., Stanisstreet, M., & Boyes, E. (2009). Incentives and disincentives for using renewable energy: Turkish students' ideas. *Renewable and Sustainable Energy Reviews, 13*(5), 1089–1095. https://doi.org/10.1016/j.rser.2008.03.007

Liarakou, G., Athanasiadis, I., & Gavrilakis, C. (2011). What Greek Secondary School Students Believe about Climate Change? *International Journal of Environmental and Science Education, 6*(1), 79–98.

Lin, J. (2016). Chinese grade eight students' understanding about the concept of global warming. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(5), 1313–1330. https://doi.org/10.12973/eurasia.2017.00672a

Malandrakis, G., Boyes, E., & Stanisstreet, M. (2011). Global warming: Greek students' belief in the usefulness of pro-environmental actions and their intention to take action. *International Journal of Environmental Studies, 68*(6), 947–963. https://doi.org/10.1080/00207233.2011.590720

McNeill, K. L., & Vaughn, M. H. (2012). Urban high school students' critical science agency: Conceptual understandings and environmental actions around climate change. *Research in Science Education, 42*(2), 373–399. https://doi.org/10.1007/s11165-010-9202-5

Monroe, M. C., Hall, S., & Li, C. J. (2016). Can climate change enhance biology lessons? A quasi-experiment. *Applied Environmental Education & Communication, 15*(2), 125–137. https://doi.org/10.1080/1533015X.2016.1164095

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2017). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research, 25*(6), 791–812. https://doi.org/10.1080/13504622.2017.1360842

Moscovici, S. (2008). *Psychoanalysis: Its Image and Its Public*. Polity press.

Niebert, K. & Gropengiesser, H. (2013). Understanding and communicating climate change in metaphors. *Environmental Education Research, 19*(3), 282–302. https://doi.org/10.1080/13504622.2012.690855

Niebert, K., & Gropengießer, H. (2014). Understanding the greenhouse effect by embodiment–analysing and using students' and scientists' conceptual resources. *International Journal of Science Education, 36*(2), 277–303. https://doi.org/10.1080/09500693.2013.763298

Nussbaum, E. M., Owens, M. C., Sinatra, G. M., Rehmat, A. P., Cordova, J. R., Ahmad, S., Harris, F., & Dascalu, S. M. (2015). Losing the Lake: Simulations to promote gains in student knowledge and interest about climate change. *International Journal of Environmental and Science Education, 10*(6), 789–811.

Öhman, J. & Öhman, M. (2013). Participatory approach in practice: An analysis of student discussions about climate change. *Environmental Education Research, 19*(3), 324–341. https://doi.org/10.1080/13504622.2012.695012

Özdem, Y., Dal, B., Öztürk, N., Sönmez, D., & Alper, U. (2014). What is that thing called climate change? An investigation into the understanding of climate change by seventh-grade students. *International Research in Geographical and Environmental Education, 23*(4), 294–313. https://doi.org/10.1080/10382046.2014.946323

Oztas, F., Tanriverdi, H., & Oztas, H. (2014). School Students Dilema about Environmental Rules and Attitudes. Do They Really Feel Responsibility for the Environment? *Journal Environmental Protection Ecolology, 1*5(3A), 1482–1492.

Parant, A., Pascual, A., Jugel, M., Kerroume, M., Felonneau, M. L., & Gueguen, N. (2017). Raising students awareness to climate change: An illustration with binding communication. *Environment and Behavior, 49*(3), 339–353. https://doi.org/10.1177/0013916516629191

Peters, V. L., & Songer, N. B. (2013). Evaluating the usability of a professional modeling tool repurposed for middle school learning. *Journal of Science Education and Technology, 22*(5), 681–696. https://doi.org/10.1007/s10956-012-9422-8

Punter, P., Ochando-Pardo, M., & García, J. (2011). Spanish secondary school students' notions on the causes and consequences of climate change. *International Journal of Science Education, 33*(3), 447–464. https://doi.org/10.1080/09500693.2010.492253

Reid, A. (2019). Climate change education and research: possibilities and potentials versus problems and perils? *Environmental Education Research*, *25*(6), 767–790. https://doi.org/10.1080/13504622.2019.1664075

Reinfried, S., Aeschbacher, U., & Rottermann, B. (2012). Improving students' conceptual understanding of the greenhouse effect using theory-based learning materials that promote deep learning. *International Research in Geographical and Environmental Education, 21*(2), 155–178. https://doi.org/10.1080/10382046.2012.672685

Reinfried, S., & Tempelmann, S. (2014). The impact of secondary school students' preconceptions on the evolution of their mental models of the greenhouse effect and global warming. *International Journal of Science Education, 36*(2), 304–333. https://doi.org/10.1080/09500693.2013.773598

Rodríguez, M., Boyes, E., & Stanisstreet, M. (2010). Spanish secondary students' willingness to undertake specific actions to combat global warming: Can environmental education help? *Psyecology, 1*(1), 73–89. https://doi.org/10.1174/217119710790709496

Rule, A. C., & Meyer, M. A. (2009). Teaching urban high school students global climate change information and graph interpretation skills using evidence from the scientific literature. *Journal of Geoscience Education, 57*(5), 335–347. https://doi.org/10.5408/1.3559674

Rye, J. A., Rubba, P. A., & Wiesenmayer, R. L. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19*(5), 527–551. https://doi.org/10.1080/0950069970190503

Schuster, D. A., Filippelli, G. M., & Thomas, C. W. (2008). Secondary students' subject matter representations of climate change. *Journal of Geoscience Education, 56*(4), 307–316. https://doi.org/10.5408/secondary_students_subject_mat

Sellmann, D., Liefländer, A. K., & Bogner, F. X. (2015). Concept maps in the classroom: A new approach to reveal students' conceptual change. *The Journal of Educational Research, 108*(3), 250–257. https://doi.org/10.1080/00220671.2014.896315

Shea, N. A., Mouza, C., & Drewes, A. (2016). Climate change professional development: Design, implementation, and initial outcomes on teacher learning, practice, and student beliefs. *Journal of Science Teacher Education, 27*(3), 235–258. https://doi.org/10.1007/s10972-016-9456-5

Shepardson, D. P., Choi, S., Niyogi, D., & Charusombat, U. (2011). Seventh grade students' mental models of the greenhouse effect. *Environmental Education Research, 17*(1), 1–17. https://doi.org/10.1080/13504620903564549

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climatic Change 104*(3–4), 481-507. https://doi.org/10.1007/s10584-009-9786-9

Shepardson, D. P., Roychoudhury, A., Hirsch, A., Niyogi, D., & Top, S. M. (2014). When the atmosphere warms it rains and ice melts: Seventh grade students' conceptions of a climate system. *Environmental Education Research, 20*(3), 333–353. https://doi.org/10.1080/13504622.2013.803037

Sternäng, L., & Lundholm, C. (2011). Climate change and morality: Students' perspectives on the individual and society. *International Journal of Science Education, 33*(8), 1131–1148. https://doi.org/10.1080/09500693.2010.503765

Stevenson, K. T., King, T. L., Selm, K. R., Peterson, M. N., & Monroe, M. C. (2018). Framing climate change communication to prompt individual and collective action among adolescents from agricultural communities. *Environmental Education Research, 24*(3), 365–377. https://doi.org/10.1080/13504622.2017.1318114

Stevenson, K. T., & Peterson, M. N. (2016). Motivating action through fostering climate change hope and concern and avoiding despair among adolescents. *Sustainability, 8*(1), 6. https://doi.org/10.3390/su8010006

Stevenson, K. T., Peterson, M. N., & Bondell, H. D. (2016). The influence of personal beliefs, friends, and family in building climate change concern among adolescents. *Environmental Education Research, 25*(6), 832-845. https://doi.org/10.1080/13504622.2016.1177712

Stevenson, K. T., Peterson, M. N., Bondell, H. D., Moore, S. E., & Carrier, S. J. (2014). Overcoming skepticism with education: interacting influences of worldview and climate change knowledge on perceived climate change risk among adolescents. *Climatic change, 126*(3), 293–304. https://doi.org/10.1007/s10584-014-1228-7

Stevenson, K. T., Peterson, M. N., & Bradshaw, A. (2016). How climate change beliefs among US teachers do and do not translate to students. *PloS One, 11*(9), e0161462. https://doi.org/10.1371/journal.pone.0161462

Tasquier, G. (2015). How does epistemological knowledge on modelling influence students' engagement in the issue of climate change? *Il nuovo cimento C, 38*(3), 1–14.

Tasquier, G., & Pongiglione, F. (2017). The influence of causal knowledge on the willingness to change attitude towards climate change: results from an empirical study. *International Journal of Science Education, 39*(13), 1846–1868. https://doi.org/10.1080/09500693.2017.1355078

Timulak, L. (2014). Qualitative meta-analysis. In U. Flick (Ed.), *The SAGE Handbook of Qualitative Data Analysis* (pp. 481–495). Sage. https://doi.org/10.4135/9781446282243.n33

UNESCO (2015). *Rethinking education: towards a global common good?* UNESCO. https://doi.org/10.54675/MDZL5552

Yazdanparast, T., Salehpour, S., Masjedi, M. R., Seyedmehdi, S. M., Boyes, E., Stanisstreet, M., & Attarchi, M. (2013). Global warming: knowledge and views of Iranian students. *Acta Medica Iranica*, 178–184.