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What does it take to develop an effective climate change curriculum?

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The present conceptual paper addresses the question: What does it take to develop an effective climate change (CC) curriculum? Three different lenses are applied in developing a comprehensive critical analysis of CC curriculum development. The first lens consists of examining current literary approaches for addressing CC curriculum development. The second lens takes an empirical approach by examining CC inclusion in two exemplary curricula, the Next Generation Science Standards (NGSS), and the State of New Jersey Student Learning Standards (NJSLS), United States of America (USA). The third lens focuses on discussing critical gaps revealed in the analysis. These include CC inclusion through a cross-curricular approach unproblematized; key socio-economic-political concepts underpinning CC not articulated; lack of thematic organization; the importance of non-linear CC thematic organization; terminological consistency; insufficient consideration given for learning progression; and disaster risk reduction—a neglected theme. The paper concludes with a set of recommendations for CC curriculum development and proposes a definition for effective CC curriculum. Overall, this analysis advances the field by identifying conceptual obstacles in existing curricula and proposing a coherent framework for more effective CC curriculum design.

KEYWORDS

climate change education, curriculum, Next Generation Science Standards, New Jersey Student Learning Standards, climate change literacy, national curriculum, curriculum gaps

1 Introduction

This study aims to identify and discuss hindrances for effective climate change (CC) curriculum development and suggest practical recommendations for informing future CC curriculum development. In doing so, it re-evaluates commonly held epistemological assumptions in the field, including those related to the educational goals of CC.

In their contemplation of the reality of education in an era of climate change (CC), Stein et al. (2022) highlighted the urgency and acuteness of the need to prepare students effectively. In their paper entitled "From 'education for sustainable development' to 'education for the end of the world as we know it'", they suggested that

the educational task is not, how do we make 'the house modernity built' more sustainable... Rather, it is, how do we prepare people for the moment when the house can no longer provide even the basic resources necessary to sustain human life? (Stein et al., 2022; p. 280).

Similarly, the philosopher Bruno Latour pondered on the immense challenges involved in transitioning humanity into living with CC, "a land so different from nature" (Latour, 2021; p. 18). He posited: "Adapting? Adjusting? Coping? All sorts of words that mean how to live in the ruins" (p. 20).

Inspired by these philosophers' provocations, this study poses the question: What does it take to educate all students to live and thrive in an era of CC? An era of uncertainties, frequent disasters, and social-economic-environmental instabilities, where tipping points are crossed leading to the unknown (Eilam, 2023). More specifically I ask: What does it take to develop an effective CC curriculum for school students?

In addressing this question, the present study put forward the objectives, to:

1. Conduct a literature review for:
   (i) examining literary approaches for addressing CC curriculum development; and
   (ii) examining reviews of existing CC curricula, with a focus on the USA.
2. Analyze and evaluate two exemplary state curricula, with the purpose of elucidating critical gaps in current approaches to CC inclusion in curricula.

The study is underpinned by an epistemological analysis, including the critical question of whether CC education can and should be integrated within existing science curricula, or whether CC necessitates a distinct curriculum in which science is one of several contributing themes. Addressing this epistemological question is essential for the development of a high-quality CC curriculum.

Methodologically, this conceptual article reaches its conclusions through critical analysis of the literature (see Objective 1); and the empirical evaluation of two existing curricula (see Objective 2).

The herby analysis commences with defining the term *curriculum*. It continues to present literary approaches for addressing CC curriculum and reviews of existing CC curricula. This is followed by an empirical analysis of CC inclusion in the Next Generation Science Standards (NGSS) and in the New Jersey Student Learning Standards (NJSLS). The Discussion that follows elucidated critical gaps in CC curriculum development, and a set of recommendations are offered in conclusion. For the convenience of the readers, a list of acronyms used in this article is presented in Appendix 1.

1.1 Defining curriculum

Curriculum can be defined broadly as "anything that schools do that affects pupils' learning" (Ross, 2000, p. 9); or it may be defined narrowly "as specialized knowledge organized for transmission" (Young, 2014, p. 198, in Eilam, 2023). Across this broad spectrum, Ornstein and Hunkins (2018) offered four categories of definitions for *curriculum*. First, curriculum is "a plan for achieving goals" (p. 26). This definition involves a formally organized set of learning intentions. A second definition perceives curriculum as dealing with 'learning experiences" (p. 26). Rooted in Dewey's philosophy, this definition allows for any educational experience in or out of school to be considered as a *curriculum*. A third definition conceptualizes *curriculum* as "a field of study with its own foundations, knowledge domains, research, theory, principles, and specialists" (p. 27). This definition focuses on curriculum primarily from a theoretical perspective. Finally, *curriculum* may be defined in relation to the subject matter or content organization, dissemination, and assimilation. Often the contents are organized by grade level.

Young emphasized the role of curriculum in enabling students "to acquire knowledge that takes them beyond their experience, and they would be unlikely to acquire it if they did not go to school" (Young, 2014, p. 196). Scholars have also noted the tendency over the past 100 years, for curricular universalization, where curricula are becoming increasingly similar (Baker, 2015). The present study takes the view of *curriculum*, as consisting of any formal document that outlines what students should learn at school and holds some level of authority (Eilam, 2023). From this perspective, both the NGSS and the NJSLS constitute curricula. The first receives its authority through its adoption by USA Departments of Education, whereas the later forms an official state curriculum, mandated by the State of New Jersey.

1.2 Literary approaches to addressing climate change curriculum

Climate change literature rarely addresses the question of what constitutes CC curriculum in a deep and epistemologically meaningful way. Studies discussing CC curriculum commonly belong to one of the following three types: (i) Ideation—studies discussing general ideas that need to be present in CC curriculum, without specifying content and concepts constituting the curriculum (e.g., Cantell et al., 2019); (ii) Science-based—studies specifying the science concepts relevant to CC processes, however, failing to specify critical non-scientific concepts responsible for causing CC and inherently implicated in CC processes (e.g., Shepardson et al., 2012); and (iii) Thematic organization—studies presenting thematic organization of CC, however, lacking concept-specificity (e.g., Eilam et al., 2020). Alongside these three main approaches for addressing CC curriculum, a fourth approach emerged in parallel with CC education literature discussing Disaster Risk Reduction (DRR) education (Selby and Kagawa, 2012). While this body of work positions itself as adjacent to CC education, in this publication it is being considered in the context of CC curriculum development because of its high relevance.

1.2.1 Ideation: studies discussing general ideas that need to inform climate change curriculum

A multitude of publications present aspirations for CC curricula. These are often quite general and not easily translatable into an applicable curriculum, as demonstrated in the following two examples.

The United Nations Educational, Scientific and Cultural Organization (2016), in its publication "Getting Climate-Ready. A guide for schools on climate action", calls for inclusion of environmental, economic, social, cultural, ethical, political, scientific and technological issues in CC education. However, UNESCO repeatedly stresses in its publication that there is no need for a special CC course, but rather, that it should be included in every subject. This approach is criticized theoretically and empirically later in this paper. The guide provides examples of ways in which CC may be included in different subjects. For example in the subject Agriculture/gardening, it is suggested to "Design and maintain a school garden and compost" (United Nations Educational, Scientific and Cultural Organization, 2016, p. 12); in the subject Biology "Measure biodiversity in the school yard or local community" (United Nations Educational, Scientific and Cultural Organization, 2016, p. 12).

However, none of the examples provided present coherent CC concepts, or fully developed themes. They read as an anecdotal collection of minor aspects related to CC.

Cantell et al. (2019) developed a model to demonstrate what the authors regard as the essential aspects of CC education. The model uses a bicycle as a metaphor for representing ten aspects: knowledge, thinking skills, values, identity, worldview, action, motivation, participation, future orientation, hope and other emotions, and operational barriers. The model remains at the ideation level and does not specify the scope of contents constituting CC education.

1.2.2 Science-based: studies specifying the science concepts relevant to climate change

In 2009, several leading United States of America (USA) science organizations, scientists, and educators created a framework entitled "The Essential Principles of Climate Science Literacy" (United States Global Change Research Program, 2009). According to this framework, CC is purely a field within science. The framework presents specific scientific concepts that are important for developing individual and community understanding about Earth's climate, including: (i) The Sun is the primary source of energy for Earth's climate system; (ii) Climate is regulated by complex interactions among components of the Earth system; (iii) Life on Earth depends on, is shaped by, and affects climate; (iv) Climate varies over space and time through both natural and man [*cisgenderism*]-made processes; (v) Our understanding of the climate system is improved through observations, theoretical studies, and modeling; (vi) Human activities are impacting the climate system; and (vii) Climate change will have consequences for the Earth system and human lives (United States Global Change Research Program, 2009, pp. 9–16). While the framework views CC as a field of science, it acknowledges that to be fully climate literate there is a need for input from the social sciences related to economic and social considerations. Regardless of this acknowledgment, the approach to CC is reductionist in that it fails to recognize that CC processes cannot be explained in full, or even in part, while disregarding socio-economic-political driving mechanisms.

In line with this CC conceptualization, Shepardson et al. (2012) developed content scoping for CC school curricula, presenting a "climate system framework for teaching about climate change" (p. 323). Their framework is guided by three questions: (i) What is a climate system and what are the components of the system? (ii) What happens to the system when components within the system change? and (iii) What are the impacts of these changes?

In addition to outlining the CC contents, Shepardson et al. (2012) provide a learning progression consisting of three levels of conceptual development related to the greenhouse effect. To the best of knowledge this is the first systematic attempt to address the issue of progression points in CC curriculum. In their progression framework, Level 1 reflects Grade 6 beginners' conceptual understanding, Level 2 reflects intermediate conceptual understanding reached by the end of Grade 8, and Level 3 reflects advanced conceptual understanding reached by a high-school graduate (Shepardson et al., 2017).

In summary, both frameworks (United States Global Change Research Program, 2009; Shepardson et al., 2012) contribute to advancing CC curriculum development by focusing on explaining the scientific basis of CC, with Shepardson et al. (2012) additionally contributing a learning progression. However, both conceptualize CC as a field of science. This narrow epistemological conceptualization ignores critical socio-economic-political concepts and paradigms that give meaning and trajectories to CC processes. In both frameworks these remain undefined, appearing as invisible unspecified forces captured by descriptors such as: "**We enhanc**e the greenhouse effect **by changing** the carbon and the broader biogeochemical cycles through changes **such as burning** fossil fuels or **changing land** cover (deforestation) ..." (Shepardson et al., 2012, p. 330). Regardless of these invisible forces having the power to "enhance", "change" and "burn", they appear nameless, conceptually unexplained, pushed into the background and overlooked, thus making their contribution to CC curriculum development, partial and incomplete. Future curriculum development needs to bring these CC driving forces to the forefront and identify the underpinning key socio-economic-political concepts. This critical issue is elaborated upon in the final section of this paper.

1.2.3 Thematic organization: studies presenting thematic organization of climate change contents

An attempt to scope CC contents beyond the scientific basis was presented by Eilam et al. (2020). Here, CC contents were presented along a continuum, ranging from Science perspectives to Humanity: Socio-economic-political structures, Networks, Ethics and Conduct Perspectives. Eight themes were identified along this continuum: Observed Changes in Climate; Drivers of CC; Future CC; Risks and Impacts; Adaptation and Mitigation; Socio-Economic; Policy and Governance; and Ethics. Each theme is based on fundamental key questions and essential content knowledge.

While the framework lays out the scope of CC, emphasizing the interconnected nature of the scientific and humanistic bases, further work is required to identify the key concepts and their organization in a curriculum. Also, it is worth noting that regardless of the critical importance of preparing students to deal with CC-related DRR, none of the frameworks developed thus far for informing CC curriculum development specifically addressed this issue.

1.3 Emphasizing the role of disaster risk reduction in climate change education

Preparing students to protect themselves from CC hazards is imperative, given that the incidence of CC disasters worldwide is increasing. In addressing the growing disaster risks, the "Sendai Framework for Disaster Risk Reduction 2015–2030" (United Nations International Strategy for Disaster Reduction, 2015), was developed as a roadmap for creating preparedness for disasters and resilience among communities and nations. The role of education is highlighted in Objective L of the framework, which aims "to promote the incorporation of disaster risk knowledge, including disaster prevention, mitigation, preparedness, response, recovery and rehabilitation, in formal and non-formal education ..." (United Nations International Strategy for Disaster Reduction, 2015, p. 10). This document and its predecessor the "Hyogo Framework for Action 2005–2015" provide the rationale for including DRR in CC education. Accordingly, Selby and Kagawa (2012) developed a list of specific learning outcomes, which could potentially be incorporated into CC curriculum, recognizing the importance of developing the learning outcomes across grade levels. These include disaster specific consequences (e.g., "Learners know of locally and bio-regionally specific hazards and potential sources of disaster" (Selby and Kagawa, 2012, p. 45) and the more general consequences (e.g., "Learners know of internationally agreed upon human and child rights and their implications for and applications in disaster scenarios" (Selby and Kagawa, 2012, p. 52).

This critical aspect seems missing from most discussions regarding CC curricula.

In 2014, UNESCO and the United Nations International Children's Emergency Fund, now referred to as the United Nations Children's Fund, (UNICEF) developed guidelines for supporting the implementation of DRR education in schools. The guidelines outline five essential dimensions of DRR education. These include: "(1) Understanding the science and mechanisms of natural disasters; (2) learning and practicing safety measures and procedures; (3) understanding risk drivers and how hazards can become disasters; (4) building community risk reduction capacity; and (5) building an institutional culture of safety and resilience" (United Nations Educational Scientific Cultural Organization United Nations Children's Fund, 2014, p. 11). Thus far there is limited research examining the application of the guidelines in the context of CC education (Eilam, 2023). In this paper, their application is analyzed in the context of analyzing CC curriculum of the state of New Jersey in the USA. The role of DRR in CC curriculum development is further discussed in the final section of this paper.

1.4 Examination of climate change curricula

Worldwide, there is dearth of fully developed and rationalized CC curricula. To the best of knowledge, the New Jersey Student Learning Standards (NJSLS) (New Jersey Department of Education, 2020) is worldwide, one of the first few fully developed K−12 CC curricula to be published in English (Eilam, 2022). Additionally, it was reported that Italy has a K−12 CC curriculum (United Nations Educational, Scientific and Cultural Organization, 2021a); and that Israel has also developed in 2022 a comprehensive mandatory K−12 CC curriculum that includes extensive teaching resources and teacher professional development workshops (Government of Israel, Ministry of Education, 2023). Both curricula are currently not accessible in English.

Based on this current state of play, the present analysis focuses on CC curricula developed in the USA, the NJSLS (NJDOE, n.d.) and the Next Generation Science Standards (NGSS) (Next Generations Science Standards Lead States, 2013). The NJSLS was selected for its innovativeness in CC curriculum development. The NGSS was selected due to its influence on CC education through Science and Engineering Education. The NGSS is not a national or state curriculum. However, it forms the main curriculum framework for teaching Science and Engineering in the USA K−12 school systems, and influences Science curriculum development worldwide. Furthermore, the NGSS is incorporated in the NJSLS, thus forming a structural component of this CC curriculum. Together the examination of the two curricula provides critical insights into current practices in CC curriculum development, and the evidence-basis for identifying gaps in existing curricula.

In what follows, a brief literature review of CC in USA Science curricula sets the background for the subsequent analysis of the two curricula, first the NGSS, followed by the NJSLS. The analyses include examining CC conceptualization, approach to CC curricular inclusion, and scope of CC contents.

1.4.1 Climate change presence in the USA science curricula

Thus far, few studies have conducted in-depth analysis of CC in existing curricula. Such evaluation was conducted by Johnson and Anderson (2017), and the National Center for Science Education, and Texas Freedom Network Education Fund (2020), in relation to CC representation in the NGSS (Eilam, 2023).

Johnson and Anderson (2017, in Eilam, 2023) highlighted as strengths the aspects of addressing: CC mechanisms; analyzing large-scale data; developing arguments from evidence; characterizing uncertainty; making predictions about the future; and linking Earth's physical and biological processes at multiple scales. In relation to weaknesses, Johnson and Anderson (2017) criticize the curriculum for not recognizing the limits of science, not recognizing the important role of political and economic aspects and ignoring issues of social justice. Overall, they suggest that "the NGSS Performance Expectations fall short of describing the knowledge and practices students will need to be ethical and effective decision makers about climate-change-related issues" (Johnson and Anderson, 2017; p. 118).

The National Center for Science Education, and Texas Freedom Network Education Fund (2020), conducted an in-depth analysis of CC in the Science curricula of the 50 USA states. Three expert CC reviewers assessed the standards by answering six focus questions[1]

1 The reviewers considered six focus questions for each state's science curriculum:

(A) To what extent is the treatment of the issue in the standards helpful in permitting students to reach these conclusions? (B) To what extent is the treatment of the issue in the standards appropriately explicit? (C) To what extent is the treatment of the issue in the standards integrated in a coherent learning progression? (D) To what extent do the standards make it clear to teachers what knowledge and skills students are expected to and assigning a numerical score ranging from A+ (highest score) to F (lowest score). The overall score of a given curriculum was calculated as the average score across the six focus areas. The findings revealed that only 27 states earned a score of B+ or above for their CC representation in the Science curricula. Of these 27 states, 20 and DC have adopted the NGSS. Another 20 states received scores of C+ or below, out of which 10 received a D. Six states received a Fail. The NGSS itself earned a B+. Four states that based their Science curriculum on the National Research Council (2012) framework, but not on the NGSS, received an A-, and one other state that did the same received an A. Importantly, the reviewers expressed concern over all the reviewed standards including the NGSS. Therefore, the authors caution that even states that received Grades A and A- require improvements in their CC education (Eilam, 2023).

The reviewers commented on a set of recurring problems in the treatment of CC within the Science curricula. The first problem was with regard to promoting false debate, where for example the curriculum requires students to debate CC in science class, regard of this being a devise employed by deniers. The reviewers noted that curricula should not yield to the misrepresentation of science facts, and furthermore, that curricula should highlight and expose attempts to manipulate and misrepresent data. Another criticism by the reviewers was the avoidance of some curricula to clearly name CC when addressing CC issues—meaning that some CC issues are addressed without explicitly naming them as such. Still further criticism relates to "muddling the science", by using ambiguous wording, suggesting unclear evidence (National Center for Science Education, and Texas Freedom Network Education Fund, 2020; p. 6). These findings are helpful in identifying some issues related to the conceptualization of CC. However, the analysis does not address the structure and organization of CC concepts in the curricula. Organization, substantive structure and syntactic structure are critical in curricular evaluation, and thus merit further examination. To gain a better understanding of the gaps in CC representation in Science curricula, further in-depth analysis of the NGSS is presented in what follows.

2 Analysis of climate change in the Next Generation Science Standards

The analysis of the NGSS begins with a brief background, followed by a critical discussion of CC conceptualization within the NGSS. It continues to discuss the inclusion of CC in the NGSS by Grade Band. Finally, the findings are summarized.

2.1 Background

The NGSS consists of three interconnected dimensions of learning: Disciplinary Core Ideas (DCIs); Science and Engineering Practices; and Crosscutting Concepts. The Performance Expectations (PE) (standards) reflect the integration of these three dimensions, specifying the knowledge and skills that students need to be able to demonstrate at or across a Grade Band (Harris et al., 2022).

The NGSS was developed on the basis of the NRC's "Framework for K—12 Science Education (National Research Council, 2012), by a consortium of states and organizations working with the NRC (National Center for Science Education, and Texas Freedom Network Education Fund, 2020). Climate change is incorporated in the NGSS as a recommended concept within the DCIs and in most of the Crosscutting Concepts. However, the topic of CC only appears explicitly in Earth and Space Science in one standard in middle-school and four standards in high-school. Foundational climate-related ideas such as the carbon cycle appear at every level from K—12, across four DCIs (DeWaters et al., 2014; Drewes et al., 2018; Next Generations Science Standards Lead States, 2013).

2.2 Interrogating climate change conceptualization within the Next Generation Science Standards

The epistemological interrogation of the NGSS consists of first identifying CC positioning within the framework, followed by examining the conceptualization of CC within the rationales of the relevant core ideas.

CC positioning among the DCIs, suggests that epistemologically, CC forms a sub-idea (ESS3.D: Global Climate Change) within a broader core idea (ESS3: Earth and Human Activity), within the discipline of Earth and Space Science. Thus, conceptually CC is conceived as an idea within another idea within the discipline (Next Generations Science Standards Lead States, 2013, in Eilam, 2023). Appendix 2 presents this epistemological positioning within the framework.

This epistemological positioning of CC becomes even more ambiguous in the reorganizing of the NRC framework into the NGSS curricular standards. In this process some core ideas were regrouped into new categories, which the NGSS identifies as *topics*. In the new topical-organization, CC appears mainly across the topics of: Weather and Climate; and Human Sustainability. Appendix 3 presents the domains and their topics for high-school.

Examination of the rationale explaining Weather and Climate reveals a reductionist approach where CC is conceptualized primarily as a science problem, "with a major emphasis on the mechanisms and implications of climate change" (Next Generations Science Standards Lead States, 2013, p. 90). The focus is on unpacking CC underlying mechanisms and their effects, in what seems to be a primarily science and engineering problem.

In the rationale explaining Human Sustainability, the term CC is conspicuous by its absence. CC is addressed without using the term. Instead, the term *climate* is used when addressing the question of: "How do people model and predict the **effects of**

attain? (E) To what extent would a student who met the performance expectations in the standards relevant to the issue be prepared for further study in higher education? (F) To what extent would a student who met the performance expectations in the standards relevant to the issue be prepared for responsible participation in civic deliberation about climate change? (National Center for Science Education, and Texas Freedom Network Education Fund, 2020, p. 3).

human activities on Earth's climate?" (Next Generations Science Standards Lead States, 2013, p. 91).

In summary, the conceptual analysis of the NGSS suggests that CC is conceptualized as a mere idea, subsumed under other ideas. A reductionist view is taken, presenting CC as primarily a scientific issue (Eilam, 2023).

2.3 Analysis of climate change in the NGSS by grade band

This section presents a brief summary derived from Eilam (2023) of the main findings concerning CC presence in each of the Grade Bands in the NGSS.

Primary-school (Grades K-5). The curriculum specifically instructs not to include CC in primary-school, in two PEs. For example, in Grade 3, PE 3-LS4-4 specifically excludes CC stating that the "assessment **does not include the greenhouse effect or climate change**" (Next Generations Science Standards Lead States, 2013, 3-LS4-4). This age-related decision is further addressed in the Discussion. However, the primary science curriculum does address the development of foundational CC science knowledge from as early as kindergarten. This foundational knowledge is systematically developed across the primary grade levels under the following topics: Kindergarten and Grade 3: Weather and Climate; Grades 2, 4, and 5: Earth Systems; and Kindergarten, Grade 2 and 3: Interdependent Relationships in Ecosystems. Additionally, aspects of DRR address PEs as early as in Grade 3.

Middle-school (Grades 6–8). The analysis reveals three main issues concerning CC representation. First, I note the ambiguous use of terms related to CC. Secondly, muddling the science by suggesting that "human activities… are major factors" (MS-ESS3-5), rather than the only factors. These two issues may be exemplified in Weather and Climate, core idea ESS3.D: Global Climate Change, as follows.

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (**global warming**). Reducing the level of **climate change** and reducing human vulnerability to whatever **climate changes** do occur depend on the understanding of **climate science**, engineering capabilities, and other kinds of knowledge… (MS-ESS3-5).

Thirdly, across the curriculum there is lack in clear distinction between current anthropogenic CC and changes in the climate over geological timescales. This will be discussed in the context of the high-school curriculum.

High-school (Grades 9–12). Five issues emerge from the analysis, which call for attention. The first finding concerns CC conceptualization primarily as a science issue. Secondly, the ambiguity concerning making a clear distinction between the current anthropogenic CC and natural changes in the climate that occurred over geological time scales. This to the extent of muddling the science by suggesting that humans are one factor among others causing CC. Thirdly, there is ambiguity and lack of consistency relating to the use of terms associated with CC. Fourthly, the term CC often appears as an effector or an example of something else. Finally, at times CC is addressed without being explicitly mentioned. Table 1 presents exemplars of these CC appearances, drawn from the high-school curriculum, and presented alongside critical commentary.

2.4 Summary

The review of the NGSS suggests that this curriculum takes CC education a step forward by formally including it in the curriculum, with particular focus on the science aspects of CC. Science concepts are introduced through a learning progression beginning in Grade Band 6–8, with the highest level of complexity introduced in Grade Bands 9–12. This form of conceptual progression seems age-appropriate, as concepts are gradually being developed from simple to complex concepts, systematically constructed.

The analysis reveals areas of ambiguity, four of which are of particular concern, including: (i) the lack in clear distinction between the current anthropogenic CC and natural changes in climate over geological time scales; (ii) lack of conceptual organization; (iii) ignoring non-science based key concepts in CC; and (iv) terminological inconsistency and incoherency. These are discussed sequentially.

The lack of a clear distinction between the current anthropogenic CC and changes in climate over geological timescales may lead to the erroneous conclusion that current anthropogenic CC involves non-human caused factors. In the present political context, there is a concern that this approach may be inadvertently contributing to the false debate about the causes of CC. The findings of the present analysis reaffirm previous critique by the National Center for Science Education, and Texas Freedom Network Education Fund (2020), which criticized the curriculum for its ambiguity by framing human activity as a "major factor" rather than the only factor causing CC.

While the NGSS is successful in addressing key scientific concepts in CC, these concepts appear scattered across various topics and disorganized. The lack of conceptual organization forms a hindrance to teaching and learning CC, as it leaves teachers and students on their own to integrate the various concepts and form a complete understanding of CC key concepts and their interactions across systems. For knowledge to be processed effectively it needs to be systematically structured and organized. In other words, there is "overwhelming research on learning showing the importance of organizational structures for helping students progress to become experts" (California State Board of Education, 2018).

The curriculum fails to identify non-science-based key concepts in CC and address them comprehensively and systematically. This issue is elaborated upon in the final section. Here it is sufficed to state that this finding echoes the critique by Johnson and Anderson (2017). Additionally, this finding has also emerged in the analysis of CC conceptualization by United States Global Change Research Program (2009) and Shepardson et al. (2012) earlier in this paper. All three frameworks leave the human originators and drivers of CC in the background, making these critical aspects invisible.

Across the curriculum there is terminological ambiguity and incoherency. For example, in the core idea Global Climate Change

TABLE 1 Exemplars of CC appearances in the NGSS high-school curriculum, by topics, DCIs/PEs, citations and comments.

Topic	DCIs/PEs	Citation	Comments
Interdependent Relationships in Ecosystems	LS2.C: Ecosystem Dynamics, Functioning, and Resilience	Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and **climate change**—can disrupt an ecosystem and threaten the survival of some species (HS-LS2-7).	CC appears by title only with no further explanations. The term is used to demonstrate an effector of something else. Here CC appears as one cause among others of ecosystems disruptions.
	LS4.D: Biodiversity and Humans	Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and **climate change**. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth … (secondary to HS-LS2-7), (HS-LS4-6).	CC appears by title only with no further explanations. The term is used to demonstrate an effector of something else. Here CC appears as an example for human activities that negatively impact biodiversity.
Natural Selection and Evolution	PE: HS-LS4-4	Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, **long-term climate change**, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.] (HS-LS4-4).	• The term *long term CC* appears unexplained. It is assumed to denote "10–100s of millions of years: long-term changes in atmospheric composition" (HS-ESS2-4). • Lack of distinction between current anthropogenic CC and natural changes in the climate that occurred over geological time scale. • The term is used to demonstrate an effector of something else.
Earth's Systems	PE: HS-ESS2-2	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include **climate feedbacks**, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice …] (HS-ESS2-2).	• The text refers to "climate feedbacks", which form CC processes. Thus, CC is discussed without explicitly being mentioned. • CC conceptualized primarily as a science issue. • Lack of distinction between current anthropogenic CC and natural changes in the climate that occurred over geological time scale.
	PE: HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in **changes in climate**. [Clarification Statement: Examples of the causes of **climate change** differ by timescale, over 1–10 years: large volcanic eruption, ocean circulation; 10–100s of years: changes in human activity, ocean circulation, solar output; 10–100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10–100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of **changes in climate** is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution] (HS-ESS2-4).	• CC conceptualized primarily as a science issue. • Lack of distinction between current anthropogenic CC and natural changes in the climate that occurred over geological time scales. The term CC is used for describing both phenomena, regardless of the fundamental differences in their root causes. The two distinct phenomena are intertwined in a way that may cause CC to be erroneously conceived as a natural phenomenon. • Ambiguous use of terms related to CC.
Weather and Climate	PE: HS-ESS3-5	Analyze geoscience data and the results from global **climate models** to make an evidence-based forecast of the current rate of global or regional **climate change** and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and **climate model** outputs, are for **climate changes** (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of **a climate change** and its associated impacts.] (HS-ESS3-5).	• CC conceptualized primarily as a science issue. • Ambiguous use of terms related to CC.
	ESS1.B: Earth and the Solar System	Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual **climate changes** (secondary to HS-ESS2-4).	Ambiguous use of terms related to CC. Here the plural form of CC is used in the context of changes in the climate over geological timescales.

(Continued)

TABLE 1 (Continued)

Topic	DCIs/PEs	Citation	Comments
	ESS2.A: Earth Materials and System	The geological record shows that **changes to global and regional climate** can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles (HS-ESS2-4).	• CC conceptualized primarily as a science issue. • Lack of distinction between current anthropogenic CC and natural changes in the climate that occurred over geological time scales. • Muddling the science by suggesting that humans are one factor among others causing CC. • CC is discussed without being explicitly mentioned.
	ESS3.D: Global Climate Change	Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts" (HS-ESS3-5).	CC is discussed without being explicitly mentioned.
Human Sustainability	PE: HS-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and **changes in climate** have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of **changes in climate** that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.] (HS-ESS3-1).	• CC is discussed without being explicitly mentioned. • Ambiguous use of terms related to CC. CC implicitly referred to by "changes in climate". • CC appears as one factor among others impacting human activity. • CC is used to demonstrate an effector of something else.
	ESS2.D: Weather and Climate	Current models predict that, although future regional **climate changes** will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global **climate models** strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere (ESS2.D).	• CC conceptualized primarily as a science issue. • CC is discussed without being explicitly mentioned. • Ambiguous use of terms related to CC.
	ESS3.A: Natural Resources	All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors (HS-ESS3-2).	CC is discussed without being explicitly mentioned.
	ESS3.D: Global Climate Change	Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities" (HS-ESS3-6).	CC is discussed without being explicitly mentioned.

Adapted from Next Generations Science Standards Lead States (2013). https://www.nextgenscience.org/search-standards?&tid[]=107.

(HS-ESS3-5), the term *global climate change* reads ambiguous. It suggests that when conceived as a phenomenon, there may be alternative types of CC, which is *local*, or *regional CC*. In other words, there may be two types of CC—*global* and *local*. The fact is that CC is a global phenomenon. While local and regional drivers, processes and impacts may differ, CC is still essentially global, and there are no two types. Further ambiguity appears throughout the curriculum in relation to the use of terms, such as: "climate changes" (MS-ESS3-5), "long-term climate change" (HS-LS4-4), "changes in climate" (HS-ESS2-4), "changes to global and regional climate" (HS-ESS2-4), "… affect climate" (HS-ESS2-4), "global climate models" (ESS2.D). Together, the diverse terms associated with CC, signify that epistemologically, CC is not conceived as a coherent body of knowledge to which there is a designated term. This is a conceptual problem no less than referring to the noun *Biology* by using a verb such as *Biologes* (as analogous to *climate changes*); or disregarding the designated term *Biology* by referring to it by another noun such as *Global bio models* (as analogous to *global climate models*). Furthermore, clarity required regarding the use of the term *long term CC*. The explanation of the term needs to go beyond the definition presented in PE HS-ESS2-4 concerning CC timescales. The current use of the term *long-term CC* may inadvertently be misleading, suggesting that there may be two types of CC, *short term CC* and *long term CC*, further leading to the erroneous conclusion that the current CC is of a *short-term* type (and would potentially go away soon?), as opposed to CC over extended geological periods.

Finally, the review of CC representation in the NGSS reveals the limited suitability of a science curriculum to address the CC in a comprehensive way.

3 Analysis of climate change in the New Jersey Student Learning Standards

Climate change education in the NJSLS to the best of knowledge, is the first effort in the USA, and among the few worldwide, to develop a comprehensive CC curriculum that goes beyond the representation of CC in the Sciences. In June 2020, the State Board of Education adopted the "2020 New Jersey Student Learning Standards", making New Jersey the first state in the USA to incorporate K−12 CC education across Content Areas (New Jersey Climate Change Education Hub, n.d.). The enactment of the new standards began in September 2022. The NJSLS CC curriculum is presented in Appendix 4, by CC core ideas and PEs, Grade Bands and Content Areas. The CC curriculum analysis presented hereby addresses key aspects, including: conceptualization and theoretical rational; use of terminology; content scoping, organization and progression; and DRR (Eilam, 2023).

Notably, NJSLS adopts the NGSS as the curriculum for Science and Engineering. The previous section discusses the NGSS extensively. Thus, the analysis below focuses primarily on the other Content Areas of the NJSLS, excluding Science.

3.1 Conceptualization and theoretical rational

CC is conceptualized as a multidisciplinary topic appearing across all Content Areas in an approach identified by the NJSLS as a cross-curriculum approach (New Jersey Climate Change Education Hub, n.d.). The various parts of the contents making up the topic tend to be included in their relevant Content Areas. However, within each Content Area CC is perceived as multidisciplinary. The curriculum does not provide a rationale or justification for its cross-curriculum approach. It is not clear whether alternative approaches for inclusion were considered; and the extent to which the inclusion approach was substantiated theoretically and empirically.

Pedagogically, the curriculum advocates authentic learning experiences, consideration of a range of perspectives, and collective action. The curriculum states: "Districts are encouraged to utilize the NJSLS to develop interdisciplinary units focused on climate change that include authentic learning experiences, integrate a range of perspectives and are action oriented" (NJDOE, n.d.).

3.2 Use of terminology

Overall, the curriculum attempts to keep the terminology consistent, using the term *CC*. With the current tendency of the mass media to use catchy, sensationalist terms, such as *climate crisis*, this curriculum may be commended for its overall consistency in CC terminology. However, two exceptions were found, where in one PE (Code: 7.1.NM.IPERS.6), CC contents are addressed by the term *climate* instead of *CC*; and in another PE (Code: 1.1.12adv.Cn10b), the term *global warming* appears instead of *CC*. However, these two minor deviations highlight the overall consistent use of the term *CC*.

3.3 Content scoping, organization, and progression

Concerning content scoping, the curriculum does not outline the boundaries of CC as a field of knowledge and the scope of CC contents. The curriculum also presents limited internal organization.

Concerning internal organization, for most other fields, such as History or Biology, content organization is thematic, where themes are methodologically constructed across Grade Bands. When it comes to CC, some thematic organization is found in Social Sciences, mainly in Grade Band 9–12. In the other Content Areas (excluding Science), CC appears mostly by title, giving the reader the impression that CC is metaphorically *sprayed* across the curriculum, rather than being methodologically structured and constructed around specified contents. In these other Content Areas, where CC appears primarily as a title, it seems that teachers and students are left to select their own CC contents. This is a cause for concern because of the high level of sensitivity associated with CC, and the risk it poses to student wellbeing and potential development of climate anxiety. Furthermore, by leaving students to select their own CC content from the media, the curriculum may be contributing to two media-related risks: developing inaccurate CC conceptions and developing CC anxiety. This approach seems counterproductive as it enhances the negative effects of the media, rather than placing schools in a remedial role. To achieve this, CC content needs to be carefully selected and delivered through evidence-based practices, rather than exposing students to unsupervised content randomly selected by the students themselves.

Lastly, the limited content scoping and internal organization across K−12 appear to result in limited attention to learning progression across Grade Bands and between Content Areas within grade bands. Appendix 5 presents the analysis of the curriculum by Grade Bands, focusing on the contents, organization, and progression across the Grade Bands.

3.4 Disaster risk reduction

A review of the curriculum reveals that DRR is addressed in Science through the NGSS, in Grade Bands 3–12. This is exemplified as follows: Grade Band 3–5, Science core idea states: "A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts" (New Jersey Department of Education, 2020). Accordingly, PE 3-ESS3-1 states: "Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard" (New Jersey Department of Education, 2020). Grade Band 6–8 Science core idea states: "Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events" (New Jersey Department of Education, 2020). Accordingly, PE MS-ESS3-2 states: "Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects" (New Jersey Department of Education, 2020). Grade Band 9–12 PE HS-ESS3-1 states: "Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards and changes in climate have influenced human activity" (New Jersey Department of Education, 2020).

The analysis of DRR inclusion in the curriculum suggests that the curriculum primarily focuses on addressing Dimensions 1 and 3 of the five essential dimensions outlined by United Nations Educational Scientific Cultural Organization United Nations Children's Fund (2014). Dimension 2: "Learning and practicing safety measures and procedures" (p. 11), is not addressed. In my view this missing Dimension is the most important of the five, because it directly deals with preparing students to take safety measures that may save lives in hazardous events. From this perspective, the curriculum focuses on the content knowledge related to hazards, neglecting critical skills, mental and physical preparation of students through drill exercises and other educational methods. The omission of practical preparation to take lifesaving measures during CC-related hazards is a concern and needs to be addressed in future CC curriculum development.

3.5 Summary

The analysis of the NJSLS reveals two distinct approaches for including CC. The first is pronounced primarily in the NGSS-based Science, and to a lesser degree in Social Science, where CC contents are specified and there is apparent learning progression, where ideas become more complex across Grade Bands. The second approach is apparent across all other Content Areas, where CC appears as a title, devoid of content. This type of CC appearance lacks learning progression, and the PEs do not seem age appropriate. I suggest that this approach may be putting young students at psychological risk. Curriculum developers should take the responsibility to specify the concepts to be taught in CC and forms of acquisition, in an age-appropriate way.

4 Discussion of critical gaps in climate change curriculum development

The literature review revealed critical gaps in literary approaches to developing CC curriculum. These were further elucidated in the analysis of CC in the two curricula, NGSS and NJSLS. Taken together, the analysis suggests that there are six key issues in CC curriculum development that require in-depth problematizing. These include CC inclusion through a cross-curricular approach unproblematized; key socio-economic-political concepts underpinning CC not articulated; lack of thematic organization; the importance of non-linear CC thematic organization; terminological consistency; insufficient consideration given for learning progression and selection of age-appropriate content; and DRR—a neglected theme.

4.1 Problematizing the cross-curriculum approach to climate change curricular inclusion—Climate change needs to be a subject in its own right

The cross-curriculum approach for including CC in the curriculum is the most advocated approach (European Commission, 2022; Mulvik et al., 2022; United Nations Educational, Scientific and Cultural Organization, 2021a,b). However, theoretical and empirical evidence clearly indicate its ineffectiveness (Eilam, 2023). This idea may be traced back to the suggestion that if CC is a multidisciplinary field of knowledge, it follows that it needs to be implemented in multiple school subjects. This conceptualization is problematic in two ways. First, by giving the false impression that multidisciplinary is a distinguishing epistemological descriptor of CC, and second, by assuming that effective teaching of multidisciplinary knowledge is by dispersing it across the curriculum.

The fact is that multidisciplinarity is a non-distinguishing epistemic characteristic of knowledge. This is because most knowledge produced by humans is essentially multidisciplinary. Science, History, Civics—they all can be characterized as multidisciplinary, and thus multidisciplinarity on its own is not helpful in characterizing CC as a body of knowledge and distinguishing it from other bodies of knowledge. Regardless, while we do not approach the teaching of History or Science by dispersing them across the curriculum, there seems to be an agreement that this approach is a good idea when it comes to CC. This form of fragmentation and dispersal of CC across the curriculum was criticized for posing a range of hindrances for effective teaching and learning, including challenges to curriculum design and implementation, resource development, teaching and teacher knowledge, and learning (Eilam, 2022).

In fact, disciplinary curricular structures are particularly suitable for addressing complex knowledge such as CC. For this reason, in upper secondary subjects, where knowledge becomes more complex, the curricular organization tends to be more disciplinary based compared to that in the lower grades. For a curriculum to be effective in achieving its educational goals, its structure must be intimately connected to the structure of knowledge and its acquisition. For knowledge to be processed effectively it needs to be systematically structured and organized, where key concepts and the connections between them are identified (California State Board of Education, 2018). The dispersal of CC content across the curriculum violates this basic principle of knowledge acquisition.

Empirically, it was found that regardless of the advocacy of the cross-curriculum approach, few countries apply this approach in their curricula, and when they do so, it scarcely filters down into actual implementation (European Commission, 2022; United Nations Educational, Scientific and Cultural Organization, 2021b). The current study supports these findings. The review of the NJSLS reveals that while at the declarative level, the aim was to include CC in a cross-curriculum approach, effectively, only the Science curriculum presented truly meaningful CC contents, with Social Studies lagging behind and presenting limited CC content, mostly in a disorganized way. No other Content Area presented CC content. Instead, CC appeared across most areas of the curriculum by title only. When addressing the discrepancy between cross-curriculum advocacy and poor implementation success, the literature commonly lays the blame on the curricula, schools, and teachers for not trying hard enough (United Nations Educational, Scientific and Cultural Organization, 2021a,b). However, this lack of success is grounded in educational theories and is the most likely expected outcome. Consequently, the complexity of CC and the high level of systems interactions calls for implementing CC as a subject on its own right with dedicated teachers trained to deal with the complexity in a systematic way.

4.2 Key socio-economic-political concepts underpinning CC—Not articulated

The literature review and the curricula analysis consistently revealed that key concepts in the humanities basis of CC are mostly missing. This is contrary to the science basis of CC, where key concepts are identified and presented in a relatively organized way. To develop a complete CC curriculum, it is essential to identify and organize key concepts in humanities. This is because the humanities basis of CC is the only basis that could provide valid explanations for the state of CC and its trajectories. The science on its own cannot provide explanations for many aspects concerning CC.

Concepts form important foundations in curricular structures, in characterizing and explaining phenomena. They provide the cognitive tools for unpacking complexity and understanding the principles of knowledge assemblage, production, verification and evaluation. Some concepts are governed by natural laws, such as the concept of *atom* or the process of *conduction*. However, some concepts in the humanities describe typifying characteristics of operation or relationships, such as the concepts of *free market* and *democracy*. Fields of knowledge are made up of concepts, each having its own explanatory power. Understanding concepts allows the students to generalize and explain phenomena. For example, understanding the concept of *free market* provides a framework for explaining other phenomena, such as why the growth in nations' Gross Domestic Product is accompanied with the growth of inequality.

The lack of key concepts in humanities is a critical omission from CC curricula, leaving it incomplete and not fit for purpose. For example, to understand the exponential rise in global CO_2 emissions since the second half of the twentieth century there is a need to understand the economic paradigm shift occurring at this period, from the Keynesian economy to the neoliberal economy of the Chicago School of Milton Friedman (with its roots in the Mont Pèlerin Society) (Laybourn-Langton and Jacobs, 2018). Among the various impacts of this shift was the opening of markets for free trade and governments stepping back from their regulatory roles, consequently creating the conditions that allowed CO_2 emissions to rise unabatedly.

Curricula reliance on science alone evades critical questions in CC. The following NGSS statement is an example of this oversight: "Changes in the atmosphere due to **human activity have increased** carbon dioxide concentrations and thus affect climate" (Next Generations Science Standards Lead States, 2013, HS-ESS2-6). The empty statement "human activity has increased ..." does not explain why emission growth was slow for over a century post the Industrial Revolution and had quadrupled by 1990 (Ritchie et al., 2020). While science does not hold the answer to this question, understanding the economic paradigm shift and its wider implications does hold the answer.

Another example of the need to develop a fully conceptualized CC curriculum that goes beyond the science, relates to explaining the thirty-year time lag in implementing measures to curb emissions. By 1992 when world leaders gathered at the Earth Summit in Rio de Janeiro, the science of CC was clear and consensual—the massive burning of carbon-based fuels is destroying the climate balance and threatening Earth life support systems (United Nations, 1992). However, thirty years later emissions are still rising. This begs the question: Why? Arguably, if the matter was only an issue of understanding the science, then CC could have been dealt with as effectively as dealing with the ozone depletion. Here again, science does not hold the answers, yet the social sciences do. To understand the thirty-year time lag we need to draw upon social science explanations about the ways in which the fossil fuel companies organized and strategically orchestrated deception and manipulation campaigns to prevent action on CC; and understand the economic political structures that allowed the denial industry to propagate unaccounted for within enabling legal frameworks.

These two examples highlight the need to position CC education on its appropriate footings. CC is not an issue only in the natural sciences, but also in the social sciences and humanities. Nor can it be explained on a science basis only. Scientific explanations form only a limited subset of concepts constituting CC. Thus far, the vast number of CC concepts related to the humanity aspects of CC have not been articulated sufficiently in CC literature, nor in curricula. Instead, the humanity aspects are presented as an amorphous un-explicated notion often disguised under ambiguous explanations such as: "Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior ..." (Next Generations Science Standards Lead States, 2013, MS-ESS3-5). Together, the assumption that CC is predominantly a field of science, and the critical lack of explication of key humanity concepts, hinder effective CC curriculum development.

4.3 Lack of thematic organization

When we think about school curricula, such as Science, Geography or History, a common feature in most curricula is thematic organization of contents. Thematic organization is a key curricular instrument for organizing information for teaching and learning. It allows the breaking down of complexity into smaller units. Within these themes we usually find key concepts that form the building blocks of the themes, and often there is a narrative connecting the concepts within themes. In this way, key concepts are used as steps that assist in constructing meaning and explanations as students develop their understanding along the thematic narrative. Such thematic organization may be demonstrated in the Science curriculum. Table 1 presents the thematic organization of the NGSS. Here each branch of the sciences is broken down into themes and sub-themes (referred to as Disciplinary Core Ideas and Sub-Ideas). For example: the theme PS1 Matter and Its Interactions includes three sub-themes: PS1A Structure and Properties of Matter; PS1B Chemical Reactions; and PS1C Nuclear Processes. In History, thematic curriculum organization may consist of historical periods or the history of different regions or areas.

Contrarily, the analysis of CC curricula revealed only one theme—the science theme. All other matters concerning CC are bundled amorphously on the edges of the science theme, lacking concept specification and thematic narratives. When it comes to the humanities aspects of CC, concept specification and thematic organization are critically important. This is because they provide inroads into the unspecified knowledge often bundled under generic descriptors, such as humanity: "is causing", "affected by", and "needs to solve" CC. The absence of thematic and conceptual organization leaves students to assume that the given packaged knowledge is the only option. It is up to students and teachers to unpack the bundled humanities aspect of CC, with all its complexity, a task which is difficult for experts, and much more so for teachers and students.

When it comes to understanding complexity—the evidence suggests that students require explicit, thematically organized instruction to support their conceptual development (Goldman et al., 2016; Sweller et al., 2019). Organized CC information is required to enable students to effectively integrate multiple concepts in Science and Humanities into coherent epistemic explanations in CC. Thus far there is a dearth of information in scholarly work proposing thematic organization for CC curricula. Eilam et al. (2020) proposed a thematic organization of CC along eight thematic narratives. The above discussion concerning DRR adds a ninth important contribution to CC themes. Further research is urgently required in identifying relevant themes and their underlying concepts for CC curriculum development.

4.4 The importance of non-linear climate change thematic organization

A word of caution is required against the tendency to organize CC curricula in a cause–effect linear form, causing the flattening of the CC body of knowledge and reducing its complexity. It seems to be a common practice to organize CC content along a linear, more-or-less cause–effect, and somewhat chronological narrative. This would commonly take the form of: Causes of CC >>> CC Processes >>> Effects and Impacts >>> Solutions (mitigation and adaptation). This highly simplistic linear organization is reductionist in the sense that it ignores the multiple thematic narratives that are co-operative in the system in multiple directions and influences, creating meanings and trajectories. Such a linear thematic organization would mostly focus on the science aspects only, while ignoring other narratives. For example, under Effects and Impacts, the discussion of impacts on humans may take the following form:

> Coastal regions will be impacted by rising oceans and according to some studies a possibility of more frequent hurricanes (Trenberth, 2005). Prolonged heat waves and drought conditions will stress water and food resources and cause more heat-related deaths (Intergovernmental Panel on Climate Change, 2007). Hotter days will result in poorer air quality and increased ozone alerts (Mickley et al., 2004). … people may be required to change their lifestyles and practices to mitigate global warming, and communities may need to become climate ready, preparing for increased flooding and storm and drought conditions, which may require changes in zoning, land use practices, and agriculture (Pielke et al., 2007; Shepardson et al., 2012, p. 335).

These projections are reflective of a science-based theme. However, other themes may have different stories to tell, in which the full story can only emerge when viewed across multiple themes in a non-linear form. For example, the economic theme may tell the story of the "Tragedy of the Commons" described by Hardin (1968). The idea suggests that in the absence of strict regulations and enforcement, common resources such as air, water and soil are destined for depletion. The neo-liberal free market economic paradigm created the perfect conditions for the CC tragedy to unfold, where many common resources ceased to be common through privatization, and the corporates were permitted to freely exploit both privatized and the commons, through favoring governmental regulations. Here the discussion of effects and impacts would include the impacts of unequal distribution and reduced social resilience on withstanding CC calamities.

Finally, to demonstrate the importance of developing non-linear thematic organization of CC curricula, it may be helpful to think of what other subjects might have looked like if such an organizational approach was applied to them. Imagine, for example, organizing the subject of Biology as follows: Cells >>> Organisms >>> Ecosystems. Evidently critical aspects of Biology become lost in this simplistic cause–effect, linear organization.

4.5 Terminological consistency

The analysis of the NGSS revealed terminological inconsistency and incoherency. This finding is not surprising given the epistemological vagueness of this body of knowledge (Eilam, 2022). Some national policy documents and scholarly research use the terms Climate Education or Climate Literacy (Bieler et al., 2017; United States Global Change Research Program, 2009). CC also seems to be associated with terms such as Carbon Literacy (Government UK Department of Education, 2022); Climate Crisis (Ángel and Cartea, 2020); and Climate Science Literacy (Busch and Román, 2017). Additionally, it is commonly conceived as a theme within multiple other fields such as Education for Sustainable Development (United Nations Educational, Scientific and Cultural

Organization, 2021a,b); and Global Citizenship Education (United Nations Educational, Scientific and Cultural Organization, 2020).

The use of terms such as *climate education* or *climate literacy* rather than *climate change education* in government policies is somewhat surprising, as climate *per se* is studied within the framework of the discipline of Climatology. Using the term *climate education* may give the erroneous impression that CC is equivalent to Climatology. While CC includes climatological concepts, it goes beyond Climatology. Thus, the term presents a reductionist view of CC. Overall, there is a need to address CC through consistent and unified terminology. The term used by the Intergovernmental Panel on Climate Change (IPCC) is *climate change* (Intergovernmental Panel on Climate Change, n.d.). This is the most scientifically accurate name that curricula should be using.

4.6 Learning progression and selection of age-appropriate content

Learning progression forms an important aspect in curriculum development, where the progression of students from novice to expert advances along conceptual progression (Busch et al., 2019). Within curricula, learning progression identifies signposts for aligning standards, instruction, and assessment (Duschl et al., 2011). Additionally, it plays an important role in ensuring age-appropriate delivery, where the concepts taught are appropriate for students' levels of conceptual development (King and Kitchener, 2004).

Regardless of the important roles of learning progression, this issue is only scarcely addressed in the literature in relation to CC curriculum (e.g., Shepardson et al., 2012).

The curricula analysis revealed duality in relation to implementing learning progression. The findings revealed clear learning progression in the NGSS Science curricula. This progression was retained in the NJSLS in relation to the application of the NGSS in Science. The decision by the NGSS not to include CC in primary-school may be underlined by epistemic considerations. As primary-school students may lack the required cognitive maturity to deal with the complex CC mechanisms and feedback loops, as well as insufficient emotional preparedness to deal with the enormity of the threat. However, in all other Content Areas, there was no identifiable conceptual progression. Contrarily some of the standards for the early grades were clearly not age-appropriate. This form of curriculum organization is inappropriate and in the case of CC may be harmful for students' wellbeing (See elaboration in Appendix 5). It is imperative that concepts be built on existing concepts and not appear disconnected and un-explicated. To ensure that CC content is delivered systematically, using age-appropriate pedagogies, future CC curriculum development needs to identify learning progression for each of its themes.

4.7 Disaster risk reduction

The literature rarely addresses DRR as a CC theme. Mapping of global DRR integration into education curricula in 30 case studies by UNESCO/UNICEF reveals that DRR is mostly included in curricula through "infusion," by which DRR topics appear in various subjects (Selby and Kagawa, 2012). The present analysis reveals that DRR is only included in Science, in the NGSS, and in the Science curriculum of the NJSLS. There was no indication for Selby and Kagawa's (2012) notion of *infusion*. Furthermore, while the Standards touch upon CC hazards, they are not presented as such in the Science curriculum. Further work is required in developing DRR in CC in a more integrated and purposeful way.

5 Conclusions

In concluding this critical analysis, a set of recommendations are offered for consideration in further development of CC curriculum:

- CC is not a field of Science. CC is a comprehensive, interconnected body of knowledge extending beyond the boundaries of Science, and thus, it should not be conceptualized as a field of Science.
- The cross-curricular approach to including CC is theoretically unsubstantiated and empirically ineffective. CC should be taught as a subject or a topic on its own right.
- CC curriculum development needs to identify thematic narratives and their constituting concepts. There needs to be organization across themes and within themes. Concepts within themes need to be organized along selected narratives. The NRC framework (National Research Council, 2012) provides a good example for thematic organization in Science. A similar approach may be applied in CC curriculum development.
- DRR needs to form part of CC curricula, most likely as a theme. Students of all ages need to participate in exercise drills preparing them to protect themselves from hazardous CC events. I suggest that drill exercises as a stand-alone learning activity could be applied across all Grade Bands.
- A complete CC curriculum needs to identify learning outcomes related to both content and skill acquisition, set performance expectations, and present forms of assessment.
- There is a need to develop learning progression across themes and/or within themes, as appropriate.
- Carefully consider age-appropriate content. CC appears to be an inappropriate subject for primary-school students. It is beyond the scope of this study to discuss the issue in-depth. However, it is evident that CC is probably one of the most complex fields of knowledge taught at school and requires sufficient cognitive and emotional epistemic development and preparedness prior to addressing this high level of complexity. However, primary years are important in forming the conceptual foundations for later understanding of CC. Such knowledge basis may include, for example, weather and climate, forms of governance and more.
- Curricula need to use one consistent term in addressing CC. It is suggested to follow the IPCC and use *climate change* as the agreed term describing the school subject.

5.1 Defining effective CC curriculum

Based on the recommendations above it is proposed to conceptualize an effective CC curriculum as follows: CC curriculum needs to be effective in preparing students to protect themselves and adapt to CC calamities, as these present themselves in various local contexts. Secondly, it needs to equip students with the knowledge and skills for understanding CC thematically, across the complex interconnected themes comprising CC. Finally, CC curriculum needs to provide students with sufficient knowledge and skills-basis for allowing them to progress their learning to become experts and work professionally in CC.

5.2 Further research

The present paper focused on tackling the problem of CC curriculum content identification and organization, as a priority. However, a complete CC curriculum needs to address additional aspects, which are beyond the scope of this position paper. These include, for example, identifying CC values, relevant skills, and pedagogies for teaching. A CC curriculum also needs to consider the critical question of how to teach students about the evident calamities of CC, while at the same time maintain students' wellbeing. Teachers need to be equipped with effective pedagogical tools for preventing the development of climate anxiety and addressing it, if arises. The present position paper aimed to contribute to some aspects involved in CC curriculum development, however, further research is required for addressing the various open questions concerning CC curriculum development and implementation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

EE: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1572965/full#supplementary-material

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