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RESEARCH ARTICLE

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Climate change education: The shape of curriculum and pedagogy

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ABSTRACT

This paper presents a two-stage scoping review of 67 studies published between 2010 and 2025, mapping the development of curriculum and pedagogy in climate change education (CCE), and serves as the introduction to a special issue of the Journal of Environmental Education that examines the state of curriculum and pedagogy in climate change education (CCE). The review identifies trends across theoretical framing, policy alignment, curricular design, and teacher and student perspectives. Findings show that CCE research is expanding but remains emergent, characterized predominantly by qualitative, descriptive work situated in formal education, especially university. Limited theorization, scarce policy-focused scholarship, and few evaluative or mixed-methods studies highlight key gaps. The eight papers included in this special issue address some of these gaps by advancing innovative pedagogical approaches, new curriculum designs, and insights into learner and teacher dispositions.

KEYWORDS

climate change education;
curriculum; pedagogy;
scoping review

Introduction

Climate change is a pressing issue that poses significant challenges for present and future generations of humans and more-than-humans (Duffy et al., 2019; Intergovernmental Panel on Climate Change, 2023). Accelerating climate change impacts such as extreme weather events, biodiversity loss, and social inequality have attracted global attention from politicians, policy makers, scientists, researchers, activists, the public, and more recently educators. This shift acknowledges that formal, non-formal and informal education forms part of a broader overall response to climate change mitigation, adaptation and resilience and is recognized as a critical lever for equipping current and future generations with the necessary competencies to address climate change (Cordero et al., 2020; Larri & Whitehouse, 2019; United Nations Educational, Scientific and Cultural Organization [UNESCO], n.d., 2023; White et al., 2023). International frameworks such as the United Nations Sustainable Development Goals also explicitly position education as underpinning a climate response, emphasizing the need for transformative learning that fosters agency, critical thinking, and climate justice (United Nations, 2015; UNESCO, 2021). Curriculum and pedagogy are central to education and, therefore, to any education strategy for climate change action.

This special issue of the Journal of Environmental Education is grounded in the findings of a scoping review we conducted on curriculum and pedagogy in climate change education (CCE). The purpose of the review was to examine the state of play in the field to shape the focus of this issue. Accordingly, the search for studies was intentionally opened to include diverse fields. This resulted in the inclusion of studies from disciplines such as health sciences, architecture, planning, theology, education, and social

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work. Against this background, we begin below by presenting an overview of research in the field. We then analyze the theoretical frameworks, methodological approaches and practices evident in the existing literature before identifying how the contributions to this special issue offer new insights advancing understandings of curriculum and pedagogy in CCE and conclude with where gaps remain.

The state of play

As far as we can ascertain, no previous study has provided an overview of curriculum and pedagogy in CCE. Existing reviews have tended to focus on broader research trends and innovations (e.g., Bhattacharya et al., 2021b); Borde et al., 2024; Kranz et al., 2022; Muccione et al., 2025; Rousell & Cutter-Mackenzie-Knowles, 2020; Westphal et al., 2025) and issues of justice in CCE (e.g., Trott et al., 2023). There is one systematic review (Monroe et al., 2019) that comes closer to our work, which reports on evaluations of educational practices to identify effective strategies for the teaching and learning of CCE. Our scoping review, along with the articles in this issue, seeks to build on and update Monroe et al. (2019) findings by focusing specifically on aspects of CCE curriculum and pedagogy.

Although there are some promising developments, this scoping review indicated that research on CCE curriculum and pedagogy is in its early stages. We conducted two discrete searches across three databases using identical keywords. The first in July 2023 with the keywords “climate change”, and “pedagogy” and/or “curriculum” returned 104 results, 28 and 9 respectively. A repeat search in May 2025 with the same keywords returned 186, 53 and 14 results. While higher numbers of publications in 2025 indicates growing interest and activity, the overall low publication count confirms that the field is emerging, highlighting a need for further scholarly attention and development.¹ The limited research focus on curriculum is supported by Westphal et al. (2025), who note that although curriculum-related themes are beginning to emerge, they remain underdeveloped. Following an explanation of the process and analysis of the scoping review directly below, we delve into the findings.

Scoping review process and analysis

A scoping review aims to systematically identify, map and synthesize the nature, breadth and depth of a field of research (Grant & Booth, 2009; Pollock et al., 2024). The approach provides a rigorous and transparent method for collating and describing the volume, nature, and key characteristics of the field (Arksey & O'Malley, 2005; Pham et al., 2014). In the context of this work, the scoping review method provided an efficient way to gather and organize research on CCE curriculum and pedagogy dispersed across diverse journals and fields. Importantly, the method facilitated identification of areas where research is abundant and where gaps exist, helping to shape the focus of this special issue.

The process for the scoping review was based on Arksey and O'Malley (2005) protocol with five stages, outlined below.

Formulating a research question:

The review was guided by the overarching question: What is known about CCE curriculum and pedagogy?

We elaborated this question into three sub-questions:

- (a) What is the volume, nature, and key characteristics of CCE curriculum and pedagogy research?
In what ways is research on CCE curriculum and pedagogy well developed and/or limited?
- (b) What priorities for future research in CCE curriculum and pedagogy can be identified?

Identifying relevant studies

Two separate searches were conducted across ERIC, Informit A + Education, and Scopus databases using the keywords “climate change”, and “pedagogy” and/or “curriculum” in July 2023 and again in May 2025 (Figure 1). The three databases were chosen after careful review and consideration, based on our research

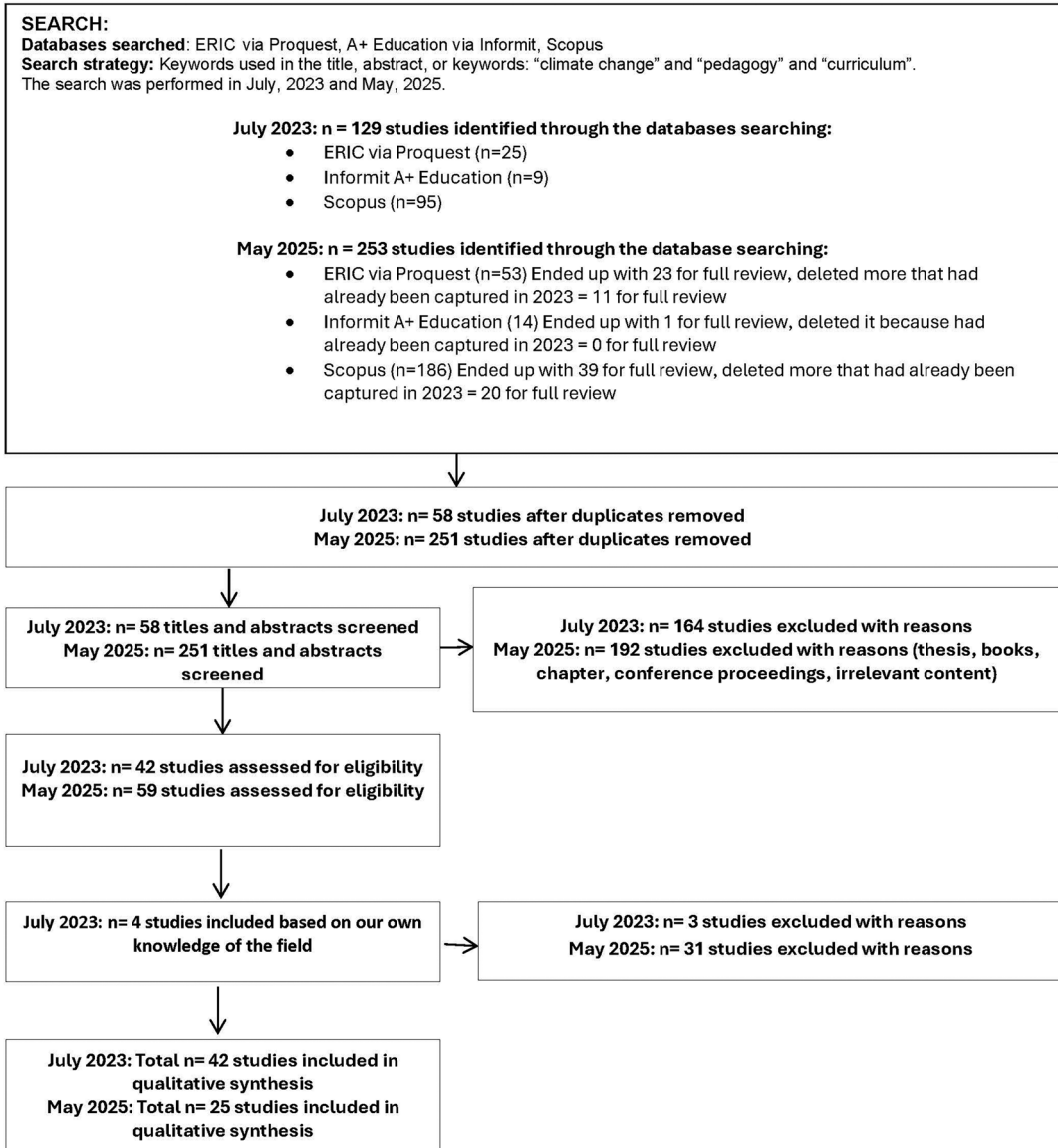


Figure 1. Summary of research process.

experience and knowledge that each database offers unique strengths and coverage relevant to education. Combined, ERIC and Informit A + Education provide extensive access to a broad range of education literature, including that pertaining to school and higher education, teacher education, and environmental and sustainability education. Scopus is the largest global abstracting and indexing database of peer-reviewed literature, including that pertaining to Education (Ghani et al., 2022; Osman & Napeah, 2021). The search was limited to peer reviewed articles written in English containing the keywords in the title and/or abstract.

Selecting studies

As noted above, we conducted two searches almost two years apart. This two-stage approach was necessary to ensure currency because the development of the special issue occurred over an extended period. The first (2023) database search yielded a total of 129 studies: 25 in ERIC, 9 in Informit A + Education,

and 95 in Scopus. In addition, during the 2023 stage of screening, four full-text studies were included based on the authors' knowledge of the field. The second (2025) database search yielded a total of 253 studies—representing all studies returned at that time (including studies already captured in 2023): 53 in ERIC, 14 in Informit A + Education, and 186 in Scopus (Figure 1).² On both occasions, the first author evaluated the titles and abstracts online for relevance according to the agreed focus of the special issue: research on CCE curriculum and/or pedagogy. Those studies that met the criteria were then downloaded into Endnote and full copies sought. This resulted in a total of 42 studies in 2023 and a further 25 in 2025 that were retained for review.

Charting the data

To extract and organize relevant information from each study, we developed a matrix using Microsoft Excel. The matrix captured key characteristics of each study, including publication year, country of origin, research type (empirical, non-empirical), research approach (qualitative, quantitative, mixed methods), research purpose (descriptive, intervention, evaluation), education sector (formal, informal, non-formal), education context (university, vocational education, primary, secondary, community) and aspect of climate change curriculum or pedagogy investigated (e.g., curriculum content, pedagogical strategies). The studies were evenly distributed among the four authors and each independently reviewed their assigned study, extracted relevant data and populated the matrix. During this process, studies were excluded if they did not directly address an aspect of CCE curriculum and/or pedagogy. For example, studies that discussed CCE in general terms, without specific focus on curriculum or pedagogy, were excluded. Upon completing independent paper reviews, the four authors met to discuss any discrepancies or uncertainties in the data extraction and/or matrix. This collaborative step ensured consistency in the interpretation and extraction of data across the review pattern.

Collating, summarizing and reporting results

This section of the scoping review involved collating data from both searches (2023 and 2025), analyzing the data and summarizing findings for reporting. The analysis provided an overview of the development of the field over time, the predominant areas of focus within the literature, (i.e., four themes pertaining to curriculum and pedagogy: Curriculum and pedagogical theory, curriculum and pedagogical policy, curriculum and pedagogical design, and teacher and student perspectives). This enabled us to identify existing gaps and underexplored topics in the field. We explain our findings below.

Scoping review findings

Demographics

Figures 2 and 3 illustrate the geographical and temporal distribution of CCE curriculum and pedagogy research *via* region and year. The geographical distribution (Figure 2) reveals a pronounced concentration of research in North America, which accounts for the majority of studies. Europe, Australasia and Asia represent a middle tier. While independently no one region matches North America's dominance, their combined output reflects emergent research capacity. This is particularly the case with Australasia given its smaller population. In contrast, Africa and South America are underrepresented with few publications, highlighting gaps in global scholarship.

The temporal distribution (Figure 3) indicates steady growth in CCE curriculum and pedagogy research, with a notable surge from 2019 and onwards. North America dominates across the timeline contributing 36 studies between 2010 and 2025; Europe (10 studies) and Australia (9 studies) account for a more moderate representation between 2012 and 2023. Asia (7 studies) shows a gradual rise between 2020 and 2023, signaling emerging representation. In contrast, Africa (3 studies) and South America (2 studies) exhibit limited activity between 2018 and 2023.

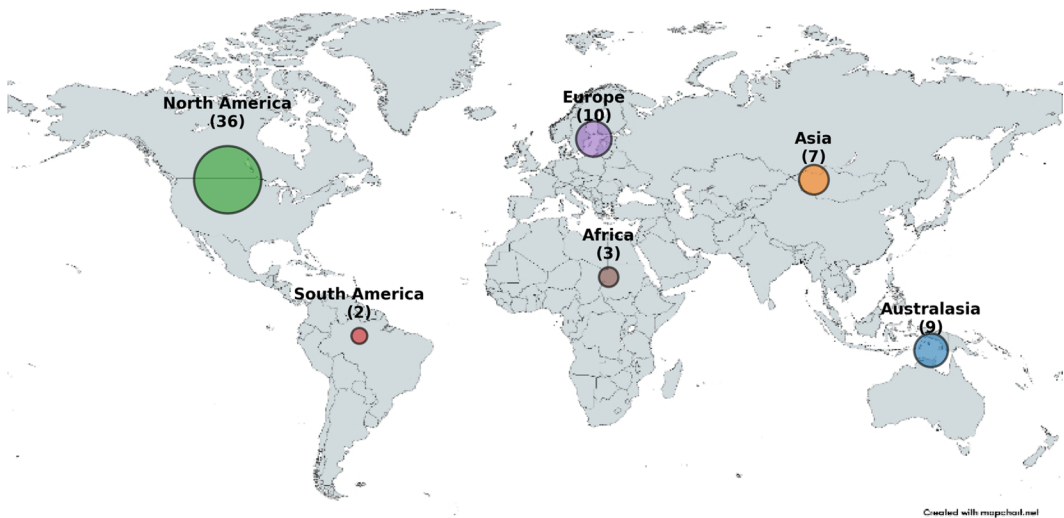


Figure 2. Geographical distribution of curriculum and pedagogy in climate change education research to May 2025.

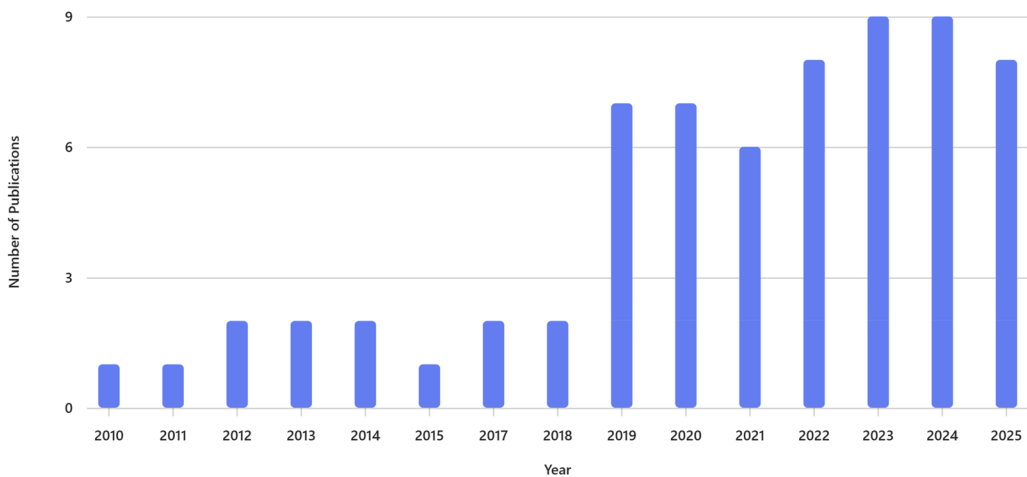


Figure 3. Temporal distribution of curriculum and pedagogy in climate change education research to May 2025.

Research approach, purpose, education sector and context

This section reports on the distribution of empirical studies according to research approach, purpose, education sector and context (Table 1). Out of a total of 67 studies, 45 were classified as empirical—those collecting and analyzing new or primary data, and 22 non-empirical—those which drew on theoretical, conceptual, or analytical arguments rather than new data. Empirical studies were subsequently classified by research approach (quantitative, qualitative, or mixed methods) and research type (descriptive, intervention, or evaluation), reflecting differences in how data were generated and the purpose for which they were used (e.g., describing phenomena, implementing new strategies, or evaluating a program or other intervention). Non-empirical studies were not assigned to categories, as the research approach and purpose typology applies to empirical work only.

Analysis of the 45 empirical studies indicates a diverse research landscape. Table 1 shows that qualitative research approaches dominate the field (26/45), followed by mixed methods (12/45) and a smaller number of quantitative designs (5/45) (two studies did not specify an approach). Descriptive studies dominate research purpose (18/45), with fewer intervention (16/45) and evaluation studies (11/45), indicating that most empirical work focuses on examining or characterizing practices rather than

Table 1. Distribution of empirical studies according to research approach, research purpose, education sector and education context.

Research approach	Citations
Qualitative	Audley and D'Souza (2024); Beasy et al. (2023); Bezner Kerr et al. (2019); Bramwell-Lalor et al. (2024); Cutter-Mackenzie and Rousell (2019); Eilam et al. (2020); Favier et al. (2024); Field et al. (2023); Hamin and Marcucci (2013); McGregor (2015); Neimanis and McLauchlan (2022); Nxumalo and Montes (2023); Perkins et al. (2018); Ranta (2023); Ross et al. (2021); Scherrer (2022); Solis et al. (2022); Szczepankiewicz et al. (2021); Thenga et al. (2021); Timon et al. (2019); Tomren (2022); Verdini et al. (2025); Verlie (2017); Volkmann and Fraunhofer (2023); Wu and Greig (2022); Yasukawa (2023).
Quantitative	DeCamp (2024); DeVincenzo et al. (2025); Duffy et al. (2019); Tang (2023); Zeeshan et al. (2021).
Mixed methods	Afroz (2020), Burkholder et al. (2017), Carroll Steward et al. (2024), Clark (2024), Cordero et al. (2020), Flener Lovitt et al. (2025), Kittipongvises and Salathong (2024), Meguro (2024), Siegner (2018), Tookes and Legee (2024), Touchet et al. (2024), and Trott (2022).
N/A	Camill (2011); Roy et al. (2022).
Research purpose	
Descriptive	Afroz (2020), Beasy et al. (2023), Ben Zvi Assaraf et al. (2025), Favier et al. (2024), Field et al. (2023), Flener Lovitt et al. (2025), Hamin and Marcucci (2013), Kittipongvises and Salathong (2024), McGregor (2015), Nxumalo and Montes (2023), Perkins et al. (2018), Roy et al. (2022), Scherrer (2022), Timon et al. (2019), Tomren (2022), Verdini et al. (2025), Wu and Greig (2022), and Zeeshan et al. (2021).
Intervention	Audley and D'Souza (2024), Camill (2011), Carroll Steward et al. (2024), Clark (2024), Cutter-Mackenzie and Rousell (2019), DeVincenzo et al. (2025), Meguro (2024), Neimanis and McLauchlan (2022), Ranta (2023), Ross et al. (2021), Solis et al. (2022), Thenga et al. (2021), Touchet et al. (2024), Trott (2022), Volkmann and Fraunhofer (2023), and Yasukawa (2023).
Evaluation	Bezner Kerr et al. (2019), Bramwell-Lalor et al. (2024), Burkholder et al. (2017), Cordero et al. (2020), DeCamp (2024), Duffy et al. (2019), Eilam et al. (2020), Siegner (2018), Szczepankiewicz et al. (2021), Tang (2023), and Tookes and Legee (2024).
Education sector	
Formal	Afroz (2020), Audley and D'Souza (2024), Beasy et al. (2023), Ben Zvi Assaraf et al. (2025), Bramwell-Lalor et al. (2024), Burkholder et al. (2017), Camill (2011), Carroll Steward et al. (2024), Clark (2024), Cordero et al. (2020), Cutter-Mackenzie and Rousell (2019), DeCamp (2024), DeVincenzo et al. (2025), Duffy et al. (2019), Eilam et al. (2020), Favier et al. (2024), Field et al. (2023), Flener Lovitt et al. (2025), Hamin and Marcucci (2013), Kittipongvises and Salathong (2024), Meguro (2024), Neimanis and McLauchlan (2022), Perkins et al. (2018), Ranta (2023), Ross et al. (2021), Roy et al. (2022), Siegner (2018), Solis et al. (2022), Szczepankiewicz et al. (2021), Tang (2023), Thenga et al. (2021), Tomren (2022), Tookes and Legee (2024), Touchet et al. (2024), Verdini et al. (2025), Volkmann and Fraunhofer (2023), Wu and Greig (2022), Yasukawa (2023), and Zeeshan et al. (2021).
Informal	McGregor (2015); Scherrer (2022)
Non-formal	Bezner Kerr et al. (2019), Nxumalo and Montes (2023), Timon et al. (2019), and Trott (2022).
N/A	Scherrer (2022).
Education context	
Primary education	Beasy et al. (2023); Cutter-Mackenzie and Rousell (2019); Ranta (2023).
Secondary education	Carroll Steward et al. (2024), Clark (2024), Eilam et al. (2020), Field et al. (2023), Ross et al. (2021), Solis et al. (2022), Thenga et al. (2021), Touchet et al. (2024), Verdini et al. (2025), and Zeeshan et al. (2021).
K-12 education	Audley and D'Souza (2024), Ben Zvi Assaraf et al. (2025), Bramwell-Lalor et al. (2024), DeVincenzo et al. (2025), Favier et al. (2024), Siegner (2018), Szczepankiewicz et al. (2021), and Tomren (2022).
VET education	Yasukawa (2023).
University education	Afroz (2020), Burkholder et al. (2017), Camill (2011), Cordero et al. (2020), DeCamp (2024), Duffy et al. (2019), Flener Lovitt et al. (2025), Hamin and Marcucci (2013), Kittipongvises and Salathong (2024), Meguro (2024), Neimanis and McLauchlan (2022), Perkins et al. (2018), Roy et al. (2022), Szczepankiewicz et al. (2021), Tang (2023), Tookes and Legee (2024), Volkmann and Fraunhofer (2023), and Wu and Greig (2022).
Non-formal	Farming community (Bezner Kerr et al. (2019); summer camp (Nxumalo and Montes (2023); church group (Timon et al., 2019); after-school program (Trott, 2022).
Informal	UK camp for climate action (McGregor, 2015); rural Louisiana neighborhood (Scherrer, 2022).

assessing the impact of specific pedagogical or curricular strategies. Research is concentrated overwhelmingly in the formal education sector (38/45), with only limited work in the non-formal (4/45) and informal (2/45) sectors. Within formal education, university settings are most frequently represented (18/45), followed by secondary (10/45) and K–12 contexts³ (8/45), with comparatively limited research in primary (3/45) or vocational education (1/45). In the non-formal sector (4/45), studies captured here took place

in alternative learning environments such as afterschool programs, summer schools, farming communities, and church settings. Informal sector studies were focused in a rural Louisiana neighborhood and a UK camp for climate action.

Findings across the categories indicate that CCE curriculum and pedagogy research is heavily weighted toward qualitative approaches, less so mixed methods, and minimally, quantitative approaches. Research purposes tend toward more descriptive than intervention and evaluation studies.

The field also appears to be more dedicated to describing CCE curriculum and pedagogy than to evaluating practices. Last, CCE curriculum and pedagogy in informal and non-formal settings is also limited, highlighting opportunities for future research. Now, to make sense of how these patterns translate into CCE scholarship, we organized the studies into four themes: Curriculum and pedagogical theory, curriculum and pedagogical policy, curriculum and pedagogical design, and teacher and student perspectives.

Curriculum and pedagogical theory

CCE curriculum and pedagogical theory appears underdeveloped. Studies exhibit several characteristics, including how pedagogical theories influence practice (Audley & D'Souza, 2024; Jorritsma, 2022; Neimanis & McLauchlan, 2022); how learning theories provide a framework for CCE (Leite, 2024), the way practice could enact such theory (Höhle & Bengtsson, 2023); or the potential for curriculum or pedagogical theory to critique existing programs, for example, corporate influence on CCE (Eaton & Day, 2020). Most of the research operated within the anthropocentric and critical traditions, including anti-oppressive and emancipatory pedagogies (Salinas et al., 2023; Scherrer, 2022; Timon et al., 2019), eco-literacy approaches in higher education (Jorritsma, 2022), and how transformative learning theory provides a holistic framework (Leite, 2024). A smaller body advances post-humanism, adopting a subject-object ethical relation through co-emergence of human subjects *with* climate change (Verlie, 2017) or exploring new metaphors that inform worldviews around climate change (Timon et al., 2019; Verlie, 2017). Collectively, these studies demonstrate there is significant capacity for deeper theorization of curriculum and pedagogy.

Curriculum and pedagogical policy

Research that explicitly focuses on curriculum and pedagogical policy is minimal. Studies examine the alignment (or misalignment) of CCE between international bodies and the Ministry of Education curricula, as well as between higher education research and public outreach, often through top-down approaches (Field et al., 2023; Kittipongvises & Salathong, 2024). Others adopt bottom-up approaches, using curriculum analysis to highlight gaps in national policy (Chew-Hung & Pascua, 2017). Although small in number, this work highlights the importance of policy in shaping possibilities. It also exposes significant capacity in curriculum and pedagogical policy for further research.

Curriculum and pedagogical design

Our review found an emerging critical analysis of what curricula does (Bramwell-Lalor et al., 2024; Eilam et al., 2020) and should contain (Shepardson et al., 2012). Studies examine where in the curriculum CCE might be taught (Beasy et al., 2023), issues such as whether CCE should focus on mitigation or adaptation (Krasny & DuBois, 2019), and how distributed leadership across siloed curriculum areas can support integration (Davison et al., 2014). A curriculum based on sustainable systems and modeling shows promise for building climate literacy and intentions to act (Bhattacharya et al., 2021a; Burkholder et al., 2017), with ICT-based systems adding further value (Markowitz et al., 2018). CCE is increasingly included across diverse fields such as planning (Hamin & Marcucci, 2013), social work (Holbrook et al., 2019), green building (Solis et al., 2022), and nursing (Wasco, 2019). Evaluations of school curricula demonstrate benefits of integrated and embodied curricula approaches (Siegnier & Stapert, 2020; Flener Lovitt et al., 2025), and that assessing climate literacy and complex reasoning is challenging (Perrin, 2023; Siegnier, 2018).

Pedagogical design work highlights transformative, affective, hope, community-based and indigenous relational pedagogies (Beasy et al., 2023; Buchanan et al., 2021; Casas et al., 2021; Leite, 2024; Nxumalo & Montes, 2023; Verlie et al., 2021). Studies highlight ideas such as embedding CCE into adult literacy development (Yasukawa, 2023) and involving the voice of youth (Rousell & Cutter-Mackenzie-Knowles, 2020). This area, however, does require more evaluative studies of pedagogical outcomes. Evaluating the effectiveness of pedagogical moves shows the potential of experiential, climate action planning projects (Camill, 2011), and of connecting to localized knowledge and groups (Ross et al., 2021), but more evaluative studies of pedagogical outcomes are required.

Teacher and student perspectives

Research on teacher perspectives reflects that teachers recognize the importance of CCE, but face implementation barriers. Teachers view CCE as a cross-disciplinary priority that extends beyond science subjects to include social justice and economic issues (Beasy et al., 2023; Ben Zvi Assaraf et al., 2025; Howard-Jones et al., 2021; Perkins et al., 2018; Yasukawa, 2023). At the same time, teachers differ in how they conceptualize the purpose of CCE—ranging from transmissive to transformative and from instrumental to emancipatory (Favier et al., 2024). Across studies common implementation challenges include personal beliefs (Plutzer & Hannah, 2018), systemic constraints—such as time, lack of professional development programs or funding, resources, and the absence of climate change in curriculum (Foss & Ko, 2019; Hestness et al., 2014), sociopolitical pressures, and contending with their own and students' emotional experiences of climate change content (Ferguson, 2022).

Studies focused on student perspectives of CCE reinforce its complexity. Youth report high levels of climate anxiety and a desire for politically literate, social justice oriented, emotional and action-focused CCE (Bright & Eames, 2020; Tomren, 2022). Students are also interested in co-designing courses (Clark, 2024) and multidisciplinary learning (Tolppanen & Aksela, 2018). Jointly, the body of work on teacher and student perspectives highlights the importance of attending to the dispositions and needs of both teachers and learners in designing effective CCE.

Taken together, this review indicates a field that is expanding in scope but still emerging in depth and maturity. Research on curriculum and pedagogical theory is limited, with most studies drawing on applied pedagogical or critical traditions and only a small number exploring emerging post-humanist perspectives. Policy focused research is particularly sparse and is largely comprised of descriptive analysis of alignment gaps or pathways for change. By contrast, work on curriculum and pedagogical design is more developed, encompassing diverse contexts, pedagogical approaches, and early evaluative studies, though evidence of impact is uneven and largely small-scale. Studies of teacher and student perspectives highlight strong demand for better support, justice-oriented pedagogies, and action-oriented learning; though also highlight constraints, emotional challenges, and variability in teacher orientations. Across these studies there is a strong case for research-informed CCE professional development for teachers, as well as a gap in research centered on child and youth perspectives on CCE curriculum and pedagogy, particularly co-designed approaches.

In summary, existing research on CCE curriculum and pedagogy is transitioning from early descriptive work to more nuanced, critical and evaluative inquiry, signaling opportunities for more theoretically grounded, interdisciplinary, and systematically evaluated studies to advance the field. Against this backdrop, the next section delves into the studies included in this special issue to consider how they offer fresh insights and advance the field.

A discussion on the new contributions

This special issue comprises eight studies, including six empirical and two non-empirical contributions, which set the stage around how CCE is conceived, where it happens, and what counts as evidence. The empirical corpus is methodologically diverse with three qualitative (Craig et al.; Karsgaard et al.; Rahmian et al.), two quantitative (Ceyhan et al.; Kruke & Sinatra), and one mixed methods study (Arcos-Alfonso

& Carranza-Barona). The two non-empirical studies include a systematic review (Lahiri et al.) and a conceptual/theoretical contribution (Stein et al.). In terms of research purpose, the balance tilts slightly toward intervention with four such studies (Rahmian et al.; Karsgaard et al.; Ceyhan et al.; Craig et al.), alongside three descriptive studies (Lahiri et al.; Stein et al.; Kruke & Sinatra) and one evaluation study (Arcos-Alfonso & Carranza-Barona). Most work is situated in the formal education sector with only one study conducted in a non-formal context (Craig et al.) and one nonspecific to any education sector (Stein et al.). Contextually, the studies are evenly distributed with four across K-12 schools (Lahiri et al.; Ceyhan et al.; Kruke & Sinatra; Craig et al.) and four across universities (Arcos-Alfonso & Carranza-Barona; Stein et al.; Rahmian et al.; Karsgaard et al.).

Across the eight studies, pedagogical innovation and analysis emerge as the dominant focus of CCE research (5/8). Rahmian et al. develop and test a person-centered CCE pedagogy that foregrounds identity interest alignment, empathic listening, and learner agency. Karsgaard et al. examine online, arts-based, place-based pedagogy, showing how participatory storytelling can foster trans-local learning and affective connection in graduate education. Stein et al. extend these pedagogical innovations to the development of what they call Critically Engaged and Complexity Informed Climate Education (CECE). CECE advances a curricular and pedagogical theory grounded in 'depth education,' inviting communities to interrupt and un/learn the harmful habits of knowing, being, and relating to ecological destruction while accepting responsibility for healing through repair and regeneration. Its design principles—emotional stability, intellectual discernment, relational maturity, and intergenerational and interspecies responsibility—offer a distinctive direction, challenging solutionist tendencies and proposing generative capacities for navigating destabilization. In this sense, Stein et al. provide an important theoretical counterpoint that complements and unsettles the more practice-focused designs in the issue. Taking a similarly critical stance, Craig et al. advance an Indigenous feminist, land-based pedagogy through the practice of visiting, emphasizing reciprocal relationships with land and more-than-human kin as a foundation for climate learning. While Kruke and Sinatra primarily address pedagogical capacity, identifying five teacher profiles based on climate related knowledge, values, concern, and self-efficacy to inform differentiated professional development for teaching climate change.

In contrast, only three studies focus predominantly on curriculum. Lahiri et al. provide a systematic review of formal climate change curricula, mapping content emphases, grade level patterns, and focusing insights on elementary science. Ceyhan et al. design a four-week, systems thinking climate curriculum for middle school, evaluating students' development of dynamic and causal reasoning skills through system dynamics tools. Arcos-Alfonso and Carranza-Barona offer a mixed methods examination of university-level CCE curricula oriented toward eco-social transitions, tracing how program structures, assessments, and pedagogical approaches support or constrain learners' capacities for climate action and justice.

Collectively, the studies in this special issue move the conversation forward in important ways. Several studies go beyond describing current practices to explore new approaches. For example, interventions include the use of system dynamics tools to strengthen students' reasoning about climate processes (Ceyhan et al.), Indigenous feminist pedagogy that connects learning to land and community (Craig et al.), person-centered strategies that align student interest with identity (Rahmian et al.), and the role that arts-based inquiry (i.e., art installation) and online Place-Based Education (PBE) can play in engaging graduate students affectively (Karsgaard et al.) These approaches broaden what counts as CCE by emphasizing relational, embodied, and contextual learning rather than only cognitive outcomes. Similarly, Stein et al.'s conceptual article introduces depth education and asks practitioners to critically and deeply reflect on the systems that contribute to the climate crisis and the generative capacities needed for navigating systems destabilization. This contribution prompts the field to consider systems, power and epistemic conditions. The inclusion of a non-formal initiative (Craig et al.) is also significant because it demonstrates that CCE can take place in community-based, land-connected after school programs, not only in formal classrooms.

Although no studies explicitly address curriculum or pedagogical policy, the assemblage nonetheless surfaces important implications for how policy frameworks shape, enable, or constrain what becomes

possible in CCE. The absence of policy-directed studies stands out, especially given how accreditation regimes, assessment standards, and political pressures influence opportunities for transformative pedagogical work. This silence highlights the need for future research that bridges classroom level innovation with the policy architectures that govern curriculum design and enactment.

The innovative curriculum and pedagogical design reported in these studies occur across different contexts. These include afterschool programs with black and indigenous youth (Craig et al.), online PBE with participatory arts-based inquiry in higher education (Karsgaard et al.), and undergraduate courses that connect climate concepts to students' identities, interests, and lived experiences (Rahmian et al.).

This special issue also offers insights for younger learners. Lahiri et al.'s systematic review shows that research on curriculum and pedagogical design in elementary settings remains comparatively underdeveloped, while Ceyhan et al. demonstrate how systems dynamics tools, including embodied learning activities, can make abstract climate processes visible to middle-school students. Taken together, these studies point toward the need for developmentally-tailored, contextually-grounded curriculum designs across the K–12 spectrum.

Across this assemblage, what stands out are the divergences in context and design. Yet these differences are generative. They collectively widen the repertoire of what CCE can look like, demonstrating that diverse pedagogical and curricular designs are possible and necessary for meeting the demands of climate learning across contexts.

Attention to teacher and student perspectives further enriches the assemblage. It shows that the possibilities for transformative CCE expand beyond curricular and pedagogical design to the dispositions, capacities, and sociopolitical imaginaries that teachers and learners bring to CCE. Kruke and Sinatra map K-12 teachers' different profiles of knowledge, values, climate concern, and self-efficacy, emphasizing the need for tailored rather than generic professional development. Arcos-Alonso and Carranza-Barona reveal how students may still interpret eco-social transitions through hegemonic, anthropocentric, and growth-oriented frames, highlighting the necessity of CCE that explicitly interrogates these assumptions. Together, the two contributions affirm that CCE is shaped as much by the psychological, affective, ideological, and sociopolitical orientations of teachers and students as by curriculum and pedagogical design. They point to the need for future research that attends to these relational and epistemic conditions across diverse educational contexts.

There are, however, gaps that remain. Only one study offers an evaluation design (Arcos-Alfonso & Carranza-Barona). While this is a welcomed contribution, it highlights a lack of evaluation across interventions which limits what can be said about CCE effectiveness. Mixed-methods studies are rare, even though they are important for building a stronger evidence base (Newman & Brown, 2017). Most studies focus on formal education, with little or no attention to vocational, informal or non-formal contexts. These silences matter because they shape where and how CCE happens. Addressing them will require research that spans across sectors and uses diverse methods to understand what works, alongside why and under what conditions (Boaz et al., 2002; Evans et al., 2014).

Conclusion

This special issue attracted approximately 70 submissions and resulted in an acceptance rate of 11.4 per cent. This indicates there is a considerable volume of research addressing CCE, including the work published here, and other submissions that represented potentially useful insights. This is heartening and indicates a healthy and expanding concern for what and how climate change can be taught and learned. Particularly pleasing was the diversity of innovative approaches that educators and researchers are collaborating on to advance this important work. There is no doubt that transformative education (approaches that support critical reflection and agency for climate action) is required right now, and several studies addressed this focus in different ways, using critical, arts-based and embodied learning approaches. These contributions are especially welcome at a time when policy trends in many countries are narrowing curriculum opportunities for critical and creative thinking through increasing emphasis on standardization and accountability (Au, 2011; Sahlberg, 2021).

At the same time, patterns in the broader submission pool suggest several tendencies in the field. A substantial proportion of studies offered descriptive accounts, advocacy pieces, or program reviews that

lacked sufficient engagement with curriculum or pedagogy. Many studies addressed sustainability, environmental education, climate awareness, or social-ecological themes, but did not explicitly engage with CCE, leading to exclusions due to a lack of alignments with the focus of the special issue. Others demonstrated promise, but lacked methodological clarity, coherent theoretical grounding, or rigorous treatment of data. Many were limited further by poor academic writing, which obscured their contributions. Last, there were also challenges in evaluation design. Very few studies offered strong empirical evaluation frameworks, mixed-methods integration, or evidence of learning impact.

Less prominent in submissions for this special issue were studies examining where and how CCE can be included in curriculum, and the provision of a range of evidence types on the efficacy of pedagogical approaches, and how student learning can be validly assessed. A notable pattern was the geographical and contextual concentration of studies. Many originated from North America and Europe, with far fewer from the Global South. Across the submission pool, curriculum-focused studies were relatively few and often underdeveloped. Studies in early childhood and primary curricula, vocational contexts, and non-formal educational settings were also scarce.

The gaps and directions identified here help to show researchers the way forward. Future research in CCE requires more studies that explicitly theorize curriculum and pedagogy, that employ mixed methods and evaluative designs capable of demonstrating whether an approach works well as to why, for whom, and under what conditions. It will need to expand geographically, culturally, and sectorally to reach into early childhood, primary, vocational, non-formal and informal education contexts that remain under-represented. Further, it will need to engage teacher and learner dispositions, identities, and sociopolitical understandings, partnering with communities and indigenous knowledges, and situating CCE within justice frameworks. Together, these directions inform the work needed to build a stronger field of CCE curriculum and pedagogy.

Notes

1. Publication trends in CCE may be shaped by scholarly interest as well as broader international political and ideological shifts. E.g., political and ideological shifts influence research agendas, funding allocations, and educators' or researchers' capacity to engage with climate related topics. Such factors may either enable or constrain the production of CCE scholarship, and future trends in publication numbers should therefore be interpreted with these contextual dynamics in mind.
2. This review is subject to the limitations of bibliographic indexing. Not all publishers or journals are indexed in Scopus, ERIC, or Informit. Therefore, some relevant studies, particularly those from smaller publishers or non-indexed outlets, may not appear in these searches.
3. Although "K–12 education" technically spans primary and secondary schooling, we report these categories separately here because the included studies used these labels in their descriptions.

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Author contributions

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