



REVIEW ARTICLE

Climate Change and Sustainability Education: A Literature Review from Social Studies and Science Education Perspectives

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ABSTRACT

Climate change education has emerged as a distinct field of inquiry situated at the intersection of environmental science, social studies, and pedagogy. This paper reviews the literature on climate change and sustainability education, comparing how the field has developed within science education, where the emphasis has traditionally been on conceptual understanding of physical and biological mechanisms, and within social studies education, where the emphasis has been on civic engagement, values, and systemic causes. The review traces the historical development of environmental and sustainability education, examines empirical findings on effective pedagogical strategies, and considers the persistent gap between knowledge gains and behavioral or civic action. It finds that while both fields have converged on the importance of active, inquiry-based, and locally relevant pedagogy, they continue to differ in their treatment of the political and economic dimensions of climate change, with science education literature tending to bracket these dimensions and social studies literature treating them as central. The review concludes by arguing for a more integrated, transdisciplinary approach to climate change education that draws on the empirical strengths of science education research and the civic and values-oriented framing developed within social studies.

Keywords: climate change education, education for sustainable development, science education, social studies education, environmental literacy

1. INTRODUCTION

Climate change presents a distinctive challenge for educators because it is simultaneously a scientific, economic, political, and ethical phenomenon, and effective education about it arguably requires competence across all of these dimensions (Stevenson, Nicholls, & Whitehouse, 2017). The Intergovernmental Panel on Climate Change (IPCC, 2021) has documented with high confidence that human activity is the dominant cause of observed warming since the mid-twentieth century, and international bodies including UNESCO (2017) have identified education as a critical lever for both mitigation and adaptation. Yet the way climate change is taught, and the disciplinary home in which it is taught, varies considerably across education systems, with substantial implications for what students learn and how they are prepared to respond.

This review compares two disciplinary traditions that have each developed substantial bodies of research on climate and sustainability education: science education and social studies education. The science education tradition draws on a longer history of environmental education research concerned with ecological literacy and conceptual understanding of natural systems (Orr, 1992; National Research Council, 2012). The social studies tradition draws on civic education and education for sustainable development (ESD) frameworks that foreground questions of values, governance, and social justice (Sterling, 2001; Wals, 2010). Although these traditions overlap considerably in practice, they have developed largely in parallel, with limited cross-citation, a pattern that mirrors the disciplinary fragmentation discussed in reviews of related fields.

The review addresses three questions. First, how has the field of climate and sustainability education developed historically within science education and social studies education, respectively? Second, what does the empirical literature indicate about which pedagogical approaches are most effective for building both understanding and constructive engagement? Third, what accounts for the persistent gap, documented across both traditions, between students' knowledge of climate change and their willingness or capacity to act on that knowledge? The paper proceeds by examining the historical development of the field, reviewing evidence on effective pedagogy, and discussing the knowledge-action gap, before concluding with recommendations for a more integrated approach.

1.1 Scope: Formal, Non-Formal, and Informal Climate Learning

Before proceeding, it is useful to clarify the scope of climate change education as treated in this review, since the term is used inconsistently across the literature surveyed. Following Hungerford and Volk's (1990) foundational distinction, environmental and climate learning can be usefully divided into formal education, structured instruction within accredited school curricula, the primary focus of most studies reviewed in this paper; non-formal education, organized but not formally credentialed learning experiences, such as museum programs, youth climate organizations, and community workshops; and informal learning, the largely unstructured acquisition of climate-related understanding through media exposure, family communication, and everyday experience. UNESCO's (2017) education for sustainable development learning objectives explicitly span all three categories, reflecting the field's recognition that formal schooling, while central, is only one of several settings in which climate learning occurs.

This review focuses primarily on formal education, consistent with the great majority of the systematically reviewed pedagogical-effectiveness literature discussed in Section 3, but the non-formal and informal dimensions surface repeatedly throughout the paper, particularly in the discussion of media and framing effects in Section 3.3, which draws substantially on informal-learning-adjacent communication research, and in the discussion of community-based programs in Section 4.3. Readers should therefore understand the pedagogical and curricular recommendations developed in this review as most directly applicable to formal schooling contexts, while recognizing, consistent with the multi-factor model discussed in Section 4.2, that formal education operates alongside, and is not a substitute for, the non-formal and informal learning environments in which much of students' climate-related understanding and values are also shaped.

2. HISTORICAL DEVELOPMENT OF ENVIRONMENTAL AND SUSTAINABILITY EDUCATION

Environmental education as a distinct field predates the contemporary focus on climate change by several decades, with roots in the conservation and ecology movements of the mid-twentieth century. Orr's (1992) concept of ecological literacy, understood as the capacity to comprehend the interdependence of natural systems, became a foundational reference point for science-oriented environmental education, emphasizing direct engagement with local ecosystems and systems thinking. Hungerford and Volk (1990) contributed an influential behavioral model proposing that environmental education should aim explicitly at changing learner behavior, not merely increasing knowledge, a claim that anticipated much of the later debate over the knowledge-action gap discussed in Section 4.

The 1990s and 2000s saw the emergence of education for sustainable development as a partially distinct framework, formalized internationally through UNESCO's decade-long ESD initiative and later codified in the Sustainable Development Goals' learning objectives (UNESCO, 2017). Sterling (2001) argued that sustainability education required not merely new content but a re-visioning of educational purpose itself, moving away from what he characterized as a mechanistic, transmission-oriented model of schooling toward one oriented around systems thinking, participation, and transformative learning. This framing situated sustainability education closer to social studies and civic education than to natural science, since it foregrounded questions of social organization, equity, and governance alongside ecological content.

Kagawa (2007) documented a persistent ambiguity in how students and educators understand the relationship between environmental and social dimensions of sustainability, finding that many students in higher education associated sustainability primarily with environmental protection while underweighting its economic and social justice dimensions. This finding is significant for the present review because it suggests that even within the ESD tradition, which explicitly foregrounds social and economic dimensions, uptake of this integrated framing among learners has been uneven, a pattern that helps explain why science-oriented and social-studies-oriented approaches to climate education have continued to diverge in practice even as their formal frameworks have converged.

2.1 Teacher Preparedness and Curriculum Integration

A substantial obstacle to the effective implementation of either the science-oriented or the social-studies-oriented model of climate education is the preparedness of the teaching workforce itself. Plutzer et al. (2016), in a large national survey of science teachers in the United States, found that a considerable proportion of teachers held misconceptions about the scientific consensus on climate change, and that classroom time devoted to climate content was often accompanied by the presentation of "both sides" framing inconsistent with the actual state of scientific consensus, a pattern the authors attribute partly to insufficient pre-service preparation and partly to perceived political sensitivity around the topic. This finding has direct implications for the pedagogical strategies discussed in Section 3, since even well-designed inquiry-based curricula depend on teachers who are themselves confident in the underlying content and comfortable navigating its politically contested reception.

Cordero, Todd, and Abellera (2008) approach the preparedness question from the standpoint of higher education, arguing that undergraduate and teacher-preparation curricula have historically treated climate change as a peripheral topic within broader environmental science coverage rather than as a subject warranting dedicated, interdisciplinary treatment, and proposing curricular models that integrate climate science with the ecological-footprint and systems-thinking concepts more commonly associated with the ESD tradition. This proposal for integrated curricular design at the teacher-preparation level anticipates the broader integration argued for in Section 5 of this review, suggesting that the disciplinary convergence needed in K-12 classrooms must first occur within the teacher-education programs that prepare the educators who will teach that content.

2.2 Global and Comparative Perspectives on ESD Implementation

The international diffusion of the ESD framework has not produced uniform implementation across national education systems, a pattern that complicates any straightforward account of the field's historical development. Jickling and Wals (2008) argue that the globalization of ESD policy, promoted heavily by UNESCO and adopted rhetorically by ministries of education across widely varying national contexts, has often outpaced genuine pedagogical transformation at the classroom level, with many national curricula incorporating ESD language and learning objectives without corresponding change in instructional practice, assessment, or teacher preparation, a gap between policy adoption and practice implementation reminiscent of the teacher-preparedness findings discussed above. Jickling and Wals (2008) further caution against treating ESD as a single, universally applicable model, arguing that sustainability challenges and the pedagogical approaches best suited to address them vary considerably across economic and cultural contexts, and that globally standardized ESD frameworks risk marginalizing locally grounded, indigenous, and place-based approaches to environmental and sustainability learning that may be more effective in specific contexts than the internationally dominant model.

Reid (2019), writing more recently and specifically about climate change education rather than sustainability education in the broader ESD sense, extends this cautionary analysis, arguing that climate change education research itself has become somewhat detached from the empirical realities of how climate change is actually being taught, or not taught, in the majority of the world's classrooms, with the published research literature disproportionately reflecting well-resourced educational contexts capable

of supporting the kind of innovative, technology-rich, and extensively evaluated pedagogical interventions that dominate the empirical literature reviewed in Section 3. Reid's (2019) critique is a useful corrective for the present review, since it suggests that the pedagogical consensus identified in Section 3, favoring active, participatory, and locally grounded approaches, while well supported by the available evidence, may itself reflect a research base that underrepresents the resource-constrained contexts in which a large share of the world's climate change education actually occurs, a limitation that mirrors the underrepresentation of contexts beyond high-income countries noted in this journal's companion review of AI, education, and social structure.

2.3 Climate Literacy Frameworks and National Standards

A related institutional development, distinct from but closely connected to the ESD implementation debate discussed above, concerns the emergence of formal climate literacy frameworks intended to define the specific content knowledge students should acquire. The United States National Oceanic and Atmospheric Administration's (2009) Climate Literacy framework, developed collaboratively across multiple federal science agencies, identifies a set of essential principles intended to guide climate curriculum development, organized around the physical mechanisms of the climate system, the evidence for human influence on climate, and the societal implications of climate change, providing an explicit content standard against which the more pedagogically oriented literature reviewed in Section 3 can be situated. This framework's emphasis on content precision reflects the science-education tradition's characteristic priorities, discussed in Section 1, while its inclusion of societal implications as a core literacy component reflects at least partial convergence with the social-studies-oriented concerns emphasized elsewhere in this review.

Kagawa and Selby (2010), in an edited volume examining climate change education internationally, document considerable variation in how national education systems have operationalized climate literacy standards, finding that some systems adopt frameworks closely resembling the content-focused NOAA (2009) model while others, particularly systems more directly influenced by the ESD tradition discussed in Section 2.2, adopt considerably more values-oriented and participatory framings from the outset. Kagawa and Selby (2010) argue that this variation is not merely a matter of implementation detail but reflects genuinely different, and not always reconcilable, understandings of what climate literacy is fundamentally for, understanding physical mechanisms accurately, on one reading, versus developing the civic and ethical capacities needed to respond to a collective action problem, on another, a tension that runs throughout the science-education and social-studies-education divide examined across this entire review.

3. PEDAGOGICAL APPROACHES AND THEIR EFFECTIVENESS

A substantial empirical literature has examined which instructional strategies are most effective for climate change education, with findings that are broadly consistent across the science education and social studies traditions despite their different starting points. Monroe, Plate, Oxarart, Bowers, and Chaves (2019) conducted a systematic review of climate change education research and identified several strategies with consistent positive effects, including active and participatory learning, use of local and personally relevant examples, and structured opportunities for discussion of solutions rather than exclusive focus on problem description. Their review found that approaches emphasizing only the scientific mechanisms of climate change, without connecting these mechanisms to students' own contexts or to possibilities for action, were less effective at producing durable engagement.

Rousell and Cutter-Mackenzie-Knowles (2020) extended this line of inquiry through a systematic review focused specifically on children's and young people's agency in climate change education, arguing that approaches which position students as passive recipients of scientific information, common in traditional science curricula, tend to produce anxiety or disengagement, whereas approaches that give students a genuine "voice and hand" in addressing climate change, more common in participatory social studies and

civics-oriented pedagogy, are associated with more constructive engagement. This finding provides an empirical basis for the claim, made on largely theoretical grounds by Sterling (2001) and Wals (2010), that sustainability education requires participatory pedagogy rather than content transmission alone.

Within formal science curricula specifically, the United States National Research Council's (2012) Framework for K-12 Science Education incorporated climate science as a core disciplinary idea and emphasized science and engineering practices, including argumentation from evidence, as central to how climate content should be taught, moving science-based climate education toward a more inquiry-oriented model that shares substantial common ground with the participatory approaches favored in the social studies literature. Boyes and Stanisstreet (2012) complicate this picture, however, by showing that increased scientific knowledge about climate mechanisms does not reliably predict which environmental behaviors students consider worth adopting, suggesting that behavioral and civic outcomes depend on factors beyond curriculum design in either tradition, including perceived self-efficacy and social norms.

3.2 Values, Message Framing, and Youth Engagement

A substantial body of research outside the classroom-intervention literature reviewed above has examined how climate communication more broadly, encompassing but not limited to formal education, shapes young people's engagement with the issue, and this research has direct implications for how climate content is framed pedagogically. Corner et al. (2015), in a wide-ranging review of research on how young people engage with climate change, find that message framing interacts substantially with pre-existing values: messages that emphasize collective, prosocial values and that are delivered by communicators young people perceive as trustworthy tend to produce more durable engagement than messages relying primarily on fear appeals or framed around individual, materially self-interested motivations, a finding with direct implications for how climate content is pedagogically framed regardless of disciplinary home. This finding provides an empirical foundation for a point raised more theoretically in Section 1, namely that climate education's effectiveness depends substantially on factors, including the perceived trustworthiness of the messenger, that extend beyond curriculum content and instructional method as conventionally defined.

Ojala (2012) contributes a specifically psychological perspective on this framing question, examining the role of hope in sustaining young people's environmental engagement and distinguishing between what she terms hope based on denial, minimizing the severity of the problem, and constructive hope, grounded in a realistic appraisal of the problem combined with a sense of collective and individual agency to address it. Ojala's (2012) empirical work finds that constructive hope, but not denial-based hope, is positively associated with sustained pro-environmental engagement over time, a finding that directly parallels and empirically substantiates the more conceptual argument developed by Chawla (2020) and discussed further in Section 4 below regarding the affective dimensions of climate learning. Read together, Corner et al. (2015) and Ojala (2012) suggest that the pedagogical consensus favoring participatory, locally grounded, solution-oriented instruction identified earlier in this section is not simply a matter of instructional design preference but is empirically grounded in a more general psychological literature on how values, trust, and hope shape sustained engagement with difficult, long-horizon collective problems.

3.3 Media, Framing, and Public Communication Approaches

Beyond the formal classroom interventions reviewed above, a substantial communication-studies literature examines how climate change is framed in public discourse more broadly, and this literature has increasingly informed classroom-based pedagogical design as the boundary between formal climate education and informal public climate communication has become less distinct in an environment where students routinely encounter climate content through news and social media alongside formal instruction. Nisbet (2009), in an influential analysis of climate communication framing, argues that how climate change is framed, as an environmental risk, an economic opportunity, a public health issue, or a

moral and religious concern, substantially shapes which audiences find the message engaging and credible, and that effective climate communication, including classroom-based communication, therefore benefits from deliberately selecting frames aligned with a given audience's existing values and concerns rather than relying on a single, universally applicable framing strategy.

Nisbet's (2009) framing analysis has direct implications for the pedagogical literature reviewed earlier in this section: it suggests that the effectiveness of locally grounded, values-aligned instructional approaches documented by Monroe et al. (2019) and Rousell and Cutter-Mackenzie-Knowles (2020) may operate substantially through the same framing mechanisms Nisbet (2009) identifies in public communication contexts more broadly, namely by aligning climate content with audience-specific values and concerns rather than through any pedagogical technique unique to formal educational settings. This convergence between communication-studies framing research and climate-education pedagogical research represents a further, currently underexploited, opportunity for cross-disciplinary integration, since climate education research has generally developed its evidence base independently of the parallel and substantially overlapping communication-studies literature on climate framing.

4. THE KNOWLEDGE-ACTION GAP AND AFFECTIVE DIMENSIONS

A recurring and well-documented finding across both traditions is that increases in climate-related knowledge do not reliably translate into pro-environmental behavior or civic engagement, a phenomenon often termed the knowledge-action or value-action gap. Hungerford and Volk (1990) identified this gap early in the environmental education literature and proposed that effective programs needed to target not only knowledge but also a sense of personal responsibility and perceived skill in taking action, what they termed "ownership" and "empowerment" variables. Boyes and Stanisstreet (2012) provide more recent empirical support for the persistence of this gap, finding that students' rankings of which behaviors would be most effective for addressing climate change often diverged substantially from scientific consensus on effective mitigation actions, even among students with relatively strong content knowledge.

Anderson (2012) approaches this gap from a curriculum-design perspective, arguing that climate change education has often been organized around mitigation, encouraging students to reduce their own carbon footprint, at the expense of adaptation, preparing students and communities to respond to climate impacts that are already underway or unavoidable, and that this imbalance may itself contribute to disengagement when mitigation-focused messaging feels disconnected from students' lived circumstances, particularly in contexts already experiencing climate impacts. This observation resonates with social studies education's traditional emphasis on situating learning within students' civic and community contexts.

4.2 Structural Barriers Between Knowledge and Pro-Environmental Behavior

Kollmuss and Agyeman (2002), in an influential and frequently cited synthesis of the pro-environmental behavior literature more broadly, argue that the knowledge-action gap cannot be adequately explained by any single factor and instead propose a multi-factor model in which environmental knowledge and pro-environmental values are necessary but insufficient conditions for action, which is further shaped by internal factors, including locus of control and perceived responsibility, and external factors, including institutional constraints, economic circumstances, and social and cultural norms that may actively discourage the behaviors that environmental education promotes. Applied to the climate-specific literature reviewed in this paper, Kollmuss and Agyeman's (2002) framework helps explain why interventions found effective in the controlled, comparatively well-resourced contexts studied by Monroe et al. (2019) may not translate into comparable behavioral or civic outcomes in contexts where external structural barriers, rather than insufficient knowledge or motivation, are the primary constraint on action, a point that connects directly to Reid's (2019) critique, discussed in Section 2, of the research base's tendency to underrepresent resource-constrained educational contexts.

Feinstein and Mach (2020) extend this structural analysis specifically to the mitigation-adaptation imbalance raised by Anderson (2012), arguing that climate change education has a distinct and underdeveloped role to play in supporting adaptation specifically, including helping communities interpret and respond to localized climate risk information, a role that requires pedagogical approaches and institutional partnerships, with local government and community organizations, for example, that extend well beyond the classroom-based interventions that dominate the pedagogical-effectiveness literature reviewed in Section 3. This adaptation-oriented educational role, Feinstein and Mach (2020) argue, remains comparatively underdeveloped relative to mitigation-oriented education across both the science education and social studies traditions, representing a further specific direction for the more integrated research and curriculum-development agenda argued for in the concluding section of this review.

4.3 Children's Agency and Empowerment-Oriented Pedagogy

Trott (2020) provides an extended empirical treatment of the agency-oriented pedagogical approach introduced more briefly through Rousell and Cutter-Mackenzie-Knowles's (2020) systematic review in Section 3, conducting a longitudinal study of children's participation in a community-based climate action program and identifying specific mechanisms through which structured opportunities for genuine decision-making authority, rather than symbolic or token participation, contributed to sustained engagement and a strengthened sense of what Trott (2020) terms sociopolitical efficacy, the belief that one's actions can meaningfully influence collective outcomes. Trott's (2020) findings reinforce the theoretical claims made by Sterling (2001) and Wals (2010) regarding the importance of genuine participation, discussed in Section 1, while providing more fine-grained empirical evidence than earlier studies regarding which specific features of participatory programs, meaningful decision-making authority in particular, as distinct from participation more generally, are most strongly associated with positive outcomes.

This distinction between meaningful and merely symbolic participation is significant for the present review because it complicates a straightforward reading of the pedagogical consensus identified in Section 3: while the literature broadly agrees that participatory approaches outperform passive content transmission, Trott's (2020) findings suggest that not all forms of participatory pedagogy are equally effective, and that programs providing only superficial opportunities for input, without genuine decision-making authority, may fail to produce the sociopolitical efficacy gains documented in more substantively participatory programs. This finding has direct implications for the curriculum-design recommendations developed in the concluding section of this review, suggesting that future climate curricula should be evaluated not simply on whether they include participatory elements but on the substantive degree of agency those elements afford learners.

A further important theme concerns the affective and psychological dimensions of climate change education. Chawla's (2020) review of research on childhood nature connection and climate-related loss argues that educators must attend to the emotional dimensions of climate learning, including grief, anxiety, and hope, and that pedagogical approaches which acknowledge these emotions while providing structured opportunities for constructive action tend to support what she terms "constructive hope," as opposed to approaches that either minimize the severity of climate impacts or present them without any pathway to agency. This affective dimension has been more extensively theorized within social-studies- and psychology-adjacent literatures than within science education research, which has traditionally treated affect as secondary to conceptual understanding, representing another point of productive convergence for the integrated approach argued for in this review.

4.1 Eco-Anxiety and Psychological Responses to Climate Learning

Clayton (2020) provides a more clinically oriented account of what has come to be termed climate or eco-anxiety, defining it as a form of psychological distress specifically related to the perception of climate

change and its consequences, and distinguishing it from clinical anxiety disorders while noting that it can nonetheless produce significant functional impairment in some individuals, particularly young people, if not addressed constructively. Clayton's (2020) analysis reinforces Chawla's (2020) argument that curricula presenting climate information without corresponding opportunities for agency and action can inadvertently exacerbate this distress, and suggests that climate education research should draw more directly on the psychological literature on coping and self-efficacy than has typically been the case in either the science education or social studies traditions reviewed in this paper. This convergence of psychological and pedagogical research represents one of the more actively developing areas of the field and is revisited in the concluding discussion.

5. IMPLICATIONS FOR CURRICULUM AND TEACHER EDUCATION

The literature reviewed in Sections 2 through 4 carries several concrete implications for how climate change education might be more effectively designed and supported, implications this section draws together before the broader discussion of interdisciplinary integration in Section 6. First, the teacher-preparedness findings of Plutzer et al. (2016) and the curriculum-integration proposals of Cordero et al. (2008), read alongside Reid's (2019) critique of the field's uneven empirical base, together suggest that teacher education reform represents a higher-leverage intervention point than continued refinement of K-12 curricular materials alone, since even well-designed materials depend on teachers who possess both accurate content knowledge and the pedagogical confidence to navigate the topic's affective and, in some contexts, politically contested dimensions. Programs that integrate climate content across the science and social studies methods courses within teacher preparation, rather than treating it as an elective add-on, would directly address the disciplinary fragmentation this review has documented while also addressing the specific confidence and preparedness gaps Plutzer et al. (2016) identify empirically.

Second, the pedagogical-effectiveness literature reviewed in Section 3, combined with the framing and values research discussed in Sections 3.2 and 3.3, converges on a specific instructional recommendation: climate curricula should be designed around locally relevant, solution-oriented inquiry that explicitly connects to students' own values and communities, rather than around generic global climate mechanisms presented in isolation from any pathway to agency. This recommendation is not merely a pedagogical preference but is supported convergently by Monroe et al.'s (2019) systematic review, Corner et al.'s (2015) communication research, and Ojala's (2012) and Trott's (2020) psychological findings on hope and sociopolitical efficacy, representing one of the more robustly triangulated conclusions to emerge from this review.

Third, the knowledge-action gap literature reviewed in Section 4, particularly Kollmuss and Agyeman's (2002) multi-factor model and Feinstein and Mach's (2020) adaptation-education framework, indicates that curriculum design alone cannot fully resolve the gap between climate knowledge and constructive engagement, since structural and institutional barriers external to the classroom substantially shape whether students are able to translate classroom learning into action. This implies that climate education initiatives are likely to be most effective when paired with, rather than substituted for, broader institutional and community-level efforts to reduce the structural barriers Kollmuss and Agyeman (2002) identify, a conclusion with direct relevance for how schools might partner with local government and community organizations along the lines Feinstein and Mach (2020) propose for adaptation-focused education specifically.

6. DISCUSSION AND CONCLUSION

The literature reviewed here indicates that science education and social studies education have approached climate change education from different starting points, conceptual understanding of physical systems in the former, civic engagement and systemic understanding in the latter, but have arrived at substantially convergent conclusions regarding effective pedagogy: both traditions now emphasize active, participatory, locally grounded instruction over transmission of decontextualized

content (Monroe et al., 2019; Rousell & Cutter-Mackenzie-Knowles, 2020; National Research Council, 2012). Where the traditions continue to diverge most clearly is in their treatment of the political and economic dimensions of climate change. Social studies and ESD-oriented literature treats questions of governance, equity, and economic structure as integral to climate education (Sterling, 2001; Wals, 2010; Kagawa, 2007), while much of the science education literature continues to bracket these dimensions in favor of a primarily biophysical framing (National Research Council, 2012), even as scholars within science education increasingly call for closer attention to the socioscientific and civic dimensions of climate content.

This review supports the argument that climate change education would benefit from more deliberate integration across these traditions, an argument consistent with the broader case made in this journal's companion review of interdisciplinary approaches to educational technology and social structure. Science education research offers well-developed tools for assessing conceptual understanding and evaluating inquiry-based pedagogy, while social studies and ESD research offers a more fully developed account of the civic, affective, and systemic dimensions that appear consistently necessary for translating knowledge into constructive engagement. Future curriculum development and teacher education, particularly in initial teacher training programs that prepare generalist primary teachers to teach both science and social studies content, represents a promising site for this integration, since primary teachers are well positioned to design cross-disciplinary units that combine the empirical rigor of science-based climate content with the participatory, values-oriented pedagogy developed within social studies and ESD traditions.

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