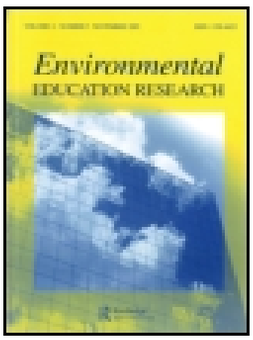

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Broadening epistemologies and methodologies in climate change education research

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ABSTRACT

In this commentary, we reflect on the articles in this special collection from our lens as scholars who have chosen to conduct research with a focus on climate change education. We start with statements of positionality, as certainly our own experiences and philosophical stances shape our work and reflections included here. Afterwards, we present a typology of climate change education research, utilizing a framework developed from research paradigms with an emphasis on epistemology and methodology. Lastly, we make recommendations for future research efforts based on suggestions within the research articles in the collection as well as from the typology presented.

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Climate change education (CCE) research has developed in parallel, although not concurrently, with the field of scientific research about climate change. The Intergovernmental Panel on Climate Change (IPCC) has synthesized the most current scientific research across numerous countries, institutions, disciplines, and scholars for decades. These invaluable reports represent the most current understanding of climate science, while also identifying gaps in knowledge that drive future research efforts. No such document exists, however, for climate change educational research. This commentary is part of a collection of climate change education articles that have been published in *Environmental Education Research*, gathered in advance of the United Nations Framework Convention on Climate Change Conference of the Parties (COP) 22 and 23 meetings. Article 12 of the Paris Agreement acknowledges the role of education as an important means to achieve the ambitious goals set by the COP. Specifically, education can contribute to: fostering a better understanding of and ability to address climate change and its effects; promoting community engagement, creativity, and knowledge in finding climate change solutions; and engaging all stakeholders in debate and partnership to respond collectively to climate change (Action for UNESCO and UNFCCC 2016). This collection serves as a starting point for identifying what is known and what is yet to be studied in CCE research to support educational opportunities that can meet these challenges.

It is important to note that the articles discussed here were not gathered through a systematic literature review process but rather were selected by the editors of the journal. Articles were chosen based on the following criteria: they were well-received in that they have been read or cited often, they are related to IPCC and UNESCO goals, and they represent the full scope of the

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journal. In light of the selection criteria, this commentary may have limitations as to how well it describes the full breadth of the entirety of research on climate change education, which is plentiful.[1] While it is beyond the scope of this paper to provide a compendium of all educational and cross-disciplinary research findings related to climate change education, our aim is to organize and comment upon the articles in this special issue in order to characterize the essence and trajectory of research in CCE. We begin this commentary by positioning ourselves as scholars and educators within this research area. Then, we present a typology of the articles included in this special collection, with an emphasis on how we come to know what we do in climate change education research. We attempt here to not summarize fully what is known *from* research; instead, our focus is on *how* research is being conducted. In addition, we offer recommendations to advance CCE research in the future, with the ultimate goal of improving climate change educational practice.

Asking the authors: why climate change education research?

The community of researchers in CCE has grown over time with many researchers choosing the topic as the focal point in their research agenda, but why do this work? What is the experience of researching a topic that, in some countries, has vast political implications and associated difficulties? What are the benefits and challenges of working within this area of inquiry? We begin this essay by sharing our own perspectives and experiences as scholars and educators in order to illuminate how our own trajectories shape the types of research decisions that we make in our own work.

Why did you start researching climate change education?

STEVENSON: I started this work looking for hope. When Kahan et al. (2012) published a study in *Nature Climate Change* highlighting how scientific literacy & numeracy seems to exacerbate, rather than overcome, worldview-driven polarization around climate change, I was disheartened. I also wanted to conduct a similar study with kids (see Stevenson et al. 2014) to see if the same trends held. They didn't. Worldview seemed to drive polarization among kids with low levels of climate change understanding, but that impact of worldview disappeared as understanding increased. The idea that worldview drives climate change perceptions is a compelling (and empirically supported) narrative, but research with kids gives me hope that younger audiences represent an opportunity to overcome barriers related to cultural and political polarization that to me, seem at times insurmountable.

HENDERSON: I was lucky to experience an undergraduate geology education that included a robust education in climate change science that also focused on the urgent need to address the issue. I carried this knowledge and interest through my days as a public-school science teacher and then into graduate school where I was able to focus more intensively on this and other environmental issues that, from my vantage point, seemed to be strangely absent from larger educational conversations. As my doctoral work neared completion, Marcia McKenzie invited me to conduct some research on climate change education in the Canadian higher education context as part of her SEPN grant-funded project work (www.sepn.ca). That focus on climate change education then carried into post-doctoral work at the University of Delaware where we conducted research that was directly the result of dedicated grant funding by the United States' National Science Foundation (NSF Grant #1239758) to establish a larger network of researchers working on climate change education (www.ccepalliance.org). So, I suppose that I have evolved into this role as years of intrinsic interest were materially supported via formal government grants and professional mentorship, without which such work would not have happened.

BUSCH: I was a secondary science teacher for twelve years, and I have a particularly clear memory from one of my first years as a middle-school, earth science teacher. I was at the chalkboard, explaining the physical mechanism behind global warming, drawing the typical cross-section view of the planet and atmosphere to show the energy budget. I distinctly remember finishing the drawing, turning around to the students, and being disappointed in their (non)reaction. I wasn't expecting an uprising, but I realized at that moment that I had failed to make it relevant to my students on any level. This experience has stayed with me and guided my research thus far. At the core of my research is an attempt to figure out how to make climate change a topic for youth to care about enough to take action. I also recognize that I have an inclination towards education for action. As a teacher, I saw my role as preparing future citizens rather than standardized test-takers. It is not that these two goals are not achievable together, but I do believe that some classrooms prepare students better for one than the other.

What are some of the difficulties you have encountered as a researcher in CCE?

STEVENSON: The biggest difficulty in conducting this work has been navigating the cultural and political context of my study sites. Most of my work around CCE has been in North Carolina, which is arguably one of the most polarized states in the country. In some ways, that makes it an interesting case study for the US, but it also means that in areas that are culturally or politically resistant to acceptance of anthropogenic climate change, getting permission to conduct CCE research can be a challenge. I have found that teachers and kids are overall receptive to the work, but larger institutions are resistant. School districts have outright denied access, individual employees have been instructed not to discuss projects with me, funding agencies have suggested a shift away from climate change and toward more general environmental topics, and some have asked to edit our educational materials to better represent 'both sides' of climate change. Research on the process of CCE research would be fascinating!

HENDERSON: I once had to ask a close relative to physically leave my home because they were apoplectic when I informed them that we were moving our family to Delaware so I could study climate change and education. I have multiple climate change deniers in my immediate family and this makes for challenging interpersonal dynamics, to say the least. Such consternation has diminished somewhat over the years, mainly because I have largely stopped caring. There are just more productive avenues for engagement and the literature shows that a large percentage of Americans, for example, largely accept climate change science (Leiserowitz et al. 2015). My larger frustration has been with an apathy present in the larger educational research community, and society writ large. It has been a long slog trying to persuade colleagues and those in positions of institutional power in educational research to take the issue seriously. There's often a 'yeah, that's important, but isn't science education already dealing with it?' mentality among colleagues in educational research, and the larger educational organizations have been almost completely missing in action on this issue. I've become so frustrated after years of trying to persuade that I've started to direct my intellectual energy elsewhere. Active denial and indifferent apathy are just different kinds of avoidance mechanisms, and the educational community is increasingly complicit.

BUSCH: Resistance, at all levels. The social and political controversy in the U.S. spills over into CCE research in ways I have not seen or would expect for other research topics. As a specific instance, an article a colleague and I wrote received some mass media attention. As a result, I received unsolicited emails from denialists asking me to recant the article. One email included a 40-page missive about how climate change is a hoax. I was personally blasted on a denialist's blog for several weeks, including comments from readers that questioned my credibility and motives. As a junior scholar, this could have been intimidating, however it only provided further reason for why this research is so important.

What are some of the advantages of researching in CCE?

STEVENSON: In some ways, I see CCE as a professional and moral imperative. As I navigate institutional barriers to conducting CCE research, I am more convinced that academics have a responsibility to conduct this work to make CCE accessible. At least where I work, very little CCE is being provided through traditional channels (e.g. state-sponsored curriculum, district-sponsored professional development). Interventionist research can provide an alternative source of professional development for teachers, and any CCE research helps spark conversation around how CCE might be delivered (including to kids or adults; in or out of school) and hopefully makes it a more salient issue. Further, from a scholarly perspective, CCE research is just interesting, largely because of the challenges inherent in doing it. Climate change is an incredibly complex topic scientifically, socially, and politically, which makes it fun to engage with.

HENDERSON: I agree with Stevenson here: the topic is so inherently complicated and that reality makes it both exciting and challenging at times, and readers of *Environmental Education Research* (EER) will probably understand better than most the complex nature of environmental issues in educational contexts. I find the topic intellectually rewarding for this reason, although its complexity also creates some challenges that impact the ability to conduct this work. For all the talk of interdisciplinarity in the academy, it does not appear that too many institutions want to actually materially support such work, and schools of education in particular as they increasingly move toward neoliberal instrumentalization of activities. That said, the complex nature of topic has taken me into some fields that I would otherwise not engage and that has been immensely fun, scary, exciting, and rewarding.

BUSCH: The flip side of my above response (regarding resistance) is the up-side of conducting research on CCE. I see this area of research as being an important way to contribute, in a professional way, to the betterment of society. This area of research is also complicated, which provides many fascinating questions for study.

As readers have at least a surface understanding of our own perspectives, we now offer an overview of one way (of which there are many) to organize the lines of inquiry within CCE research. Our typology applies research paradigms to situate the articles within this special collection. Research paradigms represent particular ways of thinking within a research community, influencing the direction of research by guiding research goals, outcomes of interest, choice of methods, and the conclusions drawn from research efforts (Schwandt 2001). Numerous research paradigms are evident in the CCE literature base, serving as a testament to the variety of research being conducted. Much like Guba and Lincoln (1994), our stance is not that there is a 'correct' or 'better' research approach, rather the diversity of paradigms provide complementary opportunities to understand how people learn about and make sense of climate change. This typology, then, offers a way to organize and characterize the field of CCE and to highlight the contributions of the articles in this special collection. The following typology includes two elements of research paradigms: epistemologies and methodologies (Patton 2002).

Epistemologies in CCE research: forms of knowledge

The research paradigms addressed in this section are: positivism/post-positivism, social constructivism, and critical/transformative (Creswell 2003). In particular, this section focuses on the question of epistemology: the form and nature of knowledge and what can be known about it (Guba and Lincoln 1994) or ways of knowing (Patton 2002).

Positivism/post-positivism: climate science knowledge

Researchers who approach their work from the positivist or post-positivist research paradigm hold that knowledge is objective, free from contextual influences (Guba and Lincoln 1994, 2005).

While positivist research would argue that knowledge is completely objective and knowable, post-positivist research acknowledges the role of human conjecture in constructing that objective knowledge. Within the CCE literature, post-/positivist perspectives are evident in research focusing on cognitive variables, such as climate science knowledge, with limited consideration of other contextual factors. The focus on knowledge of climate science as an outcome of interest is tightly linked to the conceptual change theory of learning in science education. Conceptual change refers to the 'alteration of conceptions that are in some ways central and organizing in thought and learning' (Strike and Posner 1992, 148). It is analogous to Kuhn's scientific paradigm shifts and Piaget's notion of accommodation, in that individuals learn when they accommodate (replace) or assimilate (revise) their conceptions of a phenomenon. Strike and Posner identified earlier work about scientific misconceptions (e.g. Driver and Easley 1978) as being highly influential to the development of their theory (Posner et al. 1982; Strike and Posner 1992). Misconceptions (or alternative conceptions) are scientific understandings that are not congruent with accepted scientific facts. Misconceptions can be the result of intuitive, experiential knowledge or poor formal classroom instruction and are extremely resistant to change. The theory of conceptual change was developed as an explanation of the process of correcting these misconceptions in order to illuminate effective science teaching practices. The impact of the theory of conceptual change cannot be understated; it is a cornerstone of science education research and practice. Thus, it has also had an influence on climate science education research and practice.

The numerous misconceptions of teachers and students about the science of climate change is well-defined and well-documented in CCE-related research (see Shepardson et al. 2011 for comprehensive review). In this special collection, the article by Niebert and Gropengiesser (2013) is representative of research about climate science misconceptions. Drawing on theory about the structure of knowledge (e.g. diSessa), they argue that abstract concepts can be organized into larger schemata, expressed through cognitive, linguistic metaphors related to direct experience (e.g. Lakoff). In their study, they compared scientific experts' schema of climate change to that of novice students. Within science education, the novice-expert continuum has been used to understand how people learn, defined as moving from novice to expert understanding (e.g. National Research Council 2000). They found that scientists use an open container schema to describe climate change, wherein the atmosphere is a bounded container with inputs and outputs and holding a stock of gases. The greater stock of gases within the container is causing more of the energy to remain within the container, without changes to inputs or outputs of energy. In contrast, students hold a schema of the atmosphere as a closed container. For instance, students often incorrectly state that climate change is happening because holes in the ozone are allowing a greater input of energy into the atmospheric system, resulting in increasing temperatures. The confusion between climate change and ozone depletion has been repeatedly identified in the CCE literature. Students also used a blanket schema for climate change, in which additional carbon dioxide is collected in a layer at the top of the atmosphere. This layer serves as a blanket around Earth, allowing light in and restricting heat from leaving. The blanket metaphor for climate change is a popular one, and scientists have warned of the possibility of misunderstanding because of it. The researchers designed classroom exercises with the goal of helping students to accommodate the expert schematic metaphor.

In science education research, the movement from novice to expert understanding is articulated often through learning progressions. The National Research Council (2007) called for a greater effort of coordination of learning along conceptual progressions, where students have repeated opportunities throughout their K-12 experience to build upon existing knowledge. The science education research community took on the challenge, and learning progressions are considered a *de rigueur* strategy for aligning standards, curriculum, instruction, and assessment (Duschl, Maeng, and Sezen 2011). Learning progressions provide a hypothetical model pathway of learning over time, as many learning progressions are not grounded in empirical testing. However, as the interest in creating progressions has increased, more empirically-validated

models are being developed. In this collection, Shepardson et al. (2012) contribute to the learning progressions literature by providing a three-level conceptual progression for climate change as a part of the climate system. For example, level one (the lowest) conceptual understanding of the climate system involves identification of the transfer of energy between components of the system (for example, sun, atmosphere, oceans, land). Whereas, level three (the highest) includes the addition of the concept of balance of energy inputs and outputs in the climate system as well as the role of human activities in changing that balance. The authors developed the progression through review of the literature, and the authors acknowledge that it is intended to provide a starting point and will need additional empirical validation.

Research from this theoretical perspective has shown consistently that adults and youth hold erroneous or limited knowledge about climate science. Researchers working in this paradigm often make the following argument as a motivation for their work: climate change is a real problem for which human action is required, therefore it is important that people understand climate change science. Indeed, the converse argument is also made: the public is not taking action on climate change because they do not understand the science. However, the proposed cause-and-effect relationship between knowledge and action has been challenged by research that indicates a weak relationship between knowledge of climate science and pro-environmental behavior (Pidgeon and Fischhoff 2011; Vainio and Paloniemi 2013). Research being conducted from other theoretical perspectives offer additional variables for consideration.

Social constructivism: climate attitudes, beliefs & worldviews

The social constructivism research paradigm asserts that knowledge claims are inherently human, meaning that they are socially-constructed and, therefore, subject to human experience. Knowledge is context dependent and culture-bound, and therefore the goal of research is to understand people's experiences within context (Guba and Lincoln 1994). While there are myriad ways to theorize 'culture' in educational research (e.g. Eisenhart 2001), we focus here on a general anthropological definition of culture as 'the collective processes that make the artificial seem natural' (Welsch and Vivanco 2016, 29). Such processes include the symbols, values, norms, material artifacts, and group customs that support daily practice over time. Social constructivist approaches are less common in environmental education (Ardoin, Clark, and Kelsey 2013) and science education (Lemke, 2001) research. However, in this special collection, much of the research could be considered as utilizing a social constructivist epistemology. Those researchers who do adopt such an approach tend to focus less on individual cognitive features and instead broaden the unit of analysis to focus on the role of culture and its social manifestation in shaping climate change educational contexts.

One social constructivist approach is to consider an individual's prior life experiences, value systems, and emotions as predictors of their perception of climate change. Howell and Allen (2016), in this collection, sought to identify precursors to concern about climate change and interest in taking mitigating action. The researchers used a survey to find correlations between these dependent variables (concern and mitigation) and significant life experiences and value systems. In this study and contrary to prior similar studies (e.g. Chawla 1998), significant life experiences, such as time spent outdoors as a child, was not found to be correlated to concern and action. Rather, a participant's value system, defined as guiding principles in life, was found to be related to concern. Altruistic values included equality, social justice and peace; whereas biocentric values included protection of the environment, respect for nature, and connection with nature. Participants were motivated more so by altruistic values than biocentric values. These findings are in agreement with Howell's prior work (2013) that suggests individuals with altruistic value systems are more inclined to take pro-environmental behavior.

Another social constructivist approach is to consider affective variables along with cognitive ones, which includes research considering individuals' feelings about climate change and working toward solutions. For instance, only 8% of youth agree that we can and will do something to mitigate climate change (Feldman et al. 2010), which social constructivist researchers would consider an important factor to consider when studying how youth may engage with the topic. Ojala (2012), in an article in this special collection, aimed to examine the relationship between an individual's hope (or pessimism) and engagement in pro-environmental behavior. Through a survey of 723 Swedish teenagers, Ojala found that constructive hope was positively correlated to pro-environmental behavior. Constructive hope is defined as believing that one has the ability to actualize alternative pathways to environmental problems. Whereas hope based on denial, as in hope that climate change isn't going to be a problem, was negatively correlated to pro-environmental behavior. Ojala suggests that the implications for the findings is to consider how educational programs can support the development of constructive hope, by showing the influence of one's actions and providing opportunities for developing collectively actualizable solutions to the problem.

Another key approach in social constructivism is to consider learning occurring within a community. For instance, social norms outside of the classroom can be influential within the classroom. In this collection, Hestness, McGinnis, and Breslyn (2016) investigated how students' participation with various cultural activities and media environments informed their understanding of climate change science. Stevenson, Peterson, and Bradshaw (2016) examined how adolescents' perceptions of climate change views among their friends and family, as well as how often they discussed the issue, impacted their own climate change concern levels. Sezen-Barrie, Shea, and Borman (2017) used mixed discourse analysis methods to examine how teachers leverage climate change denial arguments in their professional practice, often leading to confusion about the nature of climate change science. Stevenson, Peterson, and Bradshaw (2016) examined the relationship between teacher and student beliefs around climate change, finding that teachers who believe climate change is happening were more likely to have students who think it is happening and human caused, regardless of teachers' understanding of anthropogenic roots. Drewes, Henderson, and Mouza (2018) utilized sociocultural theories of conceptual mobility to show which cultural factors shaped climate change professional development (PD) experiences, how a teacher then embodied that PD experience in accordance with her own identity priors, and the overall effect on student climate change learning. Each of these empirical studies focus attention on the larger educative context as a means of explaining how climate change education unfolds in particular ways.

Monroe et al. (2015) assessed the role of social norms by administering the Six Americas survey (Maibach, Roser-Renouf, and Leiserowitz 2009) with Extension professionals. They found that similar to the general public, Extension professionals range from Alarmed to Dismissive, with approximately 35% of professionals included in the Disengaged, Doubtful, and Dismissive categories. The implications for this are important, considering these professionals are responsible for providing climate change-related programming. The researchers suggest that homophily – social networks that tend to include individuals with similar worldviews, attitudes, and beliefs – can be harnessed as a solution. By having Extension professionals that were categorized in the Alarmed or Concerned categories provide training to other more doubtful Extension employees, they can capitalize on the trust and respect of those in that working community to change attitudes and beliefs about climate change.

A key reason we find social-constructivist perspectives compelling for CCE research is because they relate to a dominant line of related social science research. This work finds cultural factors to be the dominate drivers of climate change perceptions and behaviors. For instance, Dan Kahan and colleagues (e.g. Kahan 2012; Kahan, Jenkins-Smith, and Braman 2011) suggest that cultural worldviews (hierarchical vs. egalitarian and individualist vs. communitarian) drive the types of information we seek as well as how we interpret new information around climate

change. For instance, Kahan et al. (2012) found that those who are more scientifically literate and numerate were more polarized along cultural worldviews, suggesting that increased scientific literacy could strengthen skepticism among hierarchical individualists. Similar research on US political affiliation has shown that Republicans are more likely to be skeptical of climate change than Democrats (Hamilton et al. 2015; Dunlap, McCright, and Yarosh 2016), education and media consumption patterns drive polarization along political lines (Bolin and Hamilton 2018; Hamilton 2011), with conservative white males the most skeptical (McCright and Dunlap 2011). The body of this work, including at least one meta-analysis (Hornsey et al. 2016), suggest that these cultural factors are by far the most powerful drivers of climate change perceptions among adults.

A few CCE researchers have begun to directly tie their work to the broader discussion of cultural worldviews and political affiliation in relation to climate change perceptions and learning. Stevenson et al. (2014) looked at how knowledge and worldviews may interact to form climate change perceptions, but among adolescents. They found different trends than Kahan et al. (2012) found with adults. Specifically, whereas scientific literacy and numeracy was polarizing among adults, climate-specific knowledge seemed to override the effect of worldview among adolescents (Stevenson et al. 2014). However, students with low understanding of climate science were still polarized along the same cultural divides described in Kahan's work, suggesting consideration of cultural worldview is useful in a CCE context.

Critical & transformative approaches: sociohistorical situatedness of knowledge

Critical and transformative approaches suggest that it is insufficient to merely interpret the world, and that, as researchers, we should work instead to change it (Marx and Engels 1970). Such critical work begins from a point of normative contestation, whereby dominant political, economic, and sociocultural trends are interrogated in order to change them via educational praxis. A common thread in this work is a focus on how power and its structural manifestations intersect with climate change and educational phenomena. Scholars working in this arena span a broad theoretical landscape from indigenous and postcolonial theory (Nxumalo 2017) to gender theory (Russell et al. 2013) to the political economy of schooling (Grandy-Benson and Sarathy 2015). Still others focus attention to the politics and policies that hinder (Colston and Ivey 2015) or promote (Henderson, Bieler, and McKenzie 2017) climate change education across a diversity of contexts. Few articles in CCE research begin from such a critical standpoint; nevertheless, some scholars persist in their goal of challenging the dominant structures that shape educational research broadly and climate change education in particular.

In this special collection, Jickling (2013) criticized the framing of environmental problems in economic terms, a 'move [which] absorbed differences, circumvented any serious discussion about values and ensured that norms and assumptions of modernity and capitalism remained unquestioned, authoritative and non-negotiable' (165). He surmised that such economic discourse and thinking reduces our capacity to enact deep, systemic change. Jickling points to education as a solution, because it offers the opportunity 'to engage in a serious conversation about social values, the status quo and ultimately to transcend social norms' (167). While we also believe in the power of education for social transformation, it must be acknowledged that many science teachers do not feel comfortable tackling controversial topics within their classrooms (Gayford 2002). In the specific case of climate change, many teachers are erroneously teaching climate change science as controversial (Plutzer et al. 2016), rather than engaging in the social debate about what to do about the problem.

Also in this special collection, Waldron et al. (2016) acknowledge that the current way of teaching about climate change – as a geographical process with a focus on individual, private mitigation action – is not effective. Much like Jickling, they hold great faith for the role education as a mechanism for societal transformation, claiming that 'a robust and justice-orientated

educational response is necessary to support the collective actions needed to mitigate climate change' (1). To accomplish this lofty goal, they suggest a holistic educational experience in which students are provided space for reflection and opportunities to engage in models of citizenship, emphasizing collective decision–making processes.

While environmental education has a long and storied history of promoting transgressive and transformative research and pedagogy (Lotz-Sisitka et al. 2015), such work is just beginning to surface in climate change education as the research begins to shift away from *the science of* climate change to *what do we actually do* about climate change. Moving humans toward action in the face of climate change necessarily involves challenging systems of entrenched power that continue to maintain status quo conditions that have created the issue in the first place (Henderson, Bieler, and McKenzie 2017). Such work is typically action-oriented and blends theoretical interpretation with practical application toward a goal of shifting consciousness and behavior via educative practice as a means of addressing climate injustice (e.g. Hayden et al. 2011).

The variation of theoretical perspectives found within CCE literature has provided a wide-ranging understanding of how people learn about the science, cultivate the attitudes, and develop the skills to take informed action. This multiplicity of perspectives naturally leads to an equally wide assemblage of methodologies. In the following, we examine the research methods employed, with an emphasis on highlighting articles within this special collection.

Methodologies in CCE research: what, how, who, and where?

Research paradigms may be associated with particular methodologies; however, this does not hold true universally. For this reason, we organize this section differently than the previous section. In this section, we will discuss outcomes of interest, methods, and cross-disciplinary research in CCE. We start with outcomes of interest in the methodologies section because choice of *what* to study informs *how* to study it.

Research questions and outcomes of interest

Although transformative theoretical perspectives are rare in CCE currently, near consensus in CCE literature suggests that climate change behavior is an important goal of CCE. An emphasis on action as an outcome also aligns with the COP goals as stated in the introduction of this commentary. Even if the measured outcome is not specifically action or behavior, researchers articulate the urgency of the problem and the importance of taking action. We use the term 'climate change behavior' in a similar way to how environmental behavior is discussed in the broader environmental education literature (Kollmuss and Agyeman 2002). That is, climate change behaviors include mitigation behaviors, both individual (e.g. energy saving measures, transportation decisions) and collective (e.g. community organizing) (Gifford, Kormos, and McIntyre 2011). Several researchers explicitly offer arguments that climate change behavior should be the primary outcome of interest of CCE (Krasny and DuBois 2016; Waldron et al. 2016). Increasingly, the need for mitigation and adaptation strategies is recognized in EE and Education for Sustainable Development (ESD) policy and research (Blum et al. 2013). Further, Krasny and DuBois (2016) suggest that CCE should extend beyond reducing impact to include adaptation, especially those measures consistent with EE values of improving environmental quality (e.g. green infrastructure). Other papers couch their research questions in the argument that behavior is a worthy goal of CCE, as they aim to uncover factors that inspire climate change behavior (Howell and Allen 2016) and mitigate barriers to it (Kenis and Mathijs 2012; Román and Busch 2016). Similar to the EE approach of promoting skills and motivations necessary for environmental action rather than specific prescriptive behaviors (Hollweg et al. 2011), other CCE researchers argue for climate

change engagement (Wibeck 2014; Howell and Allen 2016; Monroe et al. 2015). However, the intent is similar: CCE researchers are interested in encouraging climate change behaviors.

Even though much of CCE research identifies behavior either explicitly or implicitly as an outcome of interest, there is some resistance about having behavior change as an outcome, more so in some disciplines than others. Science education seems more reticent than environmental education, perhaps because action has been considered as a goal of EE since its articulation in the Tbilisi Declaration; a goal of environmental education is 'to create new patterns of behavior of individuals, groups and society as a whole towards the environment' (The Tbilisi Declaration as quoted in H. Hungerford et al. 2001, 15). In contrast, the goal of science education is oft held as increasing levels of scientific literacy, which has been characterized most often as possession of scientific knowledge by individuals (DeBoer 2000).

In addition to studying climate change behavior itself, CCE researchers have identified a myriad of potential and interrelated predictors of climate change behavior. Though many CCE researchers critique the knowledge deficit model, several do include outcomes related to knowledge. For instance, several investigate climate change understanding, which includes mental models (Niebert and Gropengiesser 2013) and conceptual models (Shepardson et al. 2012) as well as climate science knowledge (Hestness, McGinnis, and Breslyn 2016). Others emphasize critical evaluation of information, such as related to scientific arguments (Sezen-Barrie, Shea, and Borman 2017) or ability to identify and resist misleading media messages around climate change (Bentley, Petcovic, and Cassidy 2016). In general, this research implies or explicitly suggests (Dijkstra and Goedhart 2012) that knowledge is a useful outcome as a precursor to behavior. Others focus on more affective dimensions of learning, such as belief (Shealy et al. 2017), identity (Walsh and Tsurusaki 2017), attitudes (Dijkstra and Goedhart 2012), and hope (Ojala 2012), and several acknowledge social context (Hestness, McGinnis, and Breslyn 2016; Stevenson, Peterson, and Bradshaw 2016) in forming perceptions of climate change and encouraging behavior. We note that one area of research that would be particularly useful would be linking these outcomes within a theoretical framework. Although EE frameworks are likely useful in the context of CCE (Kollmuss and Agyeman 2002; Hollweg et al. 2011), unique attributes of CCE (e.g. the highly politicized context of climate change) warrant theoretical development specific to this area of research.

Variation in methods, contexts, and participants

Much like the diversity of EE research questions, the methods used to address them are varied. Several of the studies included in this collection utilize surveys (Bentley, Petcovic, and Cassidy 2016; Howell and Allen 2016; Stevenson, Peterson, and Bradshaw 2016; Dijkstra and Goedhart 2012; Ojala 2012). Although surveys have a limited ability to capture complexities likely inherent in learning about climate change (e.g. mechanisms of how cultural worldviews filter information, how knowledge is contextualized by social actors), their inclusion in CCE may be particularly useful in comparative studies (e.g. evaluating multiple CCE interventions) or determining which factors are most predictive of behavior (e.g. as in theoretical model building, as we suggest above). Others employ interviews (Krasny and DuBois 2016; Sezen-Barrie, Shea, and Borman 2017; Waldron et al. 2016; Kenis and Mathijs 2012; Boyd and Osbahr 2010), text analysis (Román and Busch 2016), and video analysis (Bentley, Petcovic, and Cassidy 2016), representing qualitative work that is most useful in understanding the complex process of learning about climate change. We are particularly encouraged to see examples of mixed methods (Hestness, McGinnis, and Breslyn 2016) and review papers (Blum et al. 2013; Brownlee, Powell, and Hallo 2013; Wibeck 2014), as this integrative and synthetic work is critical to ensuring this rapidly emerging area of research continues to move forward.

In addition to a diversity of questions and methods, this collection represents the perspectives of several populations in varied contexts. Many of the included studies focus on adults (Bentley, Petcovic, and Cassidy 2016), including teachers, other educators (Howell and Allen 2016; Sezen-Barrie, Shea, and Borman 2017; Waldron et al. 2016; Boyd and Osbahr 2010), college students (Shealy et al. 2017), and Extension agents (Monroe et al. 2015). Others focus on younger audiences (Hestness, McGinnis, and Breslyn 2016; Stevenson, Peterson, and Bondell 2016) or consider both adults and children (Niebert and Gropengiesser 2013; Ojala 2012). Those studying students or teachers commonly work within a formal education context, either as a setting for the study (Waldron et al. 2016; Dijkstra and Goedhart 2012; Niebert and Gropengiesser 2013; Román and Busch 2016) or as a way to access participants (Hestness, McGinnis, and Breslyn 2016; Shealy et al. 2017; Stevenson, Peterson, and Bradshaw 2016). Although many focus on the individual, a few studies trend toward more community-based or organizational contexts, such as NGO-level organizational learning (Boyd and Osbahr 2010) or within the Cooperative Extension Service (Monroe et al. 2015). This variety of study contexts is encouraging, as learning occurs everywhere and across the lifespan. As we see the value in synthetic methodologies, we also encourage more research to blur the boundaries from the young to old, formal to informal, and individual to community.

There is a lack of geographical diversity in the articles in this special collection, originating primarily from research being conducted in the Northern and Western hemispheres. Ten of the articles are coming from North America, and eight from Europe. This is a trend also seen in EE research related to K-12 outcomes (Ardoin, Clark, and Kelsey 2013) and climate change education research reporting on interventions (Monroe et al. 2017). This geographical predominance may be due partially to choosing articles that are published in English. However, we recognize that while there is likely an imbalance due to the language in which the articles are published, there is also need for more research from the Southern and Eastern hemispheres to be represented in international journals such as *EER*.

Working across disciplines

Much of the existing literature in climate change education has emerged within science education research (e.g. Shepardson, Roychoudhury, and Hirsch 2017) and environmental education research. More recent work has begun branching outward from and into other disciplinary domains including social studies education (Ho and Seow 2015), arts education (Bieler 2014), and even mathematics education (Barwell 2013), to name a few. On the one hand, climate change education is exciting work due to the interdisciplinary nature of the issue. On the other, integrating climate change education – like the integration of other complex environmental issues into formal school structures – has suffered due to the disciplinary nature of traditional schooling (Martina, Hursh, and Markowitz 2009). Informal educators often have more freedom to teach climate change in a more integrated fashion and researchers working in this area are beginning to publish on CCE in these settings (e.g. Stylinski et al. 2017).

The field of science communication offers one area for possible interdisciplinary work, with message framing serving as a theoretical framework that crosses over between disciplines (Busch 2017). As an example, several of the articles in this collection examined the role of messaging in educational contexts. Román and Busch (2016) conducted a systematic functional analysis – a technique used in sociolinguistics – of middle school science textbooks to determine the framing of certainty and human agency in sections related to climate change. They found that, in general, the textbooks used word choices that portrayed high levels of scientific uncertainty and disconnected humans from climate change (as either causal agents or as solution actors). In another article from this collection, Bentley, Petcovic, and Cassidy (2016) drew themes across YouTube videos to articulate common themes in anti-climate change messages. They grouped denialist messages into five categories: naive statements, sophisticated statements, 'it's natural' statements, statements focused on the good effects of climate changes, and 'it's part of a larger

cycle' statements. The researchers then used these categories to develop and validate a survey tool that measures agreement with denialist messaging to be used for audience segmentation purposes. In addition, Sezen-Barrie, Shea, and Borman (2017) examined denialist messages and counterarguments that teachers are able to construct about climate change. They found that teachers who agreed with denialist messages had greater difficulty constructing valid rebuttals, mainly attributable to conceptual and epistemic misunderstandings. Each of these studies are similar to research being conducted in science communication, either through shared conceptual and theoretical frameworks or methodologies. However, as of yet, the CCE research community is separate from the science communication research community. It is our hope that there could be greater collaboration in the future, and, in the next section, we highlight other areas that are ripe for continued research.

The future of CCE: recommendations for research

Despite being a relatively young area of research, we hope this typology has provided an overview of the richness of theoretical perspectives and research methodologies being employed. In assessing where the research has been, we have identified some areas for new opportunity.

There is a generous amount of research about what people understand (or misunderstand) about climate science, and therefore, work on reviews and syntheses would be useful for this particular outcome of interest. In addition, more research developing and utilizing interventions designed to increase learning and decrease misconceptions would be a logical next step. Niebert and Gropengiesser (2013) emphasized the importance of developing empirically-supported educational experiences. Shepardson et al. (2012) suggest collaborative research with practitioners as being an important avenue to develop these effective educational interventions. Krasny and DuBois (2016) also points to the need for additional teacher professional development to support teachers as they improve CCE in their classrooms.

A significant opportunity for research exists within the sociocultural and critical perspectives. More research is needed that includes analysis at the family level, the classroom level, the community level, and explicitly consider the impact of culture, worldview, and political identity (Hestness, McGinnis, and Breslyn 2016; Stevenson, Peterson, and Bradshaw 2016). Román and Busch (2016) and Hestness, McGinnis, and Breslyn (2016) also emphasize the need for teacher professional development and research to support the pedagogy needed to effectively include these sociocultural elements in teaching. Both of these theoretical perspectives emphasize the collective nature of knowledge and action that seem to be at the heart of stated goals for climate change education, namely mitigation and adaptation. As such, another future endeavor involves developing educational experiences that include the role of citizenship, and the social and economic elements of climate change (Waldron et al 2016; Shealy et al 2017). Jickling (2013) acknowledges the difficulties with a transformative approach to CCE but nonetheless challenges educators to enable 'learners to tackle the 'impossible'' (174).

Methodologically, there is need for the development, validation, and utilization of common instrumentation (Dijkstra and Goedhart 2012; Bentley, Petcovic, and Cassidy 2016). Furthermore, Ojala (2012) recommends the inclusion of multi-item scales to more accurately measure identified outcomes. Many authors in this special collection describe the need for additional research and practice that draws from and contributes to science communication. Wibeck (2014) suggests more integrative work around the concept of public engagement – a term common in science communication. Brownlee, Powell, and Hallo (2013) and Monroe et al. (2015) call for creating effective messages for specific audiences. Additionally, there is a lack of research that represents the full geographical range available. This, we think, is particularly important due to the inequitable causes and unbalanced effects of climate change, making this lack of representativeness in CCE research an environmental justice issue in need of rectification.

A diversity of theoretical perspectives and methodologies is valuable to shine light on CCE from different angles; however, it would be beneficial to the field to do some of the intellectual heavy-lifting that might result in an integrative theory, that spans across the theoretical perspectives. In keeping with our introduction, we come together in conversation and reflection, to pose our hopes for the field moving forward:

STEVENSON: I am encouraged by the synergies that seem to be gaining traction in the last several years. There seems to be an excitement and urgency to the work, which is appropriate; climate change is an urgent issue! I am encouraged to see the many disciplines attending to CCE, and it seems that recent efforts (like this special collection) are attempting to move from disparate multidisciplinarity to integrative interdisciplinary and transdisciplinary work. I think this will be critical to finding ways to best equip current and future generations with the tools they need to live with and respond to a changing climate.

BUSCH: I believe this area of research can move forward through a bit of work around synthesis and meta-analysis, looking across the numerous individual studies to develop a sense of 'what is known.' This step is important, as well, for the dissemination of those results to be used in practice in educational settings, making the results of the research available and useful for practitioners.

HENDERSON: The number of junior scholars and practitioners who are slowly and steadily beginning to engage heartens me. I sense a growing interest in this area of inquiry and have been trying to lay some intellectual groundwork for when those in positions of power begin to shift institutional priorities and resources toward this issue. This will not happen for some time given at the Federal level in the United States given how openly hostile the Trump Administration has been toward climate change research (CBS News 2018). But this will change eventually and there will be a large cadre of people who are working on this issue. What artifacts are we creating now for when the tide turns? I ask this question often. I've been frustrated for some time with the relatively slow uptake of CCE work within the broader field of educational research and have been trying to write with my disengaged colleagues in mind (e.g. Henderson, Bieler, and McKenzie 2017). Other professional organizations (e.g. ASA, AAA) have already empaneled expert working groups within their specific subjects to produce 'state of the field' documents that articulate research findings and avenues for future engagement. No such project has yet occurred within the educational research community. Instead CCE research remains fractured and disconnected, with mostly junior scholars working within the narrowly defined confines of their specific disciplinary traditions. This is an unsustainable situation given climate change's collective action problem: individual actions alone will not suffice given the global nature of the issue. My hope is that those with social, institutional, and financial power within education research itself will begin to direct resources toward this issue, and absent that, that a critical and organized mass of educational researchers will pressure them into action. Those of us doing work in CCE already face an openly hostile political climate from those who are culturally, politically and economically primed to resist such scholarship. Having social, institutional and financial support behind our work would go a long way toward alleviating some of the pressures that we face and would help grow this emerging field of inquiry. This needs to happen much sooner than later given what we know about the immediacy of addressing climate change.

Join us?

Notes

1. As of the publication date, EbSco Host database shows approximately 1200 written works related to climate change education since 1983. A ProQuest search identifies approximately 6,000 articles related to climate change education in the same time period.

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