


Please cite the Published Version

Rousell, D  and Cutter-Mackenzie-Knowles, A (2020) A systematic review of climate change education: giving children and young people a 'voice' and a 'hand' in redressing climate change. *Children's Geographies*, 18 (2). pp. 191-208. ISSN 1473-3277

DOI: <https://doi.org/10.1080/14733285.2019.1614532>

Publisher: Taylor & Francis (Routledge)

Version: Accepted Version

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A Systematic Review of Climate Change Education: *Giving Children and Young People a 'Voice' and a 'Hand' in redressing Climate Change*

Abstract

The reality of anthropogenic climate change has been established 'beyond reasonable doubt' by leading scientists worldwide. Applying a systematic literature review process, we analysed existing literature from 1993-2014 regarding climate change education for children and young people, with the aim of identifying key areas for further research and innovation in the field. While a number of studies have indicated that children and young people's understandings of climate change are generally limited, erroneous and highly influenced by mass media, other studies suggest that didactic approaches to climate change education have been largely ineffectual in affecting students' attitudes and behaviour. The review identifies the need for participatory, interdisciplinary, creative, and affect-driven approaches to climate change education, which to date have been largely missing from the literature. In conclusion, the authors call for the development of new forms of climate change education that directly involve children and young people in responding to the scientific, social, ethical, and political complexities of the issue.

Introduction

Children and young people are growing up in increasingly uncertain and precarious times, as the social, cultural, and environmental effects of global climate change begin to permeate their everyday lives and communities (Lee, 2013; Selby & Kagawa, 2010). Each consecutive report released by the Intergovernmental Panel on Climate Change (IPCC) has confirmed the increasing extent and impact of anthropogenic climate change at the planetary scale (IPCC, 2007; 2012; 2014). Rapid technological advances in environmental sensing, satellite imaging, and computational modelling are enabling scientists to track and predict the effects of human-induced climatic changes with increasing clarity and precision (Gabrys, 2016). This increasing quality and granularity of climate data has also brought issues of social justice to the fore, as climate change is predicted to impact most severely on Indigenous people and children in majority world countries¹ with relatively low ecological footprints (Crate & Nuttall, 2009).

Cultural issues associated with climate change have also reached a point of saturation within the public domain through diverse forms of informational, digital and social media (Stokols, et al, 2009; Lowe et al, 2006). Many children and young people are confronted on a daily basis with unsustainable patterns of human consumption, population growth, waste production, habitat destruction, pollution, and contamination that exceed the carrying capacities of the Earth's ecological systems (McNeill & Engelke, 2014). Moralizing and politicizing discourses around climate change have also become part of children and young people's everyday lives in many parts of the world. On the one hand, recent neo-conservative and populist movements in the United States, Europe and Australia are circulating wide-spread climate denial on moral and political grounds, as scientific evidence is ignored or contested under the auspices of a "post-truth" regime (Cutter-Mackenzie & Rousell, 2018). On the other hand, children and young people are increasingly exposed to apocalyptic visions of the disastrous impacts of climate change through the internet, social media, and film-based media (Colebrook, 2014). These competing contortions and entanglements of climate fact, value, and concern are contributing to a state of existential anxiety among children and young people, with a large-

¹ The term 'majority world' is used to denote non-Western countries (formerly referred to as third world or developing countries). Majority world countries constitute two-thirds of the Earth's human population (Alam, 2008).

scale Australian study finding that 25% of children were afraid that the world would end within their lifetimes (Tucci, Mitchell & Goddard, 2007).

While children and young people are being positioned as future leaders whom the public expects to overcome the legacies of environmental inaction (Lee, 2013), they currently have limited opportunities to cultivate, voice, and express their understandings, concerns, and imaginings about climate change within their local environments and communities. It is thus widely acknowledged that innovative and effective forms of climate change education are needed for children and young people worldwide, who will be forced to grapple with the uncertain effects of climate change brought forth by previous generations (Kagawa & Selby, 2012; Delelo, 2011; Ekpoh, 2011; Devine-wright, Devine-Wright & Fleming, 2004; Pruneau, Gravel, Bourque & Langis, 2003; Fortner, 2001; Hayden et al, 2011; Papadimitriou, 2004). Climate change education, however, remains a relatively nascent and under-theorised area of inquiry as considered independently from established fields such as environmental education, science education and education for sustainability (Blum et al, 2013; Laessoe et al, 2009).

This paper aims to establish the topography of existing climate change education research published between 1993 and 2014, with a specific focus on the relevance of this research to children and young people. A secondary aim of the paper is to uncover emerging trends and innovations in the literature which might inform creative and participatory approaches to climate change education. In pursuing these aims, we begin by mapping and evaluating the global distribution and typology of climate change education research using a systematic survey of 221 published works, including books, journal articles and refereed conference papers (Pickering & Byrne, 2014). We purposefully retain a broad-based approach in this survey, in order to identify the multiple disciplines, contexts and approaches which might contribute to innovative and inclusive forms of climate change education for children and young people. As Stephens and Graham (2008) argue, climate change education should not be limited to formal educational settings since the vast majority of people will engage with the issue of climate change outside of the traditional classroom. This means that children and young people will inevitably learn about climate change in many different locations: in school, in museums, on television, in the newspaper, on the internet, in films and novels, at community events, in their homes, neighborhoods, and their own backyards. For this reason, our survey includes not only research in schools and universities, but also research undertaken in informal educational settings such as museums, zoos, and national parks.

The first section of the paper establishes the method undertaken in conducting the systematic literature review, including the development of categories and grounds for inclusion of literature. The second section provides an outline and analysis of the results of the review, using graphic illustrations to map the geographical, disciplinary and contextual terrains of climate change education research. Many of the studies contextualized in primary and secondary education indicated that students' understandings of climate change are generally limited, erroneous and highly influenced by mass media (Rye, Rubba & Weisenmayer, 1997; Shephardson et al, 2009). Other studies suggest that scientific knowledge-based approaches have been largely ineffectual in affecting the attitudes and behavior of children and young people towards climate change (Dijkstra & Goedhart, 2012; Brownlee, Powell & Jeffrey, 2013). Based on the findings of this international review of the literature, we argue that creative, participatory and technologically-mediated approaches should be foregrounded as methods which can enable children and young people to engage with climate change in ways that are culturally and regionally relevant. This discussion comprises the third section of the paper, in which several exemplary studies are highlighted which have successfully engaged children and

young people with climate change awareness and action in their communities. This analysis and discussion of findings then informs our concluding section, in which we identify a pressing need for participatory research that empowers children and young people in addressing the complex implications of climate change in their communities and environments.

Methods

The method used for this literature review was based on the systematic quantitative literature review process developed by Guitart, Pickering and Byrne (2013). This method has been specifically used to address complex and interdisciplinary research areas associated with environmental studies in the natural and social sciences (Roy, Byrne & Pickering, 2012). In seeking to establish the contours and movements of climate change education in a global context, this method proved effective in mapping the existing literature across a range of categories. As we sought to track emerging trends and innovations in climate change education, this method was effective in allowing us to identify innovative research projects in domains which may have eluded our search using more constrained criteria. Museum education, for example, proved to be a fertile area for climate change education which combines experiential, technologically-mediated and creative forms of engagement for children and young people (see Cameron, Hodge & Salazar, 2013; Steiner & Crowley, 2013).

Our use of the systematic survey method was modified to suit our particular aim of establishing the field of climate change education research, while also allowing for unexpected discoveries to emerge in a variety of contexts. We began with a very wide search criteria, using ‘climate change education’ as the key words that we entered into Google scholar. We scanned over 600 of the results yielded by this search for potential relevance to climate change education for children and young people, with 270 publications initially identified for inclusion in the review. This number was eventually reduced to 220 publications after 50 works were removed due to a lack of direct relevance to children and young people. Beyond this the indicators for inclusion were kept fairly supple, allowing for the relevance of diverse educational contexts for children and young people’s learning experiences around the world. Community projects on remote islands were included, for example, along with projects undertaken at zoos and aquariums, in teacher education programs at universities, by councils in agricultural areas, as well as longitudinal research into public opinion on climate change and the effects of mass media. This approach was consistent with a relational view of climate change education as contextualized within the complex networks of everyday life, rather than being confined to the science classroom in formal education settings (Stephens & Graham, 2008). From this perspective, children and young people learn about climate change in relation to the multiple viewpoints of parents, teachers, media, communities, environments and institutions, among many other influencing factors. Our systematic review sought to account for these multiple perspectives on climate change education in establishing a diverse and inclusive geography and typology of the field to date.

To initially establish the field of inquiry, the 220 publications were analysed across five basic categories, with the results recorded in a specially designed database. The five categories included: 1) the geographical *location* of the study itself, or in the case of a conceptual paper, the location of the lead author; 2) the *date* of the publication; 3) the *contextual focus* of the study with regards to primary, secondary, tertiary or other educational setting; 4) the *discipline* which the study was grounded in; and 5) the *approach* to climate change education taken or advocated in the study.

We also conducted a second level of systematic qualitative analysis throughout the process of scanning the 220 publications. This involved looking for innovative approaches to climate change education which could work effectively across multiple disciplines and educational settings. More specifically, we identified projects which indicated new trends in the field, engaged directly with communities and regional environments, and had the potential to inform further research in climate change education. This process identified a number of multi-faceted projects which combined technology, creativity, active participation, scientific methods, and ethical inquiry in ways which were meaningful and relevant for children and young people. A critical analysis of selected projects which we identified through the survey is undertaken in the 'discussion' section, which follows the 'findings' section below.

Findings

This section of the paper provides an account of the results of our review of the literature across the five categories of geography, chronology, contextual focus, discipline and approach. In each subsection we offer an overview of climate change education research with respect to each category. We also aim to identify a number of trends and tensions which were revealed through our reading of the literature.

Geography

One of our initial aims in undertaking this review was to establish a geography of climate change education research in an international context. The common indicator used for geographical location was the actual place where the research was undertaken or produced, rather than tracking the locations of the journals and companies responsible for publishing the studies. Using this method, we found the research to be geographically widespread, with most populated regions of the world involved in some form of climate change education research with relevance to children and young people (see *Figure 1*).

Our review indicated that the United States had the greatest density of climate change education research across a wide range of disciplines and educational contexts between 1993 and 2014. American publications accounted for 77 out of the 220 studies identified through this review. The American literature tended to focus on the development of formal climate change curricula and resources in schools and universities (see Hallar, McCubbin & Wright, 2011; Choi et al, 2010), students' and teachers' understandings of climate change science (see Lombardi, 2010), and the influence on public opinion and policy associated with climate change (see Hamilton, 2010; Leiserowitz, 2006). The relevance of indigenous knowledge for climate change education was also identified as an emerging area of research in the United States (see Sommer et al, 2004; Roehrig et al, 2012; Nam et al 2013). Canada and Europe both showed significant activity in formal climate change education research, sharing a focus on curricular, pedagogical and social initiatives in schools and universities (see Nazir et al, 2011; Senbel, Ngo & Blair, 2014; Fortner, 2001; Schreiner, Henrikson & Hansen, 2005). Canadian research also had a strong association with educational programs in museums and other public institutions (see Pruneau et al, 2001). The continents of Africa and Australia each registered a similar level of 10-12 publications, mostly focusing on climate change curriculum in primary, secondary and tertiary institutions (see Delelo, 2011; Bardsley & Bardsley, 2007). Research in the Pacific Islands tended to focus on community education associated with adaptation and mitigation of disaster risks associated with climate change, such as rising sea levels (see Gero, Meheux & Dominey-Howes, 2011). Asian and South American literature was found to be quite sparse, particularly in relation to population densities in those regions.



Figure 1: Distribution and density of climate change education research publications across the world, with the size of each sphere indicating the relative density of publications in each region.

Our study was limited by the inclusion of only English-language journals, so it is quite possible that many non-English language publications were overlooked for that reason. Much of the Chinese research we did uncover was undertaken and published by European researchers in English-language journals (see Sternang, 2011; Sternang & Lundholm, 2012). While most of the publications we reviewed focused on single nations or regions, the cross-national report *Climate Change and Sustainable Development: The response from education* (Laessoe et al 2009) was a notable exception. This report provides a critical analysis of climate change education across ten countries, with an emphasis on climate change as a conceptual and practical focus area for education across disciplines, rather than a specialised component of science or environmental education (p. 15).

Chronology

To establish the chronology of climate change education research, we tracked the dates of publication for each of the studies (see **Figure 2**). Because we began the survey in the first half of 2014, many of the publications released in that year were not included in the review. The earliest distinct publications on climate change education we could find included Henderson and Holman's (1993) *Global Climate Change Education: Technology transfer to schools*. This paper describes an effective partnership between an environmental research laboratory and local science teachers in devising a climate change curriculum for secondary students in the United States. Boyes and Strannistreet (1993, 1994, 1997) also published a number of early papers on children's conceptual knowledge of ozone depletion and global warming, broadly

arguing that children need to learn these scientific concepts from a young age before ‘alternative conceptions’ became entrenched in their thinking.

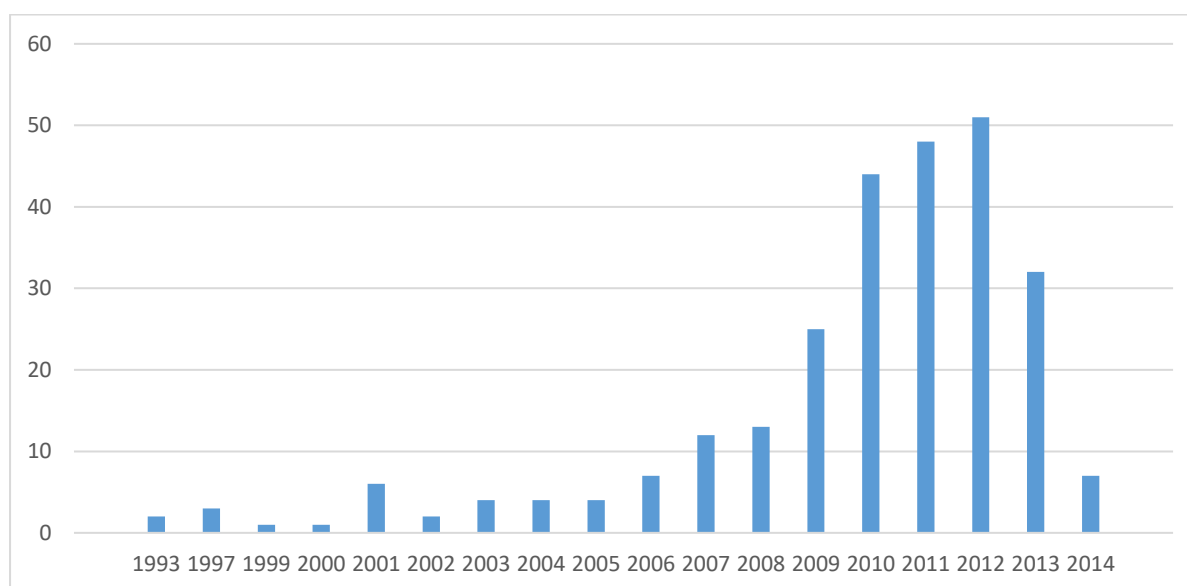


Figure 2: Publications on climate change education by year

Our findings indicate that very little research was published on climate change education throughout the 1990s and early 2000s. Since 2009, however, we can see a significant increase in publications, which also coincided with the widespread internationalization of the field of climate change education beyond the United States, Canada and Europe. Interestingly, we also registered a slight decline in research publications between 2012 and 2013, a downward trend which also appeared to be playing out in the first half of 2014.

Contextual Focus

The contextual focus for each of the publications comprised the third category of analysis undertaken in the review (see **Figure 3**). The contextual focus accounted for the educational settings which were addressed through the research. The research which was focused on primary and secondary schools tended to highlight scientific knowledge, conceptualization and agency as being of central concern for teaching and learning about climate change (see, for example, Shephardson et al, 2009; Shephardson et al, 2012; Rye, Rubba & Wiesenmayer, 1997; McNeill & Vaughn, 2012). Many of these articles approached climate change education strictly through the lens of science education, as founded on the assumption that increased knowledge of climate science is the primary goal of climate change education. This position was challenged strongly, however, by large-scale empirical studies which revealed little to no correlation between scientific knowledge and pro-environmental behavior (Dijkstra & Goedhart, 2012). A range of studies also demonstrated that cooperative (Devine-Wright, Devine-Wright & Fleming, 2004), interdisciplinary (Feierabend & Eilks, 2011), participatory (Ohman & Ohman, 2013), place-based (Bardsley & Bardsley, 2007; Hallar, McCubbin & Wright, 2011) and experiential (Pruneau et al, 2003) learning programs had significant impacts on the attitudes and actions of children and young people towards climate change. The tension between knowledge-based approaches to science education and interdisciplinary, affect-driven and experiential approaches to climate change education was revealed as a significant area of dissent in the literature associated with primary and secondary education.

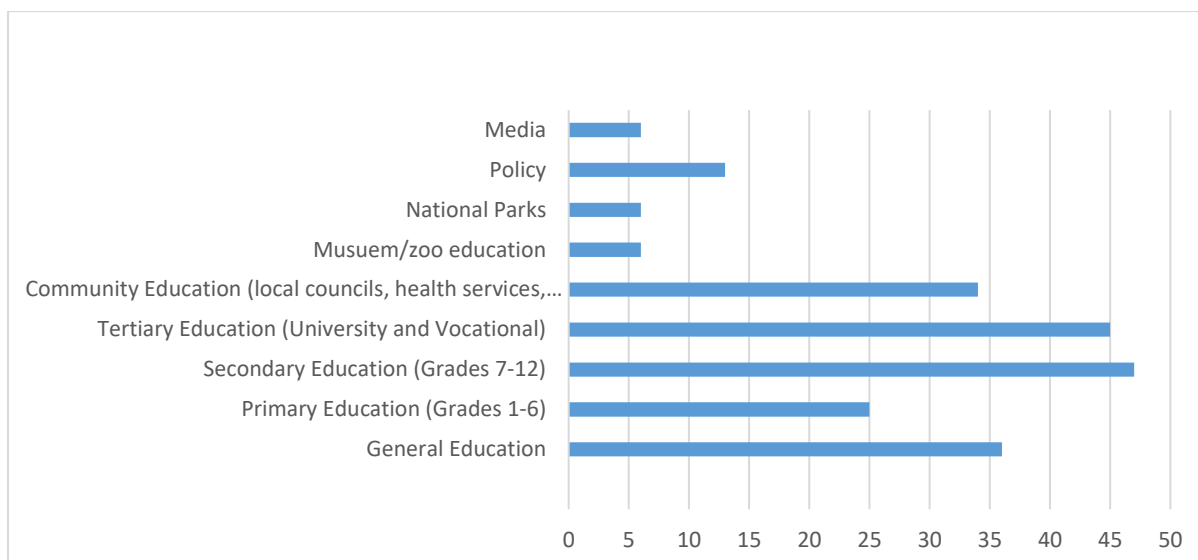


Figure 3: Contextual focus of research in climate change education

Tertiary education also registered strongly in terms of climate change education research, but was much more cohesive in calling for innovative and interdisciplinary approaches when compared to the literature on primary and secondary education. Haslett and Wallen (2011), for example, report on the development of open-source and web-based climate change education resources which can be reconfigured for different disciplines in universities around the world. Davison et al (2011) and Pharo et al (2014) both describe the development of cross-disciplinary communities of practice working within universities to create new curricular and pedagogical approaches to climate change education. Senbel, Ego and Blair (2014) further report on the effective use of digital and social media platforms to critically engage 6500 university students with energy-reducing actions in response to climate change. These examples of the current literature in higher education are indicative of a trend towards interdisciplinary teaching, learning and research which acknowledges the pivotal role of culture, media and creativity in addressing the complex issue of climate change in higher education.

Community education was also identified as a significant focus area for climate change education research. Many of these studies involved partnerships between various public and private stakeholders, such as local councils, universities, resource management bodies and community groups (see, for example, Crabbe & Robin, 2004). A number of cross-national (Puppim de Oliveira 2009) and cross-municipality (Herriman & Partridge, 2010) comparisons of local councils were effective in tracking the results of climate change education initiatives at the community level. The Sandwatch project (Cambers & Diamond, 2010) is an inspiring example of direct community participation in climate change education and action on remote islands in the Caribbean. Sandwatch provides a specific methodology for children, young people and adults to work together to monitor, analyse and take action on climate change in their own communities and environments. They also learn how to share their findings and experiences through the production of local print media, videos, online networks and social media.

Four smaller sub-categories were used to account for climate change education research associated with public policy, mass media, national parks, museums and zoos. The literature on public policy, for example, calls for science educators to actively inform climate change policy (Hill, 2010), along with critical analyses of the implications of international climate policy for remote agricultural communities (Rai, 2010). Several studies found that the role of

mass media strongly affected people's attitudes towards climate change, but rarely resulted in behavioural changes. Howell (2014), for example, found that participants' attitudes changed after exposure to the climate change documentary *The Age of Stupid*, but that this did not necessarily translate into changes in their environmental behaviour. Both Lowe et al (2006) and Leiserowitz (2004) found that participants were highly motivated to act on climate change after watching the fictional disaster film *The Day After Tomorrow*, but often lacked the knowledge of what actions they could undertake to mitigate climate change.

National parks and other 'nature-based' spaces are cited as significant places for the general public to experience and help document the effects of climate change (Brownlee, Powell & Hallo, 2012), for example through phenology and other forms of 'citizen science' (Miller-Rushing et al, 2011). Museums are also emerging as key places for the public to engage with climate change, often through interactive media and immersive learning environments (Cameron, Hodge & Salazar, 2013). Salazar (2011, p. 124) describes how museums are approaching climate change education as a form of public pedagogy, in which citizens are equipped with the 'knowledges and epistemologies to participate in actions and debates about climate change'. Zoos and aquariums are similarly being framed as places where people make personal connections with climate change issues, specifically through the activation of caring and empathy towards animals whose existence is being threatened (Grajal & Goldman, 2012). Like many museums, zoos are now developing web-based simulations and interactive learning activities which continue to engage the public beyond the boundaries of the audience's visit to the zoo.

Disciplinary Focus

The fourth category we analysed in the review was the disciplinary field associated with each publication on climate change education (see **Figure 4**). While we identified a range of eight distinct disciplinary areas, the majority of publications were associated either with STEM education (science, technology, engineering and mathematics), or with environmental and sustainability education. Resource management also accounted for a significant number of publications, which included adaptation and mitigation initiatives within businesses, local councils and municipalities, and agricultural communities. We discuss these three main disciplinary areas in relative depth below, before briefly describing the other five subcategories of teacher education, behavioural science, social science, arts and humanities and digital media.

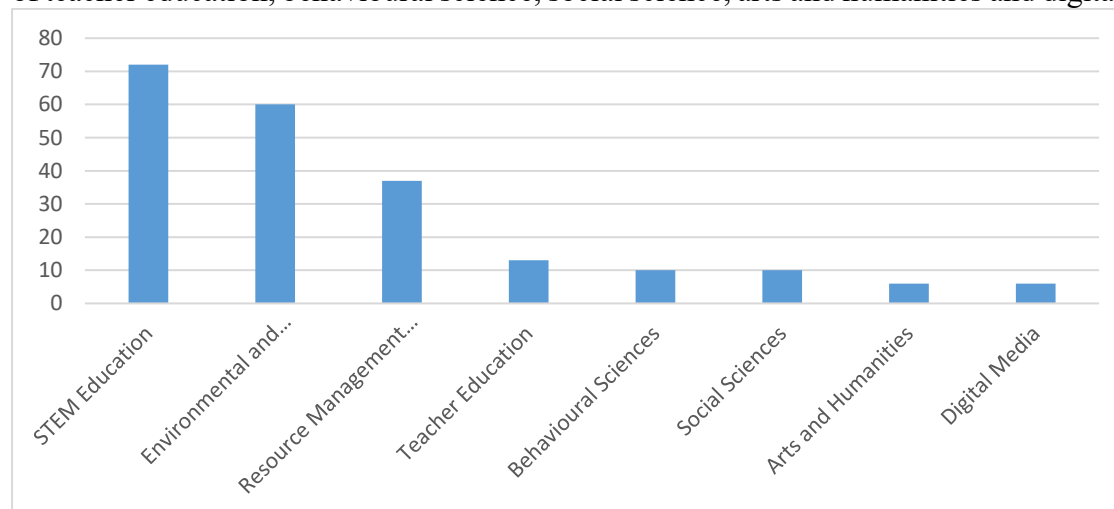


Figure 4: Disciplines associated with climate change education research

For the purposes of this review, we included all fields of education associated with the physical sciences, technology, engineering and mathematics within the category of STEM. This disciplinary category accounted for the majority of publications, most of which were associated with formal science-based education in schools and universities. Wise (2010), for example, reports on a large survey of 628 science teachers in public schools in the United States. She found that the majority of science teachers included climate change in their curriculum, even though the topic was generally not included in the state or national standards for science education. Many of these teachers also failed to demonstrate scientifically accurate understandings of climate change, and felt that an unbiased approach to the 'climate change controversy' should be presented to students. Wise (p. 297) argues for an interdisciplinary instructional approach to climate change education, which would see the topic distributed across the curricula of the physical sciences, social sciences and the humanities. This echoes Kagawa and Selby's (2012) observation, in an international context, that the socio-cultural and ethical dimensions of climate change are starting to be recognized as central to the science curriculum. Sharma (2010) further argues that science education is, in itself, a powerful societal factor which can affect climate change attitudes and behavior at the cultural level. Climate change then has the potential to both transform and elevate the status of science education more broadly, as a discipline which has both ethical and political implications. Hill (2010) similarly supports this expanded political significance of science education, in his call for science educators to directly inform climate change policy at the level of governance.

A large number of studies in the STEM category also focused on the misconceptions and 'alternative conceptions' about climate change held by students, teachers and even scientific textbooks (Hallar, McCubbin & Wright, 2011; Shepardson et al 2009; 2012; Choi et al, 2010; Fortner, 2001). One of the most common misconceptions acknowledged by multiple studies is that there is a cause-effect relationship between the depletion of the ozone layer and warming associated with the greenhouse effect (Liarakou, 2011). A variety of strategies have been proposed to increase the scientific knowledge of both teachers and their students, including the use of digital media to model climate change processes and concepts (Makrakis, Larios & Kaliantzi, p. 2012; Snow & Snow, 2010), the use of narrative to promote environmental empathy and literacy (McKnight, 2010), and participatory action-research which empowers both teachers and students (Feierabend & Eilks, 2011).

A large number of publications were also identified within the subcategory of environmental education (EE). These included publications which made direct reference to environmental education, or any of the associated fields of education for sustainability (EFS), education for sustainable development (ESD), or sustainability education. These publications tended to take a different perspective from the STEM education literature, due to the conceptual and methodological diversity that characterises research in environmental education. While there remains a unifying directive within environmental education to encourage the development of pro-environmental behaviours and values (Pruneau et al, 2006), more instrumental agendas have taken hold in the sub-disciplines of ESD and EFS. Selby and Kagawa (2010) even observe a trend towards climate change denial in mainstream programs associated with education for sustainable development. These authors specifically target ESD as complicit in downplaying the ethical implications of climate change injustice, by framing climate change 'as an issue calling for a scientific or technical fix rather than as a pathology of an ethically numb, inequitable and denatured human condition' (p. 42).

Within the field of environmental education, a pro-environmental behaviour is generally taken to be one which minimises the negative impacts of humans on social and ecological systems, or a behaviour which takes steps towards more equitable relationships between humans and their environments (Pruneau et al, 2006; Kollmus & Angyeman, 2002). One of the major shifts in the environmental education literature associated with climate change education is towards more holistic approaches to effecting behaviour change, with an increased emphasis on situational and affective influences rather than cognitive and knowledge-based influences (Devine-Wright et al, 2004). Research has indicated that, on the one hand, many people involved in substantial environmental action tend to have low levels of scientific knowledge about the environment (Kempton, Boster & Hartley, 1995). On the other hand, cognitive increases in knowledge about climate change has shown little to no correlation with pro-environmental attitudes or behaviour (Dijkstra & Goedhart, 2012).

Within the environmental education subcategory, we found considerable tension around the emergence of climate change education (CCE) as a standalone field alongside EFS and ESD, among other sub-disciplines of environmental education. Selby and Kagawa (2010), for example, advocate for climate change education as a much-needed antidote to the managerial and instrumental agendas that have overtaken the field of ESD. Anderson (2012), on the other hand, argues that climate change education should be comprehensively grounded within an ESD approach. Such an approach would involve the direct participation of children and young people as agents of change within their communities, and also establish strong partnerships between education policy-makers and climate scientists to inform climate change curricula with scientific expertise (p. 194).

In their cross-national report on climate change education, Laessoe et al (2009 p. 15) find that climate change has been a central facet of environmental education in recent decades, but has yet to be established as an independent field of practice and inquiry in many countries. The authors report that climate change education has emerged as a standalone field in the last few years, notably through government-sponsored initiatives in China, Canada, and Denmark, and non-government initiatives in Brazil (p. 15). Drawing on national reports on climate change education across ten nations, Laessoe et al (p. 16) predict three possible scenarios for the global proliferation of climate change education: 1) that climate change education will develop independently of ESD and environmental education more broadly, and become a substantial component of science education programs, as has been the tendency in the USA and China; 2) that climate change education will develop into an integral component of ESD, adopting a truly interdisciplinary approach to education with a wide variety of variations and interpretations, as has been the case in Australia, the UK, South Korea and Singapore; and 3) that a hybrid of the first two scenarios will emerge, in which climate change education will be treated as an independent field of practice and inquiry which is related, and yet distinct, from ESD and other subsets of environmental education, while also operating outside the confines of general science education.

Disciplines associated with resource management were also mentioned in a large number of publications. This subcategory includes fields such as forestry, national parks and wildlife management, agricultural extension, tourism, local governance and urban development. Cohen (2010) explains how climate change science is beginning to influence policy and decision-making across these diverse contexts of resource management. He draws particular attention to the practitioners who actually design and operate the systems which support entire social and ecological communities in both urban and regional areas, and the ways that climate information can become a crucial input for resource practitioners. Monzon, Moyer-Horner and

Palamar (2011) also argue that managers of protected wilderness areas are uniquely positioned to design and implement informal educational experiences for the general public. As climate change makes biodiversity conservation an increasingly difficult (if not impossible) task, the authors suggest that national parks and other protected areas take on a social role that involves climate change education, mitigation and research programs within the surrounding community. In the context of tourism, Dodds (2010) describes an increase in climate change awareness and new opportunities for the tourism industry to take on an educational role in society. She further stresses the need for industry members and stakeholders to be educated about ways to mitigate the effects of climate change, and calls for government policy and action which will provide incentives for more sustainable tourism practices. Climate change education is particularly crucial for resource management in majority nations which depend on agricultural production for the survival of regional communities. Ozor (2010) describes how sub-Saharan African communities now face extreme food-security risks which are the direct result of climate change. In this context, effective education is needed which will enable farmers and the broader community to quickly respond and adapt to the impacts of climate change and variability (p. 120).

Given the predominance of research in science education and environmental education, we were surprised to find the literature on teacher education to be relatively limited. Most teacher education studies we did locate focused on the climate change knowledge of pre-service teachers. In a study of 172 pre-service primary school teachers in Greece, Papadimitriou (2004) found that most believed that climate change was happening based on their experiences outside the classroom, but that very few were aware of actions or strategies for mitigating the effects of climate change. He suggests that innovative resources and instructional techniques are needed which reflect the uncertain, tenuous and interdisciplinary approaches associated with social studies of science and technology (see, for example, Latour, 2004). Celikler and Kara (2011) also provide a study which targets the climate change misconceptions of pre-service chemistry and biology teachers in Turkey, also highlighting the common lack of knowledge regarding strategies for mitigation. O’Gorman & Davis (2013, p. 780) argues that teacher education faculties can play a significant role in climate change education not only through student learning, but also through their societal connections with within the broader educational community. However, they find that in the Australian context many teacher education faculties have been reticent to take up these crucial challenges and opportunities.

The behavioural and social sciences have also become mobilised within the field of climate change education research, specifically in addressing the barriers and motivators of environmental behavior change, as well as individual and community resilience and coping strategies in response to climate change threats. Swim et al (2009) provide a comprehensive report entitled *Psychology and Climate Change*: which was commissioned and published by the American Psychological Association. The report concludes with a series of recommendations for psychologists addressing climate change in their practices, including making substantive connections to other disciplines, using psychology to contribute missing pieces to climate change analyses, and being mindful of ethical and justice issues which are associated with climate change. Crate and Nuttall (2009) also describe the critical role of anthropologists in working in tandem with Indigenous communities as they respond to the social and environmental challenges introduced by climate change. They describe how many anthropologists feel they are working ‘in an emergency state as field researchers’, and that they are constantly confronted by climate change as ‘an ethical and moral issue’ (p. 10).

We found the field of digital media to be represented in the climate change education literature across a diverse range of formal and informal contexts. Examples included the use of gamification to engage public audiences with climate change scenarios and actions (Lee et al, 2013), the development of web-based applications for conducting citizen science (Han et al, 2011; Meymeris et al, 2008), the use of interactive digital simulations (Svihla & Linn, 2012; Snow & Snow, 2010), social media (Senbel, Ngo & Blair, 2014) and web-based climate change education networks between schools (Alexandru et al, 2013) and universities (Ferreira et al, 2012). Very few publications, however, were found to directly address the role of the arts and humanities in climate change education. Duxbury (2010) argues that artists have the potential to directly engage society with affective experiences and new perceptions of climate change which can lead to significant changes in attitudes and behaviour. Braidotti (2013, p. 160) also stresses the ‘specific contribution of the Humanities to the public debate on climate change, through the analysis of the social and cultural factors that underscore the public representation of these issues’. While it is evident that many arts and humanities practitioners and institutions are substantively engaging with the issue of climate change (see Braidotti, 2013; Jacobs, 2008), this potential was found to be a relatively untapped resource in the existing literature associated with climate change education.

Educational Approaches

The category of ‘educational approach’ was used to analyse the different educational methods and practices which have been foregrounded in the climate change education literature (see **Figure 5**). This was the only category under which we recorded multiple indicators for each publication, allowing us to ascertain a more accurate reading of the different approaches which have been undertaken and advocated in the existing research. For example, a single paper argued strongly for a child-framed approach to climate change education, and also advocated the use of digital technology as a powerful modality for achieving this aim (see Makrakis, Larios, & Kaliantzi, 2012). Accordingly, this paper was counted in two subcategories as both ‘child-framed’ and ‘digital/technological’ within the category of *approach*. Our findings with regards to educational approach echoed those of the previous categories of context and discipline. As a result, we now provide a brief account of this category before moving onto the discussion section that follows.

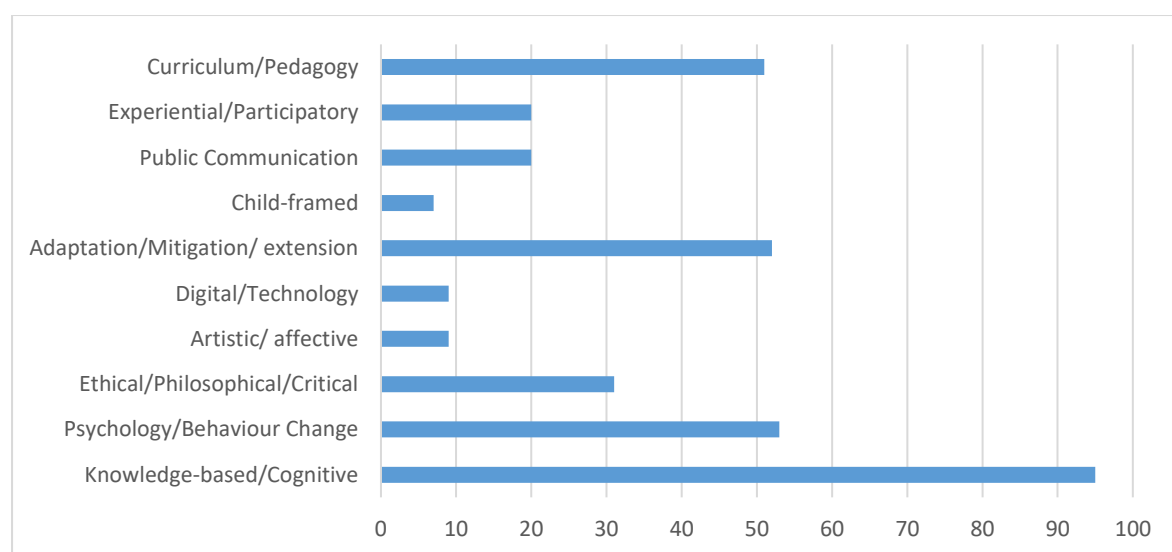


Figure 5: Approaches to climate change education research

As we found in the categories of context and discipline, there was a distinct emphasis on scientific knowledge-based approaches to climate change education, with a secondary, and closely related, emphasis on curriculum and pedagogy associated with formal education in schools and universities. Nearly half of all publications specifically referred to scientific knowledge and cognitive understandings as the primary approach towards climate change education.

Behaviour change has also been acknowledged as a primary approach for climate change education irrespective of scientific knowledge, and has been taken up in a wide range of public contexts outside of formal educational settings (see, for example, Semenza et al, 2008; Howell, 2014; Kollmus & Agyeman, 2002). Psychological approaches associated with behaviour change represented about one quarter of all publications we reviewed, revealing a significant trend in the literature over the last decade. However, while many studies reported that scientific knowledge does not correlate with changes in attitude or behavior towards climate change, there remained little to no consensus as to what approaches might be effective in promoting environmental action.

Mitigation and adaptation approaches were also referenced in about one quarter of the literature, and were generally associated with community education and local governance. These three approaches shared a similar focus on reducing the impacts of human activity on the climate, and also reducing the negative impact of climate change on both human and natural systems. While *mitigation* initiatives aim to reduce the human impacts which are contributing to climate change (Burton, 2007), *adaptation* initiatives aim to build adaptive capacity and reduce the vulnerability of individuals, communities and environments in response to changing climatic conditions (Anderson, 2012). Mitigation and adaptation approaches are often mobilised in tandem in climate change education programs which aim to reduce the risk of disaster in vulnerable communities and ecosystems (Gero, Meheux & Dominey-Howes, 2011; Kagawa & Selby, 2012).

We found that the four approaches which have dominated the literature on climate change education were generally top-down approaches, whether the focus was on scientific knowledge, formal curriculum, behavior change, or mitigation/adaptation. Yet underneath this entrenched edifice of top-down education and disaster management, a series of innovative, bottom-up approaches have begun to emerge. These include participatory approaches which empower communities of learners to design their own climate change projects and modes of engagement with the issue (Ashley, Kenton & Milligan 2009; Feirebend & Eilks, 2011; Figueiredo & Perkins, 2013). A small number of studies also focused specifically on affective approaches which provoke emotional and somatic responses to climate change issues and concerns through engagement with art, imagery and narrative (Duxbury, 2010; Leiserowitz, 2006). As mentioned above, digital technology has also emerged as an approach which has multiple applications for producing innovative and empowering forms of climate change education (Han et al, 2011; Lee et al, 2013; Meymeris et al, 2008). And lastly, a very small contingent of the literature is orientated towards child-framed approaches to climate change education, which draw on the unique perspectives and experiences of children and young people to inform new frameworks and methods for teaching and learning about climate change (Lawler & Patel, 2012; Tanner, 2010).

Discussion

In undertaking this systematic review of the literature on climate change education, we sought to map the terrain of the field and also highlight directions for future growth and development. We found the field to be geographically widespread over the last two decades, and inclusive of a diverse range of contexts, disciplines and educational approaches which are of relevance to children and young people. However, we found this diversity to be limited in scope, with top-down, science-based approaches in formal educational settings continuing to dominate the field of climate change education. Laessle et al (2009) argue that climate change education can significantly enrich, rather than limit, established modes of science education, environmental education and ESD, but only if climate change education is conceptualised as an empowering educational process which operates across disciplinary and geo-political boundaries (p. 16). In taking up this line of argument, we suggest that climate change education needs to draw on participatory and creative approaches from multiple disciplines in establishing itself as distinct from both science education and environmental education. The scientific, social, ethical, and political complexities of climate change call for such an approach, which empowers children and young people to meaningfully engage with entanglements of climate fact, value, power, and concern across multiple scales and temporalities. We further argue that climate change education should draw on the untapped capacity of children and young people themselves 'to collectively envision a better future, and then to become practical visionaries in realising that future' (Kagawa & Selby, 2009, p. 5). This requires the development of new modes of climate change education which are open to radical and visionary alternative for the future, necessarily drawing on practices associated with environmental activism, social and political intervention, digital innovation, citizen science, and the creative arts.

Conclusion

This review signals that climate change education must catch up with broader social movements and discourses which are responsive to climate change. Rather than shying away from the Earth's looming runaway climate change, the learning moment can be seized to think about what really and profoundly matters, and use children's own attitudes and beliefs as the basis for experimenting with visionary alternatives to scientific educational practices (Kagawa & Selby, 2009, p. 5). As Brownlee, Powell and Jeffrey (2013) conclude in their critical analysis of foundational processes influencing attitudes and actions towards climate change, climate change education needs to move beyond cognitive and scientific knowledge-based approaches in order to engage learners with the affective dimensions of the issue. They suggest that climate change education should become responsive to the existing beliefs, attitudes and situational contexts of specific audiences, rather than focusing on what people don't know or understand about climate change. Affective connections can then be made between diverse experiences and information about climate change, including place-based encounters with social and ecological systems, scientific data, time-lapse photography, digital simulations, maps, fictional narratives, and other forms of affect-driven educational interactions (p. 14).

As McKibben (2005, n.p.) further notes, 'we can register what is happening with satellites and scientific instruments, but can we register it in our imaginations, the most sensitive of all our devices?' In this sense, participatory and creative approaches remain relatively untouched resources for engaging children and young people with climate change. More specifically, this review identifies a pressing need for research that gives young people both a hand and a voice in addressing the complex implications of climate change in their own communities and environments. Our analysis calls for new ways of making climate change meaningful for children and young people through participatory and arts-based modes of engagement. In effect this is extending climate change education and its research beyond the realms of understanding young people's climate change science knowledge (or lack thereof), which has no bearing on

climate change itself, to far more important and pressing aims which actively empower children and young people to mitigate climate change. We therefore challenge educational researchers to be daring enough to research beyond redundant investigations interrogating children and young people's knowledge of climate change science. Such a turn may well see educational researchers working directly with children and young people themselves in genuinely collaborative, imaginative and creative ways through the emerging transdisciplinary field of climate change education.

References

Alam, S. (2008). Majority World: Challenging the West's Rhetoric of Democracy. *Amerasia Journal*, 34(1), 87-98.

Alexandru, A., Tudora, E., Bica, O., & Mayer, R. (2013). Experiences in Using Educational Resources on Climate Change Topics in Romanian schools. *International Conference on Sustainable Energy and Environment Engineering*, Proceedings of World Academy of Science, Engineering and Technology (WASET), Issue 79, Zurich.

Anderson, A. (2012). Climate Change Education for Mitigation and Adaptation. *Journal of Education for Sustainable Development*, 6(2), 191-206.

Ashley, H., Kenton, N., & Milligan, A. (Eds.). (2009). *Community-Based Adaptation to Climate Change*. London, UK: International Institute for Environment and Development.

Bardsley, D. K., & Bardsley, A. M. (2007). A Constructivist Approach to Climate Change Teaching and Learning. *Geographical Research*, 45(4), 329-339.

Blum, N., Nazir, J., Breiting, S., Goh, K. C., & Pedretti, E. (2013). Balancing the Tensions and Meeting the Conceptual Challenges of Education for Sustainable Development and Climate Change. *Environmental Education Research*, 19(2), 206-217.

Boyes, E., & Stanisstreet, M. (1993). The 'Greenhouse Effect': Children's perceptions of causes, consequences and cures. *International Journal of Science Education*, 15(5), 531-552.

Boyes, E., & Stanisstreet, M. (1994). The Ideas of Secondary School Children Concerning Ozone Layer Damage. *Global Environmental Change*, 4, 311-324.

Boyes, E., & Stanisstreet, M. (1996). Threats to the Global Environment: The extent of pupil understanding. *International Research in Geographical and Environmental Education*, 5(3), 186-195.

Burton, D. (2007). *Evaluating Climate Change Mitigation Strategies in South East Queensland*. Brisbane, Qld: Griffith University.

Braidotti, R. (2013) *The Posthuman*. Cambridge, UK: Polity Press.

Brownlee, M., Powell, R. B., & Jeffery, H. C. (2013). A Review of the Foundational Processes that Influence Beliefs in Climate Change: Opportunities for environmental education research. *Environmental Education Research*, 19(1), 1-20.

Cambers, G., & Diamond, P. (2010). *Sandwatch: Adapting to climate change and educating for sustainable development*: UNESCO.

Cameron, F., Hodge, B., & Salazar, J. F. (2013). Representing climate change in museum space and places. *Wiley Interdisciplinary Reviews: Climate Change*, 4(1), 9-21.

Çelikler, D., & Kara, F. (2011). Determining the misconceptions of pre-service chemistry and biology teachers about the greenhouse effect. *Procedia-Social and Behavioral Sciences*, 15, 2463-2470.

Choi, S., Niyogi, D., Shepardson, D. P., & Charusombat, U. (2010). Do Earth and Environmental Science Textbooks Promote Middle and High School Students' Conceptual Development about Climate Change? Textbooks' consideration of students' misconceptions. *Bulletin of the American Meteorological Society*, 91 (7), 889 -898.

Colebrook, C. (2014). *Death of the PostHuman: Essays on extinction, vol. 1*. Ann Arbor, MI: Open Humanities Press.

Crabbe, P., & Robin, M. (2004). Adaptation of Water Resource Infrastructure-Related Institutions to Climate Change in Eastern Ontario. *Community-University Research Alliance Report, University of Ottawa, Ottawa, ON*.

Crate, S. A., & Nuttall, M., eds. (2009). *Anthropology and Climate Change: From encounters to actions*. Left Coast Press: Walnut Creek, CA.

Cutter-Mackenzie, A., & Rousell, D. (2018). The Mesh of Playing and Researching in the Reality of Climate Change: Children's Research Play Spaces. In Cutter-Mackenzie, A., Malone, K., and Barrett-Hacking, E. (eds.), *International Research Handbook on ChildhoodNature*. The Netherlands: Springer.

Dalelo, A. (2011). Global climate change in geography curricula for Ethiopian secondary and preparatory schools. *International Research in Geographical and Environmental Education*, 20(3), 227-246.

Davison, A., Brown, P., Pharo, E., Warr, K., McGregor, H., Terkes, S., Boyd, D. & Abuodha, P. (2014). Distributed leadership: Building capacity for interdisciplinary climate change teaching at four universities. *International Journal of Sustainability in Higher Education*, 15 (1), 98-110.

Devine-Wright, P., Devine-Wright, H., & Fleming, P. (2004). Situational Influences Upon Children's Beliefs About Global Warming and Energy. *Environmental Education Research*, 10(4), 493-506.

Dijkstra, E. M., & Goedhart, M. J. (2012). Development and Validation of the ACSI: Measuring students' science attitudes, pro-environmental behaviour, climate change attitudes and knowledge. *Environmental Education Research*, 18(6), 733-749.

Dodds, R. (2010). Destination marketing organizations and climate change—the need for leadership and education. *Sustainability*, 2(11), 3449-3464.

Duxbury, L. (2010). A Change in the Climate: New interpretations and perceptions of climate change through artistic interventions and representations. *Weather, Climate, and Society*, 2(4), 294-299.

Ekpoh, U. I., & Ekpoh, I. J. (2011). Assessing the level of climate change awareness among secondary school teachers in calabar municipality, Nigeria: implication for management effectiveness. *International Journal of Humanities and Social Science*, 1(3), 106-110.

Feierabend, T., & Eilks, I. (2011). Innovating science teaching by participatory action research-reflections from an interdisciplinary project of curriculum innovation on teaching about climate change. *CEPS Journal*, 1(1), 93-112.

Ferreira, R., Herdman, A., Curtis, S., Chia, R., Poe, E., Thompson, R., et al. (2012). A Multinational Course on Global Climate Change. *Bulletin of the American Meteorological Society*, 93(10), 1539-1546.

Figueiredo, P., & Perkins, P. E. (2013). Women and water management in times of climate change: participatory and inclusive processes. *Journal of Cleaner Production*, 60, 188-194.

Fortner, R. W. (2001). Climate Change in Schools: Where does it fit and how ready are we? *Canadian Journal of Environmental Education*, 6, 18-32.

Gabrys, J. (2016). *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*. Minneapolis: University of Minnesota Press.

Garnaut, R. (2011). *THE GARNAUT REVIEW 2011: Australia in the Global Response to Climate Change*. New York City: Cambridge University Press.

Gero, A., Méheux, K., & Dominey-Howes, D. (2011). Integrating community based disaster risk reduction and climate change adaptation: examples from the Pacific. *Natural Hazards and Earth System Science*, 11(1), 101-113.

Grajal, A., Grajal, A., Goldman, S. R., & Marks, T. (2012). *Climate change education: A primer for zoos and aquariums*: Chicago Zoological Society.

Guitart, D., Pickering, C.M., & Byrne, J. (2012). Past results and future directions in urban community gardens research. *Urban Forestry and Urban Greening*, 11, 364-373.

Hallar, A. G., McCubbin, I. B., & Wright, J. M. (2011). CHANGE: A place-based curriculum for understanding climate change at Storm Peak Laboratory, Colorado. *Bulletin of the American Meteorological Society*, 92(7), 909-918.

Hamilton, L. C. (2011). Education, politics and opinions about climate change evidence for interaction effects. *Climatic Change*. 104 (2), 231-242.

Han, K., Graham, E. A., Vassallo, D., & Estrin, D. (2011). *Enhancing motivation in a mobile participatory sensing project through gaming*. Paper presented at the 2011 IEEE third international conference on social computing (socialcom).

Haslett, S. K., & Wallen, J. (2011). A component-based approach to open educational resources in climate change education. *Planet*, (24), 89-92.

Hayden, M. (2011). Pedagogies of empowerment in the face of climate change uncertainty. *Journal for Activist Science and Technology Education*, 3(1).

Henderson, S., & Holman, S. R. (1993). Global climate change education: technology transfer to schools. *Climate Research*, 3, 137-140.

Herriman, J., & Partridge, E. (2010). Education activities for environment and sustainability: A Snapshot of eight New South Wales councils. *Commonwealth J Local Gov*, 6, 77-89.

Hill, M. (2006). Children's Voices on Ways of Having a Voice: Children's and young people's perspectives on methods used in research and consultation. *Childhood*, 13(1), 69-89.

Hill, J. (2010). Science Education must inform and influence climate change policy. *ChemEd NZ*, 118, 9-13.

Howell, R. A. (2014). Investigating the Long-Term Impacts of Climate Change Communications on Individuals' Attitudes and Behavior. *Environment and Behavior*, 46(1), 70-101.

Intergovernmental Panel on Climate Change. (2001). *Climate Change 2001: Synthesis Report*. Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Jacobs, D. (2008). Weather Report at the Boulder Museum of Contemporary Art. *Curator: The Museum Journal*, 51(3), 319-325.

Kagawa, F., & Selby, D. (Eds.). (2009). *Education and Climate Change: Living and Learning in Interesting Times*. London, UK: Routledge.

Kagawa, F. & Selby, D. (2012). Ready for the Storm: Education for Disaster Risk Reduction and Climate Change Adaptation and Mitigation. *Journal of Education for Sustainable Development*. 6(2), 207-217.

Kempton, W. (1997). How the Public Views Climate Change. *Environment*, 39(9), 12-21.

Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, 8(3), 239-261.

Læssøe, J., Schnac, K., Breiting, S., & Rolls, S. (2009). *Climate Change and Sustainable Development: The Response from Education*. International Alliance of Leading Educational Institutes.

Lawler, J., & Patel, M. (2012). Exploring children's vulnerability to climate change and their role in advancing climate change adaptation in East Asia and the Pacific. *Environmental Development*, 3, 123-136.

Lee, N. (2013). *Childhood and biopolitics: Climate change, life processes, and human futures*. Hampshire: Palgrave Macmillan.

Lee, J. J., Ceyhan, P., Jordan-Cooley, W., & Sung, W. (2013). Greenify: A Real-World Action Game for Climate Change Education. *Simulation & Gaming*, 1046878112470539.

Leiserowitz, A. (2006). Climate Change Risk Perception and Policy Preferences: The Role of Affect, Imagery, and Values. *Climatic Change*, 77(1-2), 45-72.

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

Lombardi, D., & Sinatra, G. M. (2010). College Students' Perceptions About the Plausibility of Human Induced Climate Change. *Research in Science Education*, 42(2), 201-217.

Lowe, T., Brown, K., Dessai, S., de Franca Doria, M., Haynes, K., & Vincent, K. (2006). Does Tomorrow Ever Come? Disaster narrative and public perceptions of climate change. *Public Understandings of Science*, 15, 435-457.

Makrakis, V., Larios, N., & Kaliantzi, G. (2012). ICT-enabled climate change education for sustainable development across the school curriculum. *Journal of Teacher Education for Sustainability*, 14(2), 54-72.

McKibben, B. (2005). *What the warming world needs now is art, sweet art*. Retrieved from <http://grist.org/article/mckibben-imagine/>.

McKnight, D. M. (2010). Overcoming "ecophobia": fostering environmental empathy through narrative in children's science literature. *Frontiers in Ecology and the Environment*, 8(6), e10-e15.

McNeill, K. L., & Vaughn, M. H. (2012). Urban high school students' critical science agency: conceptual understandings and environmental actions around climate change. *Research in science education*, 42(2), 373-399.

Meymaris, K., Henderson, S., Alaback, P., & Havens, K. (2008). *Project BudBurst: Citizen Science for All Seasons*. Paper presented at the AGU Fall Meeting Abstracts.

Miller-Rushing, A., Evenden, A., Gross, J., Mitchell, B., & Sachs, S. (2011). Parks use phenology to improve management and communicate climate change. *Park Sci*, 28, 61-67.

- Monzón, J., Moyer-Horner, L., & Palamar, M. B. (2011). Climate change and species range dynamics in protected areas. *BioScience*, 61(10), 752-761.
- Nam, Y., Roehrig, G., Kern, A., & Reynolds, B. (2013). Perceptions and practices of culturally relevant science teaching in American Indian Classrooms. *International Journal of Science and Mathematics Education*, 11(1), 143-167.
- Nazir, J., Pedretti, E., Wallace, J., Montemurro, D., & Inwood, H. (2011). Reflections on the Canadian Experience With Education for Climate Change and Sustainable Development. *Canadian Journal of Science, Mathematics and Technology Education*, 11(4), 365-380.
- O’Gorman, L., & Davis, J. (2013). Ecological footprinting: Its potential as a tool for change in preservice teacher education. *Environmental Education Research*, 19(6), 779-791.
- Öhman, J., & Öhman, M. (2013). Participatory approach in practice: an analysis of student discussions about climate change. *Environmental Education Research*, 19(3), 324-341.
- Ozor, N. (2010). Difficulties in adaptation to climate change by farmers in Enugu State, Nigeria. *Journal of Agricultural Extension*, 14(2).
- McNeill, J.R., & Engelke, P. (2014). *The great acceleration: An environmental history of the Anthropocene since 1945*. Cambridge, MA: Harvard University Press.
- Papadimitriou, V. (2004). Prospective Primary Teachers’ Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion. *Journal of Science Education and Technology*, 13(2), 299-308.
- Pharo, E., Davison, A., McGregor, H., Warr, K., & Brown, P. (2014). Using communities of practice to enhance interdisciplinary teaching: lessons from four Australian institutions. *Higher Education Research & Development*, 33(2), 341-354.
- Pickering, C.M. & Byrne, J. (2014). The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early career researchers. *Higher Education Research and Development*, 33, 534-548.
- Puppim de Oliveira, J. A. (2009). The implementation of climate change related policies at the subnational level: An analysis of three countries. *Habitat International*, 33(3), 253-259.
- Pruneau, D., Liboiron, L., Vrain, É., Gravel, H., Bourque, W., & Langis, J. (2001). People’s Ideas about Climate Change: A Source of Inspiration for the Creation of Educational Programs. *Canadian Journal of Environmental Education*, 6, 121- 139.
- Pruneau, D., Gravel, H., Bourque, W., & Langis, J. (2003) Experimentation with a socio-constructivist process for climate change education, *Environmental Education Research*, 9:4, 429-446.
- Pruneau, D., Doyon, A., Langis, J., Vasseur, L., Ouellet, E., McLaughlin, E., & Martin, G. (2006). When teachers adopt environmental behaviors in the aim of protecting the climate. *The Journal of Environmental Education*, 37(3), 3-12.

Rai, J. K. (2010). Global and Local Discourses on Climate Change: A Perspective from the Concept of Embeddedness. *Dhaulagiri Journal of Sociology and Anthropology*, 4, 143-180.

Roehrig, G., Campbell, K., Dalbotten, D., & Varma, K. (2012). CYCLES: A culturally-relevant approach to climate change education in native communities. *Journal of Curriculum and Instruction*, 6(1), 73-89.

Roy, S., Pickering, C. & and Byrne, J. (2012). A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry and Urban Greening*, 11, 351– 363.

Rye, J. A., Rubba, P. A., & Wiesenmayer, R. L. (1997). An Investigation of Middle School Students' Alternative Conceptions of Global Warming. *International Journal of Science Education*, 19(5), 527-551.

Salazar, J. F. (2011). The mediations of climate change: Museums as citizens' media. *museum and society*, 9, 2.

Schreiner, C., Henriksen, E. K., & Kirkeby Hansen, P. J. (2005). Climate Education: Empowering Today's Youth to Meet Tomorrow's Challenges. *Studies in Science Education*, 41(1/2), 3-49.

Selby, D., & Kagawa, F. (2010). Runaway Climate Change as Challenge to the 'Closing Circle' of Education for Sustainable Development. *Journal of Education for Sustainable Development*. 4(1), pp. 37-50.

Semenza, J. C., Hall, D. E., Wilson, D. J., Bontempo, B. D., Sailor, D. J., & George, L. A. (2008). Public perception of climate change voluntary mitigation and barriers to behaviour change. *Am J Prev Med*, 35(5), 479-487.

Senbel, M., Ngo, V. D., & Blair, E. (2014). Social mobilization of climate change: University students conserving energy through multiple pathways for peer engagement. *Journal of Environmental Psychology*, 38, 84-93.

Sharma, A. (2012). Global Climate Change: What has Science Education Got to Do with it? *Science & Education*, 21(1), 33-53.

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2009). Seventh Grade Students' Conceptions of Global Warming and Climate Change. *Environmental Education Research*, 15(5), 549-570.

Shepardson, D. P., Niyogi, D., Roychoudhury, A., & Hirsch, A. (2012). Conceptualizing Climate Change in the Context of a Climate System: Implications for climate change and environmental education. *Environmental Education Research* 18(3), 323-352.

Snow, R., & Snow, M. (2010). The Challenge of Climate Change in the Classroom. *WSEAS Transactions on Environment and Development*, (1), 63-72.

Sommer, L., Talus, C., Bachman, M., Barnes, F., Ebinger, M., Lynch, J., & Maestas, A. (2004). *The importance of traditional knowledge in science education: ARM Education uses*

interactive Kiosks as Outreach Tool. Paper presented at the Fourteenth ARM Science Team Meeting Proceedings, Albuquerque, New Mexico.

Stephens, J. C., & Graham, A. C. (2008). Climate Science to Citizen Action: Energizing nonformal climate science education. *Eos, Transactions American Geophysical Union*, 89(22), 204-205.

Steiner, M. A., & Crowley, K. (2013). The Natural History Museum: Taking on a learning agenda. *Curator: The Museum Journal*, 56(2), 267-272.

Sternäng, L. (2011). *Ethical and normative reasoning on climate change: Conceptions and solutions among students in a Chinese context*. Stockholm, Sweden: Department of Education, Stockholm University.

Sternang, L., & Lundholm, C. (2012). Climate Change and Costs: Investigating students' reasoning on nature and economic development. *Environmental Education Research*, 18(3), 417-436.

Stokols, D., Misra, S., Runnerstrom, M. G., & Hipp, J. A. (2009). Psychology in an Age of Ecological Crisis: From personal angst to collective action. *American Psychologist*, 64 (3), 181-193.

Svihla, V., & Linn, M. C. (2012). A design-based approach to fostering understanding of global climate change. *International Journal of Science Education*, 34(5), 651-676.

Swim, J., Clayton, S., Dohery, T., Gifford, R., Howard, G., Reser, J., et al. (2009). *Psychology and Climate Change: Addressing a Multi-facteted Phenomenon and Set of Challenges*. American Psychological Association.

Tanner, T. (2010). Shifting the Narrative: Child-led responses to climate change and disasters in El Salvador and the Philippines. *Children and Society*, 24, 339-351.

Tucci, J., J. Mitchell, and C. Goddard. (2007). *Children's fears, hopes and heroes: Modern childhood in Australia*. Melbourne: Australian Childhood Foundation.

UNESCO. (27-29 July 2009). *UNESCO International Seminar on Climate Change Education*. UNESCO, Paris.

Wise, S. B. (2010). Climate change in the classroom: Patterns, motivations, and barriers to instruction among Colorado science teachers. *Journal of Geoscience Education*, 58(5), 297-309.

Figures



Figure 1: Distribution and density of climate change education research publications across the world

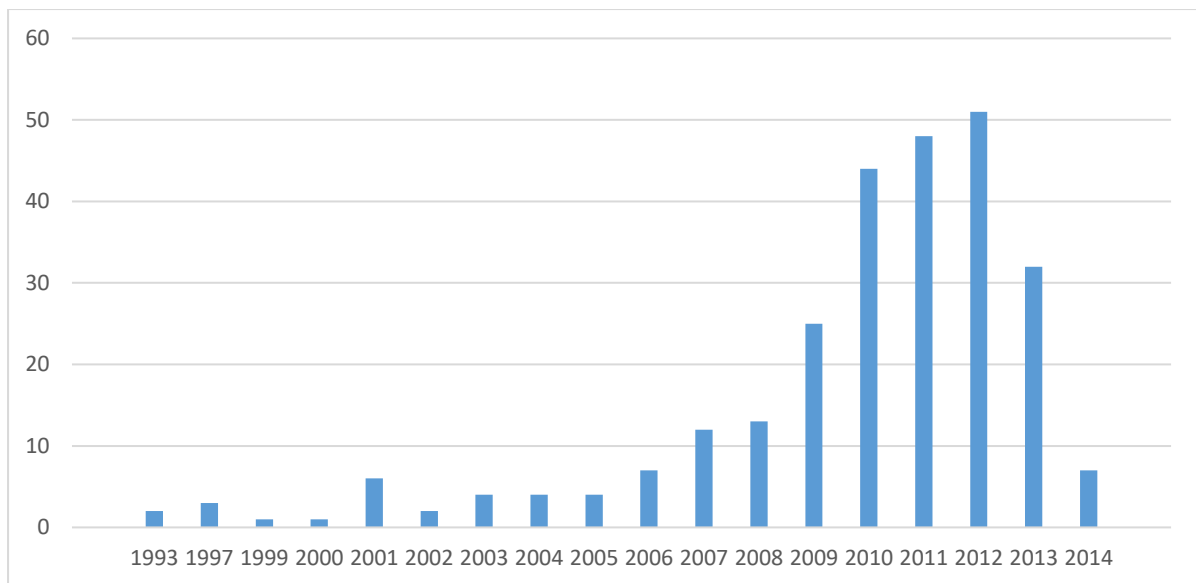


Figure 2: Publications on climate change education by year

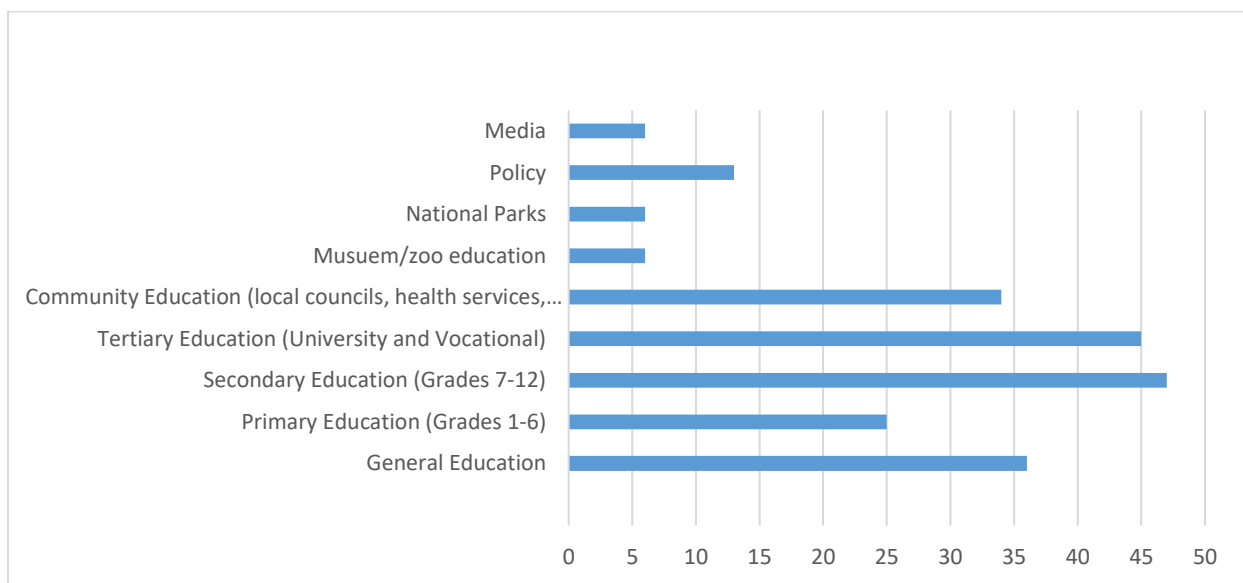


Figure 3: Contextual focus of research in climate change education

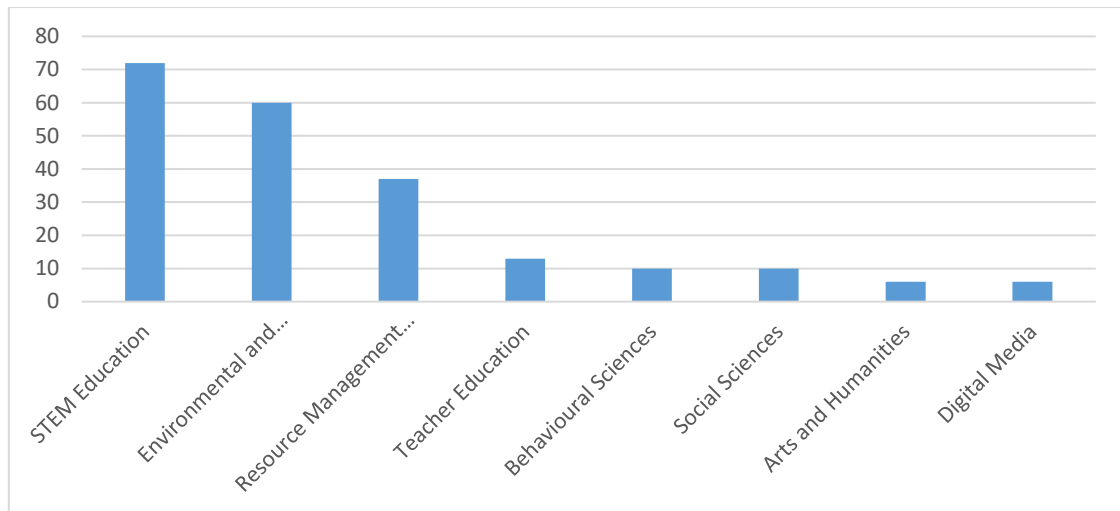


Figure 4: Disciplines associated with climate change education research

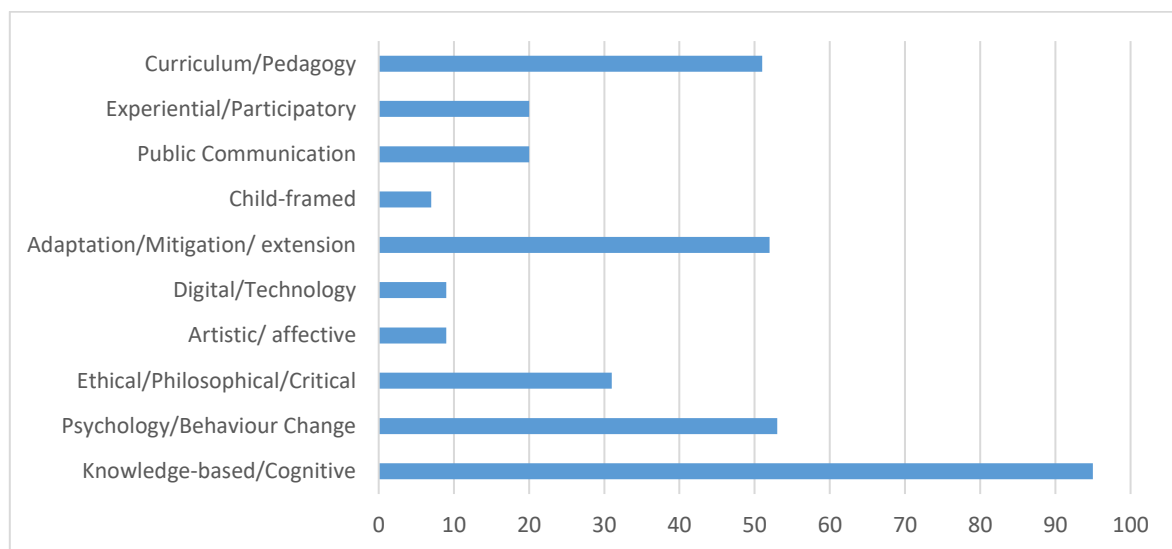


Figure 5: Approaches to climate change education research