ADVANCED REVIEW

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Youth perceptions of climate change: A narrative synthesis

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Abstract

Despite the scale of the predicted impact of climate change on future generations, most of the academic literature investigating perceptions of climate change relates to adults or young adults rather than children and adolescents. In this review, we synthesize literature relating to 8- to 19-year-old's perceptions and understandings of climate change, in order to identify trends and inconsistencies, potential gaps in knowledge, and directions for future research. A comprehensive search strategy identified 51 international studies, using quantitative ($n = 36$), qualitative ($n = 9$), and mixed methods ($n = 6$). The included studies date from 1993 to 2018. The analysis outlines levels of reported belief and concern about climate change and perceptions of its causes and consequences. It also details reported perceptions of viable solutions to climate change and notions of responsibility for implementing these. Scientifically accurate knowledge generally increased with age, although misconceptions persisted across the age range. In some studies, younger children expressed greater concern and were more willing to take action than older adolescents. Levels of belief, concern, and willingness to take action were lower in the United States, United Kingdom, and Australia than in other countries. In conclusion, we discuss potential explanations for these age and place-related differences, examining the age-related findings in the context of concepts and theories in developmental psychology. We outline the limitations of our review and the reviewed studies, and note potential avenues for future research and implications for educational policy and practice.

This article is categorized under:
    Perceptions, Behavior, and Communication of Climate Change >
        Perceptions of Climate Change

KEYWORDS
adolescents, children, climate change, review

1 | INTRODUCTION

Youth voices on climate change have never been more important, or more widely publicized. The first sign of youths' growing unrest on climate action appeared when students skipped school to attend a "climate strike" to

coincide with the 2015 UN Conference of the Parties (COP21) in Paris. In August 2018, the 15-year-old Swedish climate activist Greta Thunberg started a protest: "Skolstrejk för klimatet" ("School strike for climate"). Thunberg caught international press attention, and the campaign—known by various names, including "Fridaysforfuture," "Youthforclimate," and "Youthstrike4climate"—snowballed, following the COP24 in December 2018. On March 15, 2019, thousands of young people from more than 100 countries walked out of school to demand that their governments take action to prevent further climate change. These demands were explicitly related to the fact that their generation will be more affected by a failure to deal with climate change (Warren, 2019). Their action and demands received the support of many scientists and scholars (Hagedorn et al., 2019; Scientists for Future, 2019).

Monthly protests have continued, with an estimated 6 million young people across the world taking action during the week commencing September 20, 2019 (Taylor, Watts, & Bartlett, 2019). Notably, the September strike reached beyond youth voices to engage a wider public audience (Thunberg, 2019). These young voices have raised concern that they will be faced with the ongoing and escalating challenges that climate change will present and that their future lives will be affected by its impact. Their ongoing action has the potential to influence public opinion, which may in turn determine the direction of travel of future climate change policy (Capstick et al., 2015). In this context, it is a matter of urgency that we understand the way children and adolescents view climate change—and where they see themselves and their actions in relation to it. This can inform the design of appropriate educational opportunities and identify other ways of supporting and equipping them to contend with these challenges in an age-appropriate manner.

To date, the majority of academic research investigating perceptions of climate change and responses to it, relates to adults (Weber, 2010). Work that does examine youth voices tends to focus on, or include, data relating to young adults (Corner et al., 2015; Hibberd & Nguyen, 2013) rather than on children or adolescents. Here, we attempt to understand what is currently known about children and adolescents' understandings of climate change at the individual level. To do so, and to highlight gaps in current knowledge, we explore their conceptualizations of climate change by reviewing the existing academic literature. We synthesize evidence from the fields of educational science, psychology, geography, and the broader environmental social sciences. We outline what the reviewed studies reveal about children and adolescents' beliefs and concerns about climate change and their perceptions of its causes, impacts, and solutions. We focus on these particular concepts due to a significant body of evidence which suggests that they relate to a wide range of pro-environmental behaviors (Bord, O'connor, & Fisher, 2000; Capstick et al., 2015). We aim to identify trends and inconsistencies and to discuss the substantive and methodological implications of our findings. We also situate findings in relation to developmental psychology theories, and highlight gaps in knowledge to signal fruitful directions for further research in this field.

The research questions are as follows:

1. What are children and adolescents' perceptions of climate change in relation to its causes, impacts, and solutions?
2. What differences in perceptions can be observed across time, space, and age of participants?

2 | METHODS

2.1 | Search strategy

The literature search was conducted in May 2017 and updated in May 2019. The following databases were searched: PsychNet (including PsychInfo and PsychArticles), Web of Science, Scopus, Eric, British Education Index, Child Development and Adolescent Studies, Science Direct, IBSS, A+ Education, Education Source, PLoS One, and Ovid.

The keyword Boolean search included the following words: (child* OR adolesc* OR teen* or youth) AND ("climate change" OR "climatic changes" OR "global warming") AND (conce* OR perc* OR "ideas about" OR "views about" OR belie* OR think* OR understand* OR comprehend* OR literacy OR assump* OR attitude* OR idea*).

In line with our first research question, the search was designed to capture literature relating specifically to "perceptions" of climate change, rather than to any related concepts such as emotions or coping. It was also designed to include only peer-reviewed journal articles, since searching for gray literature can be problematic (Monroe et al., 2017). This search strategy was intended to strike a balance between being sufficiently broad (to facilitate the inclusion of a wide range of studies) and sufficiently bounded (to enable the synthesis of these studies). The inclusion and exclusion criteria are detailed in Table 1. The initial search yielded 1,396 results screened by abstract or title.

Duplicates were removed and 127 studies were obtained and the full texts examined in relation to the inclusion and exclusion criteria. Where there was uncertainty about the fit to the criteria, one of the authors reviewed the paper and any disagreement was resolved before proceeding. Twenty-seven studies were included and 100 were excluded. In addition, we conducted backward (by searching citations of the included papers) and forward (via Google Scholar citations) searches to source relevant additional papers. An additional 22 studies were found that met the inclusion criteria. Most of these studies were international and used the word "student" rather than "child," or specified synonym, and were not picked up in the original search. Three further studies were added in 2019. Detail of the application of the inclusion and exclusion criteria is outlined in Figure 1.

TABLE 1 Inclusion and exclusion criteria

| Inclusion criteria	Exclusion criteria
• Participants (living anywhere in the world) aged between 6 and 18 years • The research question or objective refers to the participants' beliefs, attitudes or conceptualization of climate change, in relation to concept, cause, consequence, or solution • Studies that include a measure of, or report on, children's perceptions of climate change. If the study reports an educational intervention, it must include a baseline or control measure of these perceptions • Studies relating to the greenhouse effect, since this is explicitly linked to climate change. Papers relating to sustainable practices such as recycling included only if reported in relation to climate change • Studies written in English • Studies are published in peer-reviewed journals	• Studies where more than a third of the participants are outside of the age range of 6–18 years • Theoretical studies with no empirical findings • Intervention studies that did not provide any pre-intervention or control data
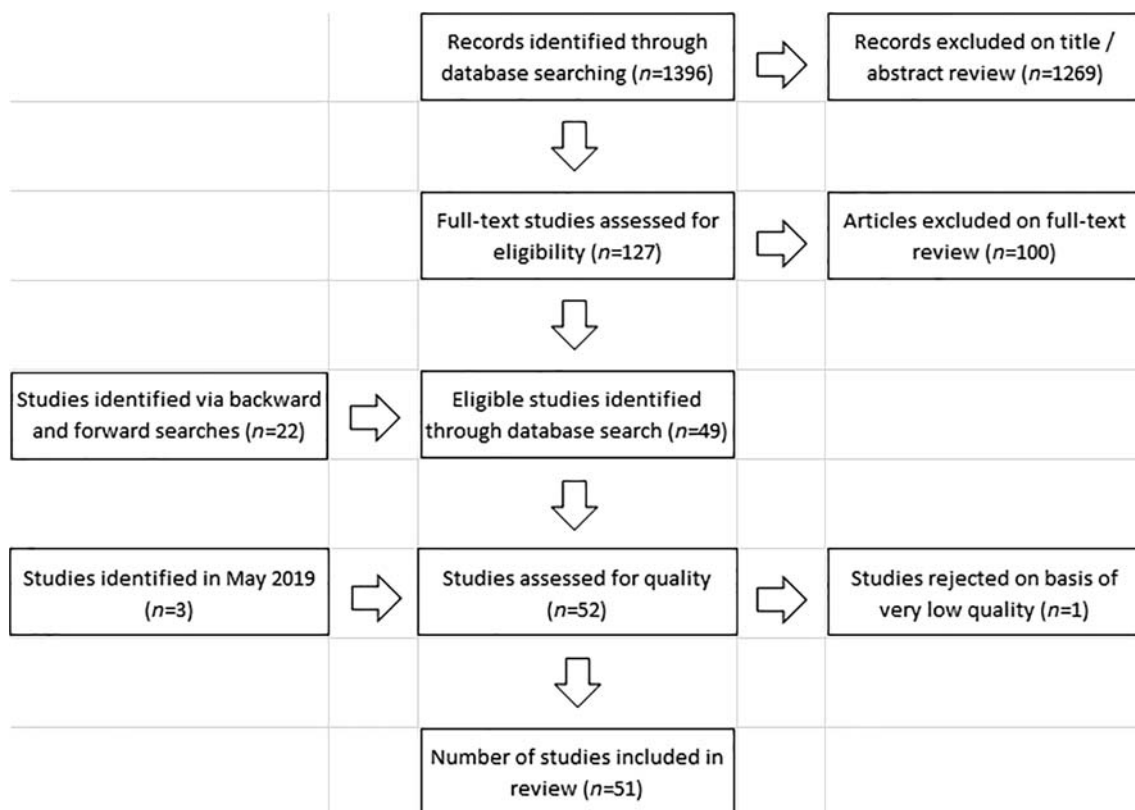
FIGURE 1 Result of search and quality control process

2.2 | Quality control

Each paper was rated for quality against 14 quantitative and 10 qualitative criteria (Kmet, Lee, & Cook, 2004). This assessment tool was chosen because of: its applicability to a variety of disciplines; its use in a variety of reviews since its creation (Barnett et al., 2019; Williamson et al., 2017); and its detailed evaluation criteria for qualitative and quantitative studies. If a study employed mixed methods, it was assessed in each category, with evaluation criteria applied to each section and a mean score calculated. Quality ratings for the 52 studies were between 0.5 and 2.0 out of 2.0 (possible range 0–2). The study which scored 0.5 was removed as this was considered an unacceptably low rating, leaving 51 studies scoring between 1.1 and 2.0, where 1.4 and below was considered low quality, 1.5–1.7 medium, and 1.8 and above high quality. Lower quality studies typically scored poorly on criteria such as "clearly outlining research questions or objectives," "outlining the recruitment process and participant characteristics," or "reporting results in sufficient detail."

2.3 | Analysis

Narrative synthesis (Popay et al., 2006) was used to synthesize the studies. This is appropriate for incorporating different types of evidence and for broader research questions than those addressed in effectiveness studies (Lucas et al., 2007). After studies were collated, the relevant detail was tabulated and textual descriptions produced for each of the included studies. This facilitated the development of groupings and clusters in relation to similarities, differences, and issues salient to the research questions.

3 | RESULTS

3.1 | Description of included studies

We included 51 studies, of which 10 were rated low quality, 25 medium quality, and 16 high quality. Of these, 36 were quantitative, six mixed methods, and nine qualitative studies.

The total number of participants was 41,515 across all 51 studies. The largest participant sample from a single study was 12,627 and the smallest was nine participants. The youngest participants were 8 and the oldest were 19. In 18 studies, the gender of participants was not stated, but where it was, the split was broadly even. The research was almost exclusively carried out in school settings. The studies focused on at least one of the following; climate change belief, concern, causes, impacts, and solutions. Eight of the studies employed an intervention design. The earliest papers were dated 1993, and 41 were published between 2007 and 2018. The number of studies published by year is shown in Figure 2. Of the 51 studies, 24 were conducted in the United States, United Kingdom, or Australia, and 38 were conducted in high income countries. The number of studies by country of origin and income status are shown in Table 2.

3.2 | Analysis of included studies

When reviewing the studies, it became evident that the concepts of climate change belief, climate change concern, the causes and impacts of climate change, and solutions to climate change, were examined through a range of terminological lenses. In recognition of the broad terminology employed in the reviewed studies, we use the term "reported perceptions" to encompass these diverse terms. Table 3 shows some exemplar terms that were used in the reviewed studies.

The sub-sections below relate to reported beliefs and concerns about climate change and perceptions about causes, impacts, and solutions. Studies relating to solutions have been separated into beliefs about viable solutions and notions of responsibility. Where appropriate, comparisons across age of participants, country of origin, and time were carried out.

3.3 | Reported belief and concern about climate change

The studies investigating belief typically asked participants to indicate how sure they were that climate change is happening. Belief has been interpreted here to have measured levels of certainty (as opposed to ignorance; Center for
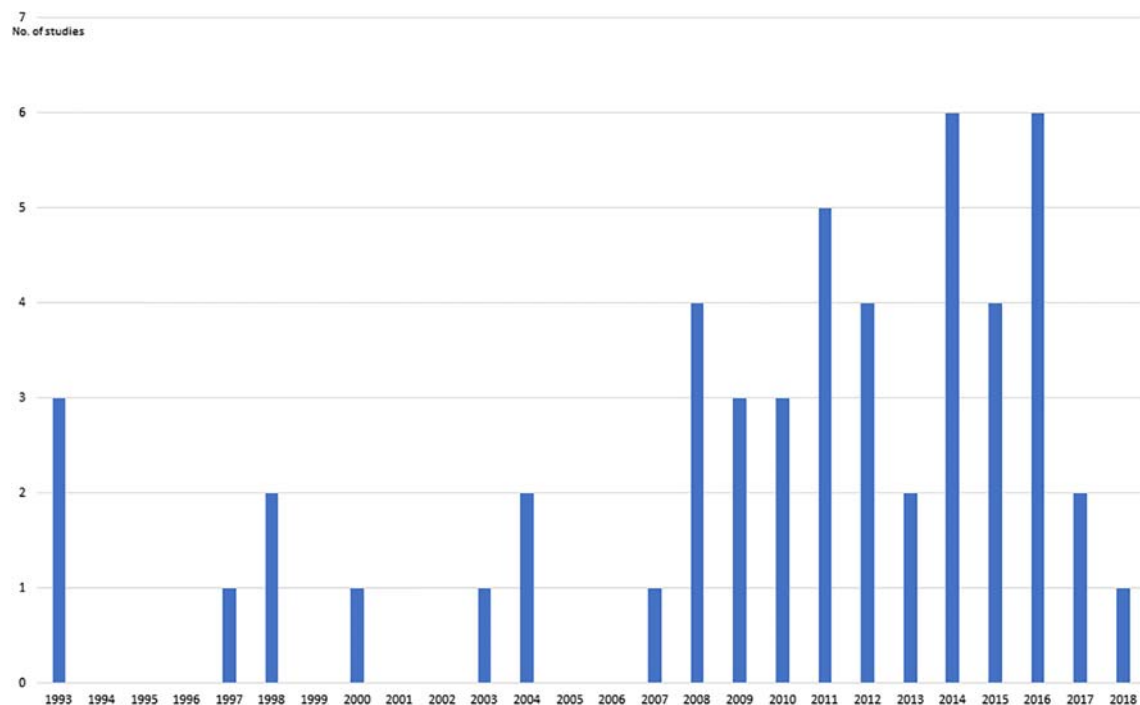
FIGURE 2   Number of reviewed studies per year

Research on Environmental Decisions, 2009), rather than skepticism (which is instead associated with a value-based rejection of the widespread scientific consensus of climate change; Capstick & Pidgeon, 2014). Levels of reported belief and concern about climate change were closely aligned. Belief and concern were higher in lower middle and upper middle income countries than in high income countries. There were 13 studies which detailed participants' levels of belief that climate change is occurring (Ambusaidi et al., 2012; Boyes et al., 2014; Boyes, Skamp, & Stanisstreet, 2008; Boyes & Stanisstreet, 2012; Chhokar et al., 2011, 2012; Devine-Wright et al., 2004; Malandrakis et al., 2011; Skamp et al., 2009; Stevenson et al., 2014; Stevenson, Peterson, & Bondell, 2016; Stevenson, Peterson, & Bradshaw, 2016; Tranter & Skrbis, 2014) and 15 studies which examined participants' level of concern about climate change (Ambusaidi et al., 2012; Boyes et al., 2014; Boyes, Skamp, & Stanisstreet, 2008; Boyes & Stanisstreet, 2012; Boyes, Stanisstreet, & Yongling, 2008; Chhokar et al., 2011, 2012; Hermans & Korhonen, 2017; Jackson & Pang, 2017; Line et al., 2010; Malandrakis et al., 2011; Prudente et al., 2015; Skamp et al., 2009; Stevenson, Peterson, & Bondell, 2016; Tranter & Skrbis, 2014). These studies employed a Likert-scale questionnaire (one study investigating belief utilized a 1–10 scale; Tranter & Skrbis, 2014). Belief—defined as being "sure" or "thinking" climate change is occurring—and concern—defined as being "very" or "quite" worried about climate change—was highest in Turkey, at 93 and 91%, respectively. Belief (61%) and concern (50%) was lowest in the United Kingdom (Boyes et al., 2014). There was evidence of local differences, with children living in coastal areas more concerned than those living in rural areas of the Philippines, for example, Prudente et al. (2015).

Some studies explored the relationship between situational or personal factors and climate change belief and concern. A more collaborative and nature-oriented learning environment was associated with higher levels of belief that the climate is changing in the United Kingdom (Devine-Wright et al., 2004). Levels of belief were higher for 11–15-year-old American children who held "communitarian" rather than "individualistic" worldviews, where knowledge about climate change was "low" (Stevenson et al., 2014). At "high" knowledge levels, the difference between the two groups' scores were not substantial, suggesting that knowledge may supersede the effects of worldview to impact climate change belief. However, information inconsistent with worldview did not influence belief in climate change in 16–17-year-old Australian participants (Tranter & Skrbis, 2014). Talking about climate change, even with someone skeptical about it, was related to increased levels of concern (Stevenson, Peterson, & Bondell, 2016). Concern about climate change was not necessarily static but context-dependent. In one qualitative study using visual methods and interviews (Line et al., 2010), participants did express some concern about climate change but this was lessened in the context of considering the personal benefits of actions, such as driving rather than taking a bus. Here, climate change was also reported to be less important than more immediately pressing issues such as exams and homework.

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TABLE 2 Country of origin of reviewed studies split by income status (World Bank, 2019)

Location	No. of studies
International (Australia, Brunei, Greece, India, Korea, Oman, Singapore, Spain, Turkey, USA, UK)	1
High income countries	
USA	11
UK	7
Australia	6
Greece	2
Australia and UK	1
England and Sweden	1
Sweden	1
Singapore	1
Italy	1
Canada	1
New Zealand	1
Oman	1
France	1
Spain	1
Finland	1
Hong Kong	1
Upper middle income countries	
China	3
Fiji	1
Malaysia	1
Lower middle income countries	
Turkey	3
India	3
Philippines	1

TABLE 3 Exemplar terms used in reviewed studies

Reported perceptions of	Exemplar terms used in the studies
Belief	Certainty that global warming is happening Belief that climate is changing
Concern	Climate change concern Concern over the risks of global warming
Causes	Conceptions, attitudes, ideas, alternatives or misconceptions, understanding, notions, prior knowledge, preconceptions, understandings, alternative conceptions, beliefs, perceptions
Impacts	Ideas, misconceptions, conceptions, notions, prior knowledge, preconceptions, perceptions
Solutions	Degree of willingness to act (in relation to particular solution) Believed usefulness of action (of particular solution), ideas, alternatives or misconceptions, conceptions, understanding, notions, prior knowledge, preconceptions, moral reasoning, perspectives, attitudes, beliefs, interpretative repertoires

Where age-related comparisons could be made, some differences were noted. In two Indian studies with participants aged 17–18 years (Chhokar et al., 2012), and 11–16 years (Chhokar et al., 2011), the level of belief was almost the same. However, more of the 11–16-year-olds (90%) were very or quite worried about global warming

than the 17–18-year-olds (82%). One study examining the responses to global warming of children in their last year of primary school and first year of secondary school (Skamp et al., 2009), reported that more of the primary-aged children (75%) believed that global warming was happening now than the secondary-aged children (65%). In the same study, 66% of the primary students were worried about global warming compared to 55% of the secondary students.

3.4 | Reported perceptions about causes of climate change

There were 26 studies that detailed participants' reported perceptions about the causes of climate change (Andersson & Wallin, 2000; Boyes et al., 1993; Boyes & Stanisstreet, 1993, 1997; Chang & Pascua, 2016; Dawson, 2015; Frappart et al., 2016; Garg & Lal, 2013; Hestness et al., 2016; Jackson & Pang, 2017; Karpudewan et al., 2015; Kilinc et al., 2008; Koulaidis & Christidou, 1999; Lee et al., 2007; Mason & Santi, 1998; Özdem et al., 2014; Prudente et al., 2015; Pruneau et al., 2003; Punter et al., 2011; Puttick et al., 2015; Scott-Parker & Kumar, 2018; Shepardson et al., 2009, 2011; Stevenson, Peterson, & Bradshaw, 2016; Taber & Taylor, 2009; Varma & Linn, 2012). The studies mostly employed questionnaires (Boyes & Stanisstreet, 1997), but also used interviews (Chang & Pascua, 2016; Karpudewan et al., 2015; Mason & Santi, 1998; Pruneau et al., 2003), draw and explain tasks (Shepardson et al., 2009, 2011), open-ended writing prompts (Lee et al., 2007), interviews and drawing tasks (Hestness et al., 2016), and focus groups (Scott-Parker & Kumar, 2018).

Participants' ideas about the causes of climate change tended to be vague and general (Dawson, 2015; Taber & Taylor, 2009; Varma & Linn, 2012). Concepts were often broad and unspecific, relating to "pollution" rather than to particular gases or underlying mechanisms (Koulaidis & Christidou, 1999). Participants were often aware that burning fuels creates carbon dioxide (Boyes & Stanisstreet, 1997), although this was more often attributed to transport and factories than to household energy use (Punter et al., 2011). There was some appreciation of the wider basket of greenhouse gases contributing to anthropogenic climate change (Hestness et al., 2016), but carbon dioxide was the most highly identified greenhouse gas (Chang & Pascua, 2016).

Scientifically accurate knowledge about the causes of climate change tended to increase with the age of participants. For example, a study of youth voices from the Scout Movement found that participants aged 9–11 had less accurate knowledge about causes than those aged 12–14 (Puttick et al., 2015). In a French study, participants aged 17 gave more correct answers to questions about causes of the enhanced greenhouse effect than those aged 12 or 15 (Frappart et al., 2016). However, persistent misconceptions about the causes of climate change were frequently reported, irrespective of age. One recurring observation was the tendency to conflate the concepts of climate change and ozone layer depletion. This was reported consistently in earlier studies (Boyes et al., 1993), with over 80% of participants in all age groups (between 10 and 16) suggesting that the greenhouse effect is made worse by holes in the ozone layer. In later studies, climate change-ozone conflation was not always observed (Punter et al., 2011) but the proportion of participants identifying ozone depletion as a cause of climate change was still sometimes considerable (42% in one recent American study, Hestness et al., 2016 and 50% in another, Stevenson, Peterson, & Bradshaw, 2016). In a later Indian study with participants in the 9th, 10th, and 11th grades (Garg & Lal, 2013), more of the older than younger students thought ozone depletion was implicated in global warming, despite being generally better informed about causes. Other misconceptions about causes were also commonplace, with environmentally unsound actions such as street littering or river pollution reported to cause climate change (Kilinc et al., 2008).

3.5 | Reported perceptions about impacts of climate change

Overall, 18 studies outlined participants' reported perceptions about the impacts of climate change (Boyes et al., 1993; Boyes & Stanisstreet, 1993; Dogru & Sarac, 2013; Frappart et al., 2016; Garg & Lal, 2013; Hermans & Korhonen, 2017; Hestness et al., 2016; Jackson & Pang, 2017; Karpudewan et al., 2015; Kilinc et al., 2008; Lee et al., 2007; Mason & Santi, 1998; Pruneau et al., 2003; Punter et al., 2011; Scott-Parker & Kumar, 2018; Shepardson et al., 2009, 2011; Stevenson, Peterson, & Bradshaw, 2016). Questionnaires were the most frequently used method of data collection (Kilinc et al., 2008). Studies also employed open-ended writing prompts (Lee et al., 2007), interviews (Jackson & Pang, 2017; Karpudewan et al., 2015; Mason & Santi, 1998; Pruneau et al., 2003), draw and explain tasks (Shepardson et al., 2009, 2011), interviews and drawing tasks (Hestness et al., 2016), and focus groups (Scott-Parker & Kumar, 2018).

The accuracy of reported knowledge about the impacts of climate change varied according to the method employed. In one open-response study (Pruneau et al., 2003) only two of 39 participants were able to think of any impacts of climate change. Where closed-form questionnaires were used, awareness of the most evident impacts of climate change, such as increasing temperatures and melting ice caps was high, as was the recognition that climate change would alter Earth's ecosystems (Lee et al., 2007; Shepardson et al., 2011). However, ideas were frequently incomplete, exemplified by a focus on the impact on "wild" animals and plants rather than livestock and agriculture (Shepardson et al., 2009), or a lack of appreciation that a changing climate may cause an increase in the number of crop pests (Frappart et al., 2016). Similarly, although appreciation of rising temperatures was high, the potential for increasing desertification was less well observed (Boyes et al., 1993). Nor were the wider socio-economic impacts of climate change, such as migration (Punter et al., 2011), well recognized.

There were erroneous ideas about the impacts of climate change consistent with misconceptions held about causes, particularly around the hole in the ozone layer. In one study, over 20% of participants reported that diagnoses of cancer would increase as a result of climate change (Punter et al., 2011). Awareness of climate change impacts on natural systems was typically higher than impacts on human systems.

3.6 | Reported perceptions about solutions to climate change

A majority of studies (40) reported participants' perceptions about potential solutions to climate change (Ambusaidi et al., 2012; Andersson & Wallin, 2000; Bofferding & Kloser, 2015; Boyes et al., 1993, 2014; Boyes, Skamp, & Stanisstreet, 2008; Boyes & Stanisstreet, 1993, 2012; Boyes, Stanisstreet, & Yongling, 2008; Byrne et al., 2014; Chhokar et al., 2011, 2012; Daniel et al., 2004; Devine-Wright et al., 2004; Francis et al., 1993; Frappart et al., 2016; Garg & Lal, 2013; Hermans & Korhonen, 2017; Hestness et al., 2016; Jackson & Pang, 2017; Karpudewan et al., 2015; Kilinc et al., 2008; Kirk, 2008; Lee et al., 2007; Line et al., 2010; Malandrakis et al., 2011; Mason & Santi, 1998; Özdem et al., 2014; Pruneau et al., 2003; Punter et al., 2011; Puttick et al., 2015; Scott-Parker & Kumar, 2018; Shepardson et al., 2009, 2011; Skamp et al., 2009, 2013; Sternäng & Lundholm, 2011, 2012; Taber & Taylor, 2009; Wilks & Harris, 2016). The studies mainly used questionnaires (Kilinc et al., 2008). Studies also employed interviews (Jackson & Pang, 2017; Mason & Santi, 1998; Pruneau et al., 2003), interviews and drawing tasks (Hestness et al., 2016), photo elicitation (Line et al., 2010), draw and explain tasks (Shepardson et al., 2009, 2011), focus groups/group interviews (Byrne et al., 2014; Scott-Parker & Kumar, 2018; Sternäng & Lundholm, 2011), and role play tasks (Sternäng & Lundholm, 2012).

The level of reported accuracy of knowledge varied according to the method employed. Two studies reported very low awareness of accurate solutions to climate change in response to open-ended questions (Lee et al., 2007; Pruneau et al., 2003). Generally, as with participants' concepts of causes and impacts, concepts of solutions to climate change were held at a superficial level and featured misconceptions. There was a tendency for participants to suggest actions for which they were not personally responsible (Punter et al., 2011; Shepardson et al., 2009). The most recognized solutions were planting trees (Kilinc et al., 2008) and reducing pollution (Garg & Lal, 2013), particularly from factories (Daniel et al., 2004) and transport (Bofferding & Kloser, 2015). However understanding was not complete, for example, the lag time involved in planting trees was not appreciated (Shepardson et al., 2009), and participants were not able to explain the mechanisms by which reducing pollution or planting trees would reduce global warming (Frappart et al., 2016).

Scientifically incorrect ideas about solutions were also noted, such as believing that using unleaded petrol was a solution to global warming (Kilinc et al., 2008). Levels of incorrect knowledge such as this sometimes increased with age (Boyes & Stanisstreet, 2012). Other erroneous solutions, such as reducing street litter or river pollution (Hestness et al., 2016) were observed. Again, and consistent with a conflation of the ozone layer and climate change, the suggestion that reducing chlorofluorocarbons (CFCs) would reduce global warming was frequently reported (e.g., Daniel et al., 2004), where reducing CFCs was perceived to be a more effective way of combatting climate change than flying fewer aeroplanes; although CFCs have a high radiative potential, since the implementation of the Montreal Protocol, they are no longer a significant concern for climate policy—unlike flights, which represent a currently unconstrained and rapidly growing source of greenhouse gas emissions. Nuclear power was not commonly accepted to be a solution to the problem of climate change (Boyes, Stanisstreet, & Yongling, 2008; Hestness et al., 2016), despite it being seen in general as a necessary climate change-energy stopgap (Pidgeon, Lorenzoni, & Poortinga, 2008).

3.7 | Notions of responsibility and endorsement of solutions to climate change

Nine studies used the same version of a closed-form survey (Ambusaidi et al., 2012; Boyes, Skamp, & Stanisstreet, 2008; Boyes & Stanisstreet, 2012; Boyes, Stanisstreet, & Yongling, 2008; Chhokar et al., 2011, 2012; Malandrakis et al., 2011; Skamp et al., 2009, 2013) to investigate the disparity between the extent to which participants felt that solutions to climate change were effective, and their willingness to enact them. The questionnaire paired Likert-scale ratings of the perceived effectiveness of indirect and direct actions with a rating of the participant's willingness to undertake that action personally. There were 12 direct actions (such as switching off appliances or eating less meat) and four indirect actions (such as supporting "greener" taxation or legislation). These studies were carried out across several countries, with participants of different ages.

A consistent finding in these studies was the disparity between how willing participants stated they would be to take certain actions relative to how useful they perceived them to be. This varied by country of origin and to a lesser extent age. Participants were generally more willing to take more convenient direct actions such as switching off appliances, even though they recognized that these actions were less effective (Skamp et al., 2009). They were less willing, relative to perceived usefulness, to take direct actions which had a greater personal impact, such as buying fewer new items, or taking public transport (Boyes & Stanisstreet, 2012). In high income countries such as Australia, there was a greater disparity between the perceived usefulness of indirect actions and participants' willingness to endorse them than for most direct actions. For example, participants were much less willing to vote for environmental taxation and legislation relative to the extent to which they thought they were useful actions (Boyes, Skamp, & Stanisstreet, 2008; Skamp et al., 2009). The perceived usefulness of indirect actions was high in India and Oman, and participants there were also much more willing to support these actions (Ambusaidi et al., 2012; Chhokar et al., 2011).

This disconnect between the perceived usefulness of actions and willingness to take them was mirrored in other studies not using this particular questionnaire. Indirect actions were deemed beneficial but not personally endorsed in a focus group study (Kirk, 2008). Participants expressed an understanding that reducing car usage was necessary from the point of view of climate change but their personal priorities meant they were not willing to travel by car less often (Line et al., 2010) or take actions that were personally inconvenient (Hermans & Korhonen, 2017), prioritizing their own interest and wellbeing over their environmental worries (Byrne et al., 2014). Perspective and context were related to allocation of responsibility. In a role play study (Sternäng & Lundholm, 2011) participants playing a factory owner absolved themselves of responsibility and placed it instead on technology. However, when the factory owner was an "other," they advocated the government should legislate against them.

Age appeared to be related to participants' stated willingness to take action. In some studies, younger children were more willing to take actions than older children. For example, in a Greek study fewer of the participants in Year 10 (48%) were willing to "undertake more environmental education" than those in Year 7 (62%), despite endorsing it as a useful action (Malandrakis et al., 2011). In an Omani study with participants aged 11–18, fewer of the older participants (49%) were willing to reduce their meat consumption than the younger participants (62%) (Ambusaidi et al., 2012) Older participants were less willing to use environmentally friendly transportation than younger participants, despite an increasing recognition of the benefit to the climate. In one Indian study, 47% of 16-year-olds were willing to use buses or trains instead of cars, compared to 67% of 11-year-olds (Chhokar et al., 2011). In an Australian study, 8% of participants in their first year of secondary school were willing to take public transport rather than travel in cars, compared to 26% of participants in their last year of primary school, despite similar numbers in both groups believing that using public transport would reduce global warming (Skamp et al., 2009). In the Omani study, fewer older students than younger were willing to drive smaller, more environmentally friendly cars (44% vs. 56%), or use public transport (29% vs. 37%) (Ambusaidi et al., 2012).

In an international study (Boyes et al., 2014), participants in 11 countries were asked how willing they would be to take two actions; drive smaller, more fuel efficient cars, and use public transport. They were also asked how useful they thought these actions were in reducing global warming. Overall, 84% of participants said that driving smaller cars would improve global warming by "a small but useful amount," "a fair amount," or "a lot." Fewer respondents (72%) said that they would "probably," "almost certainly," or "definitely" drive smaller cars. Participants in lower and middle income countries endorsed action more than those in Western high income nations. There were differences between high income countries too, with participants in high income Singapore much more willing to endorse action than those in the United Kingdom, United States, and Australia. Levels of agreement that taking public transport is a useful action were even higher than for driving smaller cars, at 92%. However, far fewer respondents (58%) agreed that they would be willing to take public transport. Again, geographical differences were observed with participants in the United Kingdom, Australia, and United States least willing. Ninety-six percent of Indian participants thought that the action was useful and 76% said they would take it

themselves. In Singapore, 96% agreed that the action was useful and 79% said they would take it. Belief that taking public transport is a useful action was high in the United States (87%) and United Kingdom (90%), but only 37% (United States) and 38% (United Kingdom) were prepared to take that action.

4 | DISCUSSION AND CONCLUSIONS

The aim of this review was to explore children and adolescents' perceptions of climate change in relation to causes, impacts, and solutions and, where possible, to examine potential differences in these perceptions across time, place and age of participants. Our analysis of these studies—all of which were cross-sectional—identified notable differences between participants across different countries and of different ages. Temporal differences were less prominent, probably because most studies were published post-2007 (Figure 2). One exception is the observation that the propensity to conflate climate change with the ozone layer does seem to have reduced over time. Earlier studies report higher levels of this conflation than later studies, although the numbers remain considerable. For example, in a 1993 study (Boyes et al., 1993), 63% of participants agreed that the greenhouse effect was made worse by holes in the ozone layer. In a 2016 study (Hestness et al., 2016), 42% of participants attributed global warming to ozone layer depletion. Most studies focused on the scientific accuracy of participants' knowledge. Scientifically correct knowledge of the most evident causes, impacts, and solutions, such as factory emissions, rising temperatures, and reducing CO_2 in the atmosphere was generally reasonably high. However, ideas were often confused or incomplete, and misconceptions were commonplace. The level of scientifically accurate knowledge was typically higher for impacts and solutions than for causes (Frappart et al., 2016; Puttick et al., 2015). Some ideas about impacts and solutions appeared based on misconceived causes, representing conceptualizations of climate change that are to some degree plausible, but flawed. Where reported, there was low awareness of the broader economic, geo-political, and infrastructural considerations associated with climate change (Punter et al., 2011).

A focus on accuracy of knowledge means that the review provides a partial insight into children's thinking about climate change and may not be reflective of their climate-related behavior, given the relatively minor role knowledge plays in predicting this (Kollmuss & Agyeman, 2002). Further, where climate change is concerned, knowledge may be differentiated (Frick, Kaiser, & Wilson, 2004), such that system knowledge (understanding mechanisms, such as how CO_2 increases temperatures) is only weakly associated with behavior whereas action and effectiveness knowledge (knowing what actions are effective and which actions are relatively more or less effective) are more strongly associated (Braun & Dierkes, 2019). System knowledge in these studies was generally poor and (misconceptions aside), action and effectiveness knowledge was relatively better.

4.1 | Age differences

Scientifically correct knowledge about the causes, impacts, and solutions to climate change generally increased with age, as would be expected with increased scientific education and exposure to information. However, misconceptions persisted across age groups and were in some cases reported more by older than younger children. The misconceptions recorded here mirror common youth, young adult, and adult misconceptions about climate change (Corner et al., 2015; McCaffrey & Buhr, 2008), such as misunderstandings about the relationship between the ozone layer and climate change. This likely reflects two aspects of children's learning. First, children are reliant on information given to them by adults when considering any complex scientific issue, so misconceptions recorded here probably reflect misinformation children are receiving from those around them (Harris & Koenig, 2006). Previous studies have shown that these errors are sometimes reinforced by formal environmental textbooks, and that common metaphors used to explain the mechanisms of climate change are frequently misconstrued (Dijkstra & Goedhart, 2012). Children are also more vulnerable to misinformation than adolescents and adults, as they have limitations in their capacity to process complex information and to assess the credibility of information they receive (Moutier et al., 2006). The potential for misunderstandings to persist remains high, as children have greater access to information about climate change through unmoderated sources like social media.

Second, scientific misconceptions, once established, can be difficult to overwrite. A substantial body of research has shown that misconceptions often become more intractable with age (Carey, 2009; Shtulman & Harrington, 2016). There is some evidence to suggest that younger children, up to 9–10 years of age, are more flexible about overwriting information in

their existing mental models than older children and adults (Kelemen & DiYanni, 2005). However, findings from conceptual change research (Reinfried & Tempelmann, 2014) show that the preconceptions that children hold at 13 years of age predict how readily they are able to create accurate mental models of global warming and climate change when they encounter them in formal education. Importantly, children's understanding of climate change models depends heavily on which of a small sub-set of preconceptions they arrive with. Here we see that misconceptions arise early in children's understanding of climate change and act as a barrier to further learning. The same misunderstandings seem to persist through adolescence and into adulthood. Directly addressing common climate change misconceptions early in education may prove more effective in disrupting their persistence into adulthood. Identifying a child's climate change preconceptions can help to develop the appropriate learning materials that most effectively overcome them.

In this review, levels of belief and concern about climate change, and willingness to take some actions—particularly those related to personal transport—declined with age. One explanation for this, tentatively supported by findings here, is that younger children's thinking about climate change is less reflective of worldview and cultural values than older children's (Stevenson et al., 2014; Tranter & Skrbis, 2014). Further, the "adolescent dip" in environmental attitudes and behaviors has been well documented (Liefländer & Bogner, 2014; Negev et al., 2008; Olsson & Gericke, 2015; Uitto et al., 2011; Uitto & Saloranta, 2010). Most recently, a longitudinal study examining developmental change in children's environmental attitudes and behavior between the ages of 7 and 18 (Otto et al., 2019) mirrored previous cross-sectional findings. It shows an average increase in environmental concern and willingness to act between the ages of 7 and 10, followed by a period of sustained concern and behavior, and finally a dip from 14 to 18 years. Environmental attitudes and behavior became more closely correlated with age, converging reliably in early adulthood, and the authors propose that this adolescent dip reflects discontinuities in the development of broader prosocial moral reasoning (Eisenberg et al., 1995). A simple explanation for this may be methodological: younger children likely have fewer opportunities to make decisions about issues such as how they are transported so can afford to be ideological. Adolescents, in contrast, will already be making some of these decisions and appreciate better the lack of convenience associated with more environmentally friendly choices. If the questions had revolved around choices in realms where younger and older children had roughly equal autonomy, these age differences may have been less apparent. It is also possible that adolescents go through a stage of more hedonistic values, which results in a period of lowered concern for others (Uitto & Saloranta, 2010), and lessened interest in nature (Kaplan & Kaplan, 2002). A more complex explanation suggests that rejection of climate change or reduced concern and willingness to act, may reflect coping strategies for young people who feel powerless to exert change (Ojala, 2012a, 2012b). So while scientifically accurate knowledge overall was shown to increase with age, the relationship between knowledge and willingness to take action was not at all straightforward. These findings are especially interesting in the context of recent youth climate strikes as many of the strikers would fall within the proposed "adolescent dip." Further research is required to examine whether this apparent inconsistency is methodological (perhaps self-report on surveys does not reflect real-world behavior in this context), or reflects compelling contextual factors that override the adolescent dip, such as social pressure, greater exposure to age-related climate change information, a celebrity figurehead, and mounting societal concern.

4.2 | Place differences

The differences in levels of belief, concern, and willingness to act across location suggest that young people may be more or less concerned and willing to take action about climate change relative to the extent to which they feel the impacts are salient to them. This appears the case with adults (Spence, Poortinga, & Pidgeon, 2012) (although it should be noted that the link between psychological distance and action is not straightforward, Brügger et al., 2015). The lower levels of belief, concern, and willingness to act expressed by children in countries such as the United Kingdom, United States, and Australia could be explained by their viewing climate change as a distant and global (Chamila Roshani Perera & Rathnasiri Hewege, 2013) rather than local problem. This explanation is supported by the findings of a recent study investigating adolescents' perceptions of the psychological distance of climate change (Gubler, Brügger, & Eyer, 2019). Here, participants viewed climate change as a real and current threat, but one that affected other people and places more than themselves. Misconceptions aside, children in the same three countries seemed to have reasonably high awareness about which solutions to climate change are effective. However, relative to how effective they perceive those solutions to be, they were less willing to endorse them personally than they were to endorse actions they viewed as less effective, but less personally inconvenient. Their stated intention to perform these behaviors lagged well behind those in other high income countries such as Singapore or Oman. This potential psychological distancing (Trope &

Liberman, 2010) of the problem may reflect greater confidence in some countries that responsibility for climate change initiative lies with governments than with individuals (Pidgeon, 2012). Previous research (Otto et al., 2016) shows that income positively affects some pro-environmental behaviors (such as recycling) but negatively affects others (in sum, some environmentally unfriendly behaviors such as owning more than one car are dependent on resources) but here we find cultural variation in pro-environmental behavior even across countries where income is high.

This cross-cultural difference in young people's responses may also be explained by a nation's position on the democratic-autocratic or individual-collective indices, an interpretation considered in one study (Boyes et al., 2014). This could account for why children in more democratic countries such as the United Kingdom and United States, where power distance is less hierarchical than in relatively more autocratic nations such as Brunei or Oman, tend to put their own interests and desires above climate concern or why children in more collectivistic nations such as Singapore report higher levels of willingness to act because they are more inclined to think "for the greater good" (Triandis, 2001), than those in more individualistic nations such as Australia (Bronfenbrenner & Vasta, 1989; Whiting & Whiting, 1975). This interpretation is supported by the fact that even within the same country, belief and concern about climate change is higher in children with a more communitarian worldview than those with a more individualistic worldview (Stevenson et al., 2014). Studies with adults suggest that explanations for cross-cultural differences could include differences in underlying values, the influence of wider political systems, or educational experiences (Poortinga et al., 2019); factors which also play a role in young peoples' responses.

4.3 | Limitations

4.3.1 | Limitations of the review

We recognized that in order to provide meaningful insights in the context of a disparate literature, we had to set constraints on the bounds of the search. This has had an impact on the scope of the review, which relates only to perceptions of climate change, and excludes literature relating to relevant concepts such as coping with emotional responses to climate change. As we reviewed only peer-reviewed journal articles, the review did not include other potentially valuable sources of information, such as national and international polls (Eurobarometer, 2019; Yale Program on Climate Change Communication, 2019), or theses. Any relevant articles that were published outside of the searched databases could not have been captured. Only including articles written in English meant that important findings reported in other languages were not accessed. Given the recently increased scientific interest in this age group in the context of climate change, it is likely that additional, interesting insights—published in and after 2019—are not included in this review. There are clear limitations to the conclusions we have drawn about temporal and geographical variability. There was only one international study in the review, the majority of studies were conducted in high income countries (United Kingdom, United States, and Australia in particular), post-2007. In the main, we did not compare like for like across time and place, given studies employed different methods, and asked different questions to dissimilar samples of children and adolescents. We are beginning to see cross-cultural research relating to climate change perceptions in adults, but this is an emerging literature (Nash et al., 2019), particularly outside of Western settings.

4.3.2 | General limitations of studies included in the review

Some of the studies in the review were judged to be of relatively low quality. A number of quantitative studies did not adequately describe the characteristics of participants, or describe results in sufficient detail. Some qualitative studies did not describe their analysis in a systematic manner, or feature any reflexive commentary. Although several countries were represented in the review, the majority were high income nations. The largest number of studies were conducted in the United States, Australia, and the United Kingdom. Some studies examined the impact of situational factors but the majority focused on individual cognition, thus providing a narrowly focused understanding of the factors impacting children's climate change beliefs and potential behaviors (Gifford, Kormos, & McIntyre, 2011). The research was overwhelmingly conducted in school settings. Conducting research in school does of course aid recruitment and speeds the process of getting parental consent, where it is required (Fisher, 2019). However, participants may have felt they were sitting a "test," potentially making them feel inhibited or pressured to find the "right" answer. All studies were cross-sectional, which does not allow us to draw conclusions about how climate change conceptions may change over time in the same population.

4.3.3 | Methodological limitations of studies included in the review

Most of the studies in the review were quantitative and a large number of these utilized closed-form surveys. The use of introspective measures can lead to a number of common method biases, such as social desirability, item ambiguity, or demand characteristics. These are a source of measurement error (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) and are known to affect research in this area (Otto, Kröhne, & Richter, 2018). Employment of the same survey in several studies was useful because it facilitated comparisons across locations, although comparisons need to be drawn with caution because questions may mean different things to participants in different countries. Local infrastructural factors will likely exert an influence on willingness and ability to act in certain ways. For example, in Hong Kong, public transport is heavily relied upon by necessity (Jackson & Pang, 2017) and stated willingness to use public transport could be predicated on the quality of transport infrastructure, rather than climate concern. There may be cultural differences in the way participants respond to Likert-style survey questions (Lee et al., 2002). Some of the survey questions were rather abstract, with children being asked about the likelihood of their carrying out behaviors that they will not be in a position to perform for many years, such as paying more for green energy, or paying more tax in order for more trees to be planted (Ambusaidi et al., 2012).

Survey and interview questions may be understood differently by children at different ages, making it difficult to interpret apparent developmental change. Language comprehension, cognitive development, and understanding of inner feelings relative to outward behavior all improve across the age-range of the participants in the reviewed studies, and all have been shown to have an impact on how children interpret and respond to the same survey and interview questions (Bishop & Said, 2012; Borgers, De Leeuw, & Hox, 2000; Morison, Moir, & Kwansa, 2000; Otto et al., 2018; Piaget, 1929; Podsakoff et al., 2003). For instance, children aged 8–11 years have more difficulties than older children with questions that are ambiguous or asking about broad rather than specific concepts. Questions with negations, such as "The government does not do enough to promote recycling" are commonly used in adult surveys and are considered good practice to ensure respondents are paying attention but are problematic for children below 11 years of age and yield inconsistent responses (Borgers et al., 2000). Children below 11 are also more likely to become inattentive or lose motivation than older children (Borgers et al., 2000). Both years in education and gender have been shown to reliably predict internal validity and non-responsiveness to survey questions (Benson & Hocevar, 1985; De Leeuw & Otter, 1995). Younger children are less likely to admit they have not understood a question and are more susceptible to leading questions (Morison et al., 2000). Between 8 and 18, substantial improvements are seen in children's ability to create accurate mental models of scientific concepts with multiple interacting variables (such as climate change) and their ability to articulate or externalize these mental models in a variety of ways (Carey, 2009). As such, researchers interested in establishing children's level of understanding emphasize the importance of piloting and pre-testing questions with children of different ages and from different locations when planning cross-age and cross-cultural comparisons. Drawing, making models, and using other visual aids to communication are often more effective for collecting high quality and reliable data from younger children in studies involving complex concepts such as climate change (Dahlquist, 1990; Priestley & Pipe, 1997).

It is revealing that in studies using more open methods, knowledge levels were much lower (Pruneau et al., 2003) than in closed-form questionnaire studies. This may be due to closed questionnaires—with response options outlined—enabling participants to display what appears to be higher knowledge levels, "creating" rather than "accessing" cognitions (Ogden, 2003). Or it could reflect a difference between measures that tap into implicit but superficial understanding and those that require children to explicitly articulate their understanding and thus reveal gaps in those understandings (Perner, 1991). More generally, while surveys are useful for telling us the prevalence of particular views, they do not reveal much about why people hold these views (Wolf & Moser, 2011), nor do they necessarily allow for specific contexts to be considered (Mason, 2017). For example, in a Chinese closed questionnaire study (Boyes, Stanisstreet, & Yongling, 2008) reported concern was very high while two other Chinese studies using qualitative methods (Sternäng & Lundholm, 2011, 2012) painted a more nuanced picture. When faced with an either or scenario, participants often prioritized economic development over preserving nature (Sternäng & Lundholm, 2012), suggesting that concern about climate change is situated in context rather than being stable. This is in line with findings from studies with adults (Smith & Joffe, 2013).

4.4 | Implications for future research

Future studies in this area could provide greater definitional clarity about the nature of the public "perceptions" that they are reporting. The main focus of the studies included in this review was the accuracy of participants' knowledge about climate change. It would be worthwhile for future research to explore how children and adolescents

conceptualize climate change more broadly, given that climate change beliefs are known to relate to: worldview and environmental values (Hornsey et al., 2016); economics and infrastructure (Gifford et al., 2011); efficacy beliefs and parental influence (Mead et al., 2012); and emotions (Ojala, 2012a, 2016). Such research should employ a variety of methods, both quantitative and qualitative, to elicit the broadest understanding of factors in addition to knowledge. This should be at the individual, collective (the potential role of the climate strikes and identification with that movement), and situational levels as all of these impact adolescents' climate-related concepts. The use of open-ended questions would be valuable in accessing the views of this group without limiting their responses. Using reverse coding rather than questions with negations would be a useful strategy to address cognitive limitations in younger children.

The differences in reported belief, concern, and willingness to take action by place and age of participant found here warrants further investigation. International studies and studies conducted outside of high income countries would enhance understanding of these differences and where relevant, cross-cultural differences in relation to methodology (Lee et al., 2002) should be taken into consideration. The differences observed in relation to age should also be examined further. Research exploring possible explanations for age differences would be useful in informing future policy and practice in relation to engaging children of different ages with the issue of climate change. Longitudinal studies would add valuable insight and facilitate an understanding of changes to climate change perceptions over time. Comparative studies could explore how adolescents' perceptions of climate change may differ from adults'.

Finally, a clear opportunity exists to study the nascent youth participation in climate action, and its impact on the climate change perceptions and behaviors of children and adolescents. One potential hypothesis could be that participation in the strikes facilitates increased "connectedness to nature," and an acquisition of knowledge about climate change, shown in combination to increase ecological behavior (Otto & Pensini, 2017). A motivation to behave in an ecologically friendly manner is formed in childhood and has the potential to be lifelong, so it is possible that participating in the strikes could have a long-lasting effect on the ecological behavior of this cohort (Evans et al., 2007). This raises the question of whether participating in climate strikes can or should be interpreted itself as ecological behavior at the collective level and whether a relationship may exist in the other direction, with knowledge and connectedness to nature favoring participation in strikes. An interesting direction for future research may address differences regarding predictors of individual versus collective climate engagement of young people and how participation in strikes affects these. An alternative hypothesis could be that participating—or not—in the strikes will serve to entrench existing perceptions and behaviors rather than cause behavioral shift, in line with the polarizing effect of events such as the signing of the Kyoto Protocol on adults in the United States (Capstick et al., 2015).

Future research on youth climate action should consider the ways in which young peoples' involvement in activism is influenced by their peers (Fisher, 2019), and their tendency to communicate about activism via social media rather than more traditional channels (Elliott & Earl, 2018). More informal, "on-the-ground" approaches could bring researchers closer to participants in action, although the challenge of overcoming the ethical issues involved in conducting research with minors must be overcome, particularly that of parental consent. Further, comparative studies would facilitate a comparison between those participating in strikes and those not and longitudinal studies would enable the exploration of changes over time. As such, this review of the literature up until this point in time hopefully serves as a valuable resource to measure whether the climate change social actions already underway changes these perceptions and developmental patterns.

4.5 | Implications for educational policy and practice

There are important implications of this review for education policy and practice. Although it is only one variable, a lack of knowledge does represent an important barrier to engagement on the issue of climate change (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007). If younger children are more accommodating of new scientifically correct models than older children (Kelemen & DiYanni, 2005) and their thinking is less impeded by worldview and cultural values (Stevenson et al., 2014; Tranter & Skrbis, 2014), there may be a case for ensuring that teaching about climate change features early on in school curricula in countries such as the United Kingdom, where this is not currently the case. It should aim to enhance system knowledge—found to be low in these reviewed studies, as well as action and effectiveness knowledge (Frick et al., 2004) which have greater potential to instil climate-friendly behaviors. Educational strategies may also have the ability to address other important factors that are linked to climate-friendly behaviors, such as hope (Monroe et al., 2017).

Future generations of adults will need to appreciate that effective action will require collective engagement at governmental, corporate, and individual levels. This contrasts with aiming to encourage sustainable lifestyles in individual

and domestic situations (Thøgersen & Crompton, 2009), as was the focus of the early 2000s (Defra, 2008). Now that we are seeing the emergence of collective action by young people, there should be a push to understand its role in generating changes to individual practice. A more thorough consideration of the role of collective action might open up opportunities for interventions at this level. The tendency for children in high income and Western nations in particular to endorse small, individual, less effective actions—potentially because they perceive climate change as a global, not local problem—needs to be addressed. This requires understanding what is personally relevant to young people today. One example might be to determine whether young people may be brought "closer" to a spatially and socially distant climate change (Gubler et al., 2019) via social media.

It is important that climate change education makes use of techniques already found to be effective in strategic messaging in education, such as focusing on the personally relevant and using active and engaging teaching methods (Monroe et al., 2017) or using art-based approaches (Ojala & Lakew, 2017). Further work is needed to establish how young children interpret common climate change metaphors used in education (Dijkstra & Goedhart, 2012) and what mode of communication is most effective for children and young people at different stages of development and in different geographical and sociocultural locations.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

Katharine Lee: Conceptualization; methodology; writing-original draft. **Nathalia Gjersoe:** Formal analysis; resources; writing-review and editing. **Saffron O'Neill:** Conceptualization; supervision; writing-review and editing. **Julie Barnett:** Conceptualization; supervision; writing-review and editing.

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APPENDIX DATA EXTRACTION

Author (year)	Country	No. of participants	Age of participants	Gender of participants	Design	Area of focus	Quality control	No.
Boyes et al. (2014)	International	12,627	11–15	51% male, 49% female	Quantitative cross-sectional questionnaire	Belief, concern, solution	M	20
Boyes, Skamp, and Stanisstreet (2008); Boyes, Stanisstreet, and Yongling (2008)	Australia	500	Years 7–10 (12–15?)	Not clear	Quantitative cross-sectional questionnaire	Belief, concern, solution	M	21
Boyes and Stanisstreet (2012)	UK	961	11–16	52% male, 48% female	Quantitative cross-sectional closed questionnaire design	Belief, concern, solution	L	22
Malandrakis, Boyes, and Stanisstreet (2011)	Greece	1,444	12–16	52% male, 48% female	Quantitative cross-sectional questionnaire design	Belief, concern, solution	M	23
Stevenson, Peterson, and Bondell (2016); Stevenson, Peterson, and Bradshaw (2016)	USA	369 (24 teachers)	11–15	45% male, 55% female	Quantitative cross-sectional questionnaire design	Belief, cause, impact	H	24
Chhokar et al. (2011)	India	768	11–16	58% male, 42% female	Quantitative cross-sectional questionnaire design	Belief, concern, solution	M	25
Ambusaidi et al. (2012)	Oman	1,532	Grades 6–12 (11–18?)	48% male, 52% female	Quantitative cross-sectional questionnaire design	Belief, concern, solution	L	26
Stevenson et al. (2014)	USA	387	11–15	45% male, 55% female	Quantitative cross-sectional questionnaire design	Belief	H	27
Tranter and Skrbis (2014)	Australia	3,139	16–17	Not clear	Quantitative cross-sectional questionnaire design	Belief, concern	L	28
Chhokar et al. (2012)	India	268	Grade 12 (17–18?)	54% male, 46% female	Quantitative cross-sectional questionnaire design	Belief, concern, solution	M	29

Author (year)	Country	No. of participants	Age of participants	Gender of participants	Design	Area of focus	Quality control	No.
Devine-Wright, Devine-Wright, and Fleming (2004)	UK	82 Woodcraft children, 59 comparative and 57 Woodcraft adults	9–12	30 boys and 29 girls in comparative group. Gender split in Woodcraft group unclear	Quantitative comparative questionnaire design	Belief, solution	H	30
Stevenson, Peterson, and Bondell (2016); Stevenson, Peterson, and Bradshaw (2016)	USA	426	11–15	44% male, 56% female	Quantitative cross-sectional questionnaire design	Belief, concern	H	31
Skamp, Boyes, and Stanisstreet (2009)	Australia	368	Grade 6 (238); Grade 7 (130)	Not clear	Quantitative cross-sectional questionnaire design	Solution	M	32
Boyes, Skamp, and Stanisstreet (2008); Boyes, Stanisstreet, and Yongling (2008)	China	676	11–16	335 males and 337 females (4 N/A)	Quantitative cross-sectional closed questionnaire	Concern, solution	M	33
Prudente, Aguja, and Anito (2015)	Philippines	600 Children (and 157 adults)	300 grade school; 300 high school	Not clear	Quantitative cross-sectional questionnaire design	Concern, cause	M	34
Line, Chatterjee, and Lyons (2010)	UK	47	11–18	11s 6M, 9F; 15s 9M, 8F; 18s 9M, 6F	Qualitative comparative mixed methods (discussion groups, photo elicitation)	Concern, solution	L	35
Hermans and Korhonen (2017)	Finland	549	Ninth graders	298 boys; 249 girls	Quantitative cross-sectional questionnaire	Concern, impact, solution	H	36
Jackson and Pang (2017)	Hong Kong	1,383 (survey); 34 (interviews)	Grades 7–12	Half boys, half girls	Quantitative cross sectional questionnaire; qualitative interviews	Impact, solution	M	37
Taber and Taylor (2009)	Australia	29	10–11	22 males, 7 females	Mixed methods pre- and post-intervention design (pre = closed quant questionnaire only)	Cause, solution	L	38
Lee, Lester, and Ma (2007)	USA	405	10–11	204 males and 201 females	Quantitative pre- and post-intervention open-ended writing prompt	Cause, impact, solution	H	39

Author (year)	Country	No. of participants	Age of participants	Gender of participants	Design	Area of focus	Quality control	No.
Mason and Santi (1998)	Italy	22	10–11	50% male, 50% female	Mixed methods pre- and post-intervention interviews	Cause, impact, solution	M	40
Hestness, McGinnis, and Breslyn (2016)	USA	39	Grade 6	Not clear	Qualitative case study	Cause, impact, solution	M	41
Pruneau et al. (2003)	Canada	39	13–14	Not clear	Quantitative pre- and post-intervention design with interviews	Cause, impact, solution	H	42
Karpudewan, Roth, and Chandrakesan (2015)	Malaysia	73	16–17	42 boys, 31 girls	Mixed methods quasi-experimental intervention survey and interviews	Cause, impact, solution	H	43
Shepardson et al. (2009)	USA	91	Grade 7	54% male, 46% female	Mixed methods open-response questionnaire and draw and explain task	Cause, impact, solution	H	44
Chang and Pascua (2016)	Singapore	27	14–15	Not clear	Qualitative cross-sectional paired interviews	Cause	L	45
Boyes, Chuckran, and Stanisstreet (1993)	USA	702	Grades 5–10	50% male, 50% female	Quantitative cross-sectional questionnaire design	Cause, impact, solution	M	46
Puttick et al. (2015)	USA	483	8–14	All girls (girl scouts)	Quantitative pre- and post-intervention questionnaire (qual methods used post)	Cause, solution	M	47
Punter, Ochando-Pardo, and García (2011)	Spain	379	12–16	194 boys and 171 girls	Quantitative cross-sectional open and closed questionnaire	Cause, impact, solution	M	48
Shepardson et al. (2011)	USA	51	39 junior high, 12 high school	54% male, 46% female	Qualitative cross-sectional open-response questionnaire and draw and explain task	Cause, impact, solution	M	49
Andersson and Wallin (2000)	Sweden	727	15–19	Not clear	Quantitative cross-sectional open-ended questionnaire design	Cause, solution	M	50

(Continues)

Author (year)	Country	No. of participants	Age of participants	Gender of participants	Design	Area of focus	Quality control	No.
Boyes and Stanisstreet (1997)	UK	1,637	14–15	45% male, 55% female	Quantitative cross-sectional questionnaire design	Cause	L	**51**
Kilinc, Stanisstreet, and Boyes (2008)	Turkey	Not stated (Y10 from 2 secondary schools)	15–16	Not clear	Quantitative cross-sectional questionnaire design	Cause, impact, solution	L	**52**
Varma and Linn (2012)	USA	196	Sixth graders	98 males, 92 females	Quantitative pre- and post-intervention open-ended questionnaire	Cause	H	**53**
Dawson (2015)	Australia	438	14–15	189 males, 249 females	Quantitative cross-sectional (questionnaire and interviews)	Cause	H	**54**
Özdem et al. (2014)	Turkey	646	Seventh graders	324 males, 289 girls, 33 unspecified gender	Quantitative cross-sectional open and closed questionnaire design	Cause, solution	H	**55**
Garg and Lal (2013)	India	290	12–19	Not clear	Quantitative cross-sectional questionnaire design	Cause, impact, solution	M	**56**
Boyes and Stanisstreet (1993)	UK	861	11–16	48% male, 52% female	Quantitative cross-sectional questionnaire design	Cause, impact, solution	M	**57**
Koulaidis and Christidou (1999)	Greece	40	11–12	22 boys, 18 girls	Quantitative cross-sectional semi-structured interviews	Cause	M	**58**
Frappart et al. (2016)	France	60 Children (20 over 18s)	Seventh graders, ninth graders, 11/12 graders	Grade 7 10M/10F; Grade 9 7M/13F; Grade 11/12 2M/18F	Quantitative cross-sectional questionnaire design	Cause, impact, solution	H	**59**
Scott-Parker and Kumar (2018)	Fiji	30	14–18	15 boys; 15 girls	Qualitative focus groups	Cause, impact, solution	M	**60**

Author (year)	Country	No. of participants	Age of participants	Gender of participants	Design	Area of focus	Quality control	No.
Dogru and Sarac (2013)	Turkey	362	10–16	Not clear	Mixed methods cross-sectional interviews	Impact	H	**61**
Daniel, Stanisstreet, and Boyes (2004)	UK	582	11–16	Not clear	Quantitative cross-sectional questionnaire design	Solution	M	**62**
Francis et al. (1993)	UK	563	8–11	Not clear	Quantitative cross-sectional questionnaire design	Solution	L	**63**
Skamp, Boyes, and Stanisstreet (2013)	Australia and UK	785 in UK, 500 in Australia (1285)	Years 7–10 (12–15?)	Not clear	Quantitative cross-sectional questionnaire	Solution	M	**64**
Bofferding and Kloser (2015)	USA	387	11–14 (162) and 14–18 (225)	Not clear	Quantitative pre and post intervention questionnaire	Solution	H	**65**
Kirk (2008)	New Zealand	31	9–11	Not clear	Qualitative cross-sectional focus groups	Solution	L	**66**
Sternäng and Lundholm (2011)	China	9	14	4 boys, 5 girls	Qualitative cross-sectional group interviews	Solution	M	**67**
Sternäng and Lundholm (2012)	China	12	15–16	Not clear	Qualitative cross-sectional role play exercises and longitudinal interviews	Solution	M	**68**
Byrne et al. (2014)	Sweden and UK	72 in UK, 99 in Sweden (171)	9–10	Not clear	Qualitative cross-sectional discussion groups	Solution	M	**69**
Wilks and Harris (2016)	Australia	311	12–18	44% male, 56% female	Quantitative cross-sectional closed questionnaire design	Solution	H	**70**