



Youth Climate Questions

Challenging Technofixes and a Call for Socio-political Action

Elizabeth A. C. Rushton¹ · Lynda Dunlop²

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Abstract

Anthropogenic climate change and environmental crises are pressing challenges of our time, with changes to the climate system observed in every global region. Disastrous impacts on nature, including people, have already been observed in the form of drought, floods and extreme heat events across the planet. This study examines the role of an interdisciplinary approach to exploring different responses to climate-related disasters and potential disasters. The work we report takes place in the context of recent research on dialogue on climate interventions with youth. Climate interventions are large-scale interventions into the Earth's climate system and include proposals such as solar radiation management, ocean liming, and carbon capture and storage technologies. Research and development of climate interventions as a response to one set of disasters (in the present and in-the-making), created as a result of anthropogenic climate change, are associated with much uncertainty and controversy. We explored these uncertainties and controversies with young people, scientists and policymakers, resulting in a set of illustrated climate conversation cards. In this paper, we analyse the questions produced by young people to find requests for data and knowledge from across disciplines, and for an exploration of ethics, feelings, positions and priorities. We also found problematisations of technofixes and desire for socio-political action. The implications for science and disaster education are discussed.

1 Introduction

Anthropogenic climate change and environmental crises are pressing challenges of our time, with changes to the climate system observed in every region and anticipated increased effects (IPCC, 2023a, 2023b). Attribution studies have focused on how climate change means extreme weather events and associated disasters are more common, and drawn attention to the importance of social inequalities and local adaptation efforts in mitigating these effects. The impacts of climate change raise complex and urgent questions as to what

✉ Lynda Dunlop
lynda.dunlop@york.ac.uk

¹ Faculty of Social Sciences, University of Stirling, Stirling, Scotland, UK

² Department of Education, University of York, Heslington, England, UK

risks people living today should be able to impose on future generations and ecosystems (UN, 2023) and because action or inaction has consequences for all (Klein et al., 2021). Climate change as a result of human activities associated with greenhouse gas production is an example of slow violence, defined by Nixon (2011) as ‘a violence that occurs gradually and out of sight, a violence of delayed destruction that is dispersed across time and space, an attritional violence that is typically not viewed as violence at all’ (Nixon, 2011, p.2). Disastrous impacts on people and nature have already been observed in the form of drought, floods, heat waves and wildfires across the planet. Yet government and industry responses are slow, and although education has been identified as having a key role to play in preventing, responding to and recovering from disasters (UN, 2015), countries more urgently need to address climate change and associated disasters in education (UNICEF 2019). Only a minority of countries include specific climate change responses in education, and there is little attention to disaster impact reduction, particularly in UNFCCC Annex 1 countries (industrialised countries and economies in transition). Park (2020) argues that a focus on disaster education in science education creates the conditions for a more nuanced and comprehensive teaching of disaster, taking greater account of the social and political contexts of disaster. Other scholars including Bazzul and Tolbert (2019), Levinson (2023) and Raveendran (2021) have similarly called attention to the need for greater emphasis on the social and political contexts of science. Science is a subject where many young people will learn about climate change, even though understanding of climate change requires understanding of science and non-science disciplines (Eilam, 2022). As such, it is an appropriate place to focus on disaster risk reduction and to include teaching about present and future disasters resulting from the excessive production of greenhouse gases by (some) societies in compulsory science education. In this article, we examine the role of education in understanding and responding to climate-related disasters and potential disasters.

2 Climate Interventions: Anticipating and Averting Disaster?

Climate interventions are large-scale interventions into the Earth’s climate system and include proposals such as solar radiation management, ocean liming, and carbon capture and storage technologies, which can themselves be considered ‘dicey’ as they are potentially dangerous or uncertain; difficult or; risky; tricky—just as it can be considered risky to not explore all possible responses to climate change. As well as presenting a possible—and contested—response to the disaster of climate change, they are also potentially the source of future disasters. As Marino and Ribot (2012) note, ‘climate-response measures and the discourses surrounding them have their own, even-less-understood, stratifying outcomes for vulnerable populations’ (p.323). Further, it is important to be aware that disasters have a past (often in processes associated with money-making) and a future, as well as present (Knowles, 2014). Knowledge about disasters that have already played out can help us to examine successes and failures in governance of new technologies and to act to prevent or mitigate disasters in-the-making.

The dominant approach to researching public perspectives on climate interventions to date has been to ask participants (typically adults, other than in the Ipsos MORI (2010) *Experiment Earth?* dialogue) to assess the acceptability of different methods of climate intervention, often involving presentations by researchers involved in research and development in climate interventions (Szczyszynski & Galarraga, 2013). This presents a particular challenge for new technologies because public awareness tends to be low (Cummings &

Rosenthal, 2018; Scheer & Renn, 2014), and so there has been a move towards deliberative approaches which introduce new ideas to various publics. A number of challenges with these approaches have been identified, for example deferral to scientific authority, even on non-scientific questions, problematic framings (Corner & Pidgeon, 2015), and dialogue which is often structured around specific techniques with little consideration of alternative (social, political, economic) responses to climate change. Attempts have been made to respond to these challenges (e.g. Bellamy & Lezuan, 2017) through a reduced role for scientists and the use of tentative language to design interventions.

Drawing on deliberative approaches to understanding public perspectives on climate interventions, we designed an educational approach to understanding young people's perspectives on climate interventions. Recognition of young people's views is an important aspect of intergenerational justice in climate change education (Trott et al., 2023) and every child has the right to express their views in matters affecting them and to have these considered and taken seriously (UN Convention on the Rights of the Child, 1989). There is a need to make space for education on climate change responses because of the increasing and disproportionate impacts of climate change on children and young people. Proposed climate interventions are relevant for science education because they represent a live area of scientific endeavour through which it is possible to apply learning on climate science, as well as to understand how science works, the sociology of science, explore risk and uncertainty in science, the context of scientific decision-making and about the governance of new science.

3 About the Present Study: Dialogue on Climate Interventions with Youth ('DICEY')

The project—dialogue on climate interventions with youth ('DICEY')—was designed to include the perspectives of young people in considerations about climate interventions. It consisted of three key phases: (a) youth research and education about climate interventions, (b) creation of illustrated question cards in collaboration with an artist and (c) dialogue with scientists and policymakers using the question cards. In the first phase, young people participated in online workshops and meetings to find out about different climate intervention proposals and how they are communicated. In the second phase, question creation was used as a way of sharing perspectives across differences without reducing positions to 'pro' or 'anti' labels. In the third phase, these questions were used to stimulate dialogue with scientists and policy-makers. In this article, we analyse the illustrated question cards and discuss how the themes identified can contribute to disaster education in science. We draw on two key theoretical perspectives: the idea of slow violence (Nixon, 2011), outlined above, and 'staying with the trouble' (Haraway, 2016), below, to help us explore responses to disasters in science education.

4 Staying with the Trouble of Climate Disasters and Education

As mentioned previously, Nixon's (2011) work on slow violence helps us to understand climate change as a disaster which occurs through everyday actions, is slow in the making, and which occurs at a distance, often not considered violence because it is not immediate, explosive or spectacular. Nixon identifies the divide between 'those who can act with

impunity and those who have no choice but to inhabit intimately, over the long term, the physical and environmental fallout of actions undertaken by distant, shadowy economic overlords', noting that those living in poverty are the main casualties of slow violence. Children and young people can also be considered casualties of slow violence as the effects play out over long timescales. Neville & Martin (2023) flip the concept of slow violence, to outline processes associated with incremental change over a longer time that can bring about fairer conditions, i.e. slow justice. Education, alongside the activism that Neville & Martin (2023) describe can contribute to slow justice. It too has 'consequences that are dispersed in time and place, occur in non-linear forms, and operate at multiple scales' (p.190), and therefore should be a site for exploration of the biggest challenges of our time, including disasters associated with climate change.

In interrogating how this might work in (science) education contexts, we turn to the multispecies feminist theorist Donna J Haraway and her ideas of 'staying with the trouble' (Haraway, 2016). Haraway suggests that in response to living in 'disturbing times, mixed up-times, troubling and turbid time' (p.1) that, 'our task is *to make trouble*, to stir up potent response to devastating events, as well as to settle troubled waters and rebuild quiet places' (p.1). Haraway expands:

Staying with the trouble requires learning to be truly present, not as a vanishing pivot between awful or endemic pasts and apocalyptic or salvific futures, but as mortal critters entwined in myriad unfinished configurations of places, times, matters, meanings. (Haraway, 2016, p.1)

The concept of 'staying with the trouble' therefore has a temporal dimension: in our response to 'trouble' or 'devastating events' Haraway urges us to be 'truly present' and not become lost between considerations of past events and future realities. In the context of the classroom, where disasters and disaster response are explored, Haraway reminds us of the importance of engaging with the present and to provide opportunities to consider the complexity of places, times, matters and meanings that we ourselves are entangled. This invocation to stay with the trouble is important when we consider the intergenerational dimensions of education and of disaster response, where the frequent framing of climate change education is that the burden of responsibility lies on young people. For example, in a speech to launch the Department for Education's sustainability and climate change strategy for education and children's systems services (Department for Education, 2022) in England, the then Education Secretary Nadim Zahawi said, 'Together, I know that Phoebe and her generation can do this, and they have our full backing' (Zahawi, 2022). Here, Zahawi is perhaps lost in 'salvific futures' rather than staying with the trouble and requiring his generation to be truly present and responsible.

Relatedly, Haraway's notion of 'staying with the trouble' directly challenges ideas of climate interventions or, as Haraway describes, human's 'comic faith in technofixes' which will 'come to the rescue'. However, rather than dismissing or rejecting such responses, Haraway urges us to 'stay with the trouble' of these types of responses to disaster:

In the face of such touching silliness about technofixes (or techno-apocalypses), sometimes it is hard to remember that it remains important to embrace situated technical projects and their people. They are not the enemy; they can do many important things for staying with the trouble... (Haraway, 2016, p.3)

Through the DICEY project, with its focus on climate interventions and working with scientists and policy-makers engaged in relevant research and decision-making, we have arguably created a framework for youth to 'stay with the trouble' of responding to the

climate crisis. Haraway urges that ‘staying with the trouble’ requires kinship, ‘we require each other in unexpected collaborations and combinations...We become-with each other or not at all’ (p.4). How do spaces of science education ‘cultivate robust response-ability for power and threatened places and beings’? How can youth respond to this call? What place might approaches such as those developed through DICEY have in science education? Haraway suggests that approaches which bring art and science together can create ‘intimacy without proximity’ and can build ‘caring publics’.

Ideas of ‘staying with the trouble’ and ‘care’ have resonances with the affective dimension of education including aspects which attend to the emotions of living with uncertain and climate altered futures. These ideas of emotions, interest, aesthetics and wellbeing are of concern to science education scholars (e.g. Bellocchi et al., 2016; Sinatra et al., 2014; Zembylas, 2004). Such a focus is essential to equip educators to engage with and respond to negative emotions (e.g. fear of the future, frustration) and positive emotions (e.g. hope for the future, care for the planet) young people encounter and express as part of their school education. How then can (science) education create ‘intimacy without proximity’ which attends to the emotions young people experience? We suggest that through the DICEY project, opportunities for peer collaboration, question creation and working with an artist, scientists and policy-makers in the context of climate interventions provided opportunities to create intimacy. Through analysis of the questions created as part of the DICEY project, we will reflect on the ways in which such collaborations create spaces which enable us to ‘stay with the trouble’.

5 Methods

In this section, we outline the methods of creation of question cards as a form of science education in the context of climate change and climate interventions. We then describe our methods of analysis of the questions.

5.1 Research Design

A participatory, co-creative approach was used to create a set of illustrated question cards to serve as a stimulus for dialogue between young people, policy-makers and scientists. Participatory approaches integrating science, art and environmental challenge have been used previously, e.g. with primary school students to challenge neighbourhood pollution (Watson et al., 2021). Participatory approaches ensure that the products of research (here, illustrated question cards) are relevant and usable (here, for determining the focus of dialogue on climate interventions). Here, we report on the design and analysis of the questions rather than on the resulting dialogue between young people and scientists which was not recorded to enable participants to speak more freely.

5.2 Participants

This study involved a total of 63 young people aged 16–25. Participants included school students, teachers, undergraduates, postgraduates, people employed in sustainability roles and those not in work or education. The youth expert panel consisted of a subset of 9 of the 63 young people who were interested in extended engagement beyond an initial question

creation workshop and who authored blog posts and a policy brief, and facilitated discussion with scientists and policy-makers.

In addition, 22 scientists and policy-makers identified through organisations involved in conducting or funding research on climate change responses participated in an online dialogue facilitated by the youth expert panel using the questions created by the 63 young people.

The project took place, mainly online, between January and July 2023, using a blend of workshops with the wider group of young people, scientists and policy-makers and meetings involving only the youth expert panel and the research team. One face-to-face workshop was held specifically to enable young people with additional educational needs to contribute.

5.3 Methods and Timeline of Image Creation

In this study, we asked young people to provide the stimulus material for an artist in the form of questions, metaphors and illustration suggestions. The process of image creation involved triangulation between young people, researchers and an artist. A timeline is presented in Table 1.

Firstly, creation workshops were held with young people. In order to prepare young people to identify biases in material discussing climate interventions, these workshops began with an introduction to the wide range of responses to climate change including social and political responses, as well as a review of the state of the art in relation to climate interventions, namely that ‘if...actively pursued on global scales, [climate interventions] would very unlikely be implementable prior to the second half of the century...’. The social science of climate interventions was then introduced, focusing on the challenges associated with communication on climate interventions. These challenges include problematic framings (Corner & Pidgeon, 2015), for example analogies with nature suggesting that climate interventions are ‘like a volcanic eruption’ or that carbon capture and storage is like ‘artificial trees’ which are associated with more positive responses to climate interventions as they associate with natural or familiar phenomena.

Participants were put into groups then each group tasked with finding out about a different approach to climate intervention. They conducted research in their online groups and were asked to (a) summarise how the intervention was supposed to work, (b) identify any questions they had about how the approach worked, (c) create questions that they would need to know the answer to in order to decide whether or not the approach should be deployed and (d) create questions they would want to put to a scientist or policy-maker. The approach to question creation, we argue, can be used in education on controversial and sensitive issues, with the specific advantage of being a depolarising method of having such conversations in contrast to more widely used approaches to discussion such as classroom debate.

Finally, participants were asked ‘If you could draw a picture to represent your conversations today, what would you draw?’.

Questions were grouped by the project team, edited for length and along with suggested imagery were shared with the artist.

A first draft of the cards (including questions and images) was shared with the youth expert panel for comments and feedback. Feedback on the cards was created during online meetings and shared with the artist, who created the final version of the images. Figures 1, 2 and 3 show examples of the pre- and post-feedback draft of the question

Table 1 Project timeline

Date	Activity	Purpose	Output
September and October 2022	Engaging project partners with a focus on inclusivity Review of research on climate interventions	Ensure that the project engages with people from a diverse range of contexts To ensure the project draws on recent relevant research	Reflective questions on working with young people with additional learning needs Research summary on communication on climate interventions
November 2022	Design of workshops; online (×2) and in person (×2) question creation workshops (total 63 young people)	To educate young people about different responses to climate change and hear their questions	151 questions
November and December 2022	Analysis of questions; offline reflection and editing of the questions and creation of illustrator brief (total of 13 young people)	To reduce questions to a manageable number, reflecting the interests and perspectives present in the corpus	58 questions refined from the original 151 questions and development of the illustrator brief
January and February 2023	Co-design of the workshop for policy-makers and scientists (13 young people)	To enable young people to engage with scientists and policy-makers in a way they felt comfortable with	Workshop plan drawing on the questions created
March 2023	Youth-led (total 9) workshop with policy-makers and scientists (total 22) and subsequent debrief	To explore the questions created by young people with those who have influence in the field	Dialogue between scientists, policymakers and young people
March–May 2023	Analysis and illustration including rounds of feedback for the artist	To create a resource for use in different education and public participation contexts	Feedback on illustrations; deck of question cards
June–July 2023	Interviews with youth (×9)	To understand how participants experienced the project, their learning and current thinking on climate interventions	Report

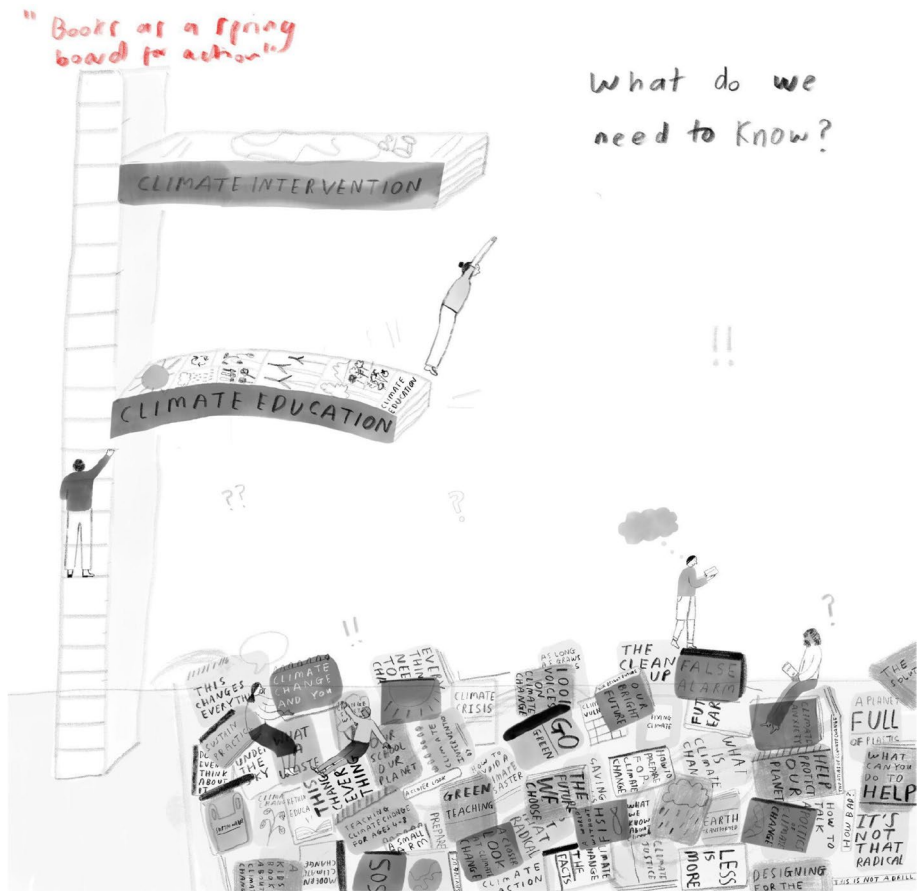


Fig. 1 Pre-feedback draft of the question card

card ‘what do we need to know?’ which features the questions: What do we need to know to decide whether to research and use climate interventions? How should compulsory education change? Do we already need climate intervention and can we ever really know that?

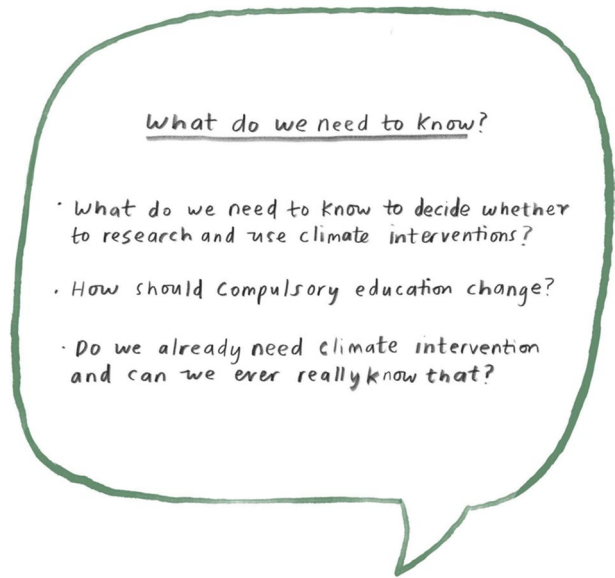
Participants reported that climate intervention being on the top diving board did not communicate a ‘springboard to action’ as intended in the original visualisation notes, but instead represented climate intervention as something to aspire to. After discussing different ways of representing the questions, they provided the following as feedback: ‘Instead of the springboards, could the books create mountain, with “climate justice” at top, books as steps (love the titles!)’ The process of learning—moving from learning, research, discussion and question creation to the production of drafts, the feedback process and creation of the final illustrated question cards—was deliberately slow to give time to ‘stay with the trouble’, to reflect and dialogue together and resolve differences of opinion through encouragement to disagree, the development of mutual understanding, and space to work across difference.

The set of question cards produced is presented as supplementary material.

5.4 Methods of Analysis

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Fig. 3 The reverse of the card: associated questions



rather incremental and accretive, its calamitous repercussions playing out across a range of temporal scales' often 'not counted, not seen' (Nixon, 2011, p.13).

As we analysed the images, we sought to make apparent the thinking of the youth about climate interventions, how these collective thoughts and ideas were made visible in the images and how these images intersect with the ideas of Haraway (2016) and Nixon (2011). The themes are represented in the 15 question cards (see supplementary material).

In the second round of analysis, questions were analysed by type. Questions can be classified in different ways, for example as alternative or polar (Biezma & Rawlins, 2012), open or settled, empirical or policy (Hess & McAvoy, 2014). In the second round of analysis, we were concerned with what questions can reveal about young people's perspectives, and therefore what function the question serves (what it seeks, asks or communicates) rather than their form (open or closed) or thematic content (what the question is about, as was the focus in the first phase). The questions were grouped by function, and labels attached to these functions to produce the typology, presented in the following section.

We attempted to avoid reductionism in the use of question creation as a methodology. The question cards and typology produced allows questions to be grouped by thematic content by function respectively. This facilitates flexible engagement with data (i.e. questions), with the former being useful for education, public engagement and other related purposes and the latter being useful for researchers to understand what question creation can reveal about youth perspectives on climate interventions.

6 Findings and Discussion

6.1 Types of Question

The analysis of 151 questions created revealed insights from participants across a number of domains: data, ethics, knowledge, affect, positions and priorities. These are presented as

a typology (Table 2). Further examples are found in the question cards (see supplementary materials).

The analysis of questions by type revealed insights from participants across a number of domains as to what was needed in order for decisions to be made. The domain of data included considerations of what the impact of different approaches are on people, planet and space; what impacts can and should be measured and what can be extrapolated from small scale studies to planetary systems. The domain of ethics explored ideas of responsibility and accountability in decision-making, exploring how to ensure just responses to climate change including the independence of and trust in scientists and politicians. Ethics also considered notions of equity and the distribution of resources including prioritising the most vulnerable nations and peoples. Turning to the domain of knowledge, this considered where uncertainties lie, the risk of misinformation (or disinformation) by omission, reflections on which worldviews are considered including the importance of the arts, humanities and social sciences as well as the sciences. As part of the domain of knowledge, there were considerations of the place of coloniality in discussions about climate interventions, what people (politicians, scientists, members of the public) and groups (intergovernmental organisations, industry, government) need to understand. Across the domain of affect, feelings such as anger, frustration, worry and fear were incorporated into questions. In the domain of position, themes included treating Earth as an experimental subject, treating symptoms over root causes, questions of justice (environmental, intergenerational, racial), climate intervention as distraction whilst destruction is ongoing. Other themes included the risk of conflict, who speaks for nature, the need for inclusive global engagement, the role of finance and funding, and the distribution of risks and benefits across the globe. Finally, in the domain of priorities, different climate interventions were compared with each other such as the prevention and reduction of greenhouse gas emissions and changes to the way we live. Different mitigation approaches were compared with climate interventions; priorities for funding in the present were compared (cost of living, food security v research on climate interventions) and different geographical regions were compared (often Global North with Global South). Time (urgency) was identified as a priority in making decisions in relation to governance and scientific research on both climate change and climate interventions.

The typology above includes different functions that the questions served, from seeking information to highlighting feelings and positions to highlighting ethical issues. These types of acts were found across the various themes of question, for example communication, conflict, distraction, economics, ethics, experimentation, justice (including intergenerational, climate, racial and distributional justices), nature, risk, trust and uncertainty (see supplementary material).

6.2 Themes Across Questions

We discuss the thematic analysis of questions below in relation to two main currents from the research literature reflected in the question cards: (1) the problematisation of technofixes and (2) the desire for socio-political action.

6.2.1 Problematising Technofixes

In analysing the questions, we drew on Haraway's (2016) concept of 'staying with the trouble' of technofixes and, rather than rejecting these as responses to disaster, we sought to

Table 2 What questions reveal across a number of domains

Domain	Definition	Example question and card	Narrative
Data	A question that requests information in the form of data or observations	With ocean fertilisation could this cause more issues with ecosystems, e.g. kill more fish?	This question asks for data on the impact on climate interventions on ecosystems, suggesting that this is an important consideration when taking a stance on climate interventions
Ethics	A question that identifies underlying ethics or assumed values	What social, environmental, economic inequalities are produced by geoengineering?	This question identifies production of inequalities as a possible negative impact of climate interventions
Knowledge	A question that asks for information from one or more disciplines	What knowledge from different disciplines is needed to understand the impacts of climate engineering?	This question identifies climate intervention as a subject that requires information from a number of disciplines
Affect	A question that reveals an emotion or feeling in response to the issue	It looks a bit scary (ocean fertilisation)—how much are we willing to risk to take carbon dioxide out of the atmosphere?	The emotional response foregrounds this question, which connects fear with risk associated with new technologies
Positions	A question that builds in a belief or stance on an issue, for example that something is true or false	How much are you willing to invest in risky technologies?	The question builds a position into a question on investment. The assumption that climate interventions are risky is taken for granted
Priorities	A question that compares two situations or scenarios in order to indicate which is more important	Are we gonna solve world hunger before we start thinning clouds?	This question compares investment in climate intervention with existing problems with resource distribution and suggests that hunger should be prioritised over climate interventions

engage with them as important ways to understand and ‘embrace situated technical projects and their people’ (Haraway, 2016, p.3). The problematising of technofixes was made visible across different groups of questions including knowledge and position (Table 1) with ideas of uncertainty, risk, conflict and justice. For example, as part of the question card ‘Experiment Earth’, climate interventions are framed as ‘risky technologies’ which may not work (How much should be invested in risky technologies? Is this an experiment on Earth? What if becomes more of an experiment than trying to actually solve climate change?). These questions provide an opportunity to (re)engage with the approaches humans explore and consider what these approaches can reveal about humans’ connection with planet Earth. Conceptions of risk and uncertainty are framed as an important aspect of staying with the trouble. Scientists’ conceptions of and interactions with Earth systems are represented to be constrained, measurable and sanitised as ‘sample 005’ rather than as relationships within Earth which ‘require each other in unexpected collaborations and combinations, in host compost piles’ as articulated by Haraway (2016, p.4). Arguably, problematising technofixes interrupts human ideas of their relationships with Earth and each other in ways which move us beyond notions of controlled experiments. Such notions can valorise western empiricism at the expense of other knowledges and wisdom (*How can scientists ensure they avoid colonial approaches to research when working with indigenous communities?*). Some of this ‘interruption’ is provided by questions which draw on the affective dimension where the inherent emotions point to more relational responses (Table 1); however, emotions are very much absent in the questions focused on experiment Earth. Instead, these emotions are connected to ideas of faith, trust and communication with those who hold authority and power to make decisions about technofixes rather than with specific climate interventions (*How can we keep faith in our political leaders? How can older generations with power demonstrate care for the world?*).

The question card *climate conflict* further underlines themes of positions and knowledge, including the uncertainty and risks involved with climate interventions as technofixes, and how these could lead to global disaster and conflict (*How can scientists, politicians and others ensure that climate interventions will not be used in war or to fuel conflict? What are the social and political risks of climate intervention? Is there a risk of weather wars?*). Consistent with the positions taken through the questions in the experiment Earth card, the questions associated with the theme of climate conflict also visualise Earth as constrained by and reduced to, a human scale. However, here the potential for future conflict is at the heart of problematising technofixes including conflict between the purpose, use and location of climate interventions. These questions, with their explicit ideas of conflict arguably depict technofixes as the enemy, less a benign, controlled experiment, and more the trigger for global ecological and economic disaster which is at odds with Haraway’s approach (Haraway, 2016). Uncertainty is a theme continued through questions focused on the knowledge needed in the context of climate interventions, including the question card *climate uncertainty*. The temporal dimension is evident as part of this uncertainty, for example what is the long-term plan to deal with climate change and its consequences? What are the long-term effects of climate interventions on human life? Here, these questions consider and ‘trouble’ the future rather than the present, using the temporal dimension to question technofixes in terms of ideas of future uncertainty, equity, accountability and risk. However, staying with the trouble which requires us to be truly present is challenging. Youth questions focused on the long-term future, considering the consequences of decisions made by scientists and politicians (*How can we ensure that politicians have the necessary knowledge and understanding to make informed decisions about climate change?*). However, they were also inherently aware of the present disaster whose occurrence and

impact remain inequitable and uncertain (*Will it be too late by the time a decision is made? How can the voices of the lowest emitting countries be heard?*). Arguably, staying with the trouble is visible through youth questions which requires decision-makers to grapple with the temporal, spatial and ethical complexities of climate interventions.

6.2.2 Desire for Socio-political Action

Desire for socio-political action was evident in a number of question cards, with questions pointing to issues around pursuing climate interventions, which cannot currently relied on to make a significant contribution in the first half of the century (Lawrence et al., 2018).

In the *million dollar question* card, the participants wanted to draw attention to the idea that capitalism (and relatedly, overconsumption, unsustainable resource use) is driving the climate crisis and that this needs to be acknowledged if there is to be a long-term change. The image represents capitalism as the elephant in the room. Questions included *should funding be used for uncertain climate interventions or should these resources be put to reducing climate emissions?* and *do climate interventions distract us from reducing consumption and emissions and making necessary lifestyle changes?* These questions highlight an important issue around the links between financial investment and climate action (and what types of climate action are incentivised through economic systems), and represent what Nixon (2011) describes as ‘death by indirection’ where plants, animals and those most affected are not seen by those responsible, and where capitalism abstracts in order to extract, distancing the mechanisms of slow violence (here, climate change) from their most acute effects.

Desire for socio-political action was also seen in the *communication across place and time* question card. This shows a diverse range of people, representing a CEO, funders, scientists, politicians, youth, policy-makers and an NGO and includes questions such as *When and how should scientists and politicians involve society in decision-making about climate change and climate interventions?* There was attention to who participates in decision-making on climate change, and the importance of ensuring that decisions are informed by evidence in the questions: *How can the voices of lowest emitting countries be heard?* and *What is needed to ensure politicians have the necessary climate science knowledge to make informed discussions?* This card illustrates the idea of creating intimacy without proximity by developing understanding and empathy without relying on physical presence (Haraway, 2016) and identifies some of the challenges in doing so, depicted by the image of the scientist’s screen buffering or trying to connect online.

Questions on the card *Can we change the way we live?* indicate a desire for socio-political action. This card depicts a bleak, dark present highlighting the consumption-based causes of climate change—existing industry, transport, food systems—and the associated negative health impacts represented by a sign to the chemist. The questions *why don’t we stop extracting fossil fuels right now?*, *how can we change the way people move around?* and *how can scientists help create a world that doesn’t rely on fossil fuels?* draw attention to responses to climate change that already exist. At the same time as highlighting everyday decisions that contribute to slow violence, the questions draw attention to ways in which slow justice may be achieved. The imagined future represents what Nixon (2011) describes as post-hydrocarbon possibilities, with renewables, a zero waste food shop and paths for sustainable ways of travelling part of everyday infrastructure.

Finally, the card *How can we build a better world?* depicts a laboratory of the future, linking inside and outside, with multiple disciplines represented working together. The

person depicted in the poster demonstrating the impacts of climate change is also depicted in the room, working with others in the room and beyond, in this laboratory of the future, drawing attention to Davies' (2022) call to take seriously the knowledge of communities who experience slow violence. The questions participants created included *how can education help build a world where climate interventions are not needed?*, *how can scientists, politicians and people work together to build a better world?* and *can we make climate positivity the easiest way to live?* These questions ask for consideration of the conditions that support socio-political responses to climate change, challenging contemporary ways of living and identifying forms of repair, restoration and resilience. This corresponds to Neville & Martin's (2023) productive inversion of the concept of slow violence which is characterised by identifying ways in which advances in justice can be realised, valuing small contributions to justice, the long-term and in causally complex ways in which more just conditions can be brought about.

7 Discussion and Limitations

The analysis of question cards above identified requests for different types of action from information and data seeking to prioritisation and exploration of ethics, a problematisation of technofixes and desire for socio-political action evident in young people's questions. In what follows, we identify some key areas and questions of relevance for science education and disaster education.

7.1 From Question Cards to Action: Future Potentials for Science Education

Firstly, the cards draw attention to the need for intentional work to change the way we live, and to challenge systems and structures that promote individual, high-consuming lifestyles. In common with the most recent IPCC synthesis report, they point to multiple existing approaches to reduce greenhouse gas emissions (IPCC, 2023a, 2023b) and the need for 'deep, rapid and sustained reduction of greenhouse gas emissions' (p.12). Given that science is the subject where many students encounter climate change, these represent potential learning outcomes for science education, not least to counter narratives of doom and denial (of the need to act) and to educate for the changes needed for a societal transition away from greenhouse gas emissions, using knowledge and responses that are currently available. Whilst some responses such as a transition to renewables feature in many curricula, there is a need to more strongly link fossil fuel consumption with disasters, and in concert with the science of renewable energy sources and how these are used, explore the social, political and economic factors which may enable or obstruct just transitions away from fossil fuels.

Secondly, the question cards depict idealised ways in which science might contribute to climate disaster risk reduction which have implications for science education. The cards show scientists working in collaboration with others, across disciplinary, generational and sector boundaries. This points to the need to recognise the limits and limitations of science, risk and uncertainty (specifically risks of both acting and not acting), how science intersects with other ways of knowing and to understand how science and society interact, for example, which responses to climate change are currently being prioritised by e.g. government, charitable and industrial funding mechanisms? These issues concern the political and social-institutional nature of science, which have been under-represented in science

education (Gandolfi, 2021; Park et al., 2019). Consistent with Gandolfi (2021) and Park et al. (2019), we have identified that young people were interested in questions pertaining to social organisations and interactions, political power structures and financial systems related to science, i.e. the socio-institutional nature of science (Demirel et al., 2022). Climate change as a subject area or topic in school science provides a highly relevant context to foreground the social-institutional nature of science. Indeed, as a ‘hyper complex concept’, climate change education brings together two independently complex concepts of ‘education’ and ‘climate change’ together (Læssøe et al., 2009) which requires science education to have more expansive conceptions of what constitutes climate change education. We have identified a way in which science education can equip young people to learn about, engage with and evaluate responses to climate change, by creating questions and creating opportunities for these questions to be addressed by professional stakeholders in science and policy positions. This model is potentially useful for supporting young people to engage with prospective and emerging science more broadly, including as part of science education in the context of formal school education. For example, the question cards provided here could be used in classrooms to explore issues around climate change. Alternatively, the use of question creation could be incorporated into science teaching across a range of topics from climate change to biotechnology, energy and space science. We recognise that in many contexts, including England, teachers frequently experience barriers when seeking to incorporate deliberative and/or creative approaches in their teaching, including overcrowded curricula, accountability pressures and lack of confidence due to limited professional learning opportunities. The approach described here demonstrates how something relatively simple (question creation) can open a range of themes to deliberative discussion.

Finally, in terms of disaster risk reduction, the questions suggest the need to take deliberate action to respond now to climate change in order to reduce the risk of disaster. This is consistent with the Sendai Framework for Disaster Risk Reduction (UN, 2015), which recognises the importance of formal and non-formal education to ensure understanding of disaster risk and enhance preparedness for effective prevention of and responses to disaster. Related to disaster education, the cards illustrate in common with Knowles’ (2014) conceptualisation that disasters are not natural but rather they are ‘normal’, the by-products of the forces of modernisation, particularly urbanisation, industrialisation, and the creation and maintenance of complex technological systems, and that disasters have a past, a present and a future. Knowles (2014) has cautioned against the claim that a disaster opens the door to learning from mistakes, on the grounds that this conceptualisation suggests that disaster may be considered a marker of ‘progress’. How then can we support students to conceptualise learning about and from topics such as disasters and climate interventions which are ethically, scientifically and politically complex? Firstly, according to the UN Office of Disaster Risk Reduction, better decisions about risk require a deeper understanding of its complexities and relationship with development—here technological development. Given the uncertainty associated with climate interventions and that they do not represent a technoscientific ‘fix’ or ‘silver bullet’, teaching and learning focused on climate interventions should be enacted with caution. Importantly, we suggest that where climate interventions are discussed or taught, this should be set against the context of broader social and political responses to climate change which can be enacted immediately to highlight that there is knowledge about what can be done to reduce greenhouse gas emissions and avert or mitigate further climate change before putting faith in early stage technofixes which do not address the root of the problem of unsustainable ways of living and being which have taken us outside the Earth’s safe operating space for humanity (see e.g. Rockstrom et al., 2009).

Indeed, communicating uncertainty in science is associated with higher levels of trustworthiness compared with communication that functions as advocacy (Hendriks, Janssen, & Jucks, 2022).

Looking across the broader climate change education literature, Monroe et al. (2019) highlight that effective climate change education includes opportunities for students to focus on personally relevant and meaningful climate change information which goes beyond simply foregrounding the impacts of climate change on humans and that effective climate change education should use student-centred, active and engaging teaching methods. Examples of active and engaging teaching methods include role-play, the use of visual imagery and inquiry-based activities such as student investigations. Inquiry and use of visual imagery both featured in the DICEY project, and we propose that question creation is an example of such an active teaching method. Both strategies identified by Monroe et al. (2019) are highly relevant to the teaching of responses to climate change in the context of science education. For example, investigative work allows young people to consider the local, global and differential impacts of implementing (or not) different sorts of response to climate change such as the removal of tax exemptions on airline fuel and tickets, introduction of bans on developing new oil fields and coal mines, to the development of new technologies such as stratospheric aerosol injection. Through dialogic and collaborative approaches such as co-creating illustrated question cards and using these with active scientists and policymakers, we argue that DICEY is consistent with climate change education which engages with the scientific, social, ethical and political complexities and seeks to empower young people to meaningfully engage with, 'entanglements of climate fact, value, power and concern across multiple scales and temporalities' (Rousell & Cutter-Mackenzie-Knowles, 2020, p.203).

The DICEY project allowed us to explore questions such as, what is needed of society and, specifically, education in the context of the climate crisis?, what is the role for young people? and how can young people be empowered without transferring sole responsibility to identify and enact solutions? Science education is an important part of these discussions, which are necessarily interdisciplinary and could take place both within and beyond science classrooms. However, we recognise that the DICEY project took place in a voluntary context which did not have explicit subject framings or boundaries beyond that of 'climate intervention'. As such we had greater flexibility in terms of subject knowledge coverage including sequencing and the range of teaching and learning approaches implemented throughout the project. Questions remain as to the existing opportunities for some school-based science curricula to incorporate such approaches where challenges such as a focus on examinations and already 'full' curriculum persist. Nevertheless, formal science education, including in schools, is a vital part of ensuring all young people access high-quality climate change education. Some of the dialogic and collaborative approaches implemented through DICEY could helpfully inform science education and cross-curricular activities, which bring together students (and teachers) from different subject and disciplinary backgrounds, including science, geography, politics and art.

8 Conclusion

This study has explored how climate disasters and disasters-in-the-making can be treated within science and disaster education. We have identified how question creation can bring to the fore issues associated with evaluating different responses to climate change

connected with nature of science, specifically the role of data and ethics in decision-making, a consideration of risk, and the need for knowledge from different disciplines. The questions created by young people identify a desire for socio-political action connected with the problem with relying on technofixes.

The study has demonstrated that question creation can, collaboratively across difference and distance, create space for expression of positions, priorities and feelings and emotions, and indicates one way in which science education can develop young people's knowledge and capabilities to engage with concepts of uncertainty, risk and trust.

Science education and disaster education have important contributions to make to ensure there are spaces for learning where young people can become entangled with issues such as climate interventions and which engage with the socio-political aspects of disasters and climate change. Education researchers should continue to provide opportunities for young people, teachers, scientists, social scientists and policy-makers to question, explore and reflect together in ways which promote kinship when exploring responses to climate change, and identify new ways in which young people can develop knowledge and capabilities to become a more integrated part of decision-making in the present and future and stay with the trouble of climate change through education.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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