Investigating teachers' use of information about cutting edge research

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Introduction

In this small-scale scoping study funded by STEM Learning, we investigated whether and how teachers of STEM subjects access information about cutting edge research to inform their classroom practice, and the impacts of this on the students they teach.

This study supports STEM Learning's aims to explore the effective teaching of STEM research skills by identifying:

- What approaches do teachers of STEM subjects use to teach research knowledge and skills in their lessons?
- What examples and case studies of research do they draw on?
- How confident are they in their expertise in this area?

We focused on a particular area of cutting-edge research: climate change and sustainability. This is a cross-cutting topic for teachers of STEM subjects, with relevance to multiple areas of the curriculum and student age groups. Research in this area is highly relevant to young people, in terms of tackling the climate crisis as well as future "green careers".

There is increasing evidence that teachers lack confidence and knowledge in delivering climate education with issues ranging from dealing with eco-anxiety and political neutrality, to ensuring they are delivering a solution focussed approach (for example, King et al., 2021). Meanwhile, the Department for Education's Climate Change and Sustainability Strategy (launched in April 2022) gives direction to this area of work within schools.

Further, we hoped to generate important knowledge about the impacts of using cutting edge research relating to climate change, with the beneficial outcomes of this work including:

- support for teachers in the use of research in their practice, thereby potentially reducing their and students' anxiety as they develop an understanding of how climate scientists are exploring and developing solutions to address the climate crisis
- understanding climate researchers' approaches and how they can be adapted and used by young people to explore their own questions about climate change and sustainability.

This focus on climate change and sustainability (rather than considering all research in the sciences) enables us to build an understanding of how teachers' access, understand and use cutting edge research in their teaching which can then be extended to other areas of research.

We are grateful to STEM Learning for funding this study and to the teachers who gave up their time to participate in interviews and focus groups.

Our approach

We carried out two overlapping phases of research: a rapid evidence review of published literature, looking nationally and internationally, and a series of teacher interviews and focus groups with teachers of a range of school types, subjects and phases (Table 1). Together, we hoped these would provide an overview of the ways in which teachers of STEM subjects access and use research in their practice relating to climate change and sustainability the barriers and enablers associated with this and the impact on student learning.

Phase 1	Review of published evidence	Focus on published evidence, from peer-reviewed and 'grey' literature, nationally and internationally, identifying how teachers use cutting edge research, and the barriers and enablers associated with this
Phase 2	Teachers' experiences and perspectives	Individual interviews and small focus groups with teachers of STEM subjects from a range of school types, subjects, and phases, exploring how they identify and use cutting edge research, the barriers and enablers associated with this and the impact on student learning

Table 1. Our approach

Our research questions were:

- Where and how do teachers access information about research relating to climate change and sustainability?
- How do they use this information in their teaching and what are the impacts on students' knowledge, understanding and skills?
- What are the barriers and enablers to accessing and using information about research relating to climate change and sustainability in teaching?
- What differences are there, if any, for teachers of different phases and subjects?

Methods

Phase 1: Review of published evidence

In line with good practice in conducting a literature review, a range of inclusion and exclusion criteria were applied when searching for literature. We did not aim for a systematic review of the literature, instead looking for an overview of current and recent research into teachers' use of cutting edge science relating to climate change.

Articles were identified through a search of standard databases of education publications (e.g. ProQuest Education) and 191 papers were returned. These papers were then uploaded into Covidence software which removed three duplicates, leaving 188 papers. Titles and abstracts were screened, rejecting 122 as irrelevant. The remaining 66 papers were full text reviewed leading to 27 papers being included. This process is illustrated in Figure 1. Grey literature, including project reports and evaluations, was searched for using the terms "Climate change" + "education" + "research".

The search and screening process used the following criteria:

- Papers were searched for in high income countries with comparable economic and education systems to the UK including, but not limited to, the US, Australia, Finland, Netherlands, Singapore, Japan etc.
- The timeframe was limited to the last ten years.
- Peer reviewed papers were prioritised, including reviews that summarised findings from a number of studies. However relevant grey literature found was also used as part of the review where appropriate.
- All articles chosen were in English text, with full-text available. A small number of papers were requested through library research request.

The papers that remained were analysed to draw out any significant findings and details for the review.

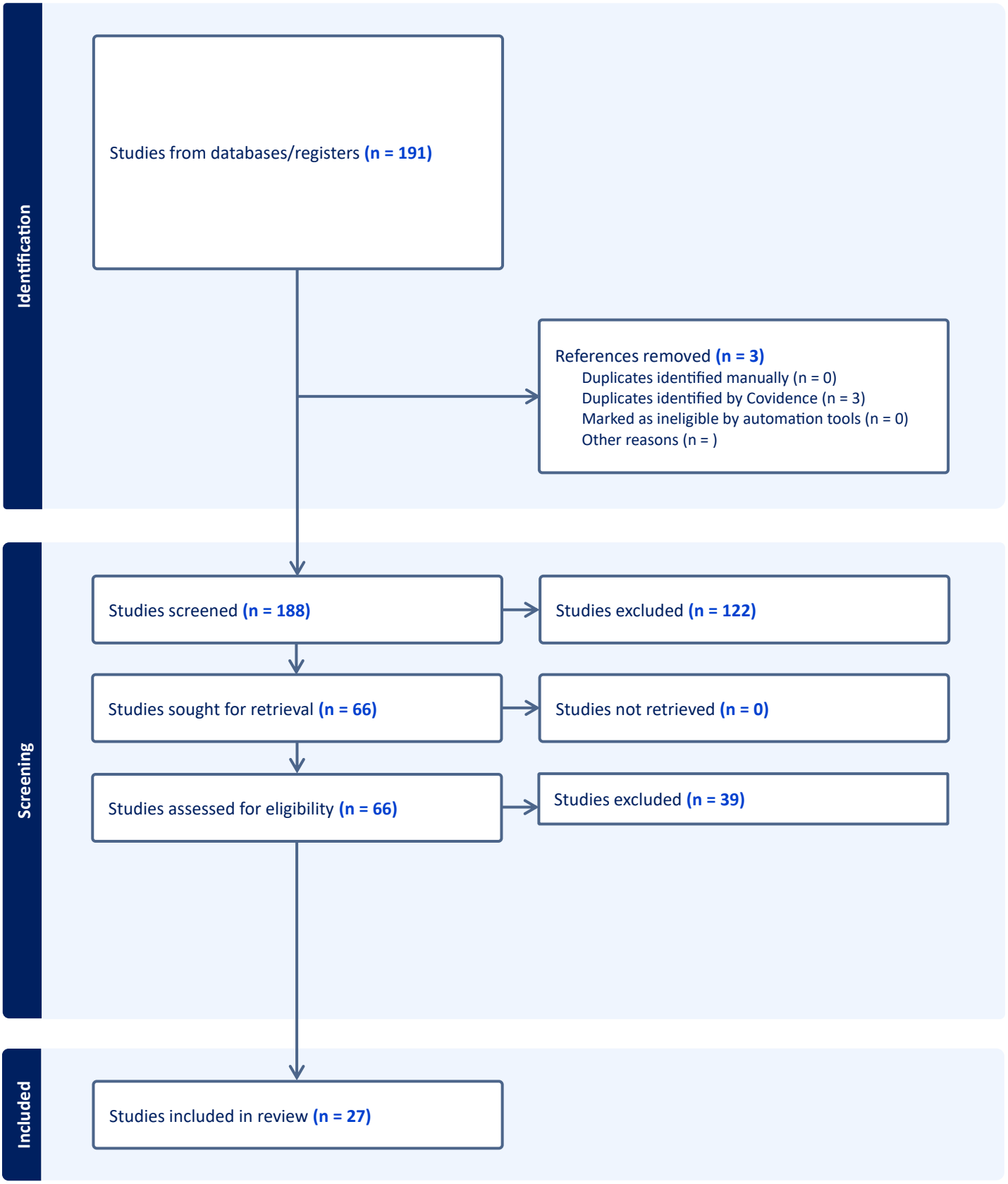

Figure 1. Search and screening process

Phase 2: Teachers' experiences and perspectives

Teachers were recruited via existing professional networks. We carried out five interviews with eleven primary teachers (in pairs and groups of three) and nine secondary teachers (individually and in pairs). Participants came from a total of twelve schools in Sheffield and Leicester. Participants were offered a gift voucher to incentivise their participation in the research. These interviews were carried out either online using Microsoft Teams or in person.

Interviews lasted between 30 and 45 minutes and were carried out by a team of four researchers. Participants' roles and groupings can be found in Appendix 1.

Questions were asked around where teachers access sources related to climate change & sustainability and frequency, the reliability of the information, as well enablers and barriers to engaging in cutting edge research.

The full interviews schedules can be found in Appendix 2.

Interviews were recorded, either online or using audio recorders, and transcribed. Transcripts were analysed using a framework based on the research questions above and themes identified.

Ethical approval was sought before the study took place in line with Sheffield Hallam University's ethics policy[1]. Interviewees were given participant information sheets and online consent forms. All participants gave informed consent before interviews to indicate they understood the purpose and aims of the study, and how their data would be used.

[1] https://www.shu.ac.uk/research/excellence/ethics-and-integrity

Findings

In this section we present the findings of the two phases of the study. We consider when and how teachers use cutting edge research about climate change in their teaching, how they access information relating to this and the barriers and enablers to using this research in their practice. We start by presenting the findings of the review of published evidence and then move on to what we learned from interviews with teachers about their experiences and perspectives.

Phase 1: Review of published evidence

How teachers use cutting-edge climate change research

Through our analysis of published evidence, we identified four main themes relating to how teachers use cutting edge research about climate change: curriculum integration, problem-based learning, collaboration with researchers and use of technology.

Curriculum integration

Through curriculum integration teachers incorporate the latest research findings into their lesson plans, ensuring that students are learning the most current information about climate change. Several papers identified approaches to teachers integrating research into their classroom practice. For example, although focussed on an intervention aimed at improving written argumentation skills, Dawson and Carson (2020) found that using climate change as a socio-scientific issue within lessons led to a significant change in student knowledge of the topic. Similarly, McNeill and Pimentel (2009) focussed on verbal argumentation skills. They found that using climate change as a theme promoted student talk, dialogic interactions between students, and greater justifications of their claims with appropriate evidence and reasoning.

Lammert's (2024) small scale study of how teacher trainees rated picture books on energy production showed that while participants thought the books were generally enjoyable for students and would not make them apprehensive, there was variation in terms of how the credibility of authors was perceived. Trew et al. (2021) demonstrate how a wide range of research articles associated with the biological sciences can be disseminated to a primary school audience and how children can carry out investigations associated with cutting edge research in the classroom.

Problem-based learning (PBL)

By engaging students in projects that require them to investigate and propose solutions to real-world climate issues, teachers can make research more relevant and engaging. Problem Based Learning (PBL) and learner-centred inquiry are both identified by Mavuso et al. (2022) as enablers for incorporating climate change research, which ultimately, they argue enables "Teachers' roles to shift dramatically as a result of these approaches: they become facilitators and activators, or change agents, working with students to co-create (i.e., arrive at) information, ideas, and actions for innovative change" (p187).

Collaboration with researchers

Some teachers collaborate directly with climate scientists and researchers to bring first-hand knowledge into the classroom. A range of studies described projects or programmes around climate change. These either enabled collaborations between schools/teachers and scientists or provided structures so that scientists were able to share their knowledge in educational environments via outreach programmes, with positive outcomes noted. For example, a collaboration between teachers, students and researchers on citizen science projects (Klütsch et al., 2021) may have contributed to increased student awareness of environmental issues, while also facilitating the collection of useful data. This required training for teachers and students from researchers. Grasso et al. (2017) gave an account of the development of climate change education modules as part of the outreach activities of LaMMA, the weather service for Tuscany. However, the authors suggest that scientific researchers may be less

inclined to pursue outreach and public educational work, as it is not consistently recognised as being of high value for academic and research staff. This may be different in the UK where the Research Excellent Framework (REF) encourages outreach activity.

Kermish-Allen et al.'s (2019) study showed that an online citizen science collaboration between teachers, students, staff of the fisheries sector, and research scientists created an "effective learning community" (p637) on the topic of local climate change. The project also resulted in significant positive impacts in students' learning around earth science and in the interpretation of graphs. High levels of both student and teacher engagement in outreach activities were experienced in a project run by air quality researchers in Canada (Khalaf et al., 2023). These activities sought to build an understanding of air quality and how it can link both to climate change and health, with researchers reporting that students felt empowered and that the scientists themselves believed that both their communication and leaderships skills had improved as a result.

A further example by Piccione et al. (2024) described their project as highlighting scientific researchers and teachers working together. The programme included seminars, laboratory work and optional follow up with researchers in their classrooms. Initial satisfaction surveys showed teachers benefited from the collaboration. Meanwhile, Liu et al. (2012) collaborated between elementary teachers and university teachers to develop a building energy curriculum. Participating students showed positive attitudes regarding energy conservation and carbon dioxide reduction as well as increases in behaviour performance. As a final example, the UK Research Councils showcased opportunities in a 2010 publication which highlighted climate change as a theme for researchers to work with schoolteachers and students (UK Research Council, 2010). One case study showed A-Level chemistry students working with researchers from Swansea University. Students gained firsthand experience as well as the class teacher "allowed me to examine the bigger picture and explore areas of climate science that I would not otherwise have had the opportunity to do (p4)."

Asimakopoulou et al. (2021), Gold et al. (2015), Grasso et al. (2018) and Klütsch et al. (2021) all note that collaboration needs appropriate resourcing, with the former giving an overview of a cooperative process between scientists, curriculum specialists and educators in the development of data rich Arctic Climate Connections resources.

Use of technology

The use of technology can offer a different approach which provides a stimulus for students to understand often complex processes. For example, in one study (Bouchard et al., 2019), a collaboration of artist and scientists developed innovative approaches to explaining the impacts of climate change such as the "Frozen-Ground Cartoons" and associated videos, augmented reality apps and games on the topic of permafrost. Meanwhile, Asimakopoulou et al. (2021) discussed the use of remote sensing for Earth Observations and online tools to engage learners. This also created high interest in how satellites depict environmental phenomena which is seen as a vehicle to illustrate climate impacts most effectively. In a similar approach, Nepraš et al. (2022) reference the use of computer modelling as having significant advances in the learning of secondary students they worked with.

Barriers and enablers

We analysed the literature to identify barriers and enablers to teachers' use of cutting education research about climate change (Table 2). Below, we consider each of these in turn.

Barriers	Enablers
Lack of professional development	Professional development programmes
Resource limitations	Supportive policies
Curriculum constraints	Innovative teaching resources and methods

Table 2. Barriers and enablers

Lack of professional development at all levels

A lack of teacher professional development was found to be a reccurring theme across several studies (e.g. Devarati et al., 2021; Klütsch et al., 2020; Pavlova, 2012). Morote et al.'s (2021) Spanish study found that teachers felt unprepared to teach on the topic of flooding, whether or not they had participated in relevant training, indicating that training is needed, but the training received by some was either insufficient or not effective. This was seen across both primary and secondary teachers, however the study's authors noted that the training provided to teachers improved as they moved through the educational stages particularly in reference to those who studied geography and history.

These findings are in line with those of Devarati et al. (2021), who carried out a systematic review of K-16 (equivalent of Early Years to Year 11) climate education in the US, asking a series of questions including "How are teachers prepared to teach about Earth's climate and Global Climate Change?". Again, it was found that teacher trainees and qualified teachers felt unprepared for teaching these topics, finding them difficult to teach and that they lacked both pedagogical and content knowledge, including on areas such as greenhouse gases, the anthropogenic causes of climate change and the consequences of this. Those already teaching, while recognising the importance of student knowledge of the areas, felt that they had not received sufficient training when learning to be a teacher. Klütsch et al. (2020) also suggest that teachers need additional support in bringing project-based learning into school, as well as stating that "some teachers need further education in multi- and interdisciplinary pedagogics" (p3251) due to the nature of environmental education.

Marchezini & Londe's (2020) study of teachers in Brazil identified that over 60% did not have any classes or training on climate change when they were graduate students. Instead, teachers used a wide range of self-updating methods including the internet, books, scientific meetings, TV and news, since "sources of information are not being provided by the educational system through either workshops or other capacity building activities to improve teachers' skills on developing innovative methods and/or new forms of pedagogy" (p2331).

Resource limitations

In all school systems there are limitations on resources. Teachers need time and resources to be able to attend regular training as well as implement and sustain projects; without this there a risk of attrition (Klütsch et al. 2020). Piccione et al. (2024) note that with the implementation of emerging technologies (linked to climate change) in education practice, continuing professional development is always necessary. In reality resources are often limited for teachers to do this.

Curriculum constraints

The context of which schools work within their respective national curricula appears to play an important role in the way that teachers can deliver climate education. Several studies identify constraints with the curriculum. For example, in a study described by Klütsch et al. (2020) a citizen science project in Norway, Russia, and Finland is embedded in the curriculum over an extended two-three years period. Using a simple protocol and working in groups, students, supported by their teachers, observe changes in a specific area of their local environment across the year and how these link to ecosystem services. The project has several aims, one of which is to connect students to nature locally in a way that enhances sustainable development education, therefore building understanding of climate change and how it crosses international lines. The authors note that, despite the project being successful over a long period, sustaining school involvement and collaborations is difficult, particularly across international contexts where school systems differ, due to the crowded but also "shallow" nature of school curricula, and teacher and school leadership turnover.

Dawson et al.'s (2022) comparison of the science and geography middle school curricula in six countries with a focus on climate change found that only Canada and Indonesia have specific units in science on climate change, with the former being the most comprehensive. Finland and Israel's curricula covered similar areas as those found in Indonesia and Canada, but these were not taught as discreet units, with the authors suggesting that this may

prevent students from having “an integrated understanding of climate change” (p17). The topic was hardly mentioned in Australia and England. Several suggestions are given as to why this might be the case, including climate change competing with other topics in science and geography, a focus on international rankings and testing that prioritise literacy and numeracy, and that teachers are not encouraged to teach climate change as an interdisciplinary topic that “includes ethics and values, social, economic and political aspects, emotions and behavioural changes” (p19). Parry and Metzger (2023) identify very few opportunities in the secondary national curriculum of England to cover climate change and sustainability. Likewise, they note that Earth Science is not well represented in the English national curriculum and is absent or of poor quality in many schools internationally, although, they argue, Earth Science could be a way of embedding climate change into the national curriculum.

Disciplinary silos, particularly in secondary schools, leaves students attempting to make connections themselves, which is less than satisfactory. As Parry and Merzger (2023) say: “The core content on sustainability is spread over more than one school department, with a disconnect between (a) teaching the science behind sustainability challenges such as climate change and (b) consideration of the consequences and effects within the geography department.”

Professional development programmes

The first enabler is, perhaps not surprisingly, the provision of professional development. Several studies identified continuing professional development (CPD) as a clear focus to enable climate change and sustainability to be taken forward. As Deverati et al. (2021) say: “Teachers believe that CPD focussed on climate change would improve their competency of integrating global climate change (GCC) in their instruction, with a mix of pedagogical and content knowledge being needed” (p231). However, as we have seen, it appears that there are limited opportunities for this learning. Nepraš et al. (2022) note the call of Porter et al. (2012) that non-governmental organisations active in climate change education should invest in the development of teaching materials and subsequent professional development for teachers rather than focusing on in-school presentations.

Several studies recommend that teacher education institutions should introduce climate change education modules for all pre-service teachers. This could lead to the integration of climate change education at all levels of the schooling system (Mavuso et al., 2022) which would encourage teachers to confidently delivery cutting edge climate education. McGregor & Christie (2021) echo this need to work with pre-service teachers in order to develop greater awareness and understanding.

Boháč and Drápela (2023) note that a fieldwork-based research summer school, although not focussed on climate change, enabled teachers to “spontaneously” (p18) link its impacts to the data they had collected and their own understanding. Saribaş et al. (2016) took a different approach, evaluating the impact of pre-service teachers visiting a museum exhibition (which broadly was understood to be a form of CPD) focusing on climate change education. Their findings showed improvement in pre-service teachers’ understanding about reducing and coping with climate change.

Asimakopoulou et al, (2021) recommend teacher-training initiatives should be adopted by the education authorities, academia, and in their field space agencies at a national level, while using existing well-established national or pan-European teacher training structures, which offer a wealth of online courses, webinars, tutorials, and teaching materials to thousands of teachers across Europe. They highlight how these structures maintain networks of local ambassadors who support local curricular and language needs. By training expert teachers from within these structures, awareness and interest could be amplified.

Supportive policies

Wider policies around education were identified as an enabler of climate education. Mavuso et al. (2022) state there is a need for a clear framework that will specifically guide teachers on how climate change education should be integrated into lessons, whilst also pedagogical strategies to be curriculum aligned and locally relevant to the

need of each country. In a similar vein Pavlova (2013) state that “policy and curriculum development should respond to national and, if possible, regional, economic, social and environmental trends (p737).”

Innovative teaching resources and methods

Asimakopoulou et al. (2021) reference Monroe et al.’s (2019) work which shows that the two common teaching strategies to engage climate education are making information personally relevant and meaningful for learners and using active and engaging teaching methods. Meanwhile, the approach that Liu et al. (2012) used was a combination of “practical learning, photos and videos to guide children to understand the meaning and method of energy conservation and carbon reduction” (p188). This was deemed innovative in a primary education setting.

Through climate justice research undertaken by McGregor and Christie (2021), they identified perspective-taking through roleplay in fictional scenarios, discussed by teachers and young activists alike. This was seen to be a useful pedagogical tool in contexts where children and young people came from different communities and social backgrounds, and where teachers, like some activists, recognised that having the agency to act on climate, and define what it means to act, is itself a justice issue. Finally, Nepraš et al. (2022) identified a number of innovative approaches which include intergenerational discussions, children acting as co-researchers and digital games which lead to increased scientific knowledge and social dimension.

Phase 2: Teachers' experiences and perspectives

We present here the findings of our interviews with teachers, looking at each of our research questions in turn.

Where and how do teachers access information about research relating to climate change and sustainability?

Participants reported using a wide range or resources to teach climate change and sustainability, including national and international charities, businesses and other organisations. For most teachers, BBC websites are a reliable and valued source of information (for example BBC News, Spring Watch, BBC Bitesize and Newsround were all mentioned).

> *I'm a big fan of BBC, but I'll go to BBC Bitesize and have a look and see what's there. I'd usually go above so I look at key stage three and then kind of pull it down a little bit and then on there's usually [content] the on the BBC News website.* ***Primary Deputy Headteacher***

One reason for the prevalence of BBC sources was their perceived impartiality. The only exception to this, noted by one participant, were BBC opinion pieces, which could be perceived as being biased. Participants noted a wide range of other online, non-education specific resources that they accessed including the World Health Organization, National Geographic, The Wildlife Trusts and WWF. Several participants noted they would be sceptical of the use of organisations with perceived agendas including Greenpeace (pro-environmental), BP and EDF (seen as pro-fossil fuel), but may still use them as they sparked debate and discussion.

> *There's lots of materials from companies and I'm concerned around bias here and those like big oil companies funding materials.* ***Secondary Biology Teacher***

Specific education publishers were mentioned by several primary participants. However, those participants that mentioned this felt the need to review content of some of these resources to check for accuracy.

> *[Named publisher] is another really good source, and it's quite, it's quite reliable. You do have to sort of check the quality ... It's not all amazing quality, but it's a really good starting point and it's often written in a very child friendly way.* ***Primary PHSE Lead***

Two participants, both primary science leads, noted the use of Primary Science Teaching Trust (PSTT)/STEM Learning resources, including "Explorify". One primary lead listed a range of other useful organisations that provided resources for teachers and students including the Ogden Trust, teaching unions, Association for Science Education (ASE), Royal Society for Biology and other subject associations. Participants said that they valued these resources as they were already 'fact checked' and could be used with students without any concerns about the accuracy of the science. In secondary schools, participants described the use of publishers' class textbooks, supplemented with online materials. However, several participants noted the need for more dynamic resources since these books go out of date very quickly. This was also noted by two primary participants.

In general, secondary participants accessed more subject specific content, for example Chemistry World Magazine (published by the Royal Society of Chemistry), New Scientist and occasionally academic journals. However, there was little evidence of sharing academic journals with students, other than as part of a literacy drive.

The use of websites such as X (formerly Twitter), YouTube and Wikipedia varied between participants. Most participants regularly used YouTube as a source of personal information and a resource to use in the classroom. However, they identified the need to review the quality of all content even from education providers that use YouTube as a platform (e.g. TEDTalks). Only secondary participants mentioned using Wikipedia and their views were divided. One secondary teacher said, "I don't mind Wikipedia, because in terms of science, I've never had a problem with it.", while two others said they would avoid its use.

> *And almost it's like it gives you too much information. Rather than if you go to, maybe Bitesize or the BBC website. It just seems to break it down in a much easier understandable way and uses terms that maybe the students can understand too.* ***Secondary Science Teacher***

Another said:

> *If and when I get [students] to do any research on anything I tell them don't use Wikipedia, don't ever use Wikipedia because it's not reliable. Anyone can edit it and change it and just make it factually incorrect ... I'd like to believe that the majority information there is OK to use. It's just if you do in-depth research on something where you need to make sure it's like 100% factually correct, don't use that as your first port of call for information.* **Secondary Science Teacher**

X (formally Twitter) was typically used by primary and secondary participants for personal use only and would only be used with students were evidence was linked to reputable websites such as those described above.

How do teachers use this information in their teaching and what are the impacts on students' knowledge, understanding and skills?

We identified a variety of ways in which teachers used information relating to climate change research in their practice, including for their own professional development. Teachers had limited evidence of the impact of this information on their students' knowledge, understanding and skills, perhaps because of the lack of relevant content in the curriculum.

The majority of participants regularly used information both for their own continuing professional development (CPD) as well as directly with students. Participants' own CPD varies widely and, on the whole, is self-directed. For example, several secondary participants discussed accessing podcasts and social media for their own professional development, occasionally sharing these with students where relevant. There was only one mention across all the interviews of directed CPD (whole department training), which we report below. Likewise, there was variation in how participants used the materials and resources they accessed. The most commonly discussed practice was accessing educational resources to directly use with students in the classroom. These resources were usually selected, edited and tailored to the age and ability of the students.

Participants noted a small number of impacts on students using cutting edge research in the classroom, but it was a challenge to elicit responses directly relating to impacts on pupil learning. Several secondary science teacher participants emphasised the importance of research being relevant to young peoples' lives to engage them and helping them to understand the big picture of the school curriculum. An example given by one participant was the replacement of plastic straws with paper, saying that this is highly relevant, because: "they all go to McDonalds". However, she noted that it is not easy to find any data on the energy and material required to make other types of straws which can be shared with students to help them understand the decision-making process. Similarly, several participants (primary and secondary) noted the need for students to understand climate change and sustainability, which was not covered in the national curriculum. Those teachers went beyond the school and national curriculum to ensue students had the best understanding available.

Active learning was identified by one secondary participant as a skill which students developed through using climate change and sustainability research. It enabled them to consider different viewpoints and realise there isn't one solution to combatting climate change by engaging in real life context. One pair of primary teachers (in the same school) used the topic of climate change to provide context to improve critical thinking skills, as the topic is one that students can discuss and have different opinions around. Their perception was that a lot of the national curriculum is knowledge based and not open to debate and discussion.

What are the barriers and enablers to accessing and using information about research relating to climate change and sustainability in teaching?

Many of the barriers identified by participants were not unique to this study but are barriers common to teachers' experiences of innovation or adaptation of the curriculum. These include the need to stay close to schools' curricula, especially with the prevalence of testing, teacher confidence and limited training opportunities.

Time was a common barrier mentioned by nearly all participants, both primary and secondary. Many said they wanted to implement more research related to climate change and sustainability into their teaching, but time to develop or even just find materials was always very limited.

> *There's never enough time to do everything you're meant to be doing in terms of all, like, your planning, your preparation and assessment*. **Secondary Science Teacher**

As we have seen, the reliability of resources was seen as a challenge amongst many participants, whether from reputable organisations or otherwise. Those participants that felt they were confident in their understanding of climate change restated their lack of time to check the reliability of resources. Several secondary participants felt that often the latest research contradicted what was written in the exam specifications and textbooks. Examples were given by secondary teacher participants which were not climate or sustainability specific, for example the temperature at which foods need to be heated to. It was acknowledged that exam specifications were written at a certain time and inevitably go out of date. However, the concern raised was that students find contradicting information confusing and at worse may lose marks on exams, so this needs to be balanced out when sharing the latest information from research. A discussion took place between a pair of participants who agreed that awarding organisations would likely avoid these questions or provide additional guidance through mark schemes.

Both participants who teach mathematics noted a lack of curriculum-appropriate resources or signposting to resources with a mathematical perspective. This suggests that, if teachers want to use climate change and sustainability as a theme, they need to create their own materials from research. This was less of an issue for primary teacher participants and secondary science and technology teachers. For those that wanted to access academic journals, often they were behind a paywall and not publicly available. As this was often seen to be going well beyond the curriculum this was not seen as an appropriate cost.

In terms of enabling teachers' access to and use of information about climate change, participants commented that students were interested in climate change and the importance of sustainability. This encouraged and motivated them to spend time finding relevant resources.

> *As soon as they find something within what they're being taught that they can latch on to, they'll cling on to it, and then they get them engaged, because then that student now remembers that lesson, even if they're disagreed with what was said.* **Secondary Science Teacher**

> *I think it's important for students to be knowledgeable and equipped to understand real life situations and like things that affect them now and in the future. Whether that be climate change or anything else like that, I do think that's important.* **Secondary Maths Teacher**

Similarly, some participants noted the need to go beyond the curriculum to ensure students understand the "bigger picture."

> *You're saying this is what's happening at the moment. This is real stuff. This is why we must do this, this and this. So, it's about giving them a bit more of a context around it. And the bigger picture really, rather than just saying, you're learning this for your GCSE, or you think this is good for you.* **Secondary Biology Teacher**

A way of increasing frequency of use was identified, especially by primary teacher participants, as the development of relevant and timely resources which access cutting edge research in climate change and sustainability.

> *For our age group, everything seemed quite a lot higher. Even with most of the stuff that's meant to be aimed at primary, usually it's upper primary. So that kind of like translating something from research into something that you can use in practice would be a really useful step stepping stone for me to just jump on rather than have to create*. **Infant School Deputy Headteacher**

> *Ideally, we'd have some kind of, like some kind of resource where we can go and find research that's linked to curriculum. And go and get some data and some nice engaging graphs and things like that that we can just easily Creative Commons just put in your PowerPoint. That'd be wonderful.* **Primary Teacher**

> *There needs a link between research and teachers, to help create content which can be verified, e.g. turn a paper into something which is accessible for students*. **Secondary Science Teacher**

Quality assurance of resources by an external trusted organisation was also mentioned by several participants as a positive enabler. This would reduce time and workload for individuals who may not have the confidence to review resources themselves. While a small number of quality assurance schemes do exist, they are not widely known about.

Providing students with problem-based learning and allowing them to undertake their own guided research was seen as a strength, particularly from secondary participants.

> *They do a research task, then they research and that embeds their knowledge because you can say all the things, and they can do the activities, and they can write it down. But there's nothing better than them going and researching it and then applying the research because that's what's really key*. **Secondary Technology Teacher**

One primary participant noted her engagement in a local network established by Sheffield Hallam University which provides a bridge between practitioners and researchers. This network, although only recently established, shares research and knowledge exchange opportunities by academics, government and non-government agencies through termly face to face meetings and monthly electronic newsletters. This was seen as a way of providing teachers with professional development in an informal way, but also a central way to access information at a local level. One pair of secondary teachers discussed a CPD programme that their school had signed up to, which included climate related content. At the time of interview, the participants had not attended the CPD but were hopeful it would help in their classroom practice.

Interestingly, the local geographic context of the school was described by one participant as a barrier while another participant spoke about this as an enabler. A secondary science participant, who teaches in a semi-rural location, noted that students built on their knowledge around farming but was conscious that the messaging was important, for example how reducing the consumption of meat can have a positive impact on reducing climate change. By contrast, a teacher in a more urban, affluent area commented:

> *School context is important, for example reducing meat message is fine in our school (like suggested to increase beans etc) but most parents are generally well informed. We've introduced more vegetarian meals in food technology and no issues or backlash*. **Secondary Food Technology Teacher**

Interestingly, only one infant teacher participant talked about the children being scared about climate change and potentially causing worries which was perceived to be a barrier; this participant did not see this is as a personal barrier.

What differences are there, if any, for teachers of different phases and subjects?

Within the primary phase, practitioners have more flexibility to introduce additional resources or respond to timely news items. For example, one primary teacher participant quotes the BBC's Spring and Winter Watch as programmes the children enjoyed watching and she wanted to extend this in the classroom.

> *The children love it on Winter Watch and Spring Watch. They always have these amazing like graphics and data graphs and things that are, really look like some of them are, quite complicated, but some of them are like that is just a, I can't find. I want data, I want graphs. I want to present children with. Here's a line graph that shows that X,Y and Z and if you try and Google it, it's always too complex*. **Primary Teacher**

Secondary participants felt there were opportunities within their subjects to deliver cutting edge climate change and sustainability research, albeit the resources and time to either develop or assess were not always available.

They felt more pressured by the time in which to deliver their curriculum content and therefore felt there is less scope to go beyond the curriculum. This limited their opportunities to use climate change research in their practice, even though they feel it is important. As noted earlier, compared to other phases and subjects, secondary mathematics participants felt there was a real lack of materials suitable for their subject area. Otherwise, there were no other notable differences between teachers of different phases and subjects.

Discussion

The major themes emerging from our study are: curriculum integration, resource availability and teacher professional development (Table 3). In this section, we look across these themes, in order to consider what we have learned in relation to our research questions. Although there were some variations between teachers of different subjects and phases, broadly responses were similar and so we present them together here.

Curriculum integration	Teachers find it difficult to integrate cutting edge research relating to climate change into a crowded curriculum. However, some teachers incorporate climate-linked activities through problem-based learning, use climate issues provide real-life examples of curriculum issues, and/or feel that it is an issue of such importance that they find ways to teach it outside the curriculum.
Resource availability	Teachers use a variety of resources to support their own and their students' learning. The BBC is a particularly well-used source of information, perceived as high quality and unbiased. Some teachers find that published resources are not updated regularly enough to reflect emerging evidence.
Professional development	Some teachers lack confidence in identifying and using cutting edge research relating to climate change. This highlights the need for more and better professional development to support teachers.

Table 3. Emerging themes

Curriculum integration

In April 2022, the Department for Education released their strategy for climate change and sustainability. However, this policy is not mandatory and only briefly mentions support for schools within the context of the National Curriculum. This means that, as we found in both phases of this study, it can be challenging for teachers to integrate climate change research into their teaching. Teachers told us that the current English national curriculum has limited formal opportunities to learn about climate change, does not use a solution-focused approach and is often isolated into science and geography, primarily at Key Stage 4.

However, it is clear from this study that teachers feel that students of all ages are interested in, and want to understand more, about climate change and sustainability. Their teachers are rising to this challenge. Some of the participants in our study felt a moral imperative to expose their students to learning about climate change, and found a variety of ways to do this, including using climate issues to bring real-life examples of science to the classroom or teaching about climate change outside the realms of the formal curriculum. This echoes national research undertaken by Greer et al. (2023) which highlighted teachers from a wide range of subject areas are willing to incorporate these topics into their teaching.

Our evidence review identified pedagogical approaches to teaching about climate change that include: the use of technology (such as remote sensors and simulations), innovative approaches (such as augmented reality and comic books) and problem-based and inquiry-led learning.

Resource availability

Notwithstanding the constraints of the curriculum, the participants in this study used a variety of resources to support their teaching of climate change research. These included online resources and activities from highly regarded and well-established organisations such as the BBC. Teachers were sceptical about the quality of some resources and the bias of some organisations. They found that, for some classroom resources like textbooks, the content was not able to keep up-to-date with emerging research. This led to some concerns that students might be disadvantaged in formal assessments by using current research.

Our study shows that there is no consistent approach to identifying and using resources in the classroom, with variations between teachers even within the same education setting. While this alone is not necessarily a problem, our findings suggest that a bank of quality assured resources could be beneficial. This would increase teachers' confidence in resources while reducing their time and workload. A recent example of this is the approach taken by the National Education Nature Park (NENP) programme led by the Natural History Museum. The NENP is funded by the Department for Education to enable schools to improve teaching and learning in nature and improve the biodiversity of school grounds. They have developed a quality assurance framework for their own resources and are building up a bank of suitable resources for practitioners to access (National Education Nature Park, 2024). Similarly, the Royal Meteorological Society (MetLink) has developed a climate change quality control framework (in collaboration with partners such as the NENP) which includes criteria such as reliability and up-to-date information (Knight, 2024). Finally, it is noted that although the Department for Education funded "Sustainability Support for Education" programme does quality assure resources, it states on their website that "Classroom teaching materials are not currently included on the service" (TPXImpact, 2024).

Direct engagement with researchers provides a potentially beneficial opportunity for teachers. Our evidence review identified a range of research programmes which engage teachers. These programmes are expensive to deliver but can be expanded into national programmes. However, from the teachers in our study, there was only one mention of engagement with researchers. The Climate Ambassadors scheme (Climate Ambassadors, 2024), funded through the Department for Education, was recently launched in England. It is delivered by Reading University and EAUC (Environmental Association for Universities and Colleges) in partnership with STEM Learning. The programme connects those in the climate change related industry and academia with schools and education settings. Similarly, the Royal Society Partnership Grants (Royal Society, 2024) may be a way of expanding engagement with researchers and schools on climate change, through their recently launched local support programme called Partnership Seed Grants.

Professional development

Where teachers are able to go beyond the constraints of the national curriculum, and identify reliable, appropriate resources, they often still face a barrier of being able to access appropriate professional development to support them in their use of climate change research. They therefore feel unprepared, with insufficient pedagogical and subject content knowledge, and lack confidence in their ability to maximise the potential of using climate change research within their teaching. Preparation to support the integration of climate change research is rarely a formalised part of any professional learning, even during initial teacher education. Therefore, often the professional development which teachers engage in is self-directed, forming part of their lesson planning and preparation activity, but not part of any school- or system-wide approach to supporting teachers.

Indeed, we found several studies identifying a need for widespread systematic professional development opportunities for teachers to enhance their knowledge and use of climate change research in their practice. Appropriate activities might include facilitated networks of teachers and researchers, and the involvement of charities and other organisations in resource development. Regional collaboration and professional support for teachers is seen as very important way of supporting practitioners to improve confidence. The programme "Let's Go Zero" (Ashden, 2024), funded through private finance, is building capacity by region with 32 officers working regionally across England. This fully funded "one stop shop" for schools provides support, resources and professional development and may fill this gap. The government plays a crucial role here in ensuring support is available and funding is prioritised.

Conclusions and recommendations

In this study, we set out to explore whether and how teachers of STEM subjects access and use information about cutting edge research relating to climate change and sustainability to inform their classroom practice. We focussed our approach on these research questions:

- Where and how do teachers access information about research relating to climate change and sustainability?
- How do they use this information in their teaching and what are the impacts on pupils' knowledge, understanding and skills?
- What are the barriers and enablers to accessing and using information about research relating to climate change and sustainability in teaching?
- What differences are there, if any, for teachers of different phases and subjects?

We looked across age phases and STEM subject areas, carrying out a rapid review of published literature and a series of interviews and focus groups with teachers in England. We found that practice is varied, both in England and internationally, and appears to lack any consistent approaches to curriculum integration of climate change issues. We identified some examples of teachers using problem-based and inquiry-led learning, technology and other approaches, sometimes prompted by externally funded and/or delivered initiatives, such as citizen science projects or university outreach activities. In some places, teachers make use of research about climate change and sustainability, outside of standard curriculum practices, to develop their own knowledge and identify their own resources. Some of the participants in this study felt a moral imperative to support their pupils' knowledge and understanding of climate change, drawing on authentic examples to bring their teaching to life and responding to news stories, even where these did not necessarily fit within the curriculum as planned.

In England, teachers appear to draw on a range of sources for information, often using resources produced by the BBC, who were seen as reliable, and using other organisations including charities as appropriate. Some teachers expressed concern for the quality and reliability of resources. Some teachers made reference to the speed at which published resources and examination specifications go out of date in comparison to research, suggesting that this might mean pupils engaging with cutting edge research learn information which differs from that needed for external testing. We found only minor differences in practice between primary and secondary teachers, and teachers of different STEM subjects, with secondary teachers of science and geography perhaps the most likely to know about and use cutting edge research relating to climate change. We identified a series of barriers to teachers' use of cutting edge research relating to climate change and sustainability. These included the lack of explicit mention in the curriculum of climate change and sustainability; the limitations of existing resources for teaching about climate change, including the time required to identify appropriate resources and plan for their use, and the perceived quality of some resources; and teachers' lack of training and confidence in tackling climate change and sustainability in their classrooms.

Our findings from this study are likely to be similar to those relating to teachers' use of any cutting edge research in their practice. However, our focus on climate change and sustainability provides a particular imperative for change, given the need for all pupils to gain understanding of this critical issues. Therefore, we end this report with some recommendations intended to support the integration of cutting edge research about climate change and sustainability into teachers' practice.

Firstly, teachers need professional development to help them feel confident in incorporating cutting edge research about climate change into their teaching. This professional development could include a range of outcomes: updating teachers' knowledge of the science of climate change; co-design and development of resources and/or identification and adaptation of existing resources; or building links to climate change researchers who can support teachers and work directly or indirectly with pupils, such as through the design and delivery of classroom activities.

Next, publishers and awarding organisations should ensure they have methods for updating their resources and examination specifications in line with emerging scientific research, and communication systems to ensure that teachers are aware of these changes. This will reduce teachers' anxiety about sharing cutting edge research with pupils where this differs from what may be assessed in examinations.

Finally, the Department for Education has recently announced a review of curriculum and assessment in England. We recommend that organisations and individuals involved in climate change research and/or climate change education should participate in the associated consultation in order to push for two major changes: firstly, that climate change is not confined to individual, isolated subject areas, and secondly that teachers are appropriately supported to develop their knowledge and confidence in using climate change research as a cutting edge area of learning and one of vital importance to students' understanding of the world we live in.

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Appendix 1: Study participants

List of participants, roles and groupings

	Role
Participant 1	Secondary mathematics & health and social care teacher
Participant 2	Mathematics director across a Multi Academy Trust (MAT)
Participants 3 and 4	Primary deputy head and geography lead
Participants 5 and 6	Primary geography lead and PHSE lead
Participants 6, 7 and 8	Primary science lead, geography lead and outdoor learning lead
Participants 9 and 10	Secondary head of food technology and food technology teacher
Participants 11	Post-16 chemistry teacher
Participants 12	Secondary science teacher
Participants 13	Secondary science teacher
Participants 14	Secondary of biology and biology teacher
Participants 15, 16 and 17	Infant deputy head, science lead and geography lead
Participants 18 and 19	Primary science lead and geography lead

Appendix 2: Interview and focus group schedule

Introduction

This study aims to investigate whether and how teachers of STEM subjects access information about cutting edge research to inform their classroom practice, and the impacts of this on the pupils they teach. We are particularly interested in cutting edge research about climate change and sustainability. The interview will take around 45 minutes depending on how much you have to say.

- *Your data will be stored securely and anonymised and you will be anonymous wherever possible, in any and all reporting.*
- *You are free to withdraw from the interview at any time or choose not to answer any questions that you do not wish to answer.*
- *You may also request to withdraw your data up to 2 weeks after the interview, without any explanation by contacting me or any other member of the research team (details on information sheet).*
- *Do you understand the purpose of the interview and your right to withdraw? Are you still happy to proceed with the interview?*
- *Are you happy for me to record the conversation?*
- *Do you have any questions before we start the interview? Please feel free to ask any questions about the research at any time during the interview.*

Questions

1. What is your role in school?
2. Can you tell me about any climate change and sustainability initiatives that you or your school/department are involved in?
3. Do you include climate change and sustainability themes in your teaching? (What/how)
4. What sources do you use to inform your teaching and learning in relation to climate change and sustainability? *(Prompts – e.g. BBC, YouTube, social media (e.g. X), subject associations, exam board, others (e.g. STEM Learning/Ogden Trust), publishers/bought in schemes of work)*
5. How do you assess the available information? For example, about misinformation or reliability?
6. Are there sources that you are particularly confident in using? Which ones, and why is this?
7. Are there sources that you are less sure about using? Which and why?
8. How frequently do you draw on research about climate change and sustainability with your students?
9. If positive – can you give an example? Why did you choose this piece of research and to use it in this way? If negative – why not?
10. Is it important to use research and innovation about climate change and sustainability in your teaching? Why do you think this?
11. How do you judge whether your sources are research informed (about climate change and sustainability)?
12. Has using research had an impact on your students? (e.g. knowledge, understanding and development of skills)?
13. What are the challenges in finding and using research relating to climate change and sustainability in your teaching?
14. What advice would you give other teachers wanting to access and use research relating to climate change and sustainability in teaching?
15. Is there anything else you want to say about using climate change and sustainability research in teaching?

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