Integrating Climate Change into Mathematics Education: Challenges and Opportunities

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Climate change has been recognised as a global emergency, highlighting the growing need to integrate sustainability into education to prepare future generations for this crisis. In recent year, with the increasing urgency of addressing climate change, educators are seeking ways to make their teaching more relevant to global sustainability issues. However, research on how mathematics education can incorporate climate change topics remains limited, making this study a timely and crucial contribution. The present study explores the integration of climate change into secondary mathematics education, examining both its potential and challenges. It investigates how mathematical concepts can equip students with the skills to interpret climate-related data, understand trends, and make informed predictions about future environmental changes. By investigating teacher and student experiences with climate-integrated mathematics lessons, it sheds light on both the opportunities and barriers in incorporating climate change discussions into mathematics education, offering insights for curriculum design and pedagogical practice.

Keywords: climate change; sustainability; secondary mathematics education

Introduction

The escalating urgency of the climate crisis presents significant challenges not only for global policy and scientific inquiry but also for educational practice. As societies confront increasingly complex environmental issues, there is growing recognition that schools must play a central role in equipping learners with the knowledge, skills, and dispositions required for informed and responsible citizenship in a rapidly changing world (UNESCO, 2018). It is essential that educational systems prepare students not only to understand scientific facts but also to engage critically with global challenges. Although themes of sustainability and climate action have begun to enter curricular discourse, the potential role of mathematics in this endeavour remains relatively underexplored (Li, 2025). In particular, few structured opportunities exist for school students to examine environmental issues through a mathematical lens. This gap underscores the need for research and innovation in curriculum design, pedagogy, and teacher professional development to enable the meaningful integration of climate change into mathematics education.

This paper reports on a pilot study that developed and trialled a set of mathematics teaching materials aimed at embedding climate change content, with a particular focus on mathematical modelling using linear equations. The project had three main aims:

1. To contribute to the UN Sustainable Development Goals (SDGs), especially SDG 4 (Quality Education) and SDG 13 (Climate Action);

2. To design curriculum-relevant resources that embed climate change issues within secondary mathematics;
3. To explore the affordances and constraints of integrating climate issues into mathematics teaching, particularly through teacher and student perspectives.

In addressing these aims, the study focused on the following two research questions:

1. What opportunities and challenges do teachers and students perceive in integrating climate-related issues into secondary mathematics teaching?
2. How do teachers and students experience the integration of climate contexts within mathematics lessons, and what are the implications for curriculum design and pedagogical practice?

How is mathematics understood in the twenty-first century?

Mathematics can be defined in various ways depending on the philosophical perspective adopted. From a logicist standpoint, mathematics is regarded as an extension of pure logic (Russell, 1902). Intuitionists, by contrast, emphasise mental constructions that are grounded in human intuition (Snapper, 1979). Formalists conceptualise mathematics as a system of symbols governed by syntactic rules (Giaquinto, 2002), while Platonists perceive it "conceived of as a pure body of knowledge, independent of its environment, and value- free" (Renert, 2011, p. 20).

In more recent decades, there has been a growing shift towards socially and contextually grounded interpretations of mathematics (Ernest, 2021). Social constructivists understand mathematics as a product of language and social interaction, embedded within cultural and communicative practices (Zakaria & Iksan, 2007). The field of mathematics education has increasingly acknowledged the discipline's social responsibilities, emphasising how mathematics both shapes and is shaped by the social, political, and environmental contexts in which it operates. A socio-ecological perspective extends this understanding by viewing mathematics as a representational system and a set of tools used to interpret and engage with complex environmental and social systems (Coles, 2022). From a Husserlian phenomenological standpoint, mathematics is rooted in conscious intentionality and serves as a means through which individuals structure and make sense of their lived experiences (Li, 2023). Reconsidering how mathematics is understood in the twenty-first century calls for a re-examination of the role of mathematics education, not solely as a technical endeavour but also as a critical and ethical practice with important implications for addressing global challenges.

This study is informed by a range of philosophical and sociocultural perspectives on mathematics. It aligns most closely with socio-constructivist, socio-ecological, and Husserlian phenomenological views, which position mathematics not merely as a technical skill set but as a powerful lens through which to interrogate, represent, and model climate-related data and trends.

Methods

The pilot study presented in this paper involved the development and implementation of a set of mathematics teaching materials themed around climate change. The design of these materials was informed by the principles proposed by Barwell and Hauge (2021) for teaching mathematics in the context of climate change (see Table 1), which served as the foundational framework for the design of teaching materials.

The materials were designed by the author and focused on the application of linear equations to analyse climate-related data and make predictions. The teacher resource pack comprised instructional slides, student worksheets, and accompanying guidance notes to support effective classroom implementation. Moreover, drawing on the problem-based learning model proposed by Li and Stylianides (2018), each task in the resource pack followed a three-phase structure: an initial problem launch, exploration through small-group discussion, and a concluding whole-class discussion. This structure aimed to encourage students to consider issues from multiple perspectives and to promote deeper mathematical reasoning grounded in real-world contexts.

Table 1 Principles for teaching mathematics in the context of climate change (adapted from Barwell & Hauge, 2021, p.177)

Forms of authenticity	• Students should have opportunities to use problems about climate change that students find relevant in their lives. • Students should have opportunities to work with real data as much as possible. • Students' own ideas and values should have a central role. • Students should have opportunities to engage in meaningful debate relating to climate change.
Forms of participation	• Students should participate in mathematics. • Students should actively participate in their classrooms. • Students should actively participate in their communities. • Students should actively engage with and participate in public debate.
Reflecting on and with mathematics	• Students should have opportunities to reflect on how mathematics is useful. • Students should have opportunities to reflect on the limits of mathematics. • Students should consider the role of values in mathematics.

The participants in the pilot study included one mathematics teacher with two years of teaching experience, who voluntarily agreed to implement the change-themed materials. The teaching was conducted with a third-year secondary class (known as S3 in Scotland), consisting of 25 students aged 14 to 15 (equivalent to Year 10 in England), at a local state school situated within the wider Edinburgh commuter belt. The implementation was carried out over the course of two regular mathematics lessons, which were integrated into the school's existing timetable.

Data were collected through a combination of student and teacher interviews conducted after the lessons. Three student focus group interviews were held, involving a total of eight students who participated voluntarily. Each focus group session lasted between 30 and 40 minutes. In addition, a 45-minute semi-structured interview was conducted with the participating teacher to gather further insights into the teaching experience and perceived impact of the materials. To answer the two research questions, an inductive coding approach was used to identify key features from the student and teacher interview data through the steps of identifying, reducing, and summarising. This aligns with Thomas's (2006) view that inductive methods develop themes directly from raw data to better understand complex information. Ethics approval for the study was obtained from the University of Edinburgh Ethics Committee.

Findings and discussion

Students generally responded positively to the climate change-themed lessons, although many noted their unfamiliarity with applying mathematics to real-world problem contexts. Their comments highlighted the contrast between routine classroom tasks and the nature of the pilot lessons. For example, one student remarked, "We're more used to [being] given two values," whereas another observed, "It gave us like a proper example which then showed us how it works in real life" (Focus group 1 interview). These reflections suggest that integrating real-world scenarios into mathematics instruction introduced a novel and engaging dimension for learners.

The theme of unfamiliarity, or perceived newness, emerged consistently across the focus group interviews. One student described the lessons as "something new, something different that I'd never done before" (Focus group 1 interview), while another reflected, "Now I know how to work with climate change data and make predictions" (Focus group 3interview). Such statements indicate that students not only recognised the relevance of the content but also developed new skills in interpreting and applying mathematical concepts to climate-related issues.

Students also recommended allocating additional lesson time to enhance the depth and clarity of instruction. Some felt the pace of the second lesson was too fast and suggested that spreading the material over three sessions would allow for more thorough exploration and understanding. As one student put it, "If we had like a third period on it, I think it would have been fine" (Focus group 2 interview). Another commented, "You could sort of break it down a bit and go more in depth with the information" (Focus group 3 interview).

From the teacher's perspective, the practical and applied nature of the materials played a significant role in supporting student engagement. The teacher stated, "It was largely because of the hands-on and applied nature of the materials, rather than my own teaching strategies." However, the teacher also identified structural constraints that limited the feasibility of incorporating such lessons more regularly. The teacher explained, "There is a very big, restrictive amount of legal obligations [for teachers…], which leaves less time to have exploratory lessons," and further noted, "We can't creep into period 3, even if we've got a good discussion going on."

While acknowledging the pedagogical value of integrating climate change into mathematics, the teacher emphasised the need for a more coherent and sustained approach across the curriculum. Rather than delivering isolated lessons, the teacher advocated embedding the theme more comprehensively, stating "Climate change actually connects to a lot of different parts of the curriculum […] I really think it'd be worth it to have one real-life hook running through the entire curriculum." This suggests a recognition of both the potential and the challenges involved in curriculum innovation within the constraints of existing systems.

The findings reinforce the pedagogical value of real-world contexts in engaging students with mathematics (Skovsmose, 2019). Students not only gained insights into climate change data but also began to see mathematics as more than abstract procedures. From the teacher's perspective, curriculum and timetable pressures severely restrict the possibility of extended, cross-curricular exploration. The teacher also noted that while isolated lessons can raise awareness, a more systemic approach is necessary to achieve meaningful integration. The insights gained highlight the need for professional development and institutional support to help teachers build capacity in teaching climate-relevant mathematics.

Conclusion and future directions

This study is limited in scope due to its small sample size, single-site focus, and short implementation timeframe. Nevertheless, the findings offer valuable insights into the integration of climate change within secondary mathematics education. The study demonstrated that students can be meaningfully engaged and intellectually challenged through the incorporation of climate-related contexts within the mathematics curriculum. Contextualising mathematical concepts through real-world issues such as climate change appears to enhance students' interest and engagement, highlighting the potential of such approaches to make mathematics more relevant and compelling. Furthermore, the teacher acknowledged the pedagogical value of integrating climate change topics, recognising their potential to make mathematics more relevant and impactful for learners. Although facing significant structural barriers, including curriculum constraints and limited instructional time, the teacher expressed a clear commitment to embedding these themes. These insights indicate that embedding climate change into secondary mathematics education is both a necessary response to contemporary global challenges and a feasible pedagogical approach, which calls for further research into curriculum development and the establishment of institutional support.

Future research is needed to explore several critical areas that could strengthen the integration of climate change education within secondary mathematics. A comprehensive curriculum review is essential to systematically embed sustainability themes across different mathematical domains, ensuring coherence and relevance. Additionally, fostering collaboration between schoolteachers and university educators in co-developing teaching resources can bridge the gap between theory and practical classroom application, thereby enhancing the effectiveness of materials. Finally, Pringle, Mesa, and Hayesin (2017) highlight the value of educative curriculum materials in supporting teacher learning, especially when adopting innovative pedagogies. Future research should investigate how such materials can further support the integration of climate change and sustainability into mathematics classrooms. This includes exploring how teachers can be assisted in designing climate-themed mathematical tasks and how materials can develop their capacity to address pedagogical and practical challenges. Alongside this, professional learning initiatives are needed to support interdisciplinary, context-rich approaches that connect mathematics with real-world environmental issues.

Ongoing research into classroom practice will undoubtedly deepen our understanding of this complex and demanding area of education. Advancing this work requires sustained and critical reflection by both researchers and teachers on how mathematics education can simultaneously support the development of disciplinary understanding and foster students' awareness of climate-related issues. It is hoped that the insights generated by this study will encourage broader engagement with this intersection, contributing to the development of pedagogical approaches and classroom resources that are both mathematically rigorous and socially responsive to contemporary global challenges.

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