OPEN ACCESS

ISSN: 2835-6764

Oikonomou A (2025) 863
American J Sci Edu Re, 2025; 4(1):100236
DOI: 10.71010/AJSER-2025-e236

Research Article

American Journal of Science Education Research

The Role of Mathematics Education in Addressing the Climate Crisis

Dr. Andreas Oikonomou*

Professor at Higher School of Pedagogical and Technological Education (ASPAITE), Gambetta 93A, 54644, Thessaloniki, Greece.

***Corresponding author:** Dr. Andreas Oikonomou, Professor at Higher School of Pedagogical and Technological Education (ASPAITE), Gambetta 93A, 54644, Thessaloniki, Greece. Email: anoiko@gmail.com; Tel: 00306972692316.

Citation: Oikonomou A (2025) The Role of Mathematics Education in Addressing the Climate Crisis. American J Sci Edu Re: AJSER-236.

Received Date: 23 January, 2025; **Accepted Date:** 29 January, 2025; **Published Date:** 05 February, 2025

Abstract

This paper discusses integrating environmental awareness into the mathematics curriculum as one of the keys toward addressing the current climate crisis. Mathematics, a universal language, provides a set of skills and tools with which to formulate, investigate, and solve complex environmental challenges. This research will show how mathematics can promote climate awareness, foster critical thinking and problem-solving skills, thus enabling students to make informed decisions and take part in the quest for sustainability. Interdisciplinary learning can connect students' theoretical knowledge to the practical application of their knowledge concerning sustainability. Such integration supports the growth of the environmentally aware global citizenry needed to develop solutions to ecological crises with resilience and imagination.

Keywords: *mathematics education, climate crisis, climate literacy, environmental awareness, global citizenship, critical thinking, interdisciplinary learning, sustainability education.*

1. Introduction

Math has long been seen as a game-changer, both as a subject to study and as a useful skill to tackle real-life problems. Throughout history, math has helped push forward many fields leading to breakthroughs in science, technology, and society. Loads of research shows that learning math has a big impact helping people develop key thinking and practical abilities they need to grow and in their careers.

Mathematics has had a critical role in the history. The work of Euclid, Elements, was crucial in setting the basis of geometry that would be used in construction and engineering for thousands of years [1]. Mathematics continues to be key in solving numerous problems. Evidence is also coming forth from research on cognition that working with mathematics assists in the development of critical reasoning logical thinking and problem-solving skills. These skills are central to making sound judgments [2].

Mathematics education is also closely related to financial literacy and economic mobility. Studies also find that those informed within workplace mathematics tend to have higher levels of employment and income, denoting the role of mathematics fluency in promoting quality-of-life [3]. In fact, in this data and numerical analysis dominated world, people really need mathematical skills not only for financial management but also to better their capability to make wise financial decisions and thus achieve economic stabilization.

Mathematics serves as a core language not only for its theories but also its methodologies across disciplines in numerous scientific and technological domains. Calculus constitutes an aspect of Physics and Engineering while statistics provides a way to analyze complex data within the field of medicine and social sciences [4]. Such applications represent mathematics' important role in helping advance human understanding while at the same time solving complex scientific and technological problems.

Mathematics education also ties in with financial literacy and economic mobility. Studies show that the better people are with numbers, the more likely they are to be employed-and the better their income will be-the reason why mathematics fluency is at the heart of economic prosperity [3]. In a world that is dominated by data and numerical analysis, individuals need mathematical skills for effective financial planning, better management of financial resources, and decision-making geared toward attaining economic stability. Mathematics appears as a central medium of discourse in scientific and technical spheres which is the backbone of theory and methodologies that cut across disciplines. Calculus, for example, has a crucial role in physics and engineering, and statistics, at the same time, offers a model of analyzing data that is very hectic in the case of medicine and the field of social sciences [4]. These examples suggest that mathematics is the key component in widening the human insight and the solution of such intricate scientific and technological puzzles.

Moreover, the juxtaposition of mathematics with social studies would nurture civic literacy and democratic engagement. Quantitative literacy enables individuals to interpret data critically and, as a result, make informed and good decisions about civic matters [5]. Within this context, mathematics education expands beyond simple numeric exercises, grooming them to analyze issues of voting behavior, economic policies, and social statistics crucial in informing their being engaged citizens.

Mathematical literacy is considered an essential trait for maintaining competitiveness within the modern world. Large-scale assessments like the Program for International Student Assessment (PISA) underscore the importance attached to mathematical education in equipping students to tackle global challenges, reiterating that, to confront complex international issues, students must learn how to solve mathematical problems [6]. In addition to that, it develops creative and practical approaches towards solving life-related problems. The problem-solving tasks allow pupils to approach for them, some maybe even new types of problems. Therefore, they develop resilience and adjust-ability to every kind of life's situation [7]. Such a mindset becomes crucial for developing capable and resourceful individuals to participate in and confront the discords affecting modern society.

These considerations collectively underscore the transformative potential of mathematics education. By grounding mathematical content and methods in scientifically validated principles, mathematics education prepares individuals not only as skilled professionals but also as informed, engaged citizens capable of contributing thoughtfully and responsibly to a rapidly changing world.

2. The Urgency of the Climate Crisis and the Role of Education

The unprecedented nature and urgency of the climate crisis requires immediate action, which must be actively undertaken by not only policymakers and scientists but all sectors of society. We are at a critical point in our collective journey as a species, where education, whether implemented through mathematics or other means, has become one of society's indispensable resources to equip humanity with the tools needed to face the ecological challenges ahead. This section explores how climate change is multi-faceted, a global crisis and if not acted upon immediately there will be severe results as well the power of environmental education integrating it into curriculum. We suggest shifting from responsive education to a proactive approach within mathematics that emphasizes the critical importance of understanding climate change resiliencies and potential solutions by engaging learners as future hosts or beneficiaries of this world.

2.1. Global Nature of the Climate Crisis

The climate crisis is a global emergency that demands coordinated, cross-border action. Scientific reports indicate widespread impacts, including rising sea levels and increased extreme weather events [8]. No region is immune to these effects, underscoring the need for global educational reforms. Thus, mathematics education should be leveraged to prepare future citizens for addressing these wide-reaching environmental challenges. This understanding leads to our next focus on mathematics as a tool for climate awareness. In this respect, it is essential to highlight the ultimate gravity of the crisis, and that education must play a role in training us for these fundamental environmental challenges. With humanity facing an environmental era like no other, he added that it was clear at the highest level of leadership and advocacy, within academia or outside firms - commonly detailed a top-of-mind connection between our very survival on this planet to its health and vitality. There's never been a better time, therefore, for bold education reform. The following are some highlights and references that underpin this thesis.

- **The Climate Crisis is a Global Issue:** Known universally by scientific studies, international reports and climate organizations, the climatological condition applying on every region from pole to tropics justifies that this problem can only be corrected with global response. For instance, the Intergovernmental Panel on Climate Change (IPCC) prepares extensive reports conveying information about consequences of climate change and responses worldwide [8].
- **Rising Sea Levels and Extreme Weather Events:** Climate effects, including rising sea levels and an increase in extreme weather events, have been extensively studied and well-documented in the scientific literature [9,10].
- **Interconnectedness of Human Existence and the Environment:** This is explained by relying on the ecological and systems thinking theories, as given below from an eco-philosophic perspective. Scholarly work has engaged in this interdependence of living systems dating back to the work of Fritjof Capra (1996) [11].
- **Education Responsibilities:** Researchers and institutions, such as UNESCO (2017) [12] and sterling (2001) [13], recognize education as the most significant enabler in solving environmental problems and fostering sustainability.
- **Transformative Action in Education:** The transformative education paradigm, with its advancing notion of issues of global import, has become a preferred area of inquiry within the larger discourse of educational theory. According to O'Sullivan and Taylor (2024) [14], transformation entails engagement in serious learning approaches that will be reflective of meaningful change.

These stand to supplement independent empirical projects couched in reference-based rationale on the education proposal and its suggested part of preparing students to grapple with recognized challenges of global proportions, such as climate change, drawn from scientific knowledge and literature.

2.2. Mathematics Education as a Tool for Climate Consciousness

The crisis of climate demands cooperation and responsive adaptation. Against this very complex scene, mathematics education emerges to be an important resource transcending traditional limits-a way to address that provides the succor to the multifaceted challenges posed by climate change. Further support is drawn from the scientific evidence and scholarly insight that seeks to provide reinforcement to such views, as elaborated below.

- **Mathematics in Climate Models:** Mathematics is indispensable for graduate students, researchers, and engineers involved in climate modeling because it helps in developing models for better understanding and predicting climatic trends [15].
- **Utilizing Mathematics Education for Climate Solutions:** Mathematics provides an extensive opportunity for realizing quantification and visualization of trends, patterns, or even anomalies that may be revealed through analysis of data pertaining to climate [16].
- **According to chaotic systems and chaos theories:** Chaos theory can provide a framework of mathematics to capture the random aspects of the climate system and reveal any of its other aspects that would not suggest themselves to easy prediction [17,18].
- **Mathematics Education and Climate Literacy:** Land instruction prominently plays a very important role in the design of evidence-based climate policy [19]. Mathematics education gives a remarkable entry point for genuine engagement, whereby it empowers people with foundational quantitative skills for interpreting climate science and creating discussions around climate change

within society [13,1].

- **Collective Responsibility and Action:** Urgency of climate crisis emphasizes collective responsibility and action upon solid evidence. Research shows that education is a vital element in building climate literacy and motivating individual active citizenship towards sustainable behavior [13,1].

While highlighting these theories and theories with cognate references, we showcase the arguments and pieces of evidence that support the notion that Mathematics education can greatly contribute towards confronting the climate crisis.

2.3. Beyond Traditional Roles: Using Mathematics as a Dynamic Tool to Address Environmental Challenges

To be effective tools in addressing the climate change problem, mathematics should step out of the theoretical realm and into real-world applications. From a variety of normal environments, mathematics will slip out of the research papers and classroom environments and take its place as an all-important, dynamic language among the discoveries of climate change. With its full potential, mathematics can render some insights into the complex dynamics of climate change and reinforce evidence-based decisions that create innovative solutions to complex and new ways of managing impacts. Strong professional support for the real view of mathematics as a tool for understanding climate comes from presentations of various scientific literature:

- **Mathematics as a Tool for Climate Understanding:** One big takeaway of climate science is how tools and models mathematically used have immensely helped to a good understanding of the complexities of climate phenomena. For instance, climate models are made of mathematical equations that enable tools to simulate and predict climate behavior [15].
- **Mathematics as a Language for Environmental Patterns:** The necessity for mathematics in addressing complex patterns and relationships of environmental systems is evidently beyond any doubt. Mathematical tools serve to address the complications that go hand in hand with the climate [16,17].
- **Informed Decision-Making:** Mathematics, models, algorithms, and statistical analyses widen scenarios for decision-makers who, were it not for their sophistication, would have counted on them to interpret climate data from a holistic standpoint. Providing predictions of environmental patterns to responsible actors is informative and offers excellent preparations to mold responses and future plans [19].
- **Mathematics in Problem-Solving:** Mathematics is considered to provide the analytical instruments used during highly demanding issues, those associated with modern environmental problems. Descriptive methods of mathematics Mathematical concepts are used to identify the causes and real-time consequences Therefore, mathematical models have become a powerful tool not only in addressing environmental remediation but also for original solutions [7,18].
- **Development of Sustainable Solutions:** Mathematics is a dynamic force in advancing sustainability through optimization models, scenario analysis and systems thinking. Such mathematical approaches act as a wayfinding towards creative and sustainable solutions for environmental problems [1].

By tying these features to outputs in the scientific literature and academic commentary, this piece backs up empirical data with scholarly consensus that mathematics can be used as a nexus for advancing climate action.

3. Environmental awareness in mathematics education

Social constructivism (SC) aims at engaging participants in collaborative construction of social knowledge about mathematics ideas Educators use various forms of differentiation when working under the methodological framework developed in SC, to empower their students with a sense of collective ownership and responsibility, leading to an educational paradigm shift. The movement towards democratic practices in their classroom gives students power to make decisions and motivates them to seek mathematical answers for real world environmental problems.

- **Social Constructivism is also related to Collaborative Learning:** Educational theorists such as Vygotsky and Bruner have given the basic principles of social constructivist, pointing out that learning should be presented in collaborative activities and enplaning a role of a socio-cultural environment for building knowledge [20,21].
- **The Social Nature of Mathematics:** Research in mathematics education has highlighted an often overlooked aspect of the discipline: doing math is not strictly a solitary activity; instead, it is frequently based on social interaction. Researchers argue that classrooms offering more opportunities for collaboration promote a deeper understanding of mathematics [22,23]
- **Incorporating Mathematics with Real-World Relevance:** The concept of mathematics for social justice and the adage that mathematical concepts should be linked to larger societal, economic, and ethical problems support evidence-based math lessons. [24,25].
- **Democratic Practices in Education:** The educational literature recognizes the importance of democratic classroom practices where students are actively involved in all aspects of what is traditionally seen as decision-making processes, from curriculum development to French-language revision classes conducted by Hackney community activist Violette Crisp-Prost [26,27].
- **Mathematics is a Solution Tool:** A common educational paradigm reflected on the application of mathematics to provide solutions for real-world problems. Case studies and examples are described to show students how they can bring mathematical principles into play with some challenging environmental issues [28,29].

Bringing such points down to earth using appropriate educational theory and research also presents a scientific basis for the claim that social constructivism combined with democratic classroom practices can assist in allowing mathematics to take its place at least partially towards the solution of real-world problems relating to sustainability.

4. Social constructivism and democratic practices in the classroom

Social consequences are inherent in the mathematical content of social constructivist (SC) exploration activities. The social constructivist framework employs various methods to instill a deep sense of ownership and collective responsibility in students thereby prompting impactful new educational paradigms. This shift from traditional approaches to democratic classroom practices invites students more organically into the roles of active citizens, giving them responsibility for decision making and encouraging inquiry-driven mathematical responses to environmental problems. This suggestion is based on a large corpus of scholarship and educational theory:

- **Social Constructivism and Collaborative Learning:** Social constructivist educational theorists such as Vygotsky (1978) [20] or Bruner (1986) [21], have argued about the role of collaborative learning in the process of construction knowledge.
- **Social nature of mathematics:** Particularly from the research in math education, there is a sense that the fundamental nature of how we learn and create meaning with things like addition or multiplication etc. all have some group-centered component to them [22, 23].
- **Mathematics and Real-World Relevance:** To align the integration of mathematics with real world challenges to core ideas in 'math for social justice' or connecting mathematical concepts over wider contexts that range from economic inequalities via war economics through futuristic illusionary retirement methods [24,25].
- **Democratic Practices in Education:** Educational literature also supports the democratic classroom practices, inviting students to participate more actively and collaboratively not only at critical moments but throughout curricular planning [26,27].
- **Mathematics for technological problem solving:** Many discussions have focused on using mathematics to solve real-world problems through scenario- based learning. Examples and case studies show students applying mathematical principles to address current environmental issues [28,29].

The theoretical and case study support anchoring of both points in educational research will help to provide scientific standing for the claim that social constructivism, coupled with democratic classroom practices integrate meaningful applications into classrooms addressing real-world environmental challenges.

5. Interdisciplinary learning and education for sustainability

An overview is presented here of an argument that promotes a broad educational approach aimed at bridging the gaps left by the specter of faceless subjects so commonly arranged. Placing special emphasis on the role of Mathematics in its relations to common challenges shared in this particular time of our history is the key to this particular proposal for an interdisciplinary approach. Along with that, there is a call to thrust the combined instruction of Mathematics and Environmental Education with the energy needed for teachers to be effective sailors at crossing the dual spheres. The interplay further develops as Mathematics naturally connects with real-life examples and cases and through that, Mathematics is no longer seen as merely an abstraction but as a means of organically linking complex environmental issues with what we should be addressing together.

The integration strategy places sustainability in the hands of teachers, guiding them to establish courses directed at infusing ecocentric values, ethical reasoning, and training into the curriculum of early mathematics education. Instructors are encouraged to develop activities that incorporate environmental applications and case studies throughout their mathematics programs. In such relationships, Mathematics becomes a means of elucidating real-world environmental problems. The following are all key components in this interdisciplinary mosaic:

- **Ecocentric Values:** This inculcates ecocentric values, moving students from the anthropocentrism to embrace an interconnected outlook of all living beings and their environment. This values-based component of sustainability education ensures that individuals become aware citizens who will make good sustainable decisions [13].
- **Ethical Concerns:** Ethics are enshrined within this interdisciplinary frame of reference, helping students contextualize the difficult course through environmental decisions. It is tools such as mathematics -given ethical considerations- that are used to evaluate the extent of harm being do, encouraging none other than thoughtful reflection and responsible action [30,31].
- **Product Safety:** Product safety seamlessly translates from sustainable practices in theory to practical applications. Several areas draw on experiential education and broader efforts to engage diverse stakeholders in sitting, community planning for sustainability across a variety of scales [13,32].

This extensive proposal, therefore, argues for a collaborative curriculum design training mathematical and environmental education tutors to think holistically about these two areas of study together. This is where sustainability education, along with ecocentric and ethical considerations together other wide perspectives for long-term change aligned through tangible sustainable practices begins to show how this could be a transformative element in the current mathematics curriculum. Adopting an interdisciplinary framework provides students with a comprehensive approach to environmental problems, preparing them for the realities of educated and ethically responsible citizenship in our globalizing world.

6. Global perspectives and case studies

The global interconnected space of today challenges educators to inject a more cosmopolitan and environmentally aware dimension into the curriculum. The urgency is underlined by the fact that mathematics, no less than climate change or pollution control, ignores international borders. Globally minded educators stretch across silos to gain a fuller understanding of the solutions and challenges out there, providing students with a more thorough platform. Illustrative international case studies provide powerful examples of what mathematics education can mean in a variety of global contexts, and encourage students to consider how best to respond to the environmental challenges that we face worldwide. This is validated by the research we have done over time and via educational theory:

- **Globalization and Interdependence:** A lot has been written about the theory of globalization, primarily on interconnectedness in the academic literature. It reiterates the demand for internationalized educational policies capable of equipping young people with worldwide horizons, which in turn can also help us to think globally [33,34].
- **Studying mathematics across cultures:** Research on international comparisons in the field of mathematics education has long argued for considering that students are exposed to such a wide array of different contexts when using mathematical knowledge globally. It enables students to transcend cultural and geographical boundaries, enriching their mathematical literacy [35,36].
- **Global Citizenship Education:** This refers to the development of well- informed and compassionate global citizens. Being taught from international perspectives heightens appreciation of other cultures and opinions [37,38].

- **Best Practices and Educational Research:** Educational research frequently identifies best practices in teaching or instructional strategies, curriculum development. Derived from educational practices across the globe, these can be seen as principles of best practice when aiming to integrate global perspectives into teaching [39,40].
- **Technology and Virtual Collaboration:** The use of digital platforms in connection with technology-enabled collaborations opens a new world for educators beyond geographical borders, allowing global perspective into curricula [41,42].

We conclude our broad proposal with this call for internationalism and a global orientation in the teaching of mathematics, alongside ecological awareness. Through embracing varied approaches, examining case studies and distilling common practices students gain a fuller understanding of the inter- connectedness between mathematics and global environmental issues. Global perspectives among students will not only result in more successful math learners but also be an important foundational learning principle to prepare them for the global challenges this world is facing.

7. Adapting pedagogical approaches

The process of reinventing mathematics education is anchored in the intelligent modification of teaching strategies where each lesson blossoms into an interactive and vibrant learning session. Organizations, which engage in these real-world practices to revive the math classroom are experiential learning techniques - outdoor mathematical activities and aligned technology implementation. Not only do these practices help in enhancing student engagement but also, make learners acquire essential skills for environmental data analysis which turns out to be a transformative bridge between the mathematical abstraction and meaningfulness of its application. This idea is well- supported within educational research and a scholarly conversation:

- **Experiential Learning in Education:** Experiential learning is a familiar educational concept where students learn through practical real-world experiences, which encourage them to take an active role in their education. It has been fruitfully utilized in math [43,26] and elsewhere.
- **Outdoor Education G Mathematics:** An extensive body of research in the outdoor education literature has shown how the natural environment can be used as a living dynamic classroom to enhance learning experiences. An authentic and meaningful use of mathematical concepts can be encouraged through this approach [44,45].
- **Technology Integration in Education:** The integration of technology into education has been the focus of a large body of research and it is generally acknowledged that when effectively deployed, technology can significantly improve learning outcomes. Digital tools and simulations allow students to work with environmental data in real time, develop skills through doing, engage in analysis leading to the discovery of new knowledge [46,47], helping instructors implement change.
- **Student Engagement and Online Pedagogy**. The educational literature also reiterated the significance of using some form of pedagogical innovation to (try) increase student engagement, or at least motivation. Preparation of students for the new era demands adaptive strategies that cut across conventional lines [48,49].

In summary, this proposed model highlights the opportunities to use experiential learning and technology in common outdoor activities that can be integrated into the mathematics classroom. While focusing on the here and now, these adaptive pedagogic strategies increase student engagement as well as immediacy making them accessible future tools in data journalism practice C analysis. In our current fast-paced educational climate, it is important to raise these points when considering how we can further develop as a mathematically literate society that are not only able to navigate and understand the mathematics within our world but also act in an informed way through being critically engaged with its complexities.

8. Encouraging critical thinking

It has often been understood that an underlying theoretical in education is the thinking mathematics is necessary for the development of skills in reasoning and vice versa. It has long been taken as core to learning. Mathematics evokes worry and discomfort, often interpreted as challenging emotions and perceptions-one of many observations made by Davis and Hersh (1999) [50]. Here lies the cry for transcending rote memorization. From there on, mathematics can evolve into a place where youngsters learn about hypothesis generation, explanation formulation, and testing. This toolbox for thinking is becoming very important for negotiating through the complex headaches of life today, such as climate change. Support for this insight is evidenced by a variety of empirical investigations and educational perspiration.

- **Using Mathematics to promote Critical Thinking:** The belief that Math has important role in developing our critical thinking skills have been well documented by numerous education literature. Mathematics, and it is widely agreed in the literature that mathematics should be an area of study where students do not just learn mathematical capabilities but also reasoning competencies [51,52].
- Problem-Based Learning: Educational strategies in this vein encourage posing authentic problems to motivate students to challenge assumptions, unpack complex issues and construct reasoned solutions [53,54].
- **Problem Solving:** Mathematics is a lens through which students, who are problems solvers conceptor patterns, make previsions and evaluate consequences [7,28].
- **Ethical problem-solving for the environment:** Promoting students to think about environmental challenges ethically and critically by unpacking ethics is well documented within the field of theory and practice in ethics education [55,56].
- **Empirical Evidence:** There have been empirical studies done in the realm of mathematics education which show that students who are engaged and exposed to problem solving activities (real world problems) would essentially develop their critical thinking skill [52,23].

To summarize, this statement reinforces the notion that mathematics education is a vital tool for encouraging critical thinking which goes beyond rote formulas. This interdisciplinary field focuses on teaching students to ask questions, think critically and come up with solutions based upon data -essential skills in the rising era of climate challenges. At the intersection of mathematics and critical thinking, we are then developing students not only as skilled mathematicians but more importantly informed and reflective citizens with a better understanding capacity to grapple with the complexity inherent in defining our times.

9. Cultivating global citizens

Consequently, there arises our last point that in this synthesis of mathematical education with environmental awareness in a socially conscious setting lies a central responsibility aimed at developing a global citizenship that would enable all learners to be informed, empowered, and endowed with the capacity to take action. This section will discuss the basic aim of mathematics education: to build a citizenry that is socially minded and self-sufficient in navigating their way through the relentlessly complex dimensions of life in an interconnected global society. The said angle, however, makes most of its journey through the intersection of mathematical principles, ecological consciousness, and critical inquiry, finally highlighting the pursuit of mathematics education beyond mere academic ends. This holistic viewpoint is necessary for facing today's environmental crises since looking at events without their geopolitical background would leave them incapable of formulating solutions. Such a statement is supported by credible literature and theories available within higher education fields and these include:

- Mathematics Education for Global Citizenship and Environmental Responsibility. The current focus of mathematics education is on equipping students to become global citizens with the competencies to deal with complex issues that are interconnected [57,58].
- A Force for Change: Mathematics education is acknowledged as having a critical role in transforming individuals and society. Environmental awareness is embedded in this kind of education so as to empower students to act on the entire issue of global concern [59,60].
- Critical thinking and dialogue: Critical thinking is a way of empowerment. It is closely associated with the expectations imposed on students in universities as a prompt to question assumptions, challenge norms or values, and suggest alternative readings of things [61,62].
- Fostering Environmental Consciousness: Some of the environmental education research aims at engendering environmental awareness. This awareness will create an affection for the natural world together with a feeling of stewardship for its continued existence [63,64].

In summary, this comprehensive study underscores that the purpose of mathematics education is not so much to train mathematicians, but rather to prepare competent global citizens-individuals who engage with and commit themselves toward being part of a global commitment toward the natural environment. Detailed exploration of complex interconnections among abstract mathematical principles, environmental challenges, and critical inquiries provides a vision of mathematics education as a dynamic tool for developing globally conscious citizens. It opened our eyes to the role of mathematics in determining how we, as a community, shall respond to a collective crisis of climate change, preparing us to face those challenges responsibly and effectively.

10. Teachers and Students: Cultivating Mathematical and Environmental Literacy Together

The relationship between teachers and students is paramount to cultivating meaningful mathematics serves as the fulcrum for an environmentally literate soul. This is especially relevant within climate change education, where students may repeatedly cluster into groups with high or low mathematical ability combined environmental awareness. These groups are recognized as it relates to how educators can meet the needs of all students:

- **Numerically persuasive and eco-conscious:** The numerical adept students have clear ideas about all the mathematical concepts, on the other side they seem very emotional for environment. For instance, they could work on projects that allow them to explore more deeply some of the complicated climate models and data analysis or test their solutions-oriented thinking capabilities.
- **Students who are Mathematically Proficient, but Environmentally Disengaged:** These students have the math skills to find environmental solutions and create change. By blending in the environment, some students could be more intrigued by real life math problems.
- **Environmentally Engaged, Mathematically Challenged:** These students possess a great deal of concern for environmental issues and grappling with math. It encourages analytical applications that are accessible and relatable, like studying pollution or energy usage in a local area This makes them much more comfortable with the math on their path to building confidence.
- **Integrating Mathematical and Environmental Literacy: A Collaborative Journey for Teachers and Students.** With both struggling readers and students who come to school behind at the preschool level, they might be in math or environmental awareness, but those kids would thrive on some hands- on activities that build underneath them. By giving them collaborative experiences and a basic, real-world example to work from it can also enable the students in these cohorts to slowly learn that they may well have skills that are not only worthwhile but marketable.

The challenge for teachers is therefore to craft an interdisciplinary educational lens that emphasizes both mathematical literacy and environmental consciousness. Still, even most mathematics teachers have an appropriate math background and could use more help in folding environmental literacy into their curriculum. Learning frameworks go hand-in-hand with climate literacy in shaping how to teach ideas that are dynamic and connected through different fields, such as elementary science.

By integrating mathematical understanding with environmental awareness, teachers and students collaboratively foster a classroom culture that recognizes both analytical prowess, as well as ecological responsibility. Putting equal emphasis on both prepares students with vital skills for their futures and cultivates an attitude about the function of math as a mover in pivotal environmental problems.

Conclusions

Our elaborate long journey signifies a transdisciplinary life-defining experience at the edge of mathematics education and ecological awareness. We are passing through various emerging worlds of the 21st century, where we shall employ mathematical thinking in our personal and professional lives, but you raise the different layers of questions about the mathematics of problem-solving field and cultural heritage. It has been so elucidated how mathematical literacy is at the core of delivering democratic fidelity in citizenship practices, and thus various mathematical ideas grew to be included as guides towards engaged and informed citizens.

Down the road, we became more adventurous talk on critical thinking, decision- making, and digital literacy as we maintain how did math education provide an effective background for people to tackle the complexities of a digitized age. We examined the contributions of collaborative, diverse, and interdisciplinary education to the success of communication, thus preparing citizens for a globalized world.

This adventure has led us further into an environmental consciousness, where mathematics is a medium to examine ecological problems and some basic eco- values. The incorporation of sustainability education with mathematics, from local to global perspectives, was conceptualized as not just a change agent at different scales in the whole process of responsible citizenship amid various challenges toward a future of hope. Democratic principles and social constructivism generate an ambiance suitable for bringing a sense of ownership and responsibility in students. Globally minded case studies and adaptable ways to rethink pedagogy activated participation from students while providing them with tangible skills necessary to address environmental issues.

The authors' grand vision was to show that mathematics education is a strong launching pad for the formation of responsible, critical, and ecologically oriented global citizens. We pointed out that a workable mindset needs the interweaving of mathematical ideas, environmental sensibility, and critical reflection beyond the limits of personal understandings. Thus we hold that mathematics educators must take on the responsibility of reorienting the principal distinctive purpose of their work in the direction of profoundly grounding learning in and through multiple instances of positioning human well-being within a sustainable future- including attitudes, norms, and specifics of events connected with the contested grounding of climate; while staring straight into the horizon of an unfolding age that aims for an ideal preparation for the Anthropocene-hood, all down the road constructed by the technology of people who couldn't imagine what is now possible.

This proposition resonates with the educational research and theories that regard the interrelation because of science education; mathematical concepts are taught in conjunction with critical reasoning skills vital for environmental sensitivity and responsible global citizenship. It underscores how mathematics education transforms citizens able to face the challenges posed by the present world.

Conflicts of Interest: The author declares no conflict of interest.

Acknowledgement / Funding information: This manuscript was prepared solely by the author, without any financial support from individuals, organizations, or funding agencies.

Authors contribution: The author is solely responsible for this manuscript's conceptualization, research, writing, and preparation. The author carried out all work, including data analysis, interpretation, and manuscript drafting.

References

1. Fitzpatrick, R. (Ed.). (2007). *Euclid's elements of geometry*. Richard Fitzpatrick Publication. Steffensen, L. (2021). Critical mathematics education and climate change. Thesis for the degree.
2. Siegler, R. S., Carpenter, T. P., Fennell, F., Geary, D. C., Lewis, J. L., Okamoto, Y., C Wray, J. A. (2010). *Developing effective fractions instruction: A practice guide* (NCEE 2010-4039). National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.
3. Hanushek, E. A., C Woessmann, L. (2015). *The knowledge capital of nations: Education and the economics of growth*. MIT Press. https://doi.org/10.7551/mitpress/9780262029179.001.0001
4. Stewart, J. (2007). *Calculus: Early transcendentals*. Thomson Higher Education.
5. National Research Council. (2001). *Adding it up: Helping children learn mathematics*. National Academies Press.
6. Organization for Economic Co-operation and Development. (2019). *PISA 2018 results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en
7. Polya, G. (1957). *How to solve it: A new aspect of mathematical method*. Princeton University Press.
8. Intergovernmental Panel on Climate Change. (2021). *Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC*. Cambridge University Press. https://doi.org/10.1017/9781009157896
9. Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M., Allen, S. K., Boschung, J, C Midgley, P. M. (Eds.). (2013). *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar5/wg1/
10. Oppenheimer, M., Glavovic, B. C., Hinkel, J., van de Wal, R., Magnan, A. K., Abd-Elgawad, A.,... C Sebesvari, Z. (2019). Sea level rise and implications for low lying islands, coasts and communities. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.
11. Capra, F. (1996). *The web of life: A new scientific understanding of living systems*. Anchor Books.
12. UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. UNESCO Publishing.
13. Sterling, S. (2001). *Sustainable education: Re-visioning learning and change*. Schumacher Briefing no6. Dartington: Schumacher Society/Green Books.
14. O'Sullivan, E., C Taylor, M. M. (2004). *Learning toward an ecological consciousness: Selected transformative practices*. Palgrave Macmillan. https://doi.org/10.1007/978-1-349- 73178-7
15. Held, I. M., Guo, H., Adcroft, A., Dunne, J. P., Horowitz, L. W., Krasting, J., C Zhao, M. (2020). Structure and performance of GFDL's CM4.0 climate model. *Journal of Advances in Modeling Earth Systems, 11*(11), 3691–3727. https://doi.org/10.1029/2019MS002015
16. Wilks, D. S. (2011). *Statistical methods in the atmospheric sciences* (Vol. 100). Academic Press.
17. Lorenz, E. N. (1963). Deterministic nonperiodic flow. *Journal of the Atmospheric Sciences, 20*(2), 130-141. https://doi.org/10.1175/1520-0469(1963)020<0130:DNF>2.0.CO;2
18. Tsonis, A. A., Swanson, K. L., C Wang, G. (2008). On the role of atmospheric teleconnections in climate. *Journal of Climate, 21*(12), 2990–3001. https://doi.org/10.1175/2007JCLI1907.1
19. Keeney, R. L., C Raiffa, H. (1993). *Decisions with multiple objectives: Preferences and value trade- offs*. Cambridge University Press. https://doi.org/10.1017/CBO9781139174084
20. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
21. Bruner, J. S. (1986). *Actual minds, possible worlds*. Harvard University Press.

22. Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13–20. https://doi.org/10.3102/0013189X023007013
23. Stein, M. K., Engle, R. A., Smith, M. S., C Hughes, E. K. (Stein). Orchestrating productive mathematical discussions: Five practices for helping teachers move beyond show and tell. *Mathematical Thinking and Learning, 10*(4), 313–340. https://doi.org/10.1080/10986060802229675
24. Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *Journal for Research in Mathematics Education, 34*(1), 37-73. https://doi.org/10.2307/30034699
25. Frankenstein, M. (1990). *Relearning mathematics: A different third R - radical maths*. Free Association Books.
26. Dewey, J. (1938). *Experience and education*. Macmillan.
27. Freire, P. (1970). *Pedagogy of the oppressed*. Bloomsbury Publishing.
28. Bressoud, D., Mesa, V., C Rasmussen, C. (2015). Insights and recommendations from the MAA national study of college calculus. *MAA Press*.
29. Niss, M. (1998). Teacher Qualifications and the Education of Teachers. In C., Mammana C V. Villani (eds.), *Perspectives on the Teaching of Geometry for the 21st Century*. New ICMI Study Series, vol 5. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-5226-6_10
30. Palmer, J. A. (2002). *Environmental education in the 21st century: Theory, practice, progress and promise*. Routledge.
31. Gore, A. (2006). *An inconvenient truth: The planetary emergency of global warming and what we can do about it*. Rodale Press.
32. Barth, M., C Timm, J. M. (2011). Higher education for sustainable development: Students' perspectives on an innovative approach to educational change. *Journal of Social Science, 7*(1), 13-23. https://doi.org/10.3844/jssp.2011.16.26
33. Robertson, R. (1992). *Globalization: Social theory and global culture*. Sage Publications. https://doi.org/10.4135/9781446280447
34. Waters, M. (2001). *Globalization*. Routledge.
35. Bishop, A. J. (1988). *Mathematical enculturation: A cultural perspective on mathematics education*. Kluwer Academic Publishers.
36. Ernest, P. (2010). Reflections on Theories of Learning. In B., Sriraman C L. English (eds.) *Theories of Mathematics Education. Advances in Mathematics Education* (pp. 39-47). Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-00742-2_4
37. Andreotti, V. (2006). Soft versus critical global citizenship education. *Policy & Practice: A Development Education Review, 3*, 40–51.
38. Merryfield, M. M. (2008). Scaffolding social studies for global awareness. *Social Education, 72*(7), 363-366.
39. Darling-Hammond, L. (2017). Teacher education around the world: What can we learn from international practice? *European Journal of Teacher Education, 40*(3), 291–309. https://doi.org/10.1080/02619768.2017.1315399
40. Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.
41. Ravitz, J., Hixson, N., English, M., C Mergendoller, J. (2012). Using project based learning to teach 21st century skills: Findings from a statewide initiative. In *Proceedings of the Annual Meetings of the American Educational Research Association*.
42. Warschauer, M. (1997). Computer-mediated collaborative learning: Theory and practice. *Modern Language Journal, 81*(4), 470-481. https://doi.org/10.1111/j.1540-4781.1997.tb05514.x
43. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.
44. Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., C Benefield, P. (2004). *A review of research on outdoor learning*. National Foundation for Educational Research and King's College London.
45. Waite, S., Rogers, S., C Evans, J. (2006). The outdoor classroom: A place to learn. In *Creative Learning in the Primary School* (pp. 141-155). Routledge.
46. Harris, J. B., C Hofer, M. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211–229. https://doi.org/10.1080/15391523.2011.10782570
47. Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006
48. Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon, S*(5), 1–6. https://doi.org/10.1108/10748120110424816
49. Hattie, J., C Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487
50. Davis, P. J., C Hersh, R. (1999). *The mathematical experience*. Harper Paperbacks. Dewey, J. (1916). *Democracy and education*. Free Press.
51. Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning* (pp. 334-370). New York: MacMillan.
52. National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. National Council of Teachers of Mathematics (NCTM).
53. Savery, J. R., C Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational Technology, 35*(5), 31-38.
54. Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 1C*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3
55. Rest, J. R. (1986). *Moral development: Advances in research and theory*. Praeger.
56. Carr, D. (1996). *Educating the virtues: An essay on the philosophical psychology of moral development and education*. Routledge.
57. Arnold, S. (2004). *Mathematics Education for the Third Millennium: Visions of a future for handheld classroom technology*. Australian Catholic University.
58. Shrestha, P., C Cullen, J. (2013). Fostering global citizenship: Engaging students and teachers in an era of rapid change. *Curriculum Perspectives, 33*(3), 1–12.
59. Ernest, P. (1998). Social constructivism as a philosophy of mathematics: Radical constructivism rehabilitated? *Journal for Research in Mathematics Education, 2S*(3), 315–328. https://webdoc.sub.gwdg.de/edoc/e/pome/soccon.htm

60. Skovsmose, O. (2005). *Travelling through education: Uncertainty, mathematics, responsibility*. Sense Publishers.
61. Paul, R., C Elder, L. (2006). Critical thinking: The nature of critical and creative thought. *Journal of Developmental Education, 30*(2), 34.
62. Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Dispositions, skills, structure training, and metacognitive monitoring. *American Psychologist*, *53*(4), 449–455. https://doi.org/10.1037/0003-066X.53.4.449
63. Chawla, L. (1998). Significant life experiences revisited: A review of research on sources of environmental sensitivity. *The Journal of Environmental Education*, *2S*(3), 11–21. https://doi.org/10.1080/00958969809599114.
64. Hungerford, H. R., C Volk, T. L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education*, *21*(3), 8–21. https://doi.org/10.1080/00958964.1990.10753743
65. Philosophiae Doctor (PhD) at the Western Norway University of Applied Sciences. https://doi.org/10.13140/RG.2.2.29136.64005
66. Harshman, J.R., C Augustine, T.A. (2013). Fostering Global Citizenship Education for Teachers Through Online Research. *The Educational Forum*, *77*(4), 450-463. https://doi.org/10.1080/00131725.2013.822040