



Integrating Climate Literacy into Teacher Education Programs: A Framework for Future Teachers

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Received: 23-07-2025

Reviewed: 25-08-2025

Accepted: 09-10-2025

Abstract

Climate change poses significant challenges to global sustainability, making climate literacy an essential component of contemporary education. Yet, teacher education programs often lack structured approaches to prepare pre-service teachers for integrating climate-related content into their future classrooms. This paper presents a comprehensive framework for embedding climate literacy into teacher education, aiming to equip future educators with the knowledge, skills, and values needed for effective climate and sustainability instruction. The study outlines the current deficiencies in teacher preparation, defines the scope of climate literacy within the educational context, and offers interdisciplinary, actionable strategies for curriculum developers and teacher educators. By aligning teacher education with international sustainability goals, this framework supports the cultivation of environmentally responsible citizens and climate-resilient education systems.

Keywords: Climate Literacy, Teacher Education, Sustainability Education, Curriculum Development, Environmental Pedagogy, Pre-service Teachers, Climate Change Education

Introduction

Climate change is no longer a distant concern- it is an immediate and pressing global crisis with far-reaching consequences for ecosystems, economies, and societies (Intergovernmental Panel on Climate Change [IPCC], 2023). The impacts of rising global temperatures, sea-level rise, extreme weather events, and biodiversity loss are increasingly visible, posing direct threats to human well-being and sustainable development. Education, especially at the school level, plays a central role in equipping younger generations with the knowledge and skills to understand, adapt to, and mitigate climate change (Yasukawa, 2023). Teachers, therefore, serve as critical agents (Leal Filho et al., 2022) in fostering environmental awareness and empowering students to become informed and proactive citizens .

Despite this pivotal role, many teacher education programs worldwide do not systematically incorporate climate literacy into their curricula. A UNESCO (2021) global survey revealed that while 95% of teachers recognize the importance of climate change education, only 40% feel confident in teaching it, and fewer than 30% report having received relevant training (Rubel et al., 2022). Similarly, research by Anderson et al. (2020) found that pre-service teachers often lack both a foundational understanding of climate science and the pedagogical strategies needed to teach climate-related topics across disciplines (DeCamp, 2024).

This gap in preparation is particularly concerning in the face of international policy frameworks such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), which emphasize the importance of climate education (UNFCCC, 2015; United Nations, 2015). Goal 13 of the SDGs specifically calls for urgent action to combat climate change and its impacts, including through education and awareness-raising. Without adequately trained teachers, efforts to meet these targets are significantly undermined (Shwom et al., 2017).

Addressing this issue requires a systemic shift in teacher education. This paper proposes a structured and interdisciplinary framework for integrating climate literacy into pre-service teacher education programs (Álvarez-Nieto et al., 2022). The framework emphasizes three key components: scientific understanding, pedagogical competence, and socio-emotional engagement with climate issues (Senevirathne et al., 2021). By embedding these elements into teacher preparation, the aim is to cultivate educators who can confidently and effectively foster sustainability education and inspire climate action within their schools and communities.

Statement of the Problem

Despite international calls for climate education (e.g., UNESCO, IPCC), climate literacy is rarely embedded in teacher preparation curricula. Many teacher candidates graduate without the scientific understanding or pedagogical strategies to effectively teach about climate change. This lack of preparation hinders efforts to create environmentally responsible citizens and undermines national sustainability goals.

Objectives of the Study

1. To define and contextualize climate literacy within teacher education.
2. To identify current gaps in climate literacy integration in teacher education programs.
3. To propose a comprehensive, interdisciplinary framework for embedding climate literacy.
4. To provide actionable strategies for curriculum designers and teacher educators.

Significance of the Study

This study contributes to the evolving field of Education for Sustainable Development (ESD) by offering a practical, adaptable, and research-informed model for integrating climate literacy into teacher education programs. As the urgency of the climate crisis intensifies, so too

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does the need for educational systems to respond proactively. By equipping pre-service teachers with comprehensive climate knowledge, interdisciplinary teaching strategies, and values rooted in sustainability, the proposed framework addresses a critical gap in teacher preparation.

The integration of climate literacy is not only essential for meeting international commitments- such as the United Nations Sustainable Development Goals and the Paris Agreement- but also for fostering informed, engaged, and environmentally responsible citizens. Through this framework, teacher education institutions can better align their curricula with global climate priorities, build institutional capacity for sustainability education, and empower future educators to lead climate-conscious practices in schools. Ultimately, the study supports the broader goal of embedding climate action into the cultural and instructional fabric of educational systems.

Literature Review

Tabulated Review of Literature on Climate Change Education (CCE)

Authors (Year)	Context / Country	Focus	Key Findings	Themes Addressed
Monroe et al. (2019)	USA	Teacher knowledge	Teachers lack deep understanding of climate science	Knowledge
Plutzer et al. (2016)	USA	Science teacher beliefs	Misconceptions about climate change are widespread	Knowledge
Hestness et al. (2014)	USA	Complexity of climate systems	Teachers struggle to teach complex climate concepts	Knowledge
Ikonomidis et al. (2021)	Greece	Pre-service teacher knowledge	Widespread misconceptions about climate change	Knowledge
Papadimitriou (2004)	Greece	Pre-service teacher misconceptions	Scientific misconceptions affect teaching	Knowledge
Yli-Panula et al. (2022)	Finland	Student-teacher views	Limited knowledge; need for action competence	Knowledge, Practice
Singh (2020)	Global	Interdisciplinary teaching	Emphasizes transformative pedagogy and justice	Pedagogy
Obiefuna & Offorma (2014)	Nigeria	Mobile tech for CCE	Supports mobile learning for climate education	Pedagogy
Lehtonen et al. (2019)	Finland	Phenomenon-based learning	Encourages interdisciplinary, real-world approaches	Pedagogy, Practice
Field et al. (2019)	UK	Curriculum resistance	Teachers resist interdisciplinary CCE integration	Pedagogy
Tolppanen & Kärkkäinen (2020)	Finland	Teacher beliefs	Limited pedagogical strategies to teach climate	Pedagogy

Authors (Year)	Context / Country	Focus	Key Findings	Themes Addressed
Rousell & Cutter-Mackenzie-Knowles (2020)	Australia	Children's climate agency	Experiential learning improves engagement	Practice
Eco-Schools (FEE)	67 countries	Global green program	Whole-school approach improves climate literacy	Practice
Mantere (1995+)	Finland	Arts-based education	Enhances emotional connection with environment	Practice
Reid (2019)	Global	Policy-practice gap	Lack of national guidance for integrating CCE	Policy
Sarabhai & Purohit (2023)	India	National climate policy	India aligns with UNESCO but needs teacher training	Policy, Pedagogy
Kumari & Bala (2024)	India	NEP 2020 and EE	Policy supports CCE but lacks implementation strategies	Policy
Finnish National Studies (2022)	Finland	Curricular integration	Education systems vary in climate emphasis	Policy, Pedagogy
Nordic Studies (2021)	Nordic Countries	Sustainability curricula	Uneven implementation of sustainability mandates	Policy
Mohapatra et al. (2022)	India (Odisha)	Elementary teacher views	Awareness present, but pedagogical skill is lacking	Knowledge, Pedagogy
Dixit & Sehrawat (2022)	India (Bengaluru)	Sustainability integration	Fragmented curriculum; exam-focused teaching	Knowledge, Pedagogy, Policy
UNFCCC India Program (n.d.)	India	Teacher training via Moodle	Online PD reached 500+ schools	Pedagogy
British Council (2023)	India	Professional development	Emphasizes holistic EE integration	Pedagogy
UNICEF India (2025)	India	School resilience & CCE	Climate events disrupt learning; need community action	Policy, Practice
Delhi Govt & Earth Warriors (2025)	India	School-based CCE	Piloted sustainability activities in 10 schools	Practice
Gifford (2011)	Global	Psychology of inaction	Psychological biases limit climate engagement	Pedagogy

Research Method

This study uses a qualitative, conceptual research design based on:

- 1) Document analysis of national teacher education curricula, climate education policies, and sustainability frameworks.
- 2) Comparative review of successful international case studies in climate literacy integration.
- 3) Framework construction informed by interdisciplinary theories in education, climate science, and sustainability.

Results

Curriculum Integration

Integrating climate literacy into the curriculum involves embedding climate-related knowledge, values, and skills across subjects and grade levels in a coherent, interdisciplinary manner. This helps students view climate change not only as a scientific phenomenon but also as a social, cultural, and ethical issue that impacts various domains of life. Climate literacy should be integrated horizontally across disciplines and vertically across educational levels, ensuring that learners encounter age-appropriate and contextually relevant content throughout their schooling.

Key themes such as environmental justice, indigenous knowledge systems, and sustainability principles must be woven into core subjects to create a holistic understanding of the climate crisis. Studies suggest that cross-curricular integration enhances learners' ability to connect scientific knowledge with ethical reasoning, civic action, and emotional engagement (Monroe et al., 2019; Reid, 2019).

Table 1: Strategies for Curriculum Integration of Climate Literacy

Curricular Strategy	Description	Example/Application	Benefits
Cross-Disciplinary Climate Content	Embed climate-related topics in subjects like science, geography, civics, and literature.	Teaching carbon cycle in science, global warming in geography, eco-poetry in literature.	Promotes systems thinking and intersubjectivity.
Environmental Justice Education	Introduce social dimensions of climate change, focusing on equity and vulnerability.	Discuss how rising sea levels affect marginalized communities.	Develops empathy and critical consciousness.
Indigenous & Local Knowledge Integration	Incorporate traditional ecological knowledge and region-specific practices.	Teaching about tribal forest conservation or water harvesting techniques.	Strengthens cultural identity and place-based learning.
Sustainable Development Goals (SDGs) Alignment	Align curriculum outcomes with SDGs, especially Goal 13 (Climate Action).	Linking school projects to SDG targets on clean energy or sustainable cities.	Encourages global citizenship and responsibility.
Spiral Curriculum Design	Revisit climate concepts with increasing complexity at different grade levels.	Introduce pollution in early grades and deepen into mitigation in later years.	Reinforces learning through developmental progression.

Key Considerations:

- 1) Curriculum must avoid being overloaded. Instead, it should weave climate themes naturally into existing competencies and standards (UNESCO, 2021).
- 2) Localized content helps make abstract global concepts more relatable and actionable (Mohapatra et al., 2022).
- 3) Teacher autonomy in curricular adaptation must be supported through policy and resources (Kumari & Bala, 2024).

Pedagogical Approaches

To effectively integrate climate literacy into teacher education, pedagogical methods must evolve beyond traditional, content-heavy delivery. Research supports the use of active, student-centered pedagogies such as inquiry-based, place-based, and project-based learning to enhance both understanding and engagement with climate issues (Rousell & Cutter-Mackenzie-Knowles, 2020; Monroe et al., 2019).

These approaches encourage learners to explore real-world problems, engage with their local communities, and develop a sense of agency in responding to the climate crisis. Incorporating simulations, case studies, and problem-solving strategies enables learners to build critical thinking, systems thinking, and collaborative problem-solving skills—competencies that are essential for addressing complex environmental challenges.

Table 2: Climate Literacy Pedagogical Approaches

Approach	Description	Example/Application	Educational Value
Inquiry-Based Learning	Students investigate open-ended climate questions through research and analysis.	Investigating how local industries impact air quality.	Builds critical thinking and scientific literacy.
Place-Based Learning	Connects learning to students' local environments and cultures.	Analyzing nearby wetlands or urban heat zones.	Enhances relevance and place attachment.
Project-Based Learning	Extended tasks involving real-world problems and collaborative solutions.	Designing a school composting system or energy audit.	Encourages teamwork and application of knowledge.
Case Studies	Real-world climate scenarios analyzed in classroom discussions.	Studying the Kerala floods or Arctic ice melt.	Develops perspective-taking and systems understanding.
Simulations & Role-play	Students simulate negotiations or decision-making on climate issues.	UN climate negotiation role-play or disaster response planning.	Builds empathy, communication, and policy insight.
Problem-Solving Tasks	Challenge-based learning activities.	Planning water conservation for drought-prone areas.	Promotes innovation and applied reasoning.
Community Engagement	Learners participate in local environmental action.	Tree plantation drives, local climate awareness campaigns.	Strengthens civic responsibility and collective action.

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Pedagogical Implications:

- 1) These approaches require flexibility in curriculum and supportive infrastructure, including access to community partners and interdisciplinary planning time (Tolppanen & Kärkkäinen, 2020).
- 2) Emphasis should be placed on experiential learning and affective education, which help students internalize climate values and attitudes (Singh, 2020).
- 3) Teacher educators should model these approaches during training, enabling pre-service teachers to adopt and adapt them in future classrooms.

Educator Training and Resources

A major barrier to implementing effective climate change education (CCE) is the lack of teacher preparedness. Many pre-service and in-service teachers report limited content knowledge about climate science and a lack of confidence in facilitating sustainability-focused learning (UNESCO, 2021; Monroe et al., 2019). Strengthening educator capacity through professional development, strategic partnerships, and open-access educational resources is critical.

Training must focus not only on climate science but also on eco-pedagogical strategies, which blend environmental content with socially responsive and inquiry-driven methods. Collaborations with environmental organizations, universities, NGOs, and climate experts enrich teacher preparation by offering practical experiences such as workshops, field visits, and guest lectures.

In addition, widespread dissemination of open educational resources (OERs)- such as curriculum toolkits, climate literacy guides, and digital content- is essential to ensure equitable access to teaching materials, especially in under-resourced settings.

Table 3: Key Components of Educator Training and Resources

Component	Description	Example/Application	Impact
Professional Development	Training in climate science, sustainability, and pedagogical approaches.	National Green Corps teacher training; online MOOC courses on climate education.	Increases teacher competence and confidence.
Eco-Pedagogy	Integrates environmental content with justice, ethics, and critical pedagogy.	Workshops on teaching climate justice through storytelling or community mapping.	Fosters socially engaged, reflective teaching.
Partnerships & Collaborations	Linking teacher education institutions with environmental organizations.	Partnering with TERI, WWF-India, CEE, or Greenpeace for expert talks and field trips.	Brings real-world insights and networking opportunities.
Open Educational Resources	Free, accessible climate teaching resources and toolkits.	UN CC:Learn, NASA Climate Kids, NCERT's Environmental Education Modules.	Democratizes access and supports curriculum alignment.

Component	Description	Example/Application	Impact
Climate Literacy Portals	Centralized platforms for curated climate content for teachers.	Teachers' Climate Guide (Finland), CBSE's climate modules, DIKSHA app resources.	Enhances digital learning and teacher autonomy.

Key Considerations:

- 1) Continuous professional development (CPD) is more effective than one-time workshops and should be embedded within teacher education programs (Rousell & Cutter-Mackenzie-Knowles, 2020).
- 2) Context-specific training allows teachers to address local environmental issues while meeting national goals.
- 3) Integration of online, hybrid, and experiential formats can help reach teachers in rural and remote areas (UNFCCC India, 2023)

Assessment and Reflection

Traditional assessments such as standardized tests and multiple-choice questions are often insufficient for measuring climate literacy, which requires evaluating knowledge alongside attitudes, behaviors, and action competencies. To foster transformative learning, assessment must shift towards authentic, formative, and participatory practices that align with sustainability goals (Shephard, 2008; Wals, 2020).

Alternative assessments- including climate action projects, reflection journals, peer feedback, and portfolio assessments- enable learners to demonstrate not only cognitive understanding but also empathy, critical thinking, and civic responsibility. These tools also allow teacher educators to observe how pre-service teachers internalize climate values and envision their pedagogical roles in climate education.

Reflection is central to sustainability learning. Embedding structured reflection on ecological ethics, teaching philosophy, and personal values helps teachers build a lifelong commitment to environmental justice and climate action (Sterling, 2011).

Table 4: Climate Literacy Assessment and Reflection Tools

Assessment Method	Description	Example/Application	Learning Outcome Assessed
Climate Action Projects	Students plan and implement real-world initiatives.	Creating a campus waste audit or local awareness campaign.	Leadership, systems thinking, real-world problem-solving
Reflective Journals	Weekly or unit-end reflections on learning and values.	Writing about the emotional and ethical aspects of climate justice.	Self-awareness, critical reflection

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Assessment Method	Description	Example/Application	Learning Outcome Assessed
Peer Evaluation	Students assess each other's contributions to group tasks or discussions.	Group project feedback or peer grading rubrics.	Collaboration, accountability
Sustainability Portfolios	Compiled evidence of ongoing climate-related work.	Collection of posters, essays, research, and photos from field activities.	Holistic learning, integration across domains
Case-Based Assessments	Problem-solving based on real-life climate scenarios.	Analysing local floods or pollution data to make community recommendations.	Applied knowledge, decision-making
Simulation Debriefs	Reflection following role-play or simulations.	UN climate negotiations or city council meetings on environmental policies.	Policy literacy, civic engagement

Pedagogical Considerations:

- 1) Assessments should be learner-centered, promoting metacognition (thinking about one's learning) and emotional engagement (Rieckmann, 2017).
- 2) Regular reflective teaching logs help future educators evaluate their evolving understanding of sustainability and teaching practice.
- 3) Rubrics for climate literacy should be co-created with learners to foster transparency and ownership.

Components of the Proposed Climate Literacy Framework

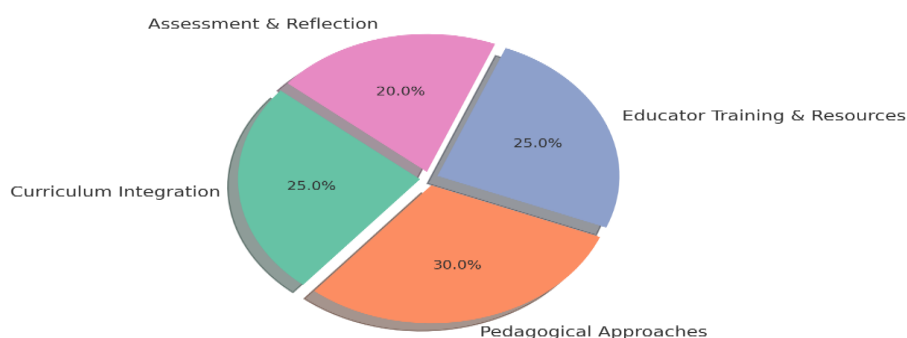


FIG:1: Componets of the Proposed Climate Literacy Framework

Implementation Strategies

Institutional Support

For climate literacy to take root within teacher education programs, it must be supported at the institutional level. Embedding sustainability into the vision, mission, and strategic goals of teacher training colleges creates a guiding philosophy that influences curriculum design, faculty hiring, and campus culture. Institutions that prioritize sustainability often allocate resources for climate initiatives, green infrastructure, and professional development. For instance, integrating Education for Sustainable Development (ESD) into institutional missions fosters a culture of ecological consciousness and prepares future educators to teach environmental responsibility (Sterling, 2011; UNESCO, 2020). In India, institutions like TISS Mumbai and Azim Premji University have embedded sustainability as a foundational principle across teacher education programs (Misra & Singh, 2021).

Cross-disciplinary Collaboration

Climate literacy is inherently interdisciplinary, cutting across natural sciences, social sciences, and humanities. Therefore, collaboration among faculty from different departments is vital for designing integrated modules that combine scientific understanding with socio-cultural, ethical, and pedagogical insights. When science educators collaborate with those in philosophy, sociology, or literature, students receive a more holistic and contextualized understanding of climate issues. Research shows that transdisciplinary curriculum design enhances teacher candidates' ability to see the interconnectedness of climate systems and human behaviour (Rousell & Cutter-Mackenzie-Knowles, 2020). Indian universities such as IISER Pune and IIT Gandhinagar are also experimenting with such transdisciplinary approaches in their teacher education courses.

Policy Alignment

For systemic impact, teacher education must be aligned with national and international policy mandates on climate education. India's National Education Policy (NEP) 2020 emphasizes environmental awareness and experiential learning, offering a policy window to embed climate literacy more meaningfully into curriculum frameworks (Ministry of Education, 2020). At the global level, documents like the UNESCO ESD Roadmap and SDG 4.7 advocate for climate literacy as a core component of quality education (UNESCO, 2020). Advocacy from academic institutions and civil society can ensure that national curriculum standards (such as those set by NCERT and NCTE) explicitly require teacher educators to address climate change, sustainability, and ecological resilience in their programs.

Student Engagement

Ultimately, climate literacy efforts must meaningfully involve student-teachers as active participants in shaping sustainable education. This includes involving them in curriculum co-design, engaging them in on-campus sustainability projects, and encouraging leadership in community outreach initiatives. Participatory learning approaches enhance student agency and promote lifelong engagement with environmental action (Wals, 2020). For example, universities can create Green Campus Committees, offer climate-related fellowships,

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or establish eco-clubs that pre-service teachers lead. A study by Rieckmann (2017) found that students who engaged in sustainability decision-making processes developed a stronger sense of responsibility and capability as future educators.

Discussion

Integrating climate literacy into teacher education is no longer a progressive ideal—it is an existential imperative. Climate change is not just an environmental issue; it is a multidimensional crisis affecting public health, food security, biodiversity, and social equity (IPCC, 2023). Therefore, preparing teachers to address this challenge is essential to building resilient, informed, and empowered future generations.

The framework proposed in this study underscores the importance of embedding climate education as a core, cross-cutting theme in teacher preparation—not as a standalone subject or optional module. This shift demands a paradigm change in how teacher education institutions conceptualize their mission, design curricula, and engage learners. Instead of viewing climate literacy as supplemental or co-curricular, the framework treats it as a foundational pedagogical responsibility that influences every discipline, teaching method, and professional value.

Critical Dimensions of Integration

1. **Climate Literacy as Transformative Education:** Rather than being limited to knowledge transmission about climate science, climate literacy must foster critical consciousness, as theorized by Paulo Freire (1970). Teachers must help students explore root causes of environmental degradation—such as consumerism, colonialism, and structural inequality—and empower them to take informed action. This transformative approach emphasizes agency, not just awareness.
2. **Bridging the Science-Society Divide :** Effective climate education bridges the gap between scientific understanding and social relevance. Teachers must learn to translate complex data and projections into meaningful, culturally responsive lessons. For example, connecting rising temperatures with local water shortages or migration patterns can make climate science more tangible for students (Monroe et al., 2019).
3. **Empowering the Teacher as a Climate Leader:** The role of teachers goes beyond instructional delivery—they are moral agents, mentors, and community leaders. By equipping pre-service teachers with real-world problem-solving tools, civic engagement strategies, and environmental ethics, institutions empower them to become change-makers who can mobilize collective climate action (Rieckmann, 2017; Wals, 2020).
4. **Equity and Justice in Climate Education:** Climate change disproportionately affects marginalized communities. Integrating climate justice and indigenous knowledge into teacher education ensures that sustainability education is inclusive and ethical. For instance, in India, local examples such as the Chipko Movement or the Jal Satyagraha can be powerful case studies in environmental activism and equity (Misra & Singh, 2021).

5. Challenges and Opportunities in the Indian Context: Despite policy support from India's National Education Policy 2020, challenges remain in scaling climate literacy across teacher education institutions-such as lack of trained faculty, curriculum overload, and uneven infrastructure. However, these challenges can be turned into opportunities through collaborative curriculum design, use of open educational resources (OERs), and policy-driven mandates at the national level (NCERT, 2022; UNESCO, 2020).

Synthesis: From Framework to Action

The proposed framework is both visionary and actionable. It offers a multi-level strategy-spanning curriculum design, pedagogical approaches, teacher training, institutional policy, and student engagement. The real challenge now lies in implementation, which requires strong institutional commitment, continuous capacity-building, and collaboration between policymakers, educators, and communities.

In essence, climate literacy should not be viewed as an environmental add-on, but as the moral compass and survival toolkit of 21st-century education. It equips teachers and students to navigate a rapidly changing world while anchoring their actions in justice, empathy, and sustainability.

Conclusion

This paper presents a comprehensive and actionable conceptual framework for embedding climate literacy into teacher education programs, addressing a critical gap in both educational policy and practice. In an era marked by intensifying climate crises, the role of educators extends far beyond classroom instruction- they are pivotal actors in fostering environmental awareness, critical thinking, and civic responsibility among young learners.

The proposed framework emphasizes that the integration of climate literacy must be:

- 1) Intentional, not incidental- embedded in institutional vision, curriculum objectives, and teaching strategies.
- 2) Interdisciplinary, weaving together scientific, social, cultural, and ethical dimensions of climate change.
- 3) Action-oriented, equipping pre-service teachers not only with knowledge, but also with the skills and moral agency to lead transformative change in their schools and communities.

Empowering future teachers as climate educators demands a systemic approach that includes: revising curricula, enhancing faculty capacity, leveraging cross-sectoral collaborations, and ensuring alignment with national and global climate education goals (UNESCO, 2020; Rieckmann, 2017). It also necessitates fostering reflective practice, community engagement, and authentic assessments that move beyond rote learning to inspire sustainable action.

This conclusion reaffirms that climate education is not a peripheral topic- it is central to quality education in the 21st century. If implemented with commitment and care, the

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framework can help teacher education institutions produce a new generation of educators who are not only climate-literate but also climate-resilient and climate-responsible.

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