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Climate Education for Sustainable Development: Integrating Environmental Literacy into Teacher Education under NEP 2020

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Abstract
Climate change is not only a scientific and policy challenge, but also an educational concern. Citizens' knowledge, values and capacities play a key role in shaping society's ability to adapt to climate change. Teachers have a significant role in this. This conceptual paper focuses on the integration of environmental literacy in the teacher education course in India during this background of National Education Policy (NEP) 2020. The paper is based on a critical review of peer-reviewed research on climate education, Education for Sustainable Development (ESD) and teacher preparation as well as an analysis of key policy documents. It brings together current knowledge regarding learner understanding, teacher readiness, competencies for sustainability and curriculum integration. The analysis suggests that the policy of NEP 2020 could provide a conducive policy ambiance for nurturing prospective teachers' scientific understanding, pedagogical preparedness, and civic awareness about climate change. But such policy does not automatically ensure that these competencies will be put into practice. The paper proposes the Integrated Climate Literacy in Teacher Education (ICLTE) framework, comprising five interrelated strands: scientific literacy, pedagogical competence, ethical and civic orientation, local environmental learning, and institutional support. The paper also outlines possible ways to integrate these strands into the four-year Integrated Teacher Education Programme (ITEP), two-year B.Ed. programmes, and in-service teacher professional development. The framework is conceptual and has not been empirically validated. The paper accomplishes with recommendations for educational institutions and policymakers, together with an agenda for future research to examine the framework's feasibility and effectiveness.

Keywords: Climate education; environmental literacy; education for sustainable development; pre-service teachers; NEP 2020

1. INTRODUCTION

Climate change is a major environmental and societal challenge in India, with rising temperatures, changes in precipitation patterns, and increased risks from extreme weather events (Krishnan et al., 2020). Addressing these challenges requires not only technological solutions and policy interventions but also citizens who can understand scientific evidence, assess competing priorities and engage in collective action. Climate education is therefore an important part of the global education agenda. Education for

sustainable development is highlighted in Target 4.7 of the United Nations' 2030 Agenda for Sustainable Development and climate change education, awareness and capacity building is highlighted in Target 13.3 (United Nations, 2015). UNESCO (2020) also emphasizes the importance of strengthening the capacities of educators to support sustainable development. These global priorities highlight the need to prepare teachers in communicate scientific evidence, in develop learners' critical understanding, and in connect climate-related issues with accountable action by individuals and collective action.

Schools can teach climate change effectively only if teachers are prepared to do so, and the available evidence suggests that this preparation is uneven. A study of teachers in the United States found that many gave uncertain or mixed messages about the science of climate change (Plutzer et al., 2016). A comprehensive review of how environmental issues are integrated in education likewise points to gaps in teacher preparation (UNESCO, 2021).

India's continuing teacher-education reforms provide an opportunity to reinforce climate education within teacher preparation. The National Education Policy (NEP) 2020 emphasizes multidisciplinary learning and the development of teachers' content knowledge, pedagogical competence and professional capacities. It also envisages the four-year Integrated Teacher Education Programme (ITEP) as a multidisciplinary pathway for preparing prospective schoolteachers (Ministry of Education, 2020, paras. 5.22 and 15.5). The National Curriculum Framework for School Education 2023 provides a further curricular context for examining environmental learning in school education (NCERT, 2023). These developments create potential opportunities to integrate climate literacy into teacher preparation; however, the extent of such integration requires examination of relevant curricula, teacher-education practices and institutional support.

Although existing research has examined environmental literacy, climate change education, sustainability competencies and approaches to integrating sustainability into teacher education, these areas need to be considered together when designing climate-literate teacher preparation in India. In particular, the relationship between scientific understanding, pedagogical practice, ethical and civic engagement, locally grounded environmental learning, and institutional support requires further conceptual examination in the context of NEP 2020. Without an integrated approach, climate education may remain fragmented across curriculum content, teaching activities and institutional initiatives. This paper addresses this conceptual need by proposing the Integrated Climate Literacy in Teacher Education (ICLTE) framework and examining its potential application to Indian teacher-education programmes.

Against this background, this paper has four objectives: (a) to synthesise relevant literature on climate education, environmental literacy, education for sustainable development, and teacher preparation; (b) to critically examine the opportunities and potential implementation gaps for integrating climate education into teacher preparation, with particular reference to NEP 2020 and other relevant policy documents; (c) to develop a conceptual Integrated Climate Literacy in Teacher Education (ICLTE) framework that connects the key dimensions of climate literacy with teacher preparation; and (d) to propose curricular and institutional strategies for teacher education institutions and policymakers to support the integration of climate education into teacher preparation.

To guide the analysis, this paper addresses the following research questions:

RQ1. What knowledge, pedagogical competencies, and ethical and civic dispositions do prospective teachers need to teach climate change and sustainability-related issues effectively?

RQ2. What opportunities and potential implementation gaps for integrating climate education into teacher preparation can be recognized in NEP 2020 and other relevant policy documents?

RQ3. How can these identified needs and policy opportunities inform the development of a conceptual framework and feasible curricular and institutional strategies for integrating climate literacy into Indian teacher education?

2. METHODOLOGY

This study adopts a conceptual, qualitative approach that combines a critical narrative review of the literature with qualitative analysis of relevant policy documents. A narrative review is appropriate for synthesising existing knowledge, examining the conceptual development of a research area, and identifying gaps that may inform theoretical and conceptual development (Snyder, 2019). Document analysis provides a systematic approach to examining documents and interpreting their relevance to a research problem (Bowen, 2009). Accordingly, this study focuses on climate change education, environmental literacy, Education for Sustainable Development (ESD), sustainability competencies, and teacher preparation, with particular attention to Indian education and the National Education Policy (NEP) 2020. The analysis informs the development of the proposed Integrated Climate Literacy in Teacher Education (ICLTE) framework.

2.1 Literature Identification and Selection

Relevant literature was identified using the research-discovery tools Consensus and SciSpace. ChatGPT was used to discover research themes and support the initial organisation of the review; it was not treated as a foundation of scholarly evidence. The literature identification process focused on climate change education, environmental literacy, Education for Sustainable Development (ESD), teacher education, sustainability competencies, and Indian education policy.

The review considered peer-reviewed empirical studies, review articles, conceptual publications, scholarly books, and relevant official policy documents. The publications on the topics of teachers' climate-related knowledge, pedagogical approaches, environment citizenship, environmental and climate competencies in teacher education programmes, and the incorporation of EE or CE into teacher preparation were given importance. Climate science publications that were not related to education were not included in the review.

The literature selection was not comprehensive, but rather purposive and interpretive. Sources were considered according to their relevance to the research questions, educational context, conceptual contribution, and implications for teacher preparation. The selected literature was examined to identify recurring ideas, complementary views, convergence points and issues pertinent to climate literacy in teacher education. The literature-identification process did not preserve complete records of the exact search strings, search dates, or screening counts. Consequently, the review is presented as a critical narrative review rather than a systematic or exhaustive review. This limitation restricts the reproducibility of the search process and should be considered when interpreting the synthesis.

The review therefore provides an interpretive synthesis of selected literature and policy documents rather than a quantitatively documented account of all potentially relevant publications.

2.2 Policy-Document Analysis

Policy-document analysis focused mainly on the National Education Policy 2020 (Ministry of Education, 2020). The National Curriculum Framework for School Education 2023 (National Council of Educational Research and Training [NCERT], 2023); the National Curriculum Framework for Teacher Education 2009 (National Council for Teacher Education [NCTE], 2009); and relevant UNESCO publications on ESD were used as complementary sources of policy and educational context.

A qualitative analysis of the documents revealed how these are dealt with in relation to multidisciplinary learning, environmental awareness, experiential and inquiry-based pedagogy, teacher education, sustainability and institutional support. Using Bowen's (2009) strategy for document analysis, it was determined that relevant policy provisions would be considered in light of the research questions and whether the integration of climate education into teacher preparation would be possible.

The analysis explored potential opportunities for integrating climate literacy into teacher training programs, the content of subjects taught in classrooms, and school-based and institutional professional development programs. It also reviewed issues of potential implementation, such as the need for curricular coordination, preparedness of teacher educators, learning resources, and institutional support. The challenges are not necessarily conclusions that appear in the policy documents, but rather interpretations of the possible gaps in implementation. The policy-document analysis informs the discussion in Section 4 and the development of the proposed ICLTE framework.

2.3 Thematic Synthesis and Framework Development

The ICLTE framework has been created by a qualitative synthesis of the literature and policy documents selected. There were five stages to the process. The first step was to review the literature to see what was known about what knowledge, skills, pedagogical strategies, and attitudes are associated with good climate education. Second, concepts and issues relevant to the questions were identified and preliminary analytical categories were developed, such as ‘scientific understanding’, ‘inquiry-based teaching’, ‘ethical responsibility’, ‘local environmental contexts’ and ‘institutional preparedness’. Third, related categories were compared and clustered into overarching themes that could be identified as the common educational needs and implementation considerations. Fourth, these themes were explored in tandem with the policy elements outlined in Section 2.2, to explore the possibilities for policy priorities to support the integration of these themes into teacher preparation and where additional curricular or institutional action may be needed. The themes were then combined to form the following five interrelated themes: scientific literacy, pedagogical competence, ethical and civic orientation, local environmental learning, and institutional support.

Thus, the framework created from this process is a conceptual proposal that aims to link climate-related knowledge to pedagogical practice, moral and civic involvement, locally situated learning, and conditions of teacher education institutions. The strands and illustrative indicators are designed to inform curriculum design and for further empirical inquiry. There is no empirical testing and validation of the framework. The study is based on published data and documents and is therefore interpretive in nature and should not be considered to provide evidence of the effectiveness of the framework in practice. Future studies could be conducted with teacher educators, prospective teachers, teacher-education curricula and institutional practices to explore its viability and possible implementation.

3. REVIEW OF RELATED LITERATURE

3.1 Environmental Literacy: From Knowing to Acting

Environmental literacy is not just about learning about the environment, as it refers to the capacity to understand the environment, and to analyse the various possibilities for action and resolution. Roth (1992) has defined environmental literacy as a spectrum of competences, and Hollweg et al. (2011) have added three aspects to that: cognitive, affective and behavioural dimensions. The above views imply that environmental literacy is not just a knowledge of systems in the environment, but also the ability to handle environmental problems.

Hungerford and Volk (1990) highlighted personal investment and empowerment, environmental sensitivity, and knowledge as key factors that promote responsible environmental behaviour. Similarly, Kollmuss and Agyeman (2002) examined the complex relationship between environmental knowledge, attitudes and behaviour, showing why knowledge alone cannot be assumed to produce environmentally responsible action. These perspectives are relevant to teacher education because prospective teachers require more than scientific information about climate change. They also need the pedagogical and reflective capacities to help learners evaluate evidence, consider different perspectives and engage constructively with environmental issues.

3.2 Climate Education and Learner Understanding

Climate change education requires learners to understand scientific explanations, interpret evidence and consider the environmental and societal implications of climate-related processes. Bhattacharya et al. (2021) systematically reviewed 178 empirical, peer-reviewed studies on climate education in formal K–16 settings. Their review examined trends in climate-education research, students' knowledge and learning, and teachers' knowledge, beliefs, practices and preparation. This body of research provides a basis for considering both learners' understanding of climate change and teachers' capacity to teach it.

Rousell and Cutter-Mackenzie-Knowles (2020) reviewed research on climate change education and highlighted the range of educational approaches through which climate change has been addressed. Monroe et al. (2019) synthesized research on climate change education strategies, identifying approaches intended to improve learners' understanding and engagement. Together, these reviews provide a basis for examining how climate education can be supported through appropriate content, pedagogy and learning experiences.

Selby and Kagawa (2010) critically studied the relationship between climate change and education for sustainable development. They notified against approaches that privilege technical and managerial responses while neglecting ethical questions and deeper social transformation. Taken together, these sources propose that climate education should connect scientific understanding with inquiry, critical reflection and consideration of the social and ethical dimensions of climate change.

3.3 Teachers' Understanding and Environmental Citizenship

Teachers have an important role to help learners to understand environmental issues and think of the impact that individual, collective and institutional decisions have on the environment. Teaching for this, however, needs to be done on both the content and the wider aims of education in the environment. In a systematic review of 16 empirical studies, Georgiou et al. (2021) concluded that the concepts of environmental citizenship in teachers' understandings were generally quite limited, focusing on the local, individual and private sphere. Their review also indicated that teacher education and professional development could help strengthen teachers' understanding of environmental citizenship. This is relevant to climate education because teaching climate change may require prospective teachers to consider environmental responsibilities alongside scientific explanations and classroom learning objectives.

Waldron et al. (2019) explored the difference between two opposing approaches to education about climate change: a geographical approach and a justice approach. Their efforts also contribute to the discussion on the social and justice-related aspects of climate change in addition to scientific explanations. Orr (1994) also emphasized the need for education to provide an understanding of the interdependence of human society and ecological systems. These perspectives indicate that teacher preparation should support scientific understanding, critical reflection and consideration of the ethical and civic implications of environmental issues.

3.4 Sustainability in Teacher Education

It is not enough to simply incorporate sustainability in current courses in teacher education; it requires a more holistic approach. It may involve the need for curriculum design changes, pedagogical changes, institutional priorities and opportunities for experiential learning. Sterling (2001) argued for a transformative approach to sustainability education that examines the assumptions and practices shaping educational systems.

Evans et al. (2017) examined different approaches to education for sustainability and highlighted the significance of the ways sustainability is conceptualised and incorporated into educational practice. Corres et al. (2020) contributed to discussions of sustainability competencies and their implications for education. Such work is relevant to teacher education because it draws attention to the need to connect sustainability-related knowledge with the capacities required to apply it in educational and professional settings.

Reddy (2021), writing in the South African context, discussed environmental education, social justice and teacher education, emphasising meaningful environmental learning grounded in local contexts. Although this work is not evidence about Indian institutions, it provides a comparative perspective on the value of connecting environmental learning with local issues and social realities.

Collectively, this literature provides a conceptual basis for considering curriculum, pedagogy, local environmental contexts and institutional support when planning climate education in teacher preparation. However, the relevance of these approaches to a particular national context must be examined in relation to its policies, curricula and institutional conditions.

3.5 Indian Context: Environmental Education and Teacher Preparation

Indian policy and scholarship provide a relevant context for examining environmental education and education for sustainable development in teacher preparation. Jetly and Singh (2019) examined teacher educators' perspectives on education for sustainable development in India through a qualitative study situated in the Chandigarh region. Their work provides regionally situated evidence relevant to understanding how ESD is perceived in teacher education, although its scope does not establish the extent of integration across all Indian institutions.

Batra et al. (2021) discussed curriculum reform in India in relation to educational inequality, social and ecological justice, and transformative pedagogies. This work offers a broader curricular perspective on the relationship between education and ecological concerns; it should not, however, be treated as direct empirical evidence of how climate education is implemented in teacher-education programmes.

Reddy (2021) provides a comparative perspective from South Africa on environmental education, social justice and teacher education. Its arguments about meaningful learning in local contexts may inform conceptual discussion, but the study does not establish conditions in Indian institutions.

The literature reviewed here therefore offers useful perspectives on environmental education, ESD, curriculum and teacher preparation. However, these sources do not establish the extent to which climate education is consistently integrated across teacher-education institutions in India. Establishing that pattern would require evidence directly examining teacher-education curricula, institutional practices, educator preparation and implementation processes. This limitation supports the need to investigate how climate literacy could be incorporated into teacher preparation in ways that are responsive to policy priorities and institutional conditions.

3.6 Research Gap

Three issues from the literature are relevant to the present conceptual paper. Climate education is about scientific knowledge, pedagogical, ethical and civic aspects, but these aspects need to be addressed

together when designing teacher preparation. Second, climate competency training needs must be linked to learning and teaching practices and experiences that future teachers can draw upon in teaching and learning contexts. Third, policy commitments for environmental awareness and multidisciplinary learning and sustainability must be considered alongside the curricular and institutional conditions that can influence their implementation.

The sources examined do not confirm the lack of climate education in teacher education in India, or that it is not uniformly applied across the country. Instead, they point to the necessity of continued conceptual and empirical exploration of how climate literacy can be realised in teacher education programmes, pedagogies and support.

To address the above challenges, the present paper suggests the Integrated Climate Literacy in Teacher Education (ICLTE) framework. The framework integrates five interconnected aspects of scientific literacy, pedagogical competence, ethical and civic orientation, local environment learning, institutional support. It is offered as a concept that is based on the literature and policy analysis, not as an empirical model. These claims need to be evaluated in teacher-training environments in order to demonstrate their feasibility and utility.

4. NEP 2020 AND TEACHER EDUCATION: OPPORTUNITIES AND GAPS

The National Education Policy (NEP) 2020 does not have a separate education programme on climate change in teacher preparation. However, several of its commitments provide a policy basis for considering how climate literacy could be incorporated into teacher education. These include holistic and multidisciplinary learning, experiential and inquiry-based pedagogy, environmental awareness, ethical values, local context and continuing professional development (Ministry of Education, 2020). The policy also states that environmental awareness and sensitivity towards conservation and sustainable development should be integrated into school curricula (Ministry of Education, 2020, para. 5.24). Although this provision concerns school curricula, it has implications for teacher preparation because prospective teachers need appropriate subject knowledge and pedagogical competence to support such learning.

The field of climate education also holds relevance for the climate policy and governance as it contributes to public awareness on climate science, environmental risks, and sustainability options, which can enable public involvement in climate decision-making processes. Teacher education can play a role in this process through the development of teacher candidates' abilities to interpret the evidence, to consider social and ethical aspects of decisions relating to climate change, and to support scientific evidence informed discussions. In the Indian context, NEP 2020 has identified some educational priorities, such as, multidisciplinary learning, experiential pedagogy, environmental awareness and teacher professional development. These priorities are potential entry points to climate literacy, but may be translated into teacher-education practices based on curriculum design, educator preparation, institutional resources, and appropriate assessment.

The policy's approach to teacher education provides further opportunities. Paragraphs 5.22–5.24 emphasise multidisciplinary teacher education, high-quality content and pedagogy, and substantial school-based practicum. Paragraph 15.5 outlines the broader knowledge and pedagogical foundations envisaged for the four-year integrated B.Ed. programme (Ministry of Education, 2020). These provisions create potential entry points for climate literacy within disciplinary courses, subject pedagogy, school internships and field-based learning. However, this curriculum application of the policy with the content of climate

change is not a mandate of these provisions. Table 1 provides a mapping of selected NEP 2020 priorities to potential opportunities for integrating climate education in teacher preparation and identifies possible implementation risks. The risks are analytical concerns raised in this paper and do not provide evidence of risks in all teacher-education institutions.

Table 1

NEP 2020 Provisions, Opportunities and Potential Implementation Gaps for Climate Education in Teacher Education

NEP 2020 emphasis	**Potential opportunity for climate education**	**Possible implementation gap or risk**
Holistic and multidisciplinary education	Climate-related themes can be explored across science, social science, languages, philosophy and the arts, supporting interdisciplinary understanding.	Without clear curricular responsibility and coordination, climate education may receive insufficient attention across disciplines.
Environmental awareness and sustainability (para. 5.24)	Environmental learning can inform teacher-education outcomes that connect scientific understanding with environmental literacy, critical reflection and informed decision-making.	Environmental awareness may remain at the level of general messages or occasional activities unless translated into meaningful learning outcomes and assessment.
Four-year ITEP and teacher-education reform (paras. 5.22–5.24 and 15.5)	Climate-related content can be considered within disciplinary learning, foundation courses, subject pedagogy, school internships and field-based activities.	Teacher educators may need additional preparation in climate science, environmental literacy and climate-specific pedagogy.
Experiential and inquiry-based pedagogy and competency-based assessment	Investigations, case studies, local environmental observations and community-based projects can connect climate concepts with real-world issues.	Assessment may continue to prioritise factual recall rather than evidence interpretation, critical thinking, problem-solving and the application of knowledge.
Indian knowledge traditions and local context	Place-based inquiry can connect climate learning with local ecosystems, livelihoods, community experiences and relevant traditional ecological knowledge.	Local knowledge may be presented without critical evaluation or adequate scientific evidence if its context and limitations are not examined.
Continuous professional development (para. 5.15)	Continuing professional development can support teachers and teacher educators in updating their climate knowledge and developing appropriate teaching strategies.	Short-term training without follow-up, mentoring or institutional support may have limited influence on classroom practice.

Note. The emphases in the policy are copied from the National Education Policy 2020. The opportunities are proposed applications for the field of climate education, and the implementation gaps are risks identified by the authors, not statistical data on what is happening in institutions across the country.

The table highlights an important difference between policy intent and educational implementation. Policy commitments can open the door for opportunities but there are several related steps in implementing the commitments. This needs to be addressed by curriculum designers who must determine what outcomes are appropriate for the learning objectives and how curricular space can be allocated; teacher educators must be equipped with subject matter knowledge and pedagogical skills in order to be able to teach the issues related to climate; prospective teachers should be given opportunities to practise these approaches; and school-based experiences should be designed to support them in classroom teaching. The translation of wider policy priorities to actual climate learning can be constricted at any level due to weakness.

For example, in the case of teachers, it may be possible to study climate change from scientific, social, ethical and cultural point of view in a multi-disciplinary approach to learning. This opportunity, however, is dependent on the coordination of courses and on understanding the desired learning outcome. Likewise, experiential pedagogy may be used to facilitate local environmental investigations and community projects, though the value of such experiences to education requires careful planning, adequate supervision, and access to relevant resources, as well as assessment of the project beyond merely factual recall.

Teacher educators have a vital role, as they are crucial in bridging the gap between policy intention and prospective teachers' learning experience. Professional development, therefore, must include not only content knowledge about climate change, but also effective methods of teaching issues that are complex, evidence-based and locally-relevant. Future teachers may have the opportunity for school-based internships or practicum experiences to design and test climate-related lessons, as part of programme requirements and institutional support.

Taken together, it is clear that amidst these concerns, climate literacy must be embedded in teacher training and go beyond the mere identification of relevant policy statements. It demands coordination between curriculum design and teacher-educator capacity, learning experiences of prospective teachers, and the institutional support and practice in schools.

5. THE INTEGRATED CLIMATE LITERACY IN TEACHER EDUCATION (ICLTE) FRAMEWORK

Drawing on the literature on climate education, environmental literacy, sustainability competencies and teacher preparation (Bhattacharya et al., 2021; Hollweg et al., 2011; Jetly & Singh, 2019), this paper proposes the Integrated Climate Literacy in Teacher Education (ICLTE) framework. The framework connects five interrelated strands: scientific literacy, pedagogical competence, ethical and civic orientation, local environmental learning, and institutional support. These strands provide a conceptual basis for integrating climate literacy into teacher preparation in the context of NEP 2020.

5.1 Scientific Literacy

Scientific literacy includes the ability to comprehend the concepts of climate, to interpret scientific evidence and differentiate between scientific explanation and misconceptions. Prospective teachers should be able to describe the processes of the climate, interpret data and answer students' questions in a credible manner (Bhattacharya et al., 2021; Hollweg et al., 2011).

5.2 Pedagogical Competence

Pedagogical competence enables prospective teachers to translate subject knowledge into effective teaching. Drawing on Shulman's (1986) concept of pedagogical content knowledge, this strand emphasises inquiry-based learning, interdisciplinary lesson planning, discussion and assessment of climate-related understanding.

5.3 Ethical and Civic Orientation

This strand addresses environmental responsibility, justice, sustainability and informed participation. Action competence emphasises critical engagement rather than prescribed behaviour (Jensen & Schnack, 1997), while sustainability competencies include systems thinking, anticipatory, normative, strategic and interpersonal competencies (Wiek et al., 2011).

5.4 Local Environmental Learning

Local environmental learning connects climate concepts with learners' communities through field observations, local case studies and community-based projects. Research on ESD in India and environmental education in South Africa provides relevant perspectives on contextual learning (Jetly & Singh, 2019; Reddy, 2021). Such activities should connect local experience with credible evidence and scientifically sound explanations.

5.5 Institutional Support

Institutional support includes curriculum coordination, teacher-educator development, learning resources, school partnerships and appropriate assessment. Sustainability-competency research highlights the importance of educator capabilities in supporting sustainability learning (Corres et al., 2020; Wiek et al., 2011). These institutional conditions may help embed climate literacy across teacher-preparation programmes.

5.6 Interrelationship Among the Five Strands

The five strands work together: scientific literacy provides the knowledge base, pedagogical competence supports effective teaching, ethical and civic orientation encourages critical reflection, local environmental learning connects concepts with community contexts, and institutional support enables sustained implementation.

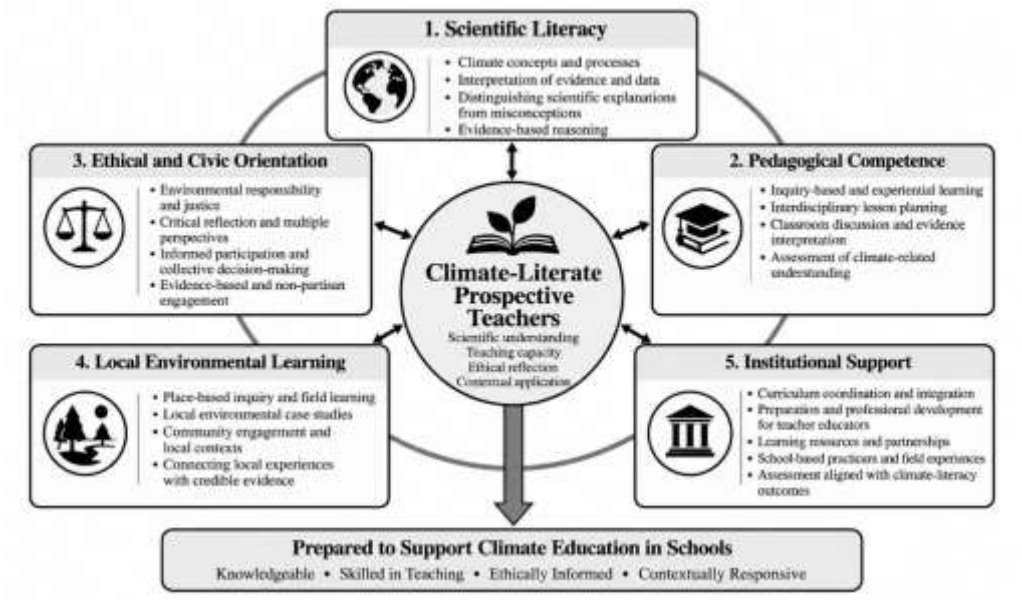


Figure 1: ***Integrated Climate Literacy in Teacher Education (ICLTE) Framework***

Note. The authors have developed this, after synthesising the literature reviewed and analysing NEP 2020. The structure is abstract and is not yet empirically tested.

The ICLTE framework can be used to guide the curriculum planning, teacher-educator development, school practicum, and teacher professional development. It needs to be tested for its feasibility and for its educational value.

6. IMPLEMENTATION PATHWAYS IN TEACHER EDUCATION

The Integrated Climate Literacy in Teacher Education (ICLTE) framework can be adopted in various ways, based on programme structure, institutional priorities, resources and regulatory requirements. This paper argues for integrating the practice of climate education with focused climate education opportunities instead of focusing on climate education as a standalone approach. Cross curricular integration can link the concepts around climate with existing courses, disciplinary and pedagogical, or, a focused module or practical component can lead to more systematic engagement with climate science, environmental literacy, and sustainability (Evans et al., 2017). This should be modified to suit the policy provisions and institutional curricula, as appropriate (Ministry of Education, 2020).

The pathways proposed below are illustrative rather than mandatory requirements. Institutions would need to adapt them to their approved curricula, programme regulations, available expertise, and local environmental contexts.

Table 2

Possible Integration Pathways for Climate Education in Teacher Education Programmes

Programme or pathway	**Proposed integration strategies**	**Connection with the ICLTE framework**
Four-Year Integrated Teacher Education Programme (ITEP)	Introduce a focused climate and environmental literacy module where curriculum space permits; integrate climate-related themes into relevant subject-pedagogy courses; include community-based projects and climate-linked lesson planning during school internships.	Connects scientific literacy and pedagogical competence with local environmental learning and institutional support.
Two-Year Bachelor of Education (B.Ed.)	Incorporate climate and sustainability themes into relevant science and social science pedagogy courses; provide practical assignments or short projects; encourage student-teachers to design lessons around locally relevant environmental issues during school internships.	Develops scientific understanding, pedagogical competence, ethical reflection, and the application of learning in school contexts.
Early-years and elementary teacher preparation	Use age-appropriate, nature-based and activity-based approaches, including stories, local examples, and simple investigations of water, waste, weather, and biodiversity.	Supports foundational environmental understanding, context-sensitive pedagogy, and connections between classroom learning and children's immediate environments.

In-service teacher professional development	Organise workshops, blended learning opportunities, professional learning communities, and follow-up classroom projects focused on climate science, teaching strategies, assessment, and local environmental issues.	Strengthens teacher capacity and supports the continuing development of scientific literacy and pedagogical competence.

Note. The strategies are proposed options developed by the authors, not claims about existing requirements in every teacher education programme. Their implementation should be adapted to institutional curricula and applicable regulations.

6.1. Integrating Climate Learning Across the Curriculum

Climate education can be incorporated into science, social science, geography, language, and other relevant pedagogical contexts. Science-related courses can develop understanding of climate processes and evidence, while social science and education courses can examine environmental justice, public decision-making, and community responses. Language and communication activities can be used to help interpret evidence and to discuss issues about climate. Such integration should retain disciplinary authenticity while at the same time facilitating meaningful links to the other subjects (Bhattacharya et al., 2021; Hollweg et al., 2011).

6.2. Connecting Learning with Local Environmental Contexts

Scientific concepts can be linked to the environmental conditions the student-teachers and the school community are familiar with through the practical activities. Possible activities are local studies into water usage, waste management, heat, biodiversity and changes to the environment. These investigations can be used by student-teachers to create case studies and classroom activities as well as lesson plan ideas to link local observations and reliable scientific facts. Contextual and Place Based approaches can enhance the relevance of environmental learning to learners' experiences (Jetly & Singh, 2019; Monroe et al., 2019). But caution is required in using isolated local observations as proof of larger scale climate variation and change.

6.3. Strengthening Teacher Educator Capacity and Institutional Support

Teacher educators need to be able to accurately and clearly communicate concepts regarding climate change to teacher educators, and apply these concepts to an appropriate pedagogical experience. Climate science, inquiry-based teaching, interdisciplinary lesson planning, assessment, and dealing with controversial or emotionally charged topics may then be a part of a teacher's professional development. The study of educator competencies in Sustainability Education (SE) emphasizes the need for teacher educator preparation in planning for implementation (Corres et al., 2020). Institutions can help this work by coordinating the curriculum and providing access to learning materials, as well as by establishing links with relevant organisations, arranging school-based practicum opportunities and reviewing the programme content on regular occasions.

6.4. Monitoring Implementation

Institutions might track implementation using evidence such as the following: climate-related lesson plans, student/teacher projects, field-related projects, assessment activity, faculty development activity, and documentation of curriculum review. These indicators are suggested as useful ways to analyse if the framework is embedded in the activities of the programme. Activities and documentation by themselves

would not show increased climate literacy or quality teaching. The outcomes would need to be evaluated and studied empirically.

Overall, the pathways for implementation spell out each of the ICLTE strands in terms of possible curriculum, pedagogical, field-based, and institutional practices. They are meant to be a starting point, not a blueprint, for institutional adaptation and future assessment of teacher preparation programmes.

7. CHALLENGES AND RECOMMENDATIONS

Addressing these challenges of integrating climate education into teacher preparation involves complex curricular, pedagogical, and institutional solutions that need to be addressed in concert. The following recommendations connect the problems found to implementation steps in the suggested Integrated Climate Literacy in Teacher Education (ICLTE).

One is that there might be a lack of capacity among teachers to accurately teach climate science and to apply sustainability pedagogy. Professional development must be sustained to address climate science, inquiry-based learning, planning interdisciplinary lessons, and facilitating and supporting discussions about climate (Corres et al., 2020).

Second, overloading and disintegration can lead to cursory coverage of climate-related issues. Institutions have the opportunity to re-vision current curricula, see how climate issues can be integrated across appropriate courses, and create and/or incorporate a dedicated module on climate literacy if appropriate. The integration of targeted learning with cross-curricular integration might help to ensure coherence and visibility (Evans et al., 2017). Third, because of the constraints of traditional assessment, institutions may be unable to determine if prospective teachers have the ability to transfer knowledge about the climate to the classroom. Assessment should, therefore, be a mix of examination, lesson plans, inquiry-based projects, portfolios, and reflective assignments related to the five ICLTE strands. Fourth, teachers and learners can experience emotional reactions and conflicting points of view that can make climate education difficult. Student teachers should be taught how to recognise risk of climate-related anxiety, assess information critically, and how to have respectful, evidence-informed conversations (Corres et al., 2020; Waldron et al., 2019). Fifth, limited institutional support can limit learning resource access, community involvement and curriculum development. Policies should be given to institutions to take the responsibility of implementation, promote collaboration among teacher educators, set up relevant community partnerships, and review the curriculum periodically.

7.1. Proposed Implementation Sequence

These recommendations can be placed into context when considering institutional practice, and so the following phased sequence is recommended:

1. **Curriculum audit:** Review and learn what topics and opportunities for climate-related topics are already in the curriculum and what is missing.
2. **Learning outcomes:** Discuss measurable learning outcomes for five strands of ICLTE.
3. **Faculty Development:** Enhance teacher educators' knowledge and pedagogy regarding climate.
4. **Curriculum integration:** Integrate climate education into appropriate courses and, if possible, a dedicated module.
5. **Practical application:** Implement local projects, climate-related lesson planning, and activities in schools.
6. **Assessment & review:** Review student-teacher learning, look at implementation evidence and adjust activities as it evolves.

This sequence is not a legislative requirement, but a potential institutional pathway. It should be adapted to the local contexts and institutional resources and the programme regulations.

Overall, the link of each challenge with a specific institutional response gives a practical underpinning for the implementation of the ICLTE framework. The framework, however, is still conceptual and has not been tested in the real world; thus, pilot studies are required to evaluate the feasibility of the approach, implementation, and educational outcomes of the framework in a variety of teacher education environments in India.

8. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper is conceptual and relies on a selective narrative review and policy-document analysis, not a primary empirical research or being comprehensive of the literature. The proposed Integrated Climate Literacy in Teacher Education (ICLTE) framework is a concept and has not yet been empirically tested. Thus, it is unclear whether it can be implemented, applied, and effective in other teacher education settings. Future research may go in four directions. Surveys and interviews might include the climate knowledge, pedagogical confidence, and professional development needs of teacher educators and student-teachers. Second, curriculum analyses can be performed to understand the representation of climate education in the curriculum of Four-Year Integrated Teacher Education Programme (ITEP) and B.Ed. at different institutions and different regions. Third, pilot implementation studies would be able to test the viability of embedding the five strands of ICLTE into teacher preparation and measure changes in prospective teachers' knowledge, lesson planning skills, and pedagogical practices. Fourth, comparative research might consider institutional type and geographical setting (rural/tribal).

The following research directions would help to strengthen the framework, add the context specific implementation needs, and provide an empirical foundation for assessing the framework's impact on climate education in the teacher education system in India.

9. CONCLUSION

Climate education is a key area of sustainable development education and teacher education provides strategic opportunity to equip prospective teachers with the scientific knowledge, pedagogical expertise, ethical sensitivity and awareness, and local context to face climate-related challenges. While the National Education Policy (NEP) 2020 has policy priorities related to environmental awareness and sustainable development, there is a need to deliberate on curriculum development, teacher-educator preparation, development of appropriate assessment methods, and institutional support to implement these policy priorities in the classroom.

This paper suggests a new framework for integrated climate literacy in teacher education (ICLTE) consisting of five strands that are interconnected: scientific literacy, pedagogical competence, ethical and civic awareness, local environmental learning, and institutional support. The main value added by the framework is the conceptual arrangement for embedding climate literacy as a topic in the teacher education curriculum and not as a separate topic. Implementation pathways are: curriculum integration, professional development, community based learning and ongoing assessment. These pathways are indicative and not mandatory requirements laid down by NEP 2020.

The ICLTE framework is still a concept and has not been tested empirically. Therefore, it needs to be systematically explored for its feasibility, applicability and its potential contribution to education. Future research might explore teacher education curricula, pilot interventions, and could involve teacher

educators and teachers in various institutional settings. These analyses could evaluate the effectiveness of the framework in practice, evaluate issues for implementation, and provide input into improvements of the framework.

Hence, in the end, climate-literacy must be embedded in teacher education through continuous improvements of scientifically informed teaching, contextualised learning, ethical and civic responsibilities, and institutional cooperation. The proposed ICLTE framework provides a basis for these efforts, which need to be tested empirically and then fine-tuned.

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