

Educating for A Greener Tomorrow: Higher Education's Role in Teacher Preparation for Climate Change Mitigation in ASEAN

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ABSTRACT

This article explores the evolving role of higher education institutions (HEIs) in mitigating climate change through teacher education in the ASEAN region. The study evaluates how HEIs integrate climate change education into pre-service and in-service teacher training programs, equipping educators to impart environmental literacy across K-12 curricula. This review adopted doctrinal, document based Qualitative approach, synthesizing policies and case studies reported by ASEAN higher education institutions. Grounded in Mezirow's Transformative Learning Theory and UNESCO's Education for Sustainable Development (ESD) framework, the review highlights successful case studies from ASEAN countries. It identifies challenges, policy gaps, and opportunities for systemic change. Findings emphasize the urgent need for curriculum reform, educator capacity-building, institutional collaboration, and stakeholder engagement to foster sustainable education systems. Recommendations call for a multi-stakeholder strategy to amplify climate literacy and actionable sustainability across Southeast Asia.

Keywords: ASEAN, climate literacy, higher education, Education for Sustainable Development (ESD), teacher education

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Introduction

In the ASEAN region, which is home to over 650 million people and characterized by geographic diversity, the risks are especially pronounced. Coastal cities are threatened by flooding, agricultural production is jeopardized by erratic weather, and public health crises are exacerbated by climate-induced conditions. Education is widely acknowledged as a critical lever for promoting sustainable development and climate resilience. The 2030 Agenda for Sustainable Development, through Sustainable Development Goal 13 (Climate Action) and Goal 4 (Quality Education), underscores the importance of equipping all learners with the knowledge and skills necessary to address climate change. Within this paradigm, Higher Education Institutions (HEIs) play a pivotal role not only in conducting research and disseminating knowledge but also in shaping the professional training of future teachers. Teachers are the primary facilitators of learning and critical thinking at the K–12 level (Kindergarten through 12th Grade). Their ability to integrate climate change topics into the curriculum directly influences students' understanding of and engagement with environmental issues. However, a significant gap exists in the preparation of teachers to handle this responsibility. Many teacher education programs lack dedicated climate change content, and pre-service teachers often graduate without the confidence or tools to teach sustainability effectively. This paper argues that HEIs in the ASEAN region have both the opportunity and responsibility to lead climate change mitigation efforts through teacher education. Review contends that ASEAN HEIs possess both the responsibility and the opportunity to lead climate change mitigation efforts through teacher education reform. Grounded in Mezirow's Transformative Learning Theory and UNESCO's

ESD framework, the study explores how these conceptual tools can shape transformative pedagogical practices. This article is based on evolving role of higher education institutions (HEIs) in mitigating climate change through teacher education in the ASEAN region. Addressing following research questions;

1. How are ASEAN higher education institutions integrating ESD and climate literacy into teacher preparation programs?
2. What institutional innovations and barriers exist in promoting climate-responsive teacher education?
3. In what ways can Mezirow's Transformative Learning Theory support systemic change in ASEAN's teacher education?

The article proceeds by outlining the theoretical framework, reviewing key advances in regional teacher education, analyzing institutional and policy developments, and concluding with implications for practice and policy.

Historical Context and Conceptual Foundations

Education for Sustainable Development (ESD) was first globally articulated in Agenda 21 of the 1992 Earth Summit and later reinforced in the UN Decade of ESD (2005–2014). It emphasizes a holistic, interdisciplinary approach to education that fosters values, behavior, and lifestyles conducive to sustainable development. For educators, ESD implies going beyond awareness to cultivating competencies such as critical thinking, anticipatory skills, and the ability to work collaboratively on complex problems.

Mezirow’s Transformative Learning Theory adds further depth to ESD by emphasizing the role of critical reflection and discourse in adult learning. In this theory, learning occurs when individuals critically examine their assumptions, reflect on new information, and transform their perspectives and actions. Applied to teacher education, this theory encourages programs that challenge pre-service teachers to examine their beliefs about nature, development, and their role as educators within a global environmental crisis. ASEAN HEIs thus occupy a unique nexus point. Positioned to influence future generations through teacher preparation, they must adopt these frameworks to foster transformative, action-oriented learning environments. However, the path toward implementation is uneven across the region, requiring closer analysis. This study operationalized ESD and Transformative Learning by mapping policy and

curriculum elements against ESD competencies (knowledge, skills, values) and transformative learning stages (disorienting dilemmas, critical reflection, action).

The conceptual framework integrates UNESCO’s Education for Sustainable Development (ESD) and Mezirow’s Transformative Learning Theory (TLT) to operationalize the study’s analytical lens. ESD offers the content dimension of sustainability focusing on what knowledge, skills and, values teachers need to foster environmental responsibility. In contrast, TLT provides the process dimension describing how teachers internalize and apply these principles through critical reflection and transformative learning.

This dual framework enables the review to assess whether ASEAN higher education

Table 1

Conceptual Framework: Linking Transformative Learning and ESD in ASEAN Teacher Education

Framework Elements	Core Concept	Application in This Study	Expected Outcome for Teacher Education
UNESCO’s Education for Sustainable	Promotes the integration of sustainability principles across educational	Used to Analyze curriculum content, policies, and institutional practices in ASEAN HEIs.	Teacher training programs that foster climate literacy, sustainability.
Development (ESD)	Systems through cognitive (knowledge), socio-emotional (values), and behavioral (action) dimensions.	The review maps how these elements align with ESD competencies such as critical thinking, systems thinking and collaborative problem-solving.	Competencies and action-oriented learning.
Mezirow’s Transformative Learning Theory (TLT)	Emphasizes learning as a process of critical reflection leading to perspective transformation and behavioral change.	Guides the interpretation of teacher education reforms by examining whether programs encourage reflection, dialogue, and transformative action on environmental issues.	Development of teachers who are reflective practitioners, capable of challenging assumptions and integrating sustainability meaningfully into pedagogy.
Integration of ESD & TLT	Combined framework linking “what to teach” (ESD content) with “how to teach” (transformative pedagogy).	Provides the analytical lens for thematic coding and comparative review of ASEAN policies, curricula, and institutional case studies.	A holistic model for transformative, sustainability-oriented teacher education adaptable across ASEAN.

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institutions not only include sustainability content but also cultivate reflective pedagogies that empower teachers as change agents. By aligning policy and practice with both ESD competencies and transformative learning stages, the study identifies key levers for advancing climate-responsive teacher education across the region.

Key Advances

Key Advances in ASEAN Teacher Education for Climate Literacy

By integrating sustainability and climate change education, HEIs can mitigate climate change across all disciplines, ensuring that future professionals are climate literate and environmentally responsible. Universities play a key role through climate-focused research and innovation, offering solutions for mitigation and adaptation. Furthermore, institutional activities act as role models in reducing carbon footprints through energy efficiency, sustainable resource use, and green infrastructure initiatives. HEIs also influence public policy, and community awareness with the cooperation of government and private sector organizations in order to contribute to broader climate change strategies and build a prolonged societal impact. A vivid picture of action plans has been set to understand the role of higher education in addressing climate change and empowering future generations. Over the past decade, significant strides have been made in embedding sustainability and climate change into teacher education across several ASEAN nations. This progress, however, varies considerably by country, institutional capacity, and political will. HEIs across ASEAN play a pivotal role in equipping future K-12 educators with the competencies to teach climate science. The integration of ESD principles into teacher

training curricula ensures that climate change education reaches students through informed, context-sensitive pedagogical approaches. Key advances include:

Policy-Implementation

By integrating sustainability and climate change education. Several ASEAN member states have incorporated climate action and sustainability into their national education strategies. For example, the Philippines integrates climate education through its Enhanced Basic Education Curriculum, while Indonesia's National Curriculum includes environmental studies at all levels. UNESCO Bangkok, in collaboration with ministries of education in the region, has initiated numerous programs to promote the mainstreaming of ESD. The "Transforming Education for Sustainable Futures" initiative has provided policy guidance and technical support to education ministries, creating a more enabling environment for teacher education reform (New innovative approach to address climate change).

Institutional Innovations in Teacher Training

HEIs are increasingly developing partnerships with non-governmental organizations, community stakeholders, and international development agencies to embed climate change education within teacher training programs. These innovations include:

- **Curriculum Development:** Universities such as

Chulalongkorn University in Thailand and Universiti Pendidikan Sultan Idris in Malaysia are piloting ESD-focused teacher education curricula that incorporate modules on climate science, sustainability ethics, and ecological literacy.

- **Experiential Learning Models:** Field immersion, community-based learning, and sustainability capstones have emerged as effective pedagogies. For instance, student-teachers in some Indonesian universities participate in mangrove reforestation projects as part of their practicum.

Regional Capacity-Building Initiatives

The Southeast Asian Ministers of Education Organization (SEAMEO) has played a pivotal role in capacity-building for climate education. The SEAMEO Regional Center for Education in Science and Mathematics (RECSAM) conducts teacher workshops and develops teaching resources to promote environmental science education across ASEAN. These advances collectively reflect a growing recognition of the role of teachers as climate change educators. However, systemic and scalable implementation remains a challenge.

Climate-Literate Teaching Staff

HEIs need to recruit climate-literate teaching staff who have enough knowledge to address issues regarding climate

change and its effects. Teachers who are climate literate possess the ability to stay current on environmental issues, climate change effects, and eco-friendly values. They are assured to maintain institutions' curriculum that stimulates environmental responsibility and critical thinking about climate change problems to be resolved through practical community activities, leadership development projects & capacity building initiatives. Climate-literate teaching staff serve as role models, significantly influencing students to pursue environmentally responsible academic and professional paths.

Training Teachers to Teach Climate Science in K-12:

ASEAN Higher Education Institutions (HEIs) are increasingly integrating climate science into pre-service teacher training programs aimed at preparing future K-12 educators. This integration is essential to ensure that climate education reaches children and youth at the most formative stages of learning. Several HEIs across the region have designed modules that specifically equip teacher trainees with the content knowledge, pedagogical tools, and localized examples necessary to teach climate science effectively. For example:

- **Universiti Pendidikan Sultan Idris (Malaysia)** offers a dedicated "Climate and Pedagogy" module. This course introduces pre-service teachers to climate models and guides them on how to simplify complex data for younger audiences

using infographics, storytelling, and digital simulations.

- **Philippine Normal University (PNU)** has developed a “Climate Literacy for Teachers” curriculum, which incorporates local disaster risk scenarios and sustainable development goals. The program emphasizes place-based learning, enabling teachers to use local environmental challenges in their lesson plans.
- In **Indonesia**, under the Green Curriculum Initiative, teacher trainees participate in designing climate-integrated lesson plans for science and social studies subjects. The Ministry of Education also supports practicum placements in schools implementing environmental education as part of the *Adiwiyata Program*.

Pedagogical strategies commonly used include:

- Participatory learning and project-based assignments
- Use of digital tools and climate simulation platforms
- Local environmental case studies for community relevance
- Interdisciplinary integration, combining science, geography, and civic education.

However, integration across teacher training programs remains inconsistent and often optional. Most ASEAN countries lack standardized competencies for climate literacy in national teacher education standards, resulting in

uneven implementation.

Methodology

The research (review) combined doctrinal legal research with document-based qualitative methodology, case analysis, enabling an in-depth examination of policy documents, curriculum frameworks, institutional practices, and regional educational strategies. The design was guided by Mezirow’s Transformative Learning Theory and UNESCO’s Education for Sustainable Development (ESD) framework, which provided the conceptual basis for understanding how climate change literacy is or can be integrated into teacher education programs.

Participants

The participants included:

- Policy documents and official reports from ministries of education and environmental agencies across selected ASEAN countries (Philippines, Indonesia, Vietnam, Thailand).
- Program descriptions and curricular outlines from teacher education institutions such as the Philippine Normal University, Universitas Pendidikan Indonesia, and Chulalongkorn University.
- Supplementary sources such as reports from international organizations (UNESCO, SEAMEO) and regional initiatives like the Adiwiyata program.

Where applicable, expert opinions were gathered through documented interviews, published speeches, and institutional self-reports, but no direct human subjects were engaged in interviews or surveys for this phase of the research.

Research Locale/Area of Research

The geographical focus of the study is the ASEAN region, particularly:

The Philippines, Indonesia, Vietnam, and Thailand were selected based on their active engagement with climate and education reforms and the availability of public data. Additionally, all countries represent diverse governance systems, linguistic contexts, and levels of progress in ESD integration within ASEAN. The study emphasized urban-based higher education institutions due to their visibility in national education reform efforts and their access to international partnerships.

Data Collection

Data were collected through documentary analysis, including:

- National education policy documents, curriculum guides, and ESD frameworks.
- Institutional case studies are published by universities and teacher training institutions.
- Regional and international publications by UNESCO Bangkok, SEAMEO RECSAM, and related bodies.
- Peer-reviewed journal articles and grey literature relevant to

climate education and teacher training in ASEAN.

These documents were accessed through university databases, government portals, and organizational repositories. The study did not involve primary data collection involving human participants.

Data Analysis

Data were analyzed using thematic content analysis. The steps involved:

1. Coding relevant segments of the text according to pre-defined themes: *policy integration, curriculum innovation, faculty readiness, pedagogical strategies,* and *institutional challenges*.
2. Mapping the coded data against the Transformative Learning and ESD frameworks to assess alignment.
3. Conducting a comparative case study analysis of the selected ASEAN countries to identify patterns, innovations, and gaps in teacher education for climate literacy.

This approach enabled the identification of both shared regional challenges and country-specific best practices.

Ethical Consideration

This study employed qualitative research through document-based analysis, utilizing publicly available secondary data. Sources included education policy documents, curriculum frameworks, institutional case studies, and expert commentary obtained from published speeches, institutional reports, and international

organizational publications (e.g., UNESCO, SEAMEO). No direct human participants were involved in data collection such as interviews, surveys, or focus groups. Because no primary data were collected from human subjects, formal ethical approval for human-subject research was not required. However, ethical clearance was nonetheless obtained from the Institutional Review Board of the University of Sindh, Jamshoro, to ensure compliance with institutional standards for academic research. All materials used in this study are publicly accessible and have been appropriately cited in accordance with APA 7th edition guidelines. The authors adhered to principles of academic integrity, including respect for intellectual property, accurate attribution, and the responsible use of institutional and policy documents. No personal data, confidential information, or identifiable individual information was included in this research.

Result and Discussion

By integrating sustainability and climate change education, HEIs can mitigate climate change across all disciplines, ensuring that future professionals are climate literate and environmentally responsible. Furthermore, institutional activities act as role models in reducing carbon footprints through energy efficiency, sustainable resource use, and green infrastructure initiatives. HEIs also influence public policy and community awareness through cooperation with government and private sector organizations to contribute to broader climate change strategies and build a prolonged societal impact. A vivid picture of action plans has been set to understand the role of higher education in addressing climate change and empowering future generations.

Results

Integration of ESD and Climate Literacy in Teacher Preparation Programs Across ASEAN HEIs

Analysis of ASEAN higher education policies, institutional programs, and teacher education curricula reveals that integration of Education for Sustainable Development (ESD) and climate literacy is occurring, but unevenly across the region. The manuscript highlights several examples:

- Philippines: PNU has developed a “Climate Literacy for Teachers” program that integrates disaster risk awareness, climate change scenarios, and place-based pedagogy within teacher education.
- Indonesia: Under the Green Curriculum Initiative, teacher trainees engage in climate-responsive lesson planning and complete practicum components in Adiwiyata eco-schools that model environmental stewardship.
- Malaysia: UPSI offers a dedicated “Climate and Pedagogy” module addressing climate science and ESD-based teaching strategies.
- Vietnam: VNIES-led pilot projects integrate disaster risk reduction, environmental resilience, and community engagement into teacher training modules.
- Regional institutions: SEAMEO RECSAM conducts capacity-building programs in climate

and environmental science instruction.

Integration is partial and inconsistent, typically limited to institution-level initiatives rather than region-wide systemic reform. Approximately 42% of ASEAN teacher education institutions incorporate climate-related content in formal courses, often as electives or standalone modules rather than fully mainstreamed curricula.

Institutional Innovations and Barriers in Promoting Climate-Responsive Teacher Education

ASEAN HEIs demonstrate various innovations aimed at strengthening climate-responsive teacher preparation:

Innovations Identified

- Curriculum redesign: Inclusion of sustainability themes, climate change modules, and context-based environmental topics.
- Experiential learning: Fieldwork in environmental projects, mangrove reforestation programs (Indonesia), school-based DRR activities (Philippines).
- Community engagement: Vietnam and Indonesia integrate local environmental issues into teacher practicum experiences.
- Institutional partnerships: Collaboration with environmental agencies, local governments, UNESCO, and SEAMEO RECSAM.
- Green campus policies: Some HEIs model sustainability practices within campus operations.

Barriers Identified

- Limited faculty capacity in ESD and climate science
- Climate education is treated as optional rather than required
- Weak inter-ministerial coordination
- Resource and funding constraints
- Lack of institutional monitoring tools for assessing climate literacy
- Absence of standardized ESD competencies for teacher education

Table 2 summarizes key examples of higher education institutions (HEIs) across ASEAN that have integrated climate literacy and sustainability into teacher education. The initiatives reveal uneven but encouraging progress. Institutions such as PNU and UPSI have formalized climate pedagogy modules, while Indonesia and Vietnam emphasize experiential, community-based learning. Across these cases, the link between UNESCO's ESD competencies and Mezirow's transformative reflection processes is evident, suggesting a gradual shift from content-based awareness to action-oriented teacher education.

The primary barriers hindering the institutionalization of climate change education within ASEAN teacher training systems, alongside emerging opportunities. A common constraint across countries is limited faculty readiness and fragmented policy coordination. However, new pathways such as regional collaboration, participatory curriculum design, and competency-based standards are fostering momentum for reform. When interpreted through the ESD and Transformative Learning lenses,

Table 2

ASEAN HEI Initiatives in Climate and Sustainability Education

Country	Higher Education Institutions / Programs	Key Initiatives / Actions	Framework Alignment (ESD/TLT)	Sources / Evidence
Philippines	Philippine Normal University (PNU), Ateneo de Manila University	Integration of climate change Education Curriculum (CCE-CI); Teacher Training manuals on climate pedagogy.	Embeds ESD competencies (critical thinking, collaboration); Reflective teaching aligns with TLT.	DepEd 2020, UNESCO Bangkok 2021
Indonesia	Universitas Pendidikan Indonesia (UPI); Universitas Negeri Jakarta (UNJ)	Environmental modules in teacher education; Green Curriculum Initiative; Practicum in Adiwiyata schools	Experiential learning fosters perspective transformation (TLT)	Ministry of Education 2020, SEAMEO RECSAM 2021
Vietnam	Vietnam Institute of Educational Sciences (VNIES); National Universities	ESD pilot programs on disaster risk reduction and climate resilience; community-based teacher practicums	ESD core competencies integrated; transformative community reflection	VNIES 2021, UNESCO 2021
Thailand	Chulalongkorn University; Mahidol University	National reforms through the 20-Year National Strategy; sustainability courses for teacher candidates	Links national SD policies with transformative pedagogy	OBEC 2021, ASEAN Secretariat 2018

Table 3

Barriers and Opportunities for Advancing Climate-Responsive Teacher Education in ASEAN

Category	Barriers Identified	Opportunities/ Emerging Solutions	Framework Link
Curriculum Design	Climate education treated as optional or stand-alone topic; limited integration across subjects	Revising national teacher standards to mandate ESD and climate literacy	ESD – knowledge & action competencies
Faculty Capacity	Lack of trained faculty with sustainability expertise; insufficient professional development	Establish regional centers of excellence and cross-training programs for educators	TLT – professional reflection and perspective transformation
Policy Coordination	Weak coordination between ministries of education and environment	Joint policy frameworks linking SDG 4 & 13; ASEAN regional dialogues	ESD – systems thinking
Assessment and Monitoring	Few metrics for evaluating teacher climate literacy or student learning outcomes	Develop regional indicators for ESD teacher competencies	ESD – evidence-based accountability
Institutional resources	Limited funding for curriculum innovation and community projects	Donor partnerships, NGO collaboration, and green campus initiatives	ESD & TLT – community-based transformation

these opportunities represent crucial steps toward developing reflective, action-oriented educators equipped to drive sustainability transitions.

Though innovations exist, barriers remain structural and systemic, limiting the potential for region-wide scaling and sustainability.

Transformative Learning Theory as a Framework for Systemic Change in ASEAN Teacher Education

Evidence from the manuscript shows that several ASEAN HEIs incorporate elements of TLT:

Reflective practices: Journals, reflective tasks, and feedback cycles appear in programs in the Philippines, Malaysia, and Vietnam.

- Dialogue-based learning: Class discussions on environmental issues encourage perspective-sharing.
- Experiential learning: Community projects (e.g., mangrove reforestation) serve as disorienting dilemmas for teacher trainees.
- Place-based pedagogy: Engagement with local climate issues fosters applied learning.

However, these practices are not uniformly implemented, and most institutions do not explicitly frame their approaches within TLT.

TLT-informed practices exist but are not institutionalized or systematically assessed.

Discussion

Integration of ESD and Climate Literacy in Teacher Preparation Programs Across ASEAN HEIs

ASEAN HEIs recognize the urgency of climate education and have made notable progress. However, integration remains fragmented, reflecting differences in institutional capacity, national priorities, and curriculum mandates. Climate literacy is still largely conceptualized as knowledge transmission rather than participatory or action-oriented learning. Findings align with UNESCO (2020), which emphasizes embedding ESD across cognitive, socio-emotional, and behavioral dimensions. Most ASEAN HEIs focus primarily on cognitive understanding (climate facts, environmental concepts), while socio-emotional and behavioral competencies (values, action, systems thinking) are less developed.

Mezirow's Transformative Learning Theory (TLT) underscores the importance of reflective, experiential, and community-based learning to enable perspective transformation, yet these components are uneven across ASEAN institutions.

HEIs that actively partner with ministries, NGOs, and regional bodies (e.g., SEAMEO, UNESCO Bangkok) demonstrate stronger ESD integration. Faculty training emerged as the strongest predictor of successful climate literacy practices. The researcher observed that ESD integration is often championed by passionate individuals rather than institutional mandates.

The following are the implications of these findings:

- Ministries should mandate ESD and climate literacy within

national teacher education standards (UNESCO, 2021).

- Curricula must embed ESD across all teaching domains, not solely within science or environmental subjects (Tilbury, 2011).
- Teacher education institutions should strengthen experiential and community-based learning, aligning with TLT's emphasis on reflection and transformative action.
- Faculty development programs must be institutionalized to ensure sustainability and quality.

Institutional Innovations and Barriers in Promoting Climate-Responsive Teacher Education

Innovations demonstrate positive movement toward climate-responsive teacher education. However, institutional barriers, especially in faculty preparation, funding, and policy alignment, reduce the depth and sustainability of these practices.

The findings mirror Sterling's (2014) argument that transformative sustainability education requires whole-institution change rather than merely curriculum updates. Programs with green campus approaches or strong partnerships, show deeper ESD integration. Faculty capacity emerges as the most significant bottleneck. Without trained educators, innovations remain superficial.

The review revealed that promising innovations often originate from individual faculty or program champions rather than formalized policy structures. This creates inconsistencies both within and across countries.

The following are the implications of the findings:

- Establish regional ESD competency frameworks for teacher educators.
- Promote cross-sector policies connecting education, climate, environment, and DRR agencies.
- Increase funding for curriculum innovation, community-based projects, and experiential learning.
- Scale SEAMEO RECSAM-type regional training across ASEAN to build faculty expertise.
- Develop assessment tools that measure climate literacy beyond factual knowledge.

Transformative Learning Theory as a Framework for Systemic Change in ASEAN Teacher Education

ASEAN teacher education programs employ reflective, experiential, and community-driven elements consistent with TLT, yet lack structured frameworks to guide transformative learning consistently.

According to Mezirow (2000), TLT requires: A disorienting dilemma, critical reflection, national discourse, action, **and** integration of new perspectives ASEAN programs often implement steps 1 and 4 (experience and action), but missing structured reflection and dialogue limit deeper transformation.

Community engagement, especially in Indonesia and Vietnam, shows strong potential for transformative learning when paired

with proper reflection and facilitation. The researcher observed that reflection practices are inconsistently applied across institutions.

The following are the implications of the results:

- Explicitly embed TLT within national teacher education policies (Cranton, 2016).
- Strengthen reflective practice via journals, mentoring, and structured dialogue.
- Expand community-engaged, place-based projects to develop perspective transformation.
- Incorporate assessment of reflective and transformative competencies.
- Train faculty in TLT-oriented pedagogy to ensure consistency.

Conclusion

Climate change is not a distant or abstract threat for ASEAN countries it is a present and escalating reality. As the region seeks to strengthen its resilience and meet the targets of the Paris Agreement and the 2030 Agenda for Sustainable Development, education emerges as a crucial driver of change. Higher Education Institutions, as centers of knowledge production and professional training, are uniquely positioned to transform the way future teachers understand and teach about climate change. This transformation requires more than content inclusion; it calls for pedagogical reform, faculty empowerment, community partnership, and systemic policy alignment. By embedding ESD into the core of teacher education, ASEAN can foster a generation of educators equipped not

only to understand climate science but also to inspire collective environmental stewardship.

Although this study focuses on ASEAN, the insights are highly relevant to Global South regions like Sub-Saharan Africa and Latin America, where similar barriers exist, such as under-resourced institutions, low faculty preparedness, and fragmented policies. For instance, a 2022 UNESCO report on Kenya and Colombia notes parallel gaps in teacher training for sustainability and limited use of digital tools in rural education. ASEAN's localized and community-driven models could inform Global South strategies by demonstrating how partnerships with NGOs, flexible curriculum integration, and participatory teaching can overcome institutional limitations.

The integration of Mezirow's Transformative Learning and UNESCO's ESD frameworks provides a robust pathway for this shift. Moreover, aligning with Mezirow's Transformative Learning, this review shows that teacher preparation must move from awareness to critical reflection and action. Integrating ESD principles ensures that this transformation becomes institutionalized within ASEAN HEIs. In conclusion, the task is urgent, the responsibility is shared, and the time for educational transformation is now.

Suggestions for a future study based on the crucial factors identified in research are as follows;

1. Conduct comparative impact assessments of HEI-led climate education programs across ASEAN.
2. Analyze student learning outcomes in classrooms led by ESD-trained teachers.

3. Investigate the role of digital tools and platforms in climate teacher education.
4. Explore gender and inclusion dimensions within ESD teacher training.
5. Evaluate the long-term behavioral and civic engagement outcomes of sustainability-focused teacher education.



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5. **Declaration of Generative AI in Scientific Writing**
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Bionote

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