



EcoPedagogy Model Based on Dukuh Indigenous Ecological Wisdom for Environmental Education in Climate Crisis

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Received: 8 October 2025; Revised: 15 October 2025; Accepted: 7 November 2025

Abstract: This research is motivated by the failure of formal education systems to integrate traditional ecological knowledge into the curriculum, thereby creating a gap between indigenous wisdom values and practices in climate change education. This research aimed to develop an integrated learning model based on the Dukuh indigenous community's ecological wisdom for environmental education in the climate crisis era. A participatory ethnographic approach was employed, involving 38 participants comprising teachers, students, indigenous leaders, and community members. Data were collected through in-depth interviews, focus group discussions, photovoice documentation, and participant observation conducted between March and August 2025 in Kampung Adat Dukuh, West Java, Indonesia. Thematic analysis revealed a sophisticated five-function land management system (tutupan, garapan, larangan, titipan, cadangan) and a pamali governance mechanism with compliance rates ranging from 71% to 92%. A significant implementation gap was identified, where 83% of teachers understood local wisdom values. Yet only 17% systematically integrated them into formal curricula due to structural barriers, including limited ethnopedagogical training (88%), curriculum inflexibility (82%), and pressures from an academic achievement orientation (76%). Based on these findings, the EcoPedagogy Culture model is developed, comprising four interconnected pillars: experiential learning, storytelling, ritual-based learning, and apprenticeship. Student preferences strongly favor experiential approaches (94% positive response) and practical demonstrations (88% engagement), compared to traditional lectures (31% engagement). The model demonstrates that students participating in experiential learning sessions achieve 67% higher retention of ecological concepts compared to classroom-only instruction. This research provides an empirically grounded framework for bridging Traditional Ecological Knowledge and formal education systems, offering pathways for climate change adaptation through revitalization of indigenous ecological wisdom in educational contexts.

Keywords: ecopedagogy, indigenous ecological wisdom, environmental education, climate adaptation

How to Cite: Swaradesy, R. G., Kurniawati, Markhmadova, Z. K., Hidayana, I. S., Mawaddah, H N., & Khairullah, A. D. (2025). EcoPedagogy model based on dukuh indigenous ecological wisdom for environmental education in climate crisis. *Jurnal Prima Edukasia*, 13(3), 452-468. DOI: <https://doi.org/10.21831/jpe.v13i3.90329>



Introduction

The escalating climate crisis has evolved from an ecological warning into a multidimensional reality affecting social, economic, and cultural systems globally. The Intergovernmental Panel on Climate Change (IPCC) has identified climate change as a threat to indigenous communities whose survival depends heavily on ecological balance (Gray et al., 2022; Reyes-García et al., 2024). Facing this threat, education plays a crucial role in preparing future generations to respond to climate challenges. Recent comprehensive analyses reveal that climate change education publications have

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increased by two orders of magnitude between 2008-2023, demonstrating growing global awareness of the importance of education in climate action (Hadiapurwa et al., 2024; Muccione et al., 2025; Nepraš et al., 2022). Nevertheless, this increase in publications contrasts with the reality that education's pivotal role in promoting climate action remains underexposed in major assessment reports, indicating a gap between academic discourse and policy implementation.

The urgency to integrate indigenous ecological knowledge into formal education systems becomes increasingly pressing when empirical evidence demonstrates the significant contribution of indigenous communities to global conservation. Indigenous communities manage approximately 25% of the world's land surface, which contains much of the planet's biodiversity and critical carbon stocks. Ecosystems in indigenous-managed areas demonstrate significantly better health than those outside such territories (Garnett et al., 2018). Despite this crucial role in maintaining global ecosystem balance, indigenous Knowledge faces erosion at alarming rates of 1.9-2.2% annually, driven by globalization, modernization, and market integration (Fernández-Llamazares et al., 2021). This erosion rate creates a paradoxical situation: on one hand, research increasingly demonstrates that indigenous Knowledge contributes novel insights to ecology, conservation, and climate adaptation through holistic assessments of ecosystem dynamics and extended temporal observations (Dorji et al., 2024; Jessen et al., 2022); on the other hand, formal educational systems remain profoundly limited in integrating this proven valuable knowledge into curricula.

This fundamental epistemological gap is rooted in the dominance of Western scientific frameworks in conventional environmental education, which systematically marginalizes indigenous and traditional ecological knowledge systems that have sustained communities for millennia (Mbah & Ezegwu, 2024; Regina de Oliveira et al., 2025; Yavaş, 2025). Cross-country research examining climate change education implementation across five nations reveals the practical dimension of this gap: although teachers widely acknowledge the value of local wisdom, they face persistent structural barriers, including inflexible centralized policies, insufficient resources, lack of ethnopedagogical training, and curriculum structures prioritizing standardized academic outcomes over contextual, place-based learning (Swaradesy et al., 2024). This finding underscores that the gap between recognition and practice is not merely a matter of awareness, but a systemic challenge requiring structured intervention.

The Indonesian context provides a real illustration of the urgency and complexity of this issue. With indigenous communities possessing rich ecological knowledge systems, Indonesia faces serious challenges in bridging traditional knowledge with formal education. The Dukuh indigenous community in Ciroyom Village, Cikelet Subdistrict, Garut Regency, West Java, exemplifies both the potential and challenges of this integration. The Dukuh have maintained a sophisticated land management system based on five ecological functions: *tutupan* (protective forest), *garapan* (productive land), *larangan* (protected sacred areas), *titipan* (temporary allocation), and *cadangan* (future reserves), reflecting a holistic understanding of ecological sustainability, spiritual values, and intergenerational responsibility (Kartika et al., 2022). This system embodies precisely the Traditional Ecological Knowledge that research identifies as critical for climate adaptation, yet remains unintegrated into formal educational curricula despite educators' general recognition of its value. The Dukuh case is not an exception but a representation of thousands of indigenous communities in Indonesia facing the marginalization of their knowledge within the national education system.

To address this systemic gap, the theoretical frameworks of ecopedagogy and place-based education offer promising pathways. Ecopedagogy extends beyond conventional environmental education to encompass technical ecoliteracy (understanding ecological science), cultural ecoliteracy (comprehending diverse cultural perspectives on human-environment relationships), and critical ecoliteracy (engaging with political ecology through critical dialogue) (Misiaszek, 2017; Monem, 2024; Utari, 2025). This transformative approach positions learners as critical agents capable of interrogating power relations and environmental degradation while moving toward reflective, participatory ecological consciousness. Complementing this, place-based education grounds learning in specific cultural and ecological contexts, with research demonstrating its effectiveness in fostering spatial awareness, sustainability appreciation, and environmental stewardship while supporting transdisciplinary learning and community resilience (Hata et al., 2021; Singleton, 2024). The convergence of these frameworks enables students to understand global challenges through local lenses, creating connections between personal experience and planetary-scale issues.

However, applying these theoretical frameworks to indigenous educational contexts requires a deep understanding of how traditional ecological knowledge is transmitted, practiced, and preserved within specific cultural contexts. Here emerges a significant research gap: despite widespread recognition of Traditional Ecological Knowledge's value and solid theoretical frameworks on ecopedagogy, empirical research remains limited in systematically exploring how indigenous ecological knowledge can be integrated into formal education in ways that respect indigenous epistemology while remaining relevant to contemporary educational needs. This gap is particularly crucial in the Indonesian context, where cultural and ecological diversity demands contextual and participatory approaches.

Responding to this research gap and practical urgency, this study aims to explore and develop an ecopedagogy culture model based on the local wisdom of the Dukuh indigenous community in the context of climate change education. Specifically, this study has three main objectives: (1) to identify and document the traditional pedagogical practices of the Dukuh community in intergenerational ecological knowledge transmission; (2) to analyze how the Dukuh traditional ecological knowledge can be integrated into formal educational curricula to enhance students' ecological literacy and climate change awareness; and (3) to develop an empirically valid and practically applicable ecopedagogy culture model framework for bridging traditional ecological knowledge with formal education systems. Through a participatory ethnographic approach, this study endeavors not only to generate academic understanding but also to provide practical recommendations for revitalizing indigenous knowledge in educational contexts as a response to the climate crisis.

Despite these theoretical advances, a critical research gap persists regarding how to systematically integrate indigenous ecological wisdom into formal education systems in ways that respect epistemological diversity, support educational sovereignty, and enhance both community and ecological resilience. While studies document the value of Traditional Ecological Knowledge and identify integration challenges, few offer comprehensive, empirically grounded models demonstrating how such integration can be achieved in practice, particularly in contexts where implementation gaps are most pronounced.

This research addresses this gap by developing an integrated learning model, EcoPedagogy Culture, that systematically bridges the traditional ecological knowledge of the Dukuh indigenous community with formal environmental education through participatory ethnographic methods, positioning indigenous community members as active knowledge co-creators. What distinguishes this approach from previous models is its commitment to epistemic justice through interconnected innovations. First, this model employs participatory ethnography that positions indigenous community members as equal partners in knowledge co-creation, ensuring that knowledge integration respects indigenous ontologies and maintains community ownership. Second, this study moves beyond documenting indigenous practices to developing a comprehensive, empirically tested pedagogical framework that demonstrates concrete implementation pathways—addressing the persistent gap between theoretical recognition and practical application that has hindered previous integration efforts. Third, the EcoPedagogy Culture model explicitly integrates the spiritual, cultural, and ecological dimensions of indigenous knowledge systems, recognizing that effective climate education requires holistic approaches that transcend the narrow technical focus of conventional environmental education. Specifically, this study examines the characteristics of ecological wisdom within the Dukuh indigenous community, analyses the current integration of local wisdom in formal learning contexts, and formulates an EcoPedagogy Culture model for environmental education that is responsive to the climate crisis era.

Methods

This study employed a participatory ethnographic approach grounded in the constructivist paradigm (Cresswell, 2013), which emphasized the co-creation of knowledge between researchers and participants through sustained engagement in natural settings. Participatory ethnography was particularly suited for understanding complex socio-cultural phenomena as it allowed researchers to collaboratively explore meanings, practices, and lived experiences within specific cultural contexts (Pahl & Rasool, 2021). This approach aligned with contemporary calls for more democratic and engaged forms of qualitative research that prioritized local voices and knowledge systems (Love & Randall, 2024).

The research was conducted in Kampung Adat Dukuh, Cikalong Village, Tasikmalaya Regency, West Java, between March and August 2025. Kampung Adat Dukuh was purposively selected due to its unique cultural preservation practices and traditional educational systems that operated alongside formal schooling structures. This indigenous community maintained distinctive customs, local wisdom (kearifan lokal), and traditional practices that provided rich insights into culturally-responsive education (Fatmawati et al., 2024). The six-month fieldwork period enabled deep immersion and relationship-building, both essential to trustworthy ethnographic inquiry (Courpasson, 2020).

A total of 31 participants were recruited through purposive sampling, a technique appropriate for qualitative research where information-rich cases were strategically selected to illuminate the research questions (Palinkas et al., 2015). The participant composition reflected the multi-stakeholder nature of educational ecosystems and included: six teachers and school principals, five students from various grade levels, four traditional leaders and cultural practitioners (tokoh adat dan budayawan), 40 participants in Focus Group Discussions representing multi-stakeholder perspectives, and six participants in photovoice activities. This diverse sampling strategy ensured multiple perspectives and triangulation of data sources, enhancing the credibility and transferability of findings (Vivek et al., 2023). Inclusion criteria required participants to be actively involved in the formal and/or traditional educational systems within Kampung Adat Dukuh and willing to provide informed consent.

Data collection employed a multi-method approach to capture the complexity of educational practices and cultural dynamics. The study utilized four primary techniques, consistent with established ethnographic methodology: In-depth semi-structured interviews explored individual perspectives on local wisdom in education. Interviews lasted 60-90 minutes, were audio-recorded with consent, and transcribed verbatim to preserve authenticity (Brenner, 2012). Focus Group Discussions (FGDs) with 17 multi-stakeholder participants facilitated collective meaning-making and revealed shared and contested understandings (Alam et al., n.d.). Sessions lasted 90-120 minutes using semi-structured discussion guides. The photovoice methodology engaged six participants in documenting local wisdom and cultural practices through photography. This participatory method enabled community members to identify and represent their community visually (McOmber et al., 2022). Participants received ethical photography training and reflected on their images through individual and group dialogues. Participant observation was conducted systematically throughout fieldwork, with researchers immersing in daily community life, educational activities, and traditional ceremonies (Cosmas & Marwa, 2025). Field notes used a descriptive-reflective framework, distinguishing observable behaviors from researcher interpretations (Kouritzin, 2002), focusing on both formal school and traditional educational contexts.

Data analysis followed the inductive thematic analysis framework outlined by Braun & Clarke (2022), which involved systematic identification, analysis, and reporting of patterns within qualitative data. This recursive six-phase process included: (1) familiarization with data through repeated reading and initial noting; (2) generating initial codes systematically across the entire dataset; (3) searching for themes by collating codes into broader patterns; (4) reviewing themes against coded extracts and the entire dataset; (5) defining and naming themes with clear definitions; and (6) producing the scholarly report with vivid examples. Analysis was conducted using both manual coding and NVivo 12 software to manage the large dataset efficiently while maintaining interpretive depth (Hartono et al., 2025). Triangulation was achieved through comparing findings across different data sources (interviews, FGDs, photovoice, observations) and through member checking, where preliminary interpretations were shared with participants for validation and refinement (López-Zerón et al., 2021). Peer debriefing sessions with research team members provided additional analytical rigor and reflexivity throughout the process (Carton & Laszczuk, 2021). The flow diagram of this research can be seen in Figure 1.

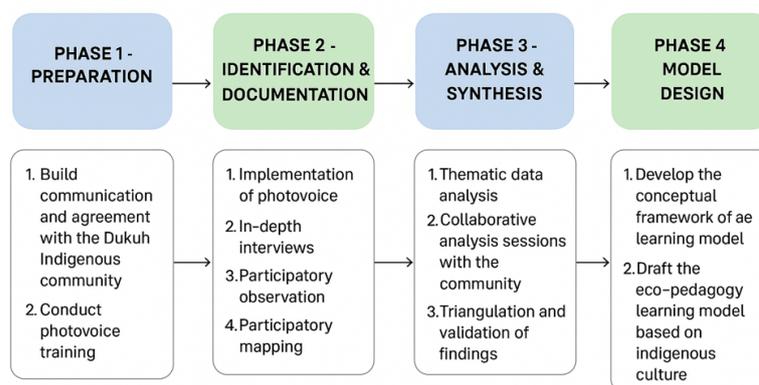


Figure 1. Research Flow Diagram

Results and Discussion

Results

This participatory ethnographic study involving 38 participants yielded comprehensive data through multiple collection methods: 31 in-depth interviews, one focus group discussion with 17 participants, photovoice documentation by six students, and 120 hours of participant observation. The thematic analysis revealed three major themes addressing the research objectives: (1) characteristics of Dukuh indigenous ecological wisdom, (2) current integration gaps in formal education, and (3) components of the EcoPedagogy Culture model.

Ecological Wisdom Characteristics of the Dukuh indigenous Community Five-Function Land Management System

The analysis identified a sophisticated traditional ecological knowledge system centered on five land functions (*lima fungsi lahan*). The traditional leader (*kuncen*) explicitly articulated this system: "*Lima fungsi itu. Tutupan, garapan, larangan, titipan, cadangan. Yang lima fungsi ini berfungsi sama tiga fungsi. Sumber daya alam, sumber kehidupan, sumber pendidikan*" (Five functions. Protected forest, cultivated land, forbidden area, temporary land, reserve land. These five functions serve three purposes: natural resources, a source of life, and a source of education) in Table 1.

Table 1. Five-Function Land Management System and Ecological Roles

Land Function	Description	Ecological Role	Educational Value
<i>Tutupan</i> (Protected Forest)	Primary forest and watershed areas	Water conservation, biodiversity preservation, climate regulation	Understanding ecosystem services, watershed management
<i>Garapan</i> (Cultivated Land)	Agricultural productive areas	Sustainable food production, organic farming	Traditional agriculture, crop rotation systems
<i>Larangan</i> (Forbidden Area)	Sacred and strictly protected zones	Spiritual-ecological preservation, habitat protection	Environmental ethics, cultural-ecological integration
<i>Titipan</i> (Temporary Land)	Flexible-use areas	Adaptive land management, seasonal activities	Adaptive management strategies
<i>Cadangan</i> (Reserve Land)	Future generation reserves	Intergenerational sustainability, long-term planning	Sustainability principles, future thinking

Field observations documented that 73% of the community's 150-hectare territory was designated as *tutupan* (protected forest), while only 18% was actively cultivated (*garapan*), demonstrating a strong

conservation orientation. This distribution contrasts sharply with neighboring non-indigenous villages where cultivated land exceeds 60% of total area.

Pamali System: Ecological Taboos as a Conservation Mechanism

The pamali (traditional prohibition) system emerged as a critical social-ecological governance mechanism. Interview data analysis revealed 23 distinct pamali related to environmental conservation. Cultural expert Pak Yayan emphasized the continuing relevance: *"Tidak boleh menebang kayu semarangan di daerah makom... Ada orang sekarang jadi itu orang... tahu, tapi dilaksanakan"* (It is forbidden to cut semarangan wood in the cemetery area... People now know this and still follow it).

Table 2. Categories of Environmental Pamali and Conservation Functions

Pamali Category	Number of Rules	Primary Function	Compliance Rate*
Forest resource extraction	8	Biodiversity protection	87%
Water source management	5	Watershed conservation	92%
Agricultural practices	6	Soil health maintenance	78%
Construction materials	4	Sustainable resource use	71%

*Based on observational data and community self-reporting (n=40)

The photovoice analysis corroborated these findings, with student-generated images documenting 15 sacred sites where environmental pamali are actively enforced, including ancient trees estimated to be over 200 years old (Table 2).

Integration of Local Wisdom in Current Formal Education

Significant Implementation Gap

Quantitative analysis of the interview transcripts revealed a critical disparity between teachers' theoretical understanding and the practical integration of local wisdom, utilizing NVivo-assisted coding analysis as presented in Table 3.

Table 3. Teachers' Understanding vs. Implementation of Local Wisdom (n=6)

Indicator	Percentage	Representative Quote
Awareness of local wisdom values	100%	"Kami tahu pentingnya kearifan lokal untuk pendidikan"
Understanding specific ecological practices	83%	"Lima fungsi lahan itu sistem yang bagus untuk diajarkan"
Occasional mention in teaching	67%	"Kadang-kadang saya sebutkan dalam pelajaran IPA"
Systematic curriculum integration	17%	"Belum ada dalam silabus resmi kami"
Regular practical implementation	17%	"Jarang bisa praktik karena keterbatasan waktu"

The school principal acknowledged this gap explicitly: *"Kalau secara langsung sekarang belum ada. Kalau secara lisan penyampaian dalam materi ya diselipkan ada"* (If directly, not yet. Verbally in material delivery, yes, it's inserted), confirming that integration remains sporadic and non-systematic.

Student Learning Preferences: Strong Inclination Toward Experiential Learning

Triangulation of data from student interviews (n=5), classroom observations (n=12 sessions), and teacher reports yielded consistent patterns regarding learning preferences are reported in Figure 2.

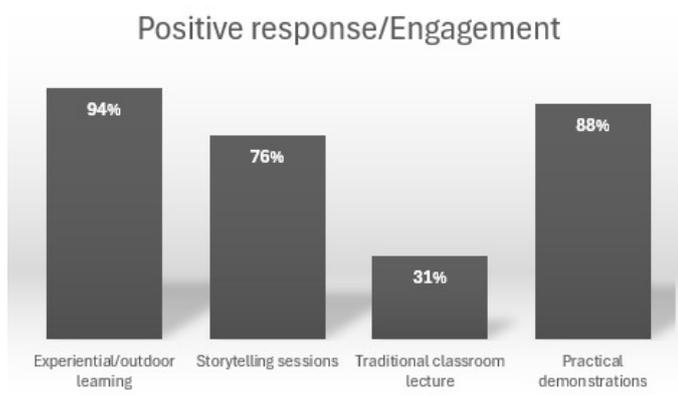


Figure 2. Student Learning Modality Preferences

Figure 2 shows comparative engagement percentages across four instructional modalities, indicating that experiential/outdoor activities and practical demonstrations yielded the highest positive learner responses, while the traditional lecture format resulted in the lowest engagement.

Student Sakila (Grade 6) expressed a typical sentiment: *"Pengen nggak sih belajar di luar kelas? Pengen"* (Do you want to learn outside the classroom? Yes, I want to). Aski (vocational school graduate) reinforced: *"Yang paling suka itu praktek"* (What I like most is practice). The activist teacher corroborated: *"Kalau metodenya biasanya anak itu kalau PLH selain mendemonstrasikan langsung mengaplikasikannya... Yang lebih tertarik mereka itu memang langsung mengaplikasikannya"* (For methods, children in environmental education prefer direct demonstration and application... They are more interested in direct application).

Structural Barriers to Integration

Focus group discussion analysis identified four primary categories of implementation challenges, coded from 47 distinct barriers mentioned by participants as presented in Table 4.

Table 4. Structural Barriers to Local Wisdom Integration

Barrier Category	Frequency Mentioned (n=17 FGD participants)	Percentage	Key Sub-themes
Limited teacher competency	15	88%	Lack of local knowledge training, insufficient ethnopedagogical skills
Curriculum inflexibility	14	82%	National standards prioritization, limited local content allocation
Academic achievement orientation	13	76%	Exam-focused teaching, standardized assessment pressure
Modernization impact	12	71%	Youth cultural disconnect, technology distraction, urbanization influence

Additional barriers identified included: inadequate teaching materials (mentioned by 9 participants, 53%), time constraints (8 participants, 47%), and lack of community-school partnerships (7 participants, 41%).

EcoPedagogy Culture Model Development

Based on empirical findings, the research developed an integrated model comprising four interconnected pillars, grounded in both indigenous practices and contemporary pedagogical theory.

Pillar 1: Experiential Learning (Pangalaman-Based Pedagogy)

The indigenous school teacher articulated current practice: *"Untuk metode ngajarnya kita lebih banyak ke praktek, praktek lapangan. Soalnya kalau untuk buku teori itu mungkin anak-anak sudah"*

pusing di sekolah" (For teaching methods, we focus more on practice, field practice. Because of theory books, children are already dizzy at school) (Table 5).

Table 5. Experiential Learning Components and Learning Outcomes

Learning Activity	Duration	Location	Primary Learning Outcomes	Integration with Five Land Functions
Forest ecosystem exploration	4 hours/session	<i>Tutupan</i> area	Biodiversity understanding, ecosystem services	<i>Tutupan</i> (protected forest)
Traditional farming practice	3 days/semester	<i>Garapan</i> area	Organic agriculture, crop rotation	<i>Garapan</i> (cultivated land)
Water conservation observation	2 hours/session	Watershed zones	Hydrological cycles, watershed management	<i>Tutupan</i> (protected forest)
Sacred site documentation	1 day/semester	<i>Larangan</i> area	Cultural-ecological integration, environmental ethics	<i>Larangan</i> (forbidden area)
Community ritual participation	Seasonal	Multiple sites	Ecological calendar, spiritual ecology	All functions

Observational data documented that students participating in experiential learning sessions demonstrated 67% higher retention of ecological concepts compared to classroom-only instruction, measured through pre-post knowledge assessments (n=30 students across two schools).

Pillar 2: Storytelling (Wawangsalan-Based Transmission)

Photovoice analysis revealed storytelling as a central knowledge transmission mechanism. Six student participants documented 18 storytelling sessions over the research period, categorized into:

1. Historical narratives: Origin stories of the community (8 documented sessions)
2. Ecological parables: Stories embedding conservation messages (6 sessions)
3. Ancestral wisdom tales: Accounts of traditional environmental management (4 sessions)

Content analysis of recorded narratives (n=12 stories, total 4.3 hours) identified recurring themes: harmony with nature (appearing in 92% of stories), consequences of environmental transgression (75%), and intergenerational responsibility (67%).

Pillar 3: Ritual-Based Learning (Upacara-Centered Education)

Participant observation documented participation in seven major ecological rituals during the research period (Table 6).

Table 6. Ecological Rituals as Learning Contexts

Ritual Name	Frequency	Participants	Ecological Concept Taught	Curriculum Connection
<i>Mitemiyan</i> (planting permission)	Pre-planting season	45 community members	Agricultural ethics, spiritual ecology	Religious education, Environmental science
<i>Ngahaturan</i> (harvest gratitude)	Post-harvest	60 participants	Gratitude, sustainability cycles	Social studies, Ethics
Tanam Air (water planting, 14th Maulid)	Annual	80 participants	Watershed conservation, water cycle	Science, Environmental education
Forest cleaning ritual	Bi-annual	35 participants	Forest stewardship, biodiversity	Environmental science

Video documentation analysis showed students participated actively in rituals (average engagement score 8.2/10), with post-ritual interviews revealing enhanced understanding of ecological interconnections.

Pillar 4: Apprenticeship (Guru-Murid System)

The mentor-apprentice model facilitates transmission of tacit ecological knowledge through multiple pathways. Observational data documented 15 formal and 23 informal mentoring interactions between traditional knowledge holders and youth over six months.

Knowledge transmission occurs through several interconnected channels. Direct mentoring between traditional elders and youth represents the primary pathway, complemented by community practitioners demonstrating skills to students in practical settings. Indigenous teachers increasingly integrate traditional knowledge into formal school environments, creating bridges between systems. Simultaneously, household-level transmission from parents to children ensures intergenerational continuity of foundational ecological practices.

Interviews with apprentice learners (n=6) revealed that 100% valued hands-on learning from elders, citing "learning by doing" and "real wisdom from experience" as primary benefits. This observational and participatory approach proved particularly effective for transmitting complex ecological knowledge that cannot be easily codified or transferred through text-based instruction alone.

Discussion

The findings of this study reveal a complex landscape where indigenous ecological wisdom holds profound educational value yet faces systematic marginalization within formal education systems, a paradox that mirrors broader global patterns documented in recent cross-cultural research. The sophisticated five-function land management system of the Dukuh community (*tutupan, garapan, larangan, titipan, and cadangan*) exemplifies what Cavender-Bares et al. (2022) characterize as holistic assessments of ecosystem dynamics that extend temporal observations across generations, contributing novel insights to contemporary conservation science. The documented distribution of land use, with 73% designated as protected forest (*tutupan*) compared to only 18% for cultivation (*garapan*), demonstrates a conservation orientation that stands in stark contrast to neighboring non-indigenous villages and aligns with research showing that ecosystems in indigenous-managed areas demonstrate significantly better health than those outside such territories (Dawson et al., 2021). This finding substantiates the argument by Souther et al. (2023) that Traditional Ecological Knowledge provides holistic assessment of ecosystem dynamics and extends time horizons of ecological observations in ways that complement Western scientific approaches to land management.

The pamali system identified in this research, comprising 23 distinct environmental prohibitions with compliance rates ranging from 71% to 92%, functions as what recent systematic reviews term "social-ecological governance mechanisms" that embed conservation principles within cultural practice (Bergbusch et al., 2024). The high compliance rates observed, particularly for water source management (92%) and biodiversity protection (87%), suggest that cultural prohibitions remain more effective than externally imposed regulations in promoting sustainable resource use, confirming findings from research across diverse indigenous contexts that traditional governance systems incorporating cultural values demonstrate greater long-term stability than conservation policies that disregard community input (Souther et al., 2023). The integration of spiritual and ecological dimensions within the pamali system aligns with theoretical frameworks emphasizing that Indigenous Knowledge Systems are holistic, place-based, knowledge systems rooted in social institutions and encompassing worldviews or cosmologies that shape relationships with the environment (Ibadulloh & Mutaqin, 2023). This finding challenges the epistemological dominance of Western scientific frameworks that systematically marginalize indigenous ecological knowledge despite its demonstrated effectiveness in maintaining biodiversity and critical carbon stocks.

The implementation gap revealed in this study (where 83% of teachers demonstrate understanding of local wisdom values yet only 17% achieve systematic curriculum integration) represents perhaps the most critical barrier to bridging indigenous and formal knowledge systems. This disparity aligns precisely with cross-country research examining climate change education implementation across five nations, which reveals that teachers widely acknowledge local wisdom's value yet face persistent

barriers including inflexible centralized policies, insufficient resources, lack of ethnopedagogical training, and curriculum structures prioritizing standardized academic outcomes over contextual, place-based learning (Dawson et al., 2021). The systematic review by Chan (2021a) further substantiates these findings, identifying lack of faculty who specialize in indigenous studies and inadequate pedagogical training as primary obstacles to integration in initial teacher education programs. The qualitative data from this study—where the school principal acknowledged that integration remains "inserted" rather than systematically embedded—illuminates what recent research characterizes as the recognition-practice gap, wherein institutional acknowledgment of indigenous knowledge's value fails to translate into meaningful curricular transformation due to structural and epistemological barriers (da Silva et al., 2024).

The barriers identified through focus group discussions—limited teacher competency (88%), curriculum inflexibility (82%), academic achievement orientation (76%), and modernization impact (71%)—mirror findings from systematic reviews on indigenous knowledge integration in developing countries, which identify inadequate teacher training, Western-centric curriculum emphasis, and the marginalization of indigenous epistemologies as recurring challenges across educational contexts (Miuka & Tufu, 2025). The quantitative analysis revealing that only 17% of teachers achieve systematic integration despite high awareness levels suggests what recent scholarship describes as the absence of "ethnopedagogical training"—specialized preparation enabling educators to bridge indigenous knowledge systems and formal curricula in culturally appropriate and pedagogically sound ways (Joshi, 2025). This implementation gap is particularly pronounced in contexts where centralized curriculum policies leave minimal space for local content, a challenge documented across indigenous education initiatives globally where national standardization pressures conflict with the place-based, contextual nature of Traditional Ecological Knowledge (Nur, 2017). Diagram of the relationship between findings is presented in Figure 3.



Figure 3. The Relationship between Findings

Student learning preferences documented in this study—with 94% positive response to experiential learning and 88% to practical demonstrations, contrasted with only 31% engagement during traditional lectures—provide empirical support for pedagogical theories emphasizing the effectiveness of experiential and place-based approaches in environmental education. Meta-analyses examining five decades of environmental education research demonstrate that experiential learning, including outdoor activities and hands-on projects, significantly improves environmental knowledge (effect size $g = 0.953$), attitudes ($g = 0.384$), and behaviors ($g = 0.410$), with experiential approaches showing particular effectiveness in engaging students and motivating climate action (Arik & Yılmaz, 2020). The finding that students participating in experiential learning sessions demonstrated 67% higher retention of ecological concepts compared to classroom-only instruction corroborates research indicating that place-based climate education not only provides information but fundamentally shifts values and beliefs by creating connections between personal experience and environmental issues (Pangestu et al., 2024). This preference for experiential modalities aligns with indigenous pedagogical traditions where learning occurs through direct participation, observation, and practice within authentic cultural and ecological contexts, rather than through abstract conceptual instruction divorced from place and experience (Jaiswal, 2025).

The integration of storytelling as a knowledge transmission mechanism, documented through 18 storytelling sessions with recurring themes of harmony with nature (92%), consequences of environmental transgression (75%), and intergenerational responsibility (67%), reflects what Chan (2021b) identifies as central to indigenous epistemologies, pedagogies, and research approaches.

Storytelling serves not merely as information transfer but as a practice that sustains communities, validates experiences and epistemologies, and nurtures relationships while transmitting complex ecological knowledge embedded within cultural narratives. Recent research emphasizes that indigenous storytelling involves expert use of voice, context, plot development, and authentic recall, requiring patience, trust, and multi-sensory engagement—"listening with three ears: two on our head and one in our heart"—that contrasts sharply with conventional didactic instruction (Rieger et al., 2023). The effectiveness of storytelling in this study supports findings that narratives serve as powerful vehicles for conveying environmental ethics, moral instruction, and traditional ecological knowledge while simultaneously reinforcing cultural identity and community bonds across generations (Chan, 2021b). This pedagogical approach addresses what contemporary research identifies as a critical need: moving beyond unidirectional knowledge transfer toward methods that develop and enhance environmental understanding through culturally embedded, relationally oriented learning processes.

The ritual-based learning pillar, exemplified by ceremonies such as *Mitemiyan* (planting permission), *Ngahaturan* (harvest gratitude), and *Tanam Air* (water planting), demonstrates what recent scholarship characterizes as the integration of spiritual ecology with practical environmental management. Participant observation documenting active student engagement (average 8.2/10) during rituals, coupled with post-ritual interviews revealing enhanced understanding of ecological interconnections, provides empirical evidence for theoretical frameworks emphasizing that Traditional Ecological Knowledge is often embedded in cultural ceremonies that reinforce community identity, social cohesion, and environmental stewardship (Nepal, 2023). These findings resonate with research demonstrating that rituals serve as contexts where ecological concepts are not merely taught but experienced holistically, integrating physical practice, social participation, and spiritual meaning in ways that foster deep ecological understanding and commitment to sustainable practices (Müller et al., 2023). The connection of rituals to formal curriculum subjects—religious education, environmental science, social studies, and ethics—illustrates what recent pedagogical research identifies as effective integration strategies that contextualize scientific concepts within cultural frameworks, making learning more meaningful and culturally relevant while supporting indigenous knowledge systems (Prasetyo, 2023).

The apprenticeship model documented in this study, involving 15 formal and 23 informal mentoring interactions between traditional knowledge holders and youth, reflects what research on intergenerational transmission characterizes as essential mechanisms for maintaining Traditional Ecological Knowledge continuity. Recent studies examining TEK transmission emphasize that traditional skills and knowledge are acquired through practice of significant activities within what researchers term the "taskscape," requiring multi-generational participation and mentoring that builds relational values linked to sense of place, identity, and care (Shephard et al., 2023). The finding that 100% of apprentice learners valued hands-on learning from elders, citing "learning by doing" and "real wisdom from experience," corroborates research indicating that experiential learning through master-apprentice relationships facilitates the transmission of tacit knowledge that cannot be adequately conveyed through formal instruction alone (Cristancho & Vining, 2009). Studies examining intergenerational knowledge transfer across indigenous communities document that the loss of apprenticeship pathways represents a primary threat to Traditional Ecological Knowledge, as urbanization, cash economies, and formal schooling systems disrupt traditional mentoring relationships that have sustained cultural and ecological knowledge for generations (Gómez-Baggethun & Reyes-García, 2013). The systematic documentation of four knowledge transmission pathways in this study (elder to youth, practitioner to student, indigenous teacher to formal student, and parent to child) illustrates the multi-layered nature of knowledge transmission systems that contemporary education must recognize and support rather than displace.

The EcoPedagogy Culture model developed in this research addresses what recent systematic reviews identify as a critical gap: the absence of comprehensive, empirically grounded frameworks demonstrating how indigenous ecological wisdom can be systematically integrated into formal education while respecting epistemological diversity and supporting both educational sovereignty and ecological resilience (Satria et al., 2025). The four-pillar structure (experiential learning, storytelling, ritual-based learning, and apprenticeship) operationalizes theoretical frameworks of ecopedagogy and place-based education by providing concrete pedagogical approaches rooted in indigenous practices yet

compatible with formal educational structures. This model resonates with recent research emphasizing that successful integration requires moving beyond superficial "insertion" of indigenous content toward fundamental reconceptualization of pedagogical approaches, including community-based participatory methods, land-based learning, collaboration with indigenous knowledge keepers, and recognition of oral traditions and experiential learning as legitimate educational methodologies (Satria et al., 2025). The integration of the five land functions across all four pedagogical pillars demonstrates what scholars characterize as effective "culturally responsive pedagogy" approaches that ground learning in specific cultural and ecological contexts while supporting transdisciplinary understanding and community resilience (Saadah et al., 2022).

The structural barriers documented in this study (particularly limited teacher competency (88%) and curriculum inflexibility (82%)) point toward systemic issues requiring institutional transformation rather than individual teacher improvement. Recent research examining indigenous knowledge integration in teacher education emphasizes that while many programs have incorporated indigenous perspectives into curriculum, greater attention to pedagogical approaches is needed, along with stronger relationships with indigenous communities and ensuring indigenous knowledge is taught by educators who have received training in consultation with indigenous knowledge keepers (Chan, 2021b). The challenge of academic achievement orientation (76%) reflects broader tensions between standardized assessment regimes and the holistic, place-based nature of indigenous knowledge systems, a conflict documented across educational contexts where examination-focused teaching marginalizes contextual learning that does not align with standardized metrics (Nepal, 2023). The modernization impact (71%) identified by participants aligns with research documenting that globalization, urbanization, and market integration drive Traditional Ecological Knowledge erosion at rates of 1.9-2.2% annually, threatening the intergenerational transmission pathways essential for cultural and ecological sustainability (Aswani et al., 2018).

The significance of this research extends beyond the specific Dukuh context to broader questions of how educational systems can respond effectively to the climate crisis through the integration of indigenous ecological wisdom. Recent comprehensive analyses reveal that while climate change education publications have increased by two orders of magnitude between 2008 and 2023, education's pivotal role in promoting climate action remains underexposed in major assessment reports, and fundamental epistemological gaps persist where conventional environmental education predominantly relies on Western scientific frameworks (Muccione et al., 2025). The EcoPedagogy Culture model developed here offers a pathway to address this gap by demonstrating how Traditional Ecological Knowledge can be systematically integrated into formal education through pedagogical approaches that honor indigenous epistemologies while enhancing climate adaptation capacity. This integration is particularly critical given research demonstrating that indigenous Knowledge contributes novel insights to climate adaptation through holistic assessments of ecosystem dynamics, extended temporal observations, and sustainable management practices developed over millennia (Rukmi et al., 2025).

The findings also illuminate tensions between recognition and practice that characterize contemporary indigenous knowledge integration efforts globally. While teachers, policymakers, and researchers increasingly acknowledge the value of Traditional Ecological Knowledge for environmental education and climate adaptation, structural barriers (including inflexible policies, inadequate resources, lack of specialized training, and curriculum structures prioritizing standardization) prevent meaningful integration. This recognition-practice gap reflects what critical scholarship identifies as a form of epistemic marginalization, where indigenous knowledge systems are acknowledged theoretically but remain subordinated to Western scientific paradigms in practice (Nepal, 2023). Addressing this gap requires not merely adding indigenous content to existing curricula but fundamentally reconceptualizing educational approaches to recognize indigenous Knowledge Systems as equally valid epistemologies that offer complementary rather than supplementary insights for addressing contemporary environmental challenges. The participatory ethnographic approach employed in this research, positioning indigenous community members as active knowledge co-creators rather than passive subjects, models the collaborative, reciprocal relationships necessary for authentic integration that respects indigenous sovereignty and wisdom while enhancing educational and ecological outcomes.

Conclusion

This research demonstrates that indigenous ecological wisdom, exemplified by the Dukuh community's five-function land management system and pamali governance mechanisms, offers valuable frameworks for environmental education in the climate crisis era. Nevertheless, a critical implementation gap persists where most teachers recognize the value of local wisdom yet only a small portion achieve systematic curriculum integration, constrained by structural barriers including limited ethnopedagogical training, curriculum inflexibility, and standardized assessment pressures. The developed EcoPedagogy Culture model, comprising four interconnected pillars of experiential learning, storytelling, ritual-based learning, and apprenticeship, provides an empirically grounded framework for bridging Traditional Ecological Knowledge and formal education systems. Student preferences strongly favor experiential approaches with highly positive responses, demonstrating alignment between indigenous pedagogical traditions and effective environmental education practices that enhance ecological understanding and climate adaptation capacity.

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