International Journal of Education and Learning Studies (IJELS) 1 (1) April 2025: 23-36 E-ISSN: xxxx-xxxx
DOI:
RESEARCH ARTICLE Nulhakim, L.

From Culture to Concept: Deep Learning Approaches to Science Literacy through Baduy Local Knowledge in Banten High Schools

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To cite this article: Nulhakim, L. (2025). From Culture to Concept: Deep Learning Approaches to Science Literacy through Baduy Local Knowledge in Banten High Schools. *International Journal of Education and Learning Studies (IJELS), 1*(1), 23-36

Articles Information

Received : 15-01-2025
Revised : 01-03-2025
Accepted : 12-03-2025
Published : 20-04-2025

Abstrak

Penelitian ini mengeksplorasi integrasi pengetahuan lokal masyarakat Baduy dalam pembelajaran sains di sekolah menengah atas di Banten melalui pendekatan pembelajaran mendalam (deep learning). Menggunakan desain studi kasus kualitatif, data dikumpulkan melalui observasi kelas, refleksi siswa, wawancara, dan analisis dokumen pembelajaran. Hasil penelitian menunjukkan bahwa pengkontekstualan konsep-konsep sains melalui kearifan ekologis Baduy—seperti pertanian tanpa bahan kimia dan konservasi hutan—meningkatkan pemahaman konseptual, keterlibatan, dan identitas kultural siswa. Siswa memperlihatkan indikator pembelajaran mendalam, termasuk berpikir kritis, berpikir sistemik, dan transfer pengetahuan, terutama saat mengaitkan sains dengan narasi budaya yang relevan. Kehadiran tokoh masyarakat Baduy dalam kelas turut memperkuat validasi budaya dan pembelajaran yang dimediasi secara sosial. Penelitian ini menegaskan bahwa pengetahuan lokal, bila dijadikan inti pedagogis, mampu mendorong pembelajaran sains yang bermakna, etis, dan kontekstual. Temuan ini memperkuat pentingnya pedagogi responsif budaya dalam meningkatkan literasi sains dan penguatan identitas siswa di komunitas marjinal.

Kata kunci: Literasi sains; Pembelajaran mendalam; Pedagogi responsif budaya; Pengetahuan lokal; Baduy; Pendidikan sains; Etika lingkungan; Pembelajaran kontekstual.

Abstract

This study explores the integration of Baduy Indigenous knowledge into high school science learning in Banten, Indonesia, using a deep learning approach. Grounded in qualitative case study methodology, data were collected through classroom observations, student reflections, interviews, and teaching materials. The findings reveal that contextualizing scientific concepts through Baduy ecological wisdom—such as chemical-free farming and forest conservation—enhanced students' conceptual understanding, engagement, and cultural identity. Students demonstrated deep learning indicators, including critical thinking, systems thinking, and knowledge transfer, especially when engaging with science through culturally embedded narratives. The presence of a Baduy community member in the classroom further validated cultural interpretations and strengthened socially mediated learning. This research shows that Indigenous knowledge, when used as a pedagogical core rather than supplementary content, can foster meaningful, ethical, and place-based science education. It highlights the importance of culturally responsive pedagogy in promoting scientific literacy and identity affirmation in underrepresented communities.

Keywords: Scientific literacy; Deep learning; Culturally responsive pedagogy; Indigenous knowledge; Baduy; Science education; Environmental ethics; Contextual learning.

1. INTRODUCTION

In the 21st century, scientific literacy has become a critical educational goal, especially in developing countries where the gap between scientific knowledge and students' real-life experiences remains significant (OECD, 2018; Yore et al., 2021). In Indonesia, results from the Programme for International Student Assessment (PISA) continue to show that students struggle with applying scientific concepts in meaningful, contextual ways (Kemendikbudristek, 2020). This issue is particularly pressing in regions like Banten, where science education often remains abstract and disconnected from students' sociocultural realities. Meanwhile, the local knowledge systems of communities such as the Baduy people, who possess rich ecological wisdom, remain largely untapped in formal science curricula.

Recent research in science education has increasingly advocated for culturally responsive pedagogy to bridge the gap between students' cultural identities and scientific understanding (Aikenhead & Michell, 2018; Lee, 2020). Scholars have demonstrated the value of integrating local or Indigenous knowledge into science learning to improve engagement, relevance, and conceptual depth (Bang & Marin, 2019; Carter et al., 2020; Snively & Williams, 2022). For example, Ritchie et al. (2021) explored Māori knowledge in New Zealand science classrooms, while Nasir et al. (2022) examined Sundanese ecological values in West Java's environmental education. Similarly, Pratiwi & Kurniasih (2021) emphasized the pedagogical potential of local wisdom in improving students' environmental awareness.

Concurrently, the deep learning approach in education, which emphasizes critical thinking, meaningful learning, and transferability of knowledge to real-life contexts, has gained traction (Fullan et al., 2018; Hattie & Donoghue, 2016). Deep learning in science education aims to go beyond surface memorization to cultivate conceptual understanding and reflective inquiry (Järvelä et al., 2021; Scott, 2022). However, most implementations of deep learning are still confined to technology-rich interventions (like flipped classrooms or online simulations), with minimal attention to cultural integration in low-resource or rural contexts (Zhou et al., 2019; Almulla, 2020; Tan & Caleon, 2022).

Despite the separate advancements in culturally relevant science education and deep learning pedagogy, there remains a research gap in synthesizing both: how can deep learning strategies be applied through the lens of local wisdom—particularly that of the Baduy community—to enhance students' scientific literacy? While studies such as Rahmawati et al. (2021) have explored chemistry learning with cultural elements, few, if any, qualitative inquiries have focused on the meaning-making processes of students engaging with science concepts rooted in traditional ecological knowledge (Yamin et al., 2022; Nugraha & Hidayati, 2023).

Therefore, this study aims to explore how Baduy local knowledge can be integrated into science learning in high schools in Banten through a deep learning approach. Specifically, it investigates how students engage in deep, reflective learning when science concepts are contextualized within the ecological and philosophical practices of the Baduy people. This qualitative research seeks to contribute to the development of more culturally grounded and pedagogically effective science education, especially in contexts where formal schooling has long overlooked Indigenous knowledge systems.

2. LITERATURE REVIEW

2.1. Scientific Literacy in Contemporary Science Education

Scientific literacy has evolved from the ability to recall scientific facts toward a more complex construct involving critical thinking, problem-solving, and decision-making in real-world contexts (Yore et al., 2021; OECD, 2018). It encompasses not only knowledge of scientific concepts but also the ability to apply that knowledge in ethical, environmental, and sociopolitical contexts (Lee, 2020). In Indonesia, studies have highlighted the challenge of fostering scientific literacy due to the dominance of content-heavy curricula and a lack of contextual learning (Rahmawati et al., 2021; Kemendikbudristek, 2020). Many students struggle to see the relevance of science to their everyday lives, leading to disengagement and superficial understanding (Pratiwi & Kurniasih, 2021).

2.2. Deep Learning Approach in Science Education

The deep learning approach in education emphasizes meaningful understanding, critical thinking, and reflective inquiry over surface-level memorization (Hattie & Donoghue, 2016; Fullan et al., 2018). In science education, this approach encourages learners to connect scientific ideas with broader themes, ask higher-order questions, and engage in problem-solving rooted in real-life scenarios (Scott, 2022). Deep learning strategies often include collaborative learning, student-driven inquiry, and metacognitive reflection (Järvelä et al., 2021; Zhou et al., 2019). While deep learning has been applied in high-tech educational settings (Almulla, 2020), it remains underexplored in cultural and low-resource contexts where traditional knowledge could provide meaningful anchors for abstract concepts (Tan & Caleon, 2022).

2.3. Culturally Responsive Science Education

Culturally responsive pedagogy in science education addresses the cultural disconnect many students experience in standardized curricula (Aikenhead & Michell, 2018; Lee, 2020). By integrating students' cultural backgrounds and local knowledge systems, learning becomes more relevant and accessible (Bang & Marin, 2019; Snively & Williams, 2022). Indigenous and local knowledge offer rich resources for exploring scientific phenomena through lived experiences. In New Zealand, for instance, Ritchie et al. (2021) successfully incorporated Māori perspectives into early childhood science. In Indonesia, Nasir et al. (2022) and Rahmawati et al. (2021) investigated the use of Sundanese and Javanese ecological knowledge to contextualize environmental and chemistry learning.

2.4. Local Wisdom and Science: The Untapped Potential of Baduy Culture

The Baduy people of Banten possess a rich ecological worldview grounded in sustainable living, resource management, and environmental harmony (Nugraha & Hidayati, 2023). These values align closely with core science education themes such as ecosystems, energy conservation, and biodiversity. Despite this, few studies have examined how Baduy knowledge could be systematically integrated into science instruction (Yamin et al., 2022). Their practices—such as land rotation, forest preservation, and abstention from modern chemicals—offer concrete, culturally embedded examples for understanding key scientific principles. Integrating such knowledge not only enhances scientific literacy but also promotes identity affirmation and respect for Indigenous heritage.

3. METHOD

3.1. Research Design

This study employed a qualitative case study design to explore how Baduy local knowledge can be integrated into science education through a deep learning approach. Qualitative research is appropriate when the goal is to understand participants' experiences, beliefs, and meaning-making processes in natural settings (Creswell & Poth, 2018; Merriam & Tisdell, 2016). A case study design allows for an in-depth, contextualized examination of teaching and learning practices within a specific high school in Banten that is geographically and culturally proximate to the Baduy community.

3.2. Participants

The study was conducted in a public senior high school located in Lebak Regency, Banten, an area with cultural and ecological proximity to the Baduy Indigenous group. Participants were selected through purposive sampling to ensure relevance and depth of insight (Patton, 2015). The participants included:

- One experienced science teacher who had attempted to integrate local knowledge into instruction,
- Twelve 11th-grade students (6 male, 6 female) who participated in learning activities using Baduy cultural context,
- One local community member familiar with Baduy practices, to validate and enrich cultural interpretation.

All participants provided informed consent, and the study followed ethical research principles including anonymity, confidentiality, and respect for cultural sensitivity (Miles et al., 2014).

3.3. Instruments

Multiple data collection methods were used to allow triangulation and enhance trustworthiness (Denzin, 2012):

- Classroom observations (4 sessions, 90 minutes each): To capture how deep learning strategies were applied and how local knowledge was embedded.
- Semi-structured interviews: Conducted with the science teacher (1x), students (2 FGDs), and one community member. Questions explored perceptions, understanding, and reflections on learning.
- Document analysis: Including lesson plans (RPP), students' learning products (e.g., concept maps, reflective journals), and teaching materials that integrated Baduy knowledge.

All sessions were audio-recorded (with consent) and transcribed verbatim for analysis.

3.4. Data Analysis

Data were analyzed using thematic analysis following the six steps by Braun and Clarke (2006): (1) familiarization with data, (2) initial coding, (3) generating themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. The focus of analysis was on:

- The depth of conceptual understanding shown by students,

- The processes of reflection and knowledge construction, and
- How Baduy local knowledge served as a pedagogical vehicle for deep science learning.

Coding was conducted inductively and reviewed by a second researcher to enhance inter-coder reliability.

3.5. Trustworthiness and Rigor

To ensure credibility, the study employed data triangulation, member checking, and prolonged engagement in the field (Lincoln & Guba, 1985). Transferability was supported through thick descriptions of the context and learning processes. Dependability and confirmability were strengthened by keeping an audit trail of research decisions and analytical steps.

4. RESULT AND DISCUSSION

This findings of the study was organized thematically based on the results of qualitative data analysis. Using classroom observations, interviews, student reflections, and document analysis, several interrelated themes emerged that illustrate how Baduy local knowledge enriched science learning when delivered through a deep learning framework. Thematic analysis was conducted following Braun and Clarke's (2006) six-phase model, allowing for a systematic interpretation of participants' experiences, behaviors, and meaning-making processes. The themes reflect students' conceptual development, cultural engagement, and the pedagogical value of Indigenous knowledge in science education. To ensure the credibility of the findings, triangulation across data sources was applied. The coding process revealed three central themes, each supported by multiple sub-nodes: (1) Contextualizing Science through Baduy Ecological Wisdom, (2) Deep Learning Processes and Meaning-Making, and (3) Cultural Knowledge as a Pedagogical Vehicle. The thematic structure is illustrated in Figure 1.

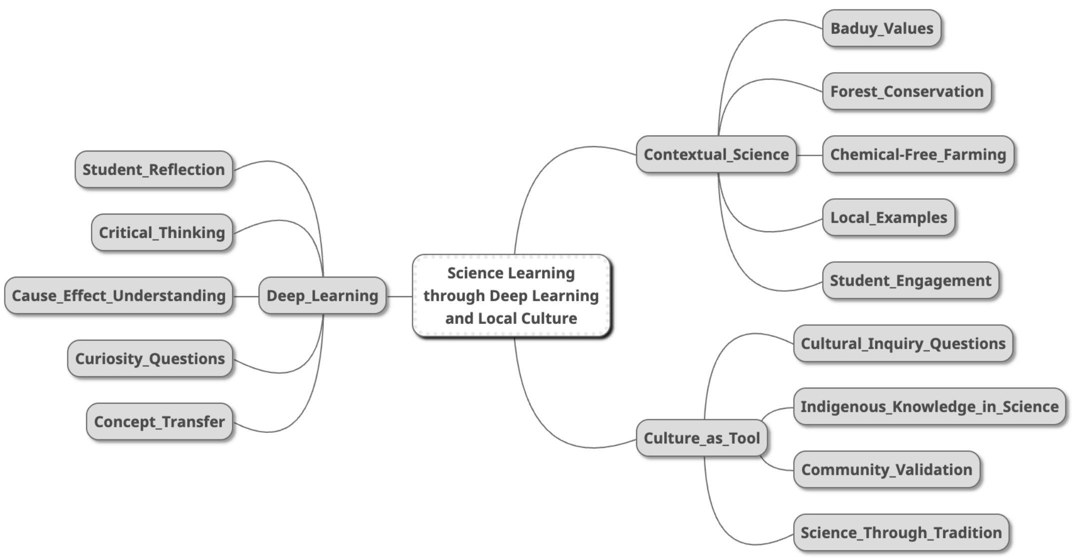

Figure 1. Thematic map of deep learning and baduy local knowledge integration in science education

4.1. Contextualizing Science through Baduy Ecological Wisdom

The integration of Baduy local knowledge—particularly the values rooted in the pikukuh philosophy—created a culturally meaningful context that helped bridge the gap between abstract scientific concepts and students' lived experiences. Pikukuh emphasizes balance and respect for natural systems, including strict prohibitions on deforestation, pollution, and chemical interference in nature. This principle was evident in classroom observations where the science teacher introduced a lesson on ecosystems by asking students to analyze how the Baduy protect their forests without modern intervention. Students connected the idea of ecological stability to pikukuh teachings, noting that the Baduy's refusal to cut down primary forest aligns with scientific principles of biodiversity conservation and habitat protection.

One particularly illustrative example of this contextual learning occurred during a group discussion when a student remarked:

> *"When we discussed ecosystems using Baduy forest preservation, I felt like I could really picture it. It's not just theory anymore—it's real and around us."*

This kind of response highlights how forest conservation, when taught through culturally embedded narratives, makes science more relatable and tangible. The students not only understood the function of forests in an ecological system, but also valued how traditional knowledge actively contributes to sustainable practices—a concept often discussed in textbooks but rarely witnessed firsthand.

Moreover, the topic of chemical-free farming provided another bridge between science and culture. The teacher introduced a comparison between industrial agriculture and Baduy farming techniques. Students examined how the Baduy use natural compost and crop rotation as a strategy to preserve soil fertility. Several students identified that these traditional methods demonstrate principles of sustainable agriculture—a key concept in environmental science. One student journal entry stated:

> *"I used to think organic farming was something new, but the Baduy have done it for generations. They know how to farm without hurting nature."*

Incorporating such local examples into science lessons significantly enhanced the students' engagement. During observation, students who typically remained passive in conventional lessons showed higher participation, asked more questions, and voluntarily related new science content back to Baduy practices. For instance, during a simulation on water cycles, students initiated a discussion on how the Baduy preserve spring water sources and prevent erosion by maintaining forest coverage—an idea they recognized as both cultural and scientific.

This heightened student engagement confirms the findings of culturally responsive pedagogy: that students learn more deeply when they see their identities, communities, and values reflected in the curriculum (Aikenhead & Michell, 2018; Lee, 2020). The teacher's use of visual aids, such as photographs of Baduy land and traditional tools, along with quotes from interviews with local elders, enriched the learning experience and made it more immersive. Students were not only learning about scientific ideas—they were actively making connections to their community, their environment, and their own identities as learners.

4.2. Deep Learning Processes and Meaning-Making

The learning process observed in the classroom revealed multiple indicators of deep learning, characterized not by the rote memorization of scientific facts, but by students' ability to engage reflectively, critically, and conceptually with the subject matter. This depth of understanding became particularly visible in students' reflective journals and concept maps, which were analyzed as part of this study. Rather than listing ecological terms, students began synthesizing information, applying principles, and relating them to real-world cultural contexts—in this case, the land-use traditions of the Baduy community.

Under the node Student_Reflection, journal entries revealed shifts in students' epistemological beliefs about science. One student wrote:

> *"I used to think sustainability was just a school term, but now I see how the Baduy actually live it out. It's like science exists in their daily lives."*

This reflection illustrates how deep learning involves internalizing concepts through personal and cultural relevance. Students no longer viewed sustainability as an abstract curriculum goal, but as a lived practice embedded within the Baduy way of life. Their reflections also echoed a broader sense of ethical awareness and social responsibility—core goals of deep science learning.

In the Critical_Thinking sub-node, student interviews and group discussions demonstrated their ability to evaluate, interpret, and extend scientific ideas. During one focus group, a student posed a question that reflected a growing curiosity and analytical approach:

> *"If the Baduy's forest remains intact because of their rules, does that mean policy can be more effective than technology in protecting nature?"*

Such statements reveal a growing ability to evaluate environmental systems from multiple perspectives—scientific, cultural, and political—thereby reinforcing Scott's (2022) claim that deep learning fosters reflective, interdisciplinary reasoning.

Evidence from class discussions also revealed strong development in Cause_Effect_Understanding. When exploring the impact of deforestation, students independently linked violations of Baduy forest practices to increased biodiversity loss, soil erosion, and disruptions in local microclimates. One student explained:

> *"If people start cutting trees like outside the Baduy area, it could destroy the water sources. That's why the Baduy forests are so clean—they protect everything."*

This understanding demonstrates the students' ability to draw logical connections across ecological systems and human activities, representing a move toward systems thinking—a hallmark of deep scientific comprehension.

The code Curiosity_Questions was populated by spontaneous student inquiries that arose during lessons. These were not superficial questions for clarification, but exploratory questions that signified epistemic curiosity. For example:

> *"How did the Baduy know which plants help the soil if they never learned from school?"*
>
> *"Could our science explain their traditional practices better, or should we also learn from their way?"*

Such inquiries show that students were not only engaging with content but also questioning the boundaries of formal science and appreciating indigenous epistemologies. This represents an active construction of knowledge through questioning, reflection, and synthesis.

Finally, under the Concept_Transfer node, students demonstrated an ability to apply culturally grounded insights into broader scientific frameworks. For instance, several students used the Baduy system of intercropping to explain nutrient cycling and soil fertility during concept map activities. Others compared Baduy rainwater harvesting practices to scientific water conservation methods taught in earlier modules.

This alignment of local knowledge with scientific principles is a strong indication that students were able to move between contexts—both cognitively and culturally—through a process of knowledge transfer. It reflects what Fullan et al. (2018) describe as the "new pedagogy for deep learning," where students gain the ability to adapt knowledge in new and meaningful ways.

Across all these sub-nodes, the presence of the six "C"s—Collaboration, Communication, Creativity, Critical thinking, Character, and Citizenship—was consistently observed. Students worked in teams, discussed ideas respectfully, connected cultural heritage with academic content, and demonstrated a sense of responsibility toward environmental preservation. The presence of a Baduy community member during one of the sessions also strengthened the cultural mediation process. This provided a living source of validation and enriched students' interpretations, aligning with Vygotsky's theory of socially mediated learning where interactions with more knowledgeable others elevate the learner's conceptual grasp.

4.3. Cultural Knowledge as a Pedagogical Vehicle

The study found that Baduy cultural knowledge was not treated as supplementary content but rather as a central pedagogical resource that structured the design and delivery of science instruction. Under the node Culture_as_Tool, observations showed how the teacher deliberately framed each science topic through culturally grounded questions, encouraging students to explore scientific phenomena from within the Baduy worldview. For example, instead of beginning with textbook definitions of sustainable agriculture, students were asked: *"Why do the Baduy avoid chemical farming?"* This kind of Cultural_Inquiry_Question triggered immediate engagement and made the lesson personally relevant.

The instructional approach aligned with inquiry-based learning, where students explored real-world practices rooted in Indigenous environmental ethics. These included forest zoning, intercropping, and water source protection—core elements of the Baduy's interaction with nature. Students responded positively to being positioned not only as learners but also as cultural interpreters. In interviews, several shared how these discussions helped them realize that Indigenous knowledge is science in practice, not just belief or tradition. One student said:

> *"I used to think the Baduy avoid chemicals only for religious reasons, but now I see it's also because they understand how the soil and rivers work."*

This reflects the coding under Indigenous_Knowledge_in_Science, where students expressed epistemic respect for local knowledge systems. The integration of cultural narratives allowed students to make conceptual connections between traditional environmental practices and formal scientific principles such as nutrient cycling, erosion control, and biodiversity protection. Rather than presenting Indigenous knowledge as "lesser" or anecdotal, the pedagogy positioned it as legitimate knowledge—complementary to modern science, not contradictory.

One of the most impactful moments occurred during a collaborative session when a Baduy community member joined the class as a guest speaker. This supported the code Community_Validation. The students were encouraged to ask questions directly, and the elder explained traditional forest boundaries (leuweung kolot) and water conservation rituals (hajat cai). The presence of a cultural authority figure helped validate students' interpretations and added depth to their understanding. It also shifted the teacher's role from knowledge transmitter to cultural mediator—facilitating a dialogue between systems of knowledge.

This dialogic process challenged the binary often found in science classrooms between "modern" and "traditional" knowledge. Instead, students began to navigate across cultural borders—a process described by Aikenhead & Michell (2018) as cultural border crossing. They were not forced to choose between two systems but were invited to explore how each informs the other. This pedagogical shift—coded under Science_Through_Tradition—encouraged students to reconstruct scientific meaning through culturally anchored experiences.

Furthermore, this instructional model contributed to more than just cognitive gains. It had significant impacts on identity formation and cultural affirmation, especially among students who share cultural or geographic proximity with the Baduy community. Rather than viewing science as detached or foreign, students began to see themselves and their heritage reflected in the curriculum. This aligns with broader literature on multicultural science education, which emphasizes that culturally relevant pedagogy can support both learning outcomes and community empowerment (Tan & Caleon, 2022; Rahmawati et al., 2021).

In conclusion, by employing Baduy ecological knowledge as a pedagogical core, this study illustrates how science learning can become inclusive, ethical, and place-based. The findings suggest that when students are empowered to learn science through the lens of their own culture, they not only understand better—they also value more deeply both science and the wisdom of their ancestors.

4.4. Discussion

The findings of this study underscore the transformative potential of integrating local Indigenous knowledge—specifically Baduy ecological wisdom—into science education through a deep learning approach. By contextualizing scientific concepts within culturally relevant experiences, the instructional process bridged abstract academic content with students' lived realities, enhancing both engagement and conceptual understanding.

First, the study confirms that cultural contextualization enhances science literacy by grounding abstract ideas in students' socio-ecological environments. The Baduy community's pikukuh philosophy, which emphasizes harmony with nature and sustainable living, served as an authentic entry point for students to explore core scientific topics such as ecosystems, conservation, and agriculture. This reflects existing findings from Bang and Marin (2019) and Carter et al. (2020), who argue that culturally situated pedagogy strengthens students' science comprehension and connection to content. Through the meaningful application of local practices—such as chemical-free farming, crop rotation, and forest conservation—students were able to visualize and internalize key ecological principles (Nasir et al., 2022; Nugraha & Hidayati, 2023).

Second, the integration of deep learning dimensions—particularly critical thinking, collaboration, and reflection—was evident throughout the instructional process. As proposed by Fullan et al. (2018), deep learning enables students to go beyond content retention toward developing skills that are transferable, ethical, and adaptive. Student reflections and concept maps demonstrated higher-order thinking, as learners connected cultural practices to scientific reasoning, questioned ecological outcomes, and imagined alternative futures. Their engagement aligns with Scott (2022), who asserts that deep learning fosters systems thinking and real-world application, especially when rooted in community knowledge.

Moreover, the use of Indigenous knowledge as a pedagogical tool shifted the classroom paradigm. Rather than treating traditional knowledge as peripheral or anecdotal, it was employed as a primary lens for inquiry. This echoes Snively and Williams (2022), who advocate for "two-eyed seeing"—a framework that respects both Indigenous and Western epistemologies in science education. Students in this study navigated what Aikenhead and Michell (2018) term "cultural border crossing", moving fluidly between cultural and scientific domains and perceiving them as complementary, not contradictory.

The inclusion of a Baduy elder during one session further reinforced socially mediated learning, consistent with Vygotsky's theory that knowledge construction is enhanced through interaction with more knowledgeable others (Vygotsky, 1978; Lee, 2020). The elder's validation of cultural interpretations provided not only affective resonance but also epistemic legitimacy, helping students see science as something already alive in their communities.

Despite the positive outcomes, the study also highlights challenges in replicating this model broadly. Current Indonesian curricula offer limited guidance for integrating Indigenous knowledge into formal science education. Teachers often lack exposure to or training in culturally responsive pedagogy, and institutional constraints can inhibit innovation (Rahmawati et al., 2021; Tan & Caleon, 2022). Therefore, professional development programs and policy frameworks must be developed to support educators in embracing local knowledge systems.

In sum, this discussion affirms that deep learning anchored in Indigenous cultural knowledge offers a powerful, equity-oriented strategy for transforming science education in multicultural contexts. It promotes scientific literacy, cultural affirmation, and ecological consciousness simultaneously. Future research may explore longitudinal impacts, test implementation models across other Indigenous communities, and develop cross-curricular integrations that reinforce science as both global and local knowledge.

5. CONCLUSION

This study concludes that integrating Baduy local knowledge into science education using a deep learning approach significantly enhances students' science literacy, cultural awareness, and engagement. The use of culturally rooted concepts—such as the pikukuh philosophy, chemical-free farming, and forest preservation—helped contextualize abstract scientific content and made it more tangible and meaningful for students.

By drawing on local ecological wisdom, the teaching process facilitated students' ability to connect scientific principles with everyday cultural practices. The findings revealed increased student participation, critical questioning, and reflective thinking. Students not only gained a better understanding of ecosystems, sustainability, and biodiversity, but also demonstrated a deeper sense of ethical responsibility toward environmental conservation.

The study also highlighted the role of cultural narratives as effective pedagogical tools. The involvement of a Baduy community member provided validation and social mediation, allowing students to actively negotiate meaning between traditional and scientific knowledge systems. This process supported both cognitive development and cultural identity formation, especially for students living near or within Indigenous communities.

Overall, this research confirms that deep learning anchored in local cultural contexts can transform the science classroom into a space of inclusive, place-based, and reflective learning. It emphasizes the importance of recognizing Indigenous knowledge not as supplementary, but as essential to promoting holistic, meaningful, and sustainable science education. The approach demonstrated in this study may serve as a model for integrating culture and curriculum in other culturally diverse regions across Indonesia and beyond.

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