# Integrating South Sumatra's Local Wisdom into Ethno-STEM Based Differentiated Learning on Global Warming: A Preliminary Study to Improve Critical Thinking and Environmental Literacy among Class X Students

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**Abstract.** Global warming education in Indonesian secondary schools often remains abstract and disconnected from students' lived realities, limiting critical thinking and environmental literacy development. This preliminary study addresses this gap by proposing an Ethno-STEM-based differentiated learning module integrating South Sumatran local wisdom; such as Rumah Limas architecture, Songket weaving, and lebung farming, as contextual anchors for climate science. Conducted at SMA Negeri 1 Palembang (March–April 2025), the study employed classroom observation using 30-second time-sampling intervals, semi-structured teacher interviews, and curriculum document analysis involving 32 Grade X students and two science teachers. Findings reveal highly teacher-dominated instruction (92% teacher talk), minimal cultural relevance, and limited student ability to connect global warming to local issues like peatland deforestation or Musi River emissions. Guided by Plomp's [15] educational design research model, we propose a three-phase conceptual framework; cultural contextualization, scientific exploration, and environmental action, that integrates differentiated instruction, Ethno-STEM principles, and SDGs 4 and 13 to support inclusive, culturally responsive, and scientifically rigorous climate education.

**Keywords:** Ethno-STEM, differentiated instruction, global warming, environmental literacy, critical thinking, South Sumatra local wisdom, SDGs.

## 1 Introduction

Climate change, particularly global warming, is one of the most significant existential threats of the 21st century. UNESCO emphasizes that climate education must be a central pillar in

SICBAS 2025, November 06, Palembang, Indonesia

DOI 10.4108/eai.6-11-2025.2364461

achieving the Sustainable Development Goals (SDGs), especially SDG 13 (Climate Action) and SDG 4 (Quality Education) [1] Climate change education aims to help populations understand and respond to climate challenges in relevant and effective ways, while empowering individuals to take part in mitigation and adaptation efforts [2].

In Indonesia, global warming content has been incorporated into the Merdeka Curriculum through topics such as the greenhouse effect, carbon emissions, and human impacts on the environment. However, implementation in classrooms often remains textual and non-contextual [3], reducing students' ability to relate global concepts to local environmental realities. Research in Javanese and Sumatran schools shows that rote-based, decontextualized science instruction inhibits affective engagement, critical thinking, and collaboration; whereas contextual and participatory approaches significantly increase creativity and environmental literacy [4].

At SMA Negeri 1 Palembang, preliminary observations indicate that global warming instruction relies heavily on lectures and textbooks, without accounting for students' cultural backgrounds or learning diversity. Consequently, student motivation is low, and few can connect global warming to local phenomena such as peatland fires, river transport emissions, or shifting rainfall patterns affecting lebung farming. Yet, South Sumatra possesses rich local wisdom that has historically addressed climate-related challenges. For instance, the lebung farming system demonstrates ecosystem-based adaptation to hydrological variability [4], and studies confirm that non-permanently flooded wetland agriculture can reduce $CO_2$ and methane emissions by avoiding anaerobic conditions that trigger methanogenesis [5]. Similarly, the cross-ventilation design of Rumah Limas has been shown to lower indoor operative temperature by up to 3.9°C [6].

The Ethno-STEM (Ethno-Science, Technology, Engineering, and Mathematics) approach offers a promising solution by integrating indigenous knowledge into science education [7], thereby enriching conceptual understanding and establishing cultural relevance [8]. When combined with Tomlinson's [9] differentiated instruction approach, this approach enables teachers to tailor learning experiences to students' readiness, interests, and learning profiles. Such integration aligns with SDG 4 by promoting inclusive, quality, and locally rooted education for sustainability [8,10].

This study is a preliminary phase in developing an Ethno-STEM-based differentiated learning module on global warming for Class X students. Its objectives are: (1) to identify gaps in current global warming instruction at SMA Negeri 1 Palembang, (2) to explore the potential of South Sumatran local wisdom relevant to climate issues, and (3) to design a conceptual framework for an innovative learning module that integrates Ethno-STEM, differentiated instruction, and the SDGs.

## 2 Theoretical framework

### 2.1 Differentiated instruction in science education

Tomlinson [9] defines differentiated instruction as an approach that tailors content, processes, products, and learning environments to individual student needs. In science education, this allows learners from diverse backgrounds to access the same concepts through pathways aligned with their cognitive styles. Meta-analyses confirm that process and product differentiation significantly improve science learning outcomes (ES = 0.49), especially among heterogeneous learners [11]. For example, visual learners might analyze historical temperature trends in Palembang, while kinesthetic learners simulate the greenhouse effect using recycled materials.

Effective differentiation requires ongoing assessment of students' readiness, interests, and learning profiles. In global warming education, this means recognizing that some students may already grasp climate science through media exposure, while others need foundational support. Cultural contexts also shape environmental perspectives: urban students may focus on air pollution, whereas rural peers may prioritize agricultural impacts. By building on these varied starting points, differentiated instruction fosters more equitable and meaningful learning.

**Ethno-STEM: bridging culture and science**

Ethno-STEM acknowledges that scientific knowledge emerges not only from Western laboratories but also from empirical, systematic local practices [7]. In South Sumatra:

1. Rumah Limas architecture uses elevated floors, steep roofs, and open cross-vents to reduce heat via convection and thermal radiation.
2. Songket weaving employs natural dyes from plants like teak leaves, reflecting principles of organic chemistry and sustainable resource use.
3. Lebung farming utilizes tidal cycles for irrigation, demonstrating deep understanding of carbon and water cycles in wetland ecosystems.

Integrating such practices validates indigenous knowledge, enhances science relevance, and empowers students by showing that scientific reasoning is embedded in their cultural heritage. This culturally responsive pedagogy strengthens both cognitive understanding and affective engagement.

### 2.3 Environmental literacy and critical thinking

Environmental literacy encompasses the knowledge, skills, and attitudes needed to understand and act responsibly on environmental issues [12]. Critical thinking in science involves analyzing data, evaluating claims, and proposing evidence-based solutions [13]. Both are essential 21st-century competencies and core to achieving SDG 13.

In global warming education, these skills develop through inquiry into authentic local problems; such as peatland degradation or transport emissions, rather than passive reception of abstract facts. Contextualized inquiry enables students to distinguish credible evidence from misinformation and evaluate the equity and efficacy of climate actions.

### 2.4 Alignment with the sustainable development goals

SDG 4 calls for inclusive, equitable, quality education that includes education for sustainable development [14]. SDG 13 emphasizes building climate resilience and public awareness. The proposed Ethno-STEM differentiated approach directly supports both goals by making climate education culturally grounded, scientifically rigorous, and action-oriented. It positions students not as passive recipients but as active agents capable of contributing to community-level climate solutions.

## 3 Research methodology

This qualitative descriptive study follows Plomp's [15] educational design research model, specifically the preliminary investigation phase. The research was conducted at SMA Negeri 1 Palembang from March to April 2025, involving 32 Grade X students and two science teachers.

Data collection included:

1. Participatory classroom observations across three 45-minute lessons on global warming, using systematic 30-second time-sampling to record speaker identity (teacher or student). Across 270 total intervals, teacher talk occurred in 248 intervals, yielding approximately 92% teacher-dominated discourse;
2. Semi-structured interviews with both science teachers to explore their pedagogical beliefs, familiarity with local wisdom, and perceived barriers to innovation;
3. Document analysis of curriculum materials, including the Merdeka Curriculum guidelines and instructional modules used in class; and
4. A brief open-ended worksheet administered to all students immediately after observed lessons to assess their ability to connect global warming to local environmental issues in South Sumatra.

Data were analyzed through thematic coding, with triangulation across observation, interview, and document data to ensure credibility and depth in identifying gaps in current practice, student needs, and opportunities for integrating local wisdom into climate education.

## 4 Findings and discussion

### 4.1 Current state of global warming instruction

Instruction was predominantly teacher-centered: 92% of class discourse was teacher-led (based on timed observational sampling across three 45-minute sessions). Students were passive; only 2 of 32 could link global warming to local contexts (e.g., Palembang floods). Teachers acknowledged limited training in differentiated instruction, lack of contextual materials, and uncertainty about integrating culture without compromising scientific rigor.

### 4.2 Contextual gaps and student misconceptions

Over 80% of students failed to recognize that peatland deforestation, a major issue in South Sumatra, contributes significantly to $CO_2$ emissions. Similarly, emissions from Musi River vessels were not perceived as climate-relevant. No student connected Rumah Limas or lebung farming to climate adaptation, missing opportunities to link heritage with science.

### 4.3 Student diversity and need for differentiation

Teachers estimated that 45% of students are visual learners, 30% auditory, and 25% kinesthetic. Yet, instruction used a single (lecture-based) modality. Readiness levels also varied widely, from students following climate news to those struggling with basic molecular concepts. This heterogeneity underscores the need for differentiated pathways.

### 4.4 The potential of local wisdom for climate education

Although local wisdom was largely absent in current classroom practices, our analysis of curriculum documents, teacher interviews, and regional environmental reports revealed rich, underutilized opportunities to integrate South Sumatran cultural practices into global warming education. Teachers acknowledged the cultural significance of traditions such as Rumah Limas, Songket weaving, and lebung farming, and expressed openness to exploring their scientific dimensions, if supported with appropriate pedagogical guidance and materials. These cultural elements not only align with climate science concepts but also resonate with students' lived experiences, offering authentic entry points for inquiry-based learning.

The architecture of Rumah Limas provides an excellent concrete example to teach the principles of heat transfer and ventilation. Its elevated floor design minimizes soil heat absorption, its steep-pitched roof facilitates rapid heat escape through convection, and the absence of walls at lower levels creates cross-vents that enhance cooling. Students can analyze how these design features reduce thermal stress without modern air conditioning, linking traditional wisdom with contemporary discussions about energy-efficient building design as a climate mitigation strategy.

The songket weaving tradition offers an opportunity to explore sustainable practices and biogeochemical cycles. Natural dyes of plant origin involve complex organic chemistry, and their use avoids the water pollution and carbon emissions associated with synthetic textile dyes. Students can investigate which local plants give which color, the chemical basis of dye fixation, and how traditional artisans developed empirical knowledge of this process. It connects the broader context of global warming sustainability while respecting crafts that are mostly practiced by women, potentially increasing female students' engagement with STEM.

The lebung farming system represents a sophisticated understanding of wetland ecology and climate adaptation. This practice involves cultivating rice in swampy areas that are naturally flooded during periods of high water, working with hydrological cycles rather than against them. Students can investigate how these systems manage carbon sequestration in wetlands, how they reduce methane emissions compared to permanently inundated rice fields, and how changes in rainfall patterns caused by climate change are challenging these traditional systems. This example makes a real and immediate climate impact while showing that adaptation strategies don't need to be high-tech but can be built on ecological knowledge from generation to generation.

## 5 Conceptual framework for module design

The proposed module has three phases:

1. **Cultural contextualization:** Students explore local wisdom (e.g., interview elders about Rumah Limas). Activities are differentiated by learning profile (e.g., models for kinesthetic learners, essays for linguistic learners).
2. **Scientific exploration:** Students investigate local climate issues (e.g., peatland emissions) with tiered tasks based on readiness (basic identification to data analysis to policy proposal).

3. **Environmental reflection and action:** Students create advocacy products (posters, videos, op-eds) aligned with their strengths, fostering civic engagement.

Assessment is multimodal: portfolios, performance tasks, self-reflections, and concept maps, ensuring all learners can demonstrate understanding.

## 6 Implications for SDGs and science education

The proposed Ethno-STEM-based differentiated approach offers significant implications for advancing global sustainability through education. Regarding SDG 4 (Quality Education), it operationalizes inclusivity by accommodating diverse learning profiles and validating local knowledge systems within science curricula. It exemplifies quality education by merging rigorous scientific content with culturally meaningful contexts, thereby enhancing relevance and engagement. For SDG 13 (Climate Action), the approach fosters climate literacy not as abstract knowledge but as actionable understanding rooted in students' lived environments. By linking peatland conservation, traditional architecture, and sustainable agriculture to climate science, it positions learners as informed participants in local climate resilience.

Beyond South Sumatra, this model is adaptable to other Indonesian contexts: Bali's subak irrigation system, Kalimantan's Dayak forest management, or Papua's agrobiodiversity could similarly anchor Ethno-STEM modules. Successful scaling requires systemic support: teacher training in "bicultural scientific literacy," curriculum policies that encourage localization, and assessment frameworks that value multimodal understanding over standardized recall.

## 7 Conclusion

This preliminary study identifies critical gaps in global warming instruction at SMA Negeri 1 Palembang; namely, teacher-centered pedagogy, lack of cultural relevance, and unmet student diversity, and proposes a responsive Ethno-STEM differentiated framework grounded in local wisdom. While findings are context-specific and not generalizable, they provide a robust foundation for design-based development.

Next steps include: (1) developing a full prototype module with detailed lesson plans and materials; (2) validating it with experts in science education, local culture, and environmental science; and (3) piloting it via quasi-experimental design to measure impacts on critical thinking (using Ennis' rubrics [16]) and environmental literacy (adapted from McBeth and Volk [17]). If effective, this model could be scaled across South Sumatra and adapted nationally, contributing to a vision of science education that is both globally informed and locally rooted.

**Acknowledgments.** The authors express sincere gratitude to: (1) Mr. H. Moses Ahmad, S.Pd., M.M., Principal of SMA Negeri 1 Palembang, for institutional support, (2) Mr. H. Andri Yanto, S.Pd., M.Pd., and Mrs. Hj. Ellyda Hizrawati, M.Si., for their openness and insights, (3) All Class X students for their honest participation, (4) Academic supervisors for theoretical and methodological guidance, and (5) The Peat and Mangrove Restoration Agency (BRGM) of South Sumatra for emission data and technical literature. This work is part of a collective effort to build fair, sustainable, and culturally rooted science education in Indonesia.

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