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ANALYZING THE ETHNO-ESD MODULE DEVELOPMENT FOR CRITICAL THINKING IN ELEMENTARY STUDENTS

Gina Tuty Alawiyah, Ghullam Hamdu
Program Studi Pascasarjana Pendidikan Guru Sekolah Dasar, Universitas Pendidikan Indonesia Kampus Tasikmalaya, Tasikmalaya
E-mail: ghullamh2012@upi.edu

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Abstract

This research was motivated by the gap between the demands for strengthening critical thinking and sustainability principles and the practice of science education in elementary schools, which has not been systematically integrated with local culture. Although the potential of ethnoscience and Education for Sustainable Development (ESD) values is considerable, learning modules that explicitly combine local culture, sustainability, and critical thinking indicators in a coherent pedagogical framework are still limited. This study aims to analyze the development of an Ethno-ESD module as a basis for designing teaching tools that support the strengthening of critical thinking in elementary school students. The research uses a qualitative approach with a needs analysis design through observation, interviews, and documentation studies. The data sources come from teachers and fourth-grade students at SDN 4 Sumelap and science learning tool documents. The results show that the integration of local cultural values and ESD in learning is still implicit and not yet structured in terms of objectives, activities, and assessments, so that critical thinking indicators have not developed optimally. This study recommends the development of an Ethno-ESD module that is systematically designed to include the context of local ethnoscience, the explicit integration of sustainability values, and activities and assessments based on critical thinking indicators. This study has an impact on strengthening science learning design that is more contextual, reflective, and sustainability-oriented, as well as providing a conceptual contribution to the integration of ethnoscience, ESD, and critical thinking development at the elementary school level.

Keywords: Critical Thinking, Elementary School, Ethno-ESD, Ethnoscience, Science Education.

INTRODUCTION

Strengthening critical thinking skills is a fundamental requirement in 21st-century education, especially in science learning. Critical thinking enables students to interpret information, analyze cause-and-effect relationships, evaluate arguments, and formulate evidence-based conclusions. UNESCO (2020), Fermanian (2025) and Popa (2024) emphasizes that education must develop systemic and reflective thinking competencies as part of the implementation of Education for Sustainable Development (ESD). Furthermore, the OECD (2019) and Juuti et al., (2021) place critical thinking as a key competency in building science literacy and readiness to face the complexity of global issues, including sustainability issues. However, various studies show that in the practice of science learning in elementary schools, students' critical thinking skills are still not optimally developed. Learning tends to be oriented towards conceptual understanding and procedural activities, while indicators of analysis, evaluation, and argumentation have not been systematically designed in teaching tools (Blegur et al., 2023; Gómiz-Aragón et al., 2025; Marthaliakirana et al., 2022; Wan et al., 2024).

However, Indonesia has a wealth of local culture that has the potential to become a source of contextual learning in science education. The ethnoscience approach places local knowledge as an epistemological bridge to understand scientific concepts in a more meaningful way (Setiyadi, 2025; Koirala, 2023). Cultural practices such as traditional food fermentation, for example, contain concepts of changes in the properties of objects and microorganism activities that are relevant to elementary school science material. In addition, these practices also contain dimensions of sustainability in economic, social, and environmental aspects that are in line with ESD principles (Anggraeni & Yanti, 2024). However, various studies reveal that the integration of local culture in learning is still incidental and has not been incorporated into pedagogically structured modules (Arjaya dkk., 2024; Gondwe

& Longnecker, 2015). Similarly, the implementation of ESD in elementary schools often appears implicitly in learning activities, but has not been explicitly formulated in objectives, indicators, and assessments (Arjaya et al., 2024; Leicht & Heiss, 2018). Based on this, an in-depth analysis of empirical needs, conceptual structures, and pedagogical components is required in the development of the Ethno-ESD module as the basis for designing integrative and systematic teaching tools. This analysis is important to comprehensively identify how local culture and sustainability values can be explicitly formulated in learning objectives, activities, and assessments oriented towards critical thinking indicators. Thus, this study focuses on analyzing the development of the Ethno-ESD module, which structurally integrates local culture and sustainability principles into science learning to strengthen the critical thinking skills of elementary school students.

This research is important because it provides conceptual and practical contributions. Theoretically, this research strengthens the integrative framework between ethnoscience, ESD, and critical thinking theory in the context of basic education, which has tended to be studied separately. Methodologically, this research produces a comprehensive analysis as a basis for developing modules based on real needs in the field. Practically, the results of this research are expected to serve as a reference for teachers and curriculum developers in designing contextual science learning modules that are sustainability-oriented and capable of stimulating students' critical thinking skills in a systematic and measurable manner. Thus, this research not only addresses implementation gaps but also contributes to strengthening the quality of science learning in elementary schools.

LITERATURE REVIEW

Science education in elementary schools plays an important role in developing critical thinking skills and building students' awareness of sustainability issues. However, various studies show that the science learning process in elementary schools still tends to emphasize cognitive mastery of concepts and does not provide enough opportunities for students to develop higher-order thinking skills such as analysis, evaluation, and scientific reasoning. Research on the development of critical thinking instruments in science education shows that these skills include several important indicators, such as providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and designing problem-solving strategies (Resti, 2025). This condition shows that science learning needs to be designed in a more contextual and challenging manner in order to stimulate students' critical thinking processes from elementary school onwards.

One of the approaches that has been developed in science education is Education for Sustainable Development (ESD). ESD emphasizes the importance of developing knowledge, attitudes, and skills that enable students to understand the interrelationships between environmental, social, and economic aspects in everyday life. In the context of science learning, ESD focuses not only on conceptual understanding but also on the ability to think systemically, think anticipatively, and think critically in facing sustainability issues. Research shows that integrating ESD into learning can increase sustainability awareness and strengthen students' critical thinking skills in understanding environmental and social issues more comprehensively (Fathurohman et al., 2023; Habibaturrohmah et al., 2023). In addition, the development of ESD competencies also requires the integration of various interrelated thinking skills, where critical thinking skills are an important foundation in building other sustainability competencies (Husamah et al., 2022; Novita et al., 2025; Nuwangi et al., 2024).

Apart from the sustainability approach, the integration of ethnoscience in science learning has also become a focus in science education research. Ethnoscience refers to the utilization of local knowledge and cultural wisdom as learning resources that can help students understand scientific concepts in a more contextual manner. Recent literature research shows that the ethnoscience approach can improve science literacy, 21st-century skills, and the connection between scientific concepts and students' daily experiences (Lestari & Zulirfan, 2024; Primadianningsih et al., 2023; Suwandi et al., 2025). In the context of primary education, ethnoscience-based science learning has also been proven to foster environmental awareness and integrate local cultural values into learning activities (Adelia, 2025; Yasir, 2024). This shows that the use of local knowledge can enrich students' learning experiences while strengthening the relevance of learning to real life.

A number of studies also show that the integration of ethnoscience in science learning can improve students' science literacy and conceptual understanding. For example, research on ethnoscience-based learning with a problem-based learning approach shows an increase in elementary school students' science literacy skills because students can relate scientific concepts to cultural and environmental practices around them (Rohmawati & Wulandari, 2023). In addition, the development of science-environment-technology-society (SETS) based modules or teaching materials has also been proven to improve students' critical thinking skills through contextual and real-world problem-based learning activities (Rini et al., 2020). These findings show that the use of real-life contexts and local

culture can strengthen the learning process and make it more meaningful. However, several literature reviews indicate that research related to the integration of ethnoscience in science education still focuses on the development of specific teaching materials or learning tools and has not yet fully integrated the dimension of sustainability in a systematic manner. A literature review of trends in ethnoscience research in science education for the period 2020–2025 shows that most studies focus on the development of teaching materials based on local wisdom, but their integration with the framework of sustainability education is still limited (Nugroho & Septianisha, 2025; Nuralita et al., 2025; Pilobu et al., 2025). In addition, there is still relatively little research that specifically links ethnoscience with the development of critical thinking skills within the ESD framework.

On the other hand, there is also debate in the literature about how local knowledge should be integrated into formal science education. Some researchers argue that the integration of local knowledge is important to increase the relevance of learning and enrich students' scientific perspectives, while others emphasize the need for a balance between modern scientific knowledge and local knowledge so that misconceptions in science learning do not occur. Therefore, a pedagogical approach is needed that is able to bridge scientific concepts and cultural knowledge in a systematic and structured manner. Based on this literature review, it can be concluded that there is still a research gap in the development of science learning tools that integrate ethnoscience, the principles of Education for Sustainable Development (ESD), and the development of critical thinking skills in elementary school students. Therefore, this study aims to develop an Ethno-ESD learning module that combines the local cultural context with sustainability values and is designed to stimulate students' critical thinking skills. This research is expected to provide theoretical contributions to the development of culture- and sustainability-based science learning models and practical contributions to teachers in designing learning that is more contextual, reflective, and relevant to the challenges of sustainability in the future.

METHOD

This study uses a qualitative approach with grounded theory in the initial analysis stage of module development. This approach was chosen because the study aims to map empirical needs, identify gaps in learning implementation, and build a conceptual basis for the development of the Ethno-ESD module inductively from field data. Grounded theory allows researchers to construct conceptual categories through a systematic process of open coding, axial coding, and selective coding (Charmaz & Thornberg, 2021; Creswell, 2019). The research was conducted at SDN 4 Sumelap, Tasikmalaya City, which was selected based on the results of a pre-assessment in the form of initial observations of science learning, exploratory interviews with teachers, and a review of teaching tools. The pre-assessment results showed that the school had integrated local culture, including the practice of peuyeum fermentation, into project-based science learning, but this integration was still contextual and not yet structured into a systematic module. In addition, sustainability values such as cooperation, simple entrepreneurship, and environmental awareness had emerged in classroom practices but had not been explicitly formulated in learning objectives and assessments. These unique characteristics and potential made SDN 4 Sumelap a relevant research location as it reflected the gap between contextual practices and the need for Ethno-ESD-based pedagogical design.

The research subjects consisted of classroom teachers or science teachers and elementary school students involved in science learning, while the research objects were local culture-based science learning practices and the teaching tools used. The types of data collected were qualitative data sourced from learning observations, in-depth interviews, and document analysis (modules, lesson plans, student worksheets, and curriculum documents). The research stage began with a literature study to formulate a conceptual framework of ethnoscience, Education for Sustainable Development (ESD), and critical thinking (Mulà et al., 2022; Redman & Wiek, 2021; Sposab & Rieckmann, 2024; Unesco, 2020), followed by a pre-assessment to map the initial needs at the research site. Data collection was conducted through participatory observation with guidelines based on indicators of local cultural integration, sustainability values (economic, social, environmental), and critical thinking indicators that included interpretation, analysis, inference, evaluation, and explanation (Facione, 2020). Semi-structured interviews were used to explore teachers' perceptions regarding the implementation of learning and the obstacles encountered, while document analysis was conducted to assess the suitability of teaching tools with the principles of Ethno-ESD.

Data validity is maintained through source triangulation (teachers and students), technique triangulation (observation, interviews, and documentation), member checking, and peer debriefing to ensure the credibility and consistency of interpretations (Ali & Asrori, 2022; Anggito & Setiawan, 2018). Data analysis was conducted simultaneously and iteratively since the data collection process began, starting with open coding to identify initial categories, followed by axial coding to connect categories and subcategories, and selective coding to formulate core categories as the conceptual basis for module development. The results of the analysis show that the integration of

local culture is still at the stage of surface contextualization, sustainability values appear implicitly, and the strengthening of critical thinking is not yet supported by systematic scaffolding. These findings form the analytical basis for designing an Ethno-ESD module that integrates local culture, sustainability principles, and critical thinking indicators explicitly and structurally as a further stage of research.

RESULTS AND DISCUSSION

Data analysis in this study used the Grounded Theory approach developed by Strauss and Corbin (1998) through the stages of open coding, axial coding, and selective coding. The results of the analysis showed a relational pattern between science learning practices in elementary schools, the integration of local culture, sustainability values, and the development of students' critical thinking skills.

The Contextual Potential of Integrating Local Culture into Science Education That Hasn't Been Systematically Structured

Based on the results of the preliminary study, it appears that teachers have attempted to connect science learning with the context of students' daily lives by using examples drawn from local culture, such as traditional foods like Peuyeum to illustrate the concept of changes in the properties of objects. This practice indicates that teachers have begun to recognize the importance of contextual learning, where scientific concepts are linked to students' real-life experiences. In the perspective of contextual and constructivist learning, students tend to understand scientific concepts more effectively when these concepts are connected to familiar phenomena in their environment. As explained by Gert Biesta, meaningful learning occurs when educational experiences are related to "the real contexts in which learners live and interact" (Biesta, 2021). In line with this view, recent studies also emphasize that contextualizing science learning through cultural experiences can increase students' engagement and conceptual understanding because students are able to interpret scientific phenomena through familiar cultural practices (Wazni et al., 2023; Yuliana et al., 2021).

However, the findings of this study reveal that the integration of cultural elements in science learning remains incidental and has not been systematically designed within teaching tools. Teachers tend to use cultural examples only as additional illustrations rather than as conceptual entry points for inquiry-based learning. As a result, local culture has not yet been positioned as an epistemological source that structures students' scientific reasoning. According to Greenall and Bailey (2022), "the integration of cultural knowledge in science education often remains superficial when it is not supported by clear pedagogical strategies and structured instructional design." This statement reinforces the argument that the presence of cultural examples alone is insufficient unless they are integrated into the entire learning process, including conceptual exploration, investigation activities, and assessment.

From the perspective of ethnoscience, local cultural practices can serve as an epistemic bridge connecting indigenous knowledge and modern scientific concepts. Ethnoscience emphasizes that knowledge embedded in traditional cultural practices contains empirical observations and logical reasoning developed through long-term interactions between communities and their environment. Gregory Cajete explains that "Indigenous knowledge systems are based on centuries of observation, experimentation, and reflection about the natural world" (Charles & Cajete, 2020). This statement highlights that traditional knowledge systems are not merely cultural traditions but represent structured ways of understanding natural phenomena. Supporting this perspective, Parmin et al., (2022) argue that ethnoscience-based learning can function as a bridge that connects students' cultural knowledge with formal scientific concepts, enabling students to construct scientific understanding through culturally relevant experiences. Similarly, Tovar-Gálvez (2021) notes that ethnoscience learning facilitates a dialogue between local knowledge and modern science, which contributes to the development of scientific literacy.

In the context of this study, the fermentation process in Peuyeum illustrates how local cultural practices contain scientific concepts that can be explored through scientific investigation. Although traditionally understood as a culinary practice passed down through generations, the fermentation process involves complex biological and chemical mechanisms. Microorganisms such as yeast convert carbohydrates in cassava into simpler compounds, producing alcohol and organic acids that cause observable changes in taste, texture, and aroma. These transformations provide a concrete example of chemical changes in matter. In the field of science education, fermentation has long been recognized as a meaningful phenomenon for illustrating microbiological processes. As noted by Harold J. Morowitz, "fermentation represents one of the most accessible biochemical processes through which students can observe microbial metabolism in everyday life." In addition, recent research confirms that integrating traditional fermentation practices into science learning can significantly strengthen students' conceptual understanding because students can observe scientific processes in contexts that are familiar in their daily lives

(Nugraha, 2024; Sihombing et al., 2025; Sudirman et al., 2025). Despite this strong potential, the findings indicate that the integration of local cultural knowledge into science learning is still limited due to the absence of systematic pedagogical planning. Cultural contexts are rarely integrated into the full cycle of scientific learning activities, such as problem formulation, hypothesis development, investigation, and reflection. Consequently, cultural integration often stops at the level of contextual examples rather than becoming part of the conceptual structure of learning. This finding is consistent with research by Kim et al., (2017), who argue that cultural contexts are frequently used only as illustrations in science lessons rather than as foundations for conceptual exploration. More recent studies also highlight similar challenges. For example, Sari et al., (2021) report that many teachers recognize the importance of local wisdom in science education but face difficulties in translating cultural practices into structured learning activities due to limited pedagogical resources.

Another important factor contributing to this gap is the lack of instructional tools that support the implementation of ethnoscience-based learning. Teachers may be aware of the educational value of local culture, but they often encounter difficulties when attempting to transform cultural phenomena into lesson plans, learning modules, or assessment instruments. Sarkingobir and Bello (2024) emphasize that "the successful integration of indigenous knowledge into science education requires not only teacher awareness but also pedagogical frameworks and learning resources that systematically guide the teaching process." Likewise, Nuralita (2020) explains that without appropriate instructional materials, cultural knowledge tends to remain descriptive and narrative rather than becoming a basis for analytical scientific learning.

Therefore, the findings of this study reveal a clear gap between the rich potential of ethnoscience as a contextual learning resource and its partial implementation in elementary science learning practices. On the one hand, cultural practices such as the fermentation process in Peuyeum provide authentic contexts that can help students understand scientific concepts through meaningful experiences rooted in their cultural environment. On the other hand, the absence of structured pedagogical frameworks limits the role of culture to superficial contextualization. In culturally responsive education, students' cultural backgrounds should serve as foundations for knowledge construction. As emphasized by Gloria Ladson-Billings, culturally responsive teaching requires that "students' cultural knowledge, prior experiences, and frames of reference are used to make learning more relevant and effective" (Ladson-Billings, 2021). Consequently, these findings highlight the importance of developing ethnoscience-based learning models and teaching tools that systematically integrate local culture into science instruction so that science learning becomes more meaningful, contextual, and culturally responsive

Transforming Science Education from Implicit Practice to Explicit and Reflective Design by Including Education for Sustainable Development (ESD) Values

The results of axial coding analysis show that sustainability values are actually present in science learning practices, even though they have not been consciously and systematically designed as part of the Education for Sustainable Development (ESD) framework. Activities such as market day represent the economic dimension through the introduction of product sales value, group work reflects the social dimension in the form of collaboration and shared responsibility, while waste management practices reflect the environmental dimension through efforts to maintain cleanliness and utilize waste. These findings indicate that learning has contained contextual elements of sustainability, but these are still at an implicit stage because they have not been explicitly formulated in learning objectives, achievement indicators, or assessments (Khosihan et al., 2024; Rieckmann, 2017; Tilbury, 2011; UNESCO, 2017).

Conceptually, ESD aims to develop systemic, reflective, and transformative thinking competencies that enable learners to understand the interrelationships between economic, social, and environmental aspects holistically (UNESCO, 2017; Azzahra et al., 2023; Dlouhá et al., 2019; Hung & Pan, 2025). Sustainability education is not enough to simply instill values normatively, but must be designed through learning experiences that encourage analysis of real problems, decision making, and critical reflection (Anggraeni, 2024; Sterling & Orr, 2001; Zsantana & Suwanda, 2023). Thus, sustainability needs to be presented as a cognitive and practical process, not just thematic content. According to the study's findings, peuyeum fermentation has significant sustainability aspects that are pertinent to the advancement of science education. Economically, peuyeum is a locally produced product with commercial value and entrepreneurial potential; socially, its production process exemplifies the community's practice of mutual cooperation; and environmentally, organic waste, like cassava peel, can be recycled, supporting waste reduction and the circular economy (Hirst, 2011; Unesco, 2020; Kemendikbudristek, 2022). This demonstrates how local culture can serve as a tangible means of concurrently incorporating the three sustainability pillars.

However, without a structured and explicit module framework, these values have not fully developed into students' reflective awareness. Students may be involved in simple economic activities or environmental hygiene practices, but they may not necessarily understand the systemic relationship between production, consumption, and ecological impacts as a whole. This condition confirms that the success of ESD implementation is largely determined by participatory, reflective, and integrated pedagogical design within the learning structure (Anggraeni, 2023). Therefore, this study emphasizes the importance of transforming implicit sustainability practices into explicit, reflective, and systematic learning designs through the development of locally-based Ethno-ESD modules.

Enhancing Critical Thinking as a Cognitive Process in Science Education Needing Structured and Methodical Scaffolding

Based on the results of interviews and documentation studies, it was identified that even though teachers had implemented Problem-Based Learning (PBL) and Project-Based Learning (PjBL) approaches, students' critical thinking skills had not developed optimally and evenly. Problem-based and project-based learning do encourage active student engagement, but without the design of explicit cognitive indicators, higher-order thinking processes do not always occur in depth. These findings indicate a gap between the learning strategies used and the expected cognitive outcomes, particularly in strengthening critical thinking skills (Crudele & Elisa Raffaghelli, 2023; Facione et al., 2021; Plummer et al., 2022; Seventika et al., 2018). Conceptually, critical thinking encompasses the abilities of interpretation, analysis, inference, evaluation, and explanation (Facione, 2011). These abilities do not develop automatically through contextual learning or practical activities alone, but require scaffolding in the form of analytical questions, reflective dialogue, and structured argument-based assessment. Crudele & Elisa Raffaghelli, (2023) emphasizes that critical thinking is a deliberate rational process (reasonable reflective thinking), so it needs to be systematically designed into each stage of learning. In the context of Indonesian education, Sapriya (2009), Allen et al., (2020), ATIKU et al., (2025), and Crudele & Elisa Raffaghelli, (2023) also emphasizes that the strengthening of critical thinking must be integrated into discussion activities, case analysis, and reason-based evaluation so that students do not merely receive information but are able to construct and defend arguments logically.

The results of this study indicate that local culture-based learning, such as exploring peuyeum fermentation, can increase student engagement because it is authentic and closely related to their lives. However, increased engagement does not always correlate directly with the depth of the cognitive process if the activity is not accompanied by questions that explicitly target critical thinking indicators (Alsaleh, 2020; Brookfield, 2020; Jr & Fair, 2020). In other words, an authentic context is an important prerequisite, but it is not the only factor in developing higher-order thinking skills. This finding is in line with Eun, (2019), Hoque (2020) and Lundgren (2023) social constructivism theory, which emphasizes the importance of structural support (scaffolding) in the zone of proximal development to help students achieve a higher level of understanding. Scaffolding in this context can take the form of provocative questions that require cause-and-effect analysis, reflective activities that connect scientific concepts with sustainability values, and assessments that ask students to justify their conclusions. This approach is also supported by (Paul & Elder, 2019), who emphasize the importance of elements of reasoning and intellectual standards in developing critical thinking skills.

Thus, the Ethno-ESD module developed in this study is designed not only to provide an authentic context in the form of peuyeum fermentation practices, but also to explicitly integrate sustainability values and present a series of questions and activities that systematically stimulate critical thinking indicators. This module organizes learning stages that guide students to interpret phenomena, analyze the process of changes in the properties of objects, draw data-based inferences, evaluate economic, social, and environmental impacts, and explain their observations argumentatively. With this approach, science learning not only becomes a contextual experience, but also a vehicle for the structured and continuous development of critical thinking skills (Jasper-Abowei & Victor-Ishikaku, 2023; Purwanto et al., 2022; Tari & Rosana, 2019).

CONCLUSION

This study shows that science education in elementary schools still faces a gap between the demand for critical thinking and the implementation of sustainability principles within the framework of Education for Sustainable Development (ESD). Although local culture has great potential as a source of relevant and contextual ethnoscience, its integration into learning is still partial and has not been systematically formulated into structured and measurable modules. Sustainability values tend to appear implicitly in learning activities, but have not been explicitly formulated in objectives, indicators, or assessments, so they have not optimally formed students' reflective awareness. In

addition, critical thinking indicators such as interpretation, analysis, evaluation, and argumentation have not been purposefully designed in teaching tools, so their development has been uneven and not based on a coherent conceptual framework. Therefore, the development of the Ethno-ESD module is a strategic necessity to integrate local culture, sustainability principles, and critical thinking indicators into a coherent, systematic, and contextual pedagogical framework, thereby strengthening science literacy and equipping elementary school students with critical thinking competencies relevant to facing future sustainability challenges.

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