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Advancing SDGs-oriented Science Learning through Ethno-STEAM-PjBL: An Integrative Review of Scientific Literacy and Environmental Attitudes

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Abstract: This integrative literature review examines how Ethno-STEAM integrated with Project-Based Learning (Ethno-STEAM-PjBL) supports scientific literacy and environmental attitudes in science education. Literature was collected from Google Scholar, SINTA-indexed journals, Scopus, and ERIC databases using keywords related to ethnoscience, Ethno-STEAM, Project-Based Learning, scientific literacy, environmental attitudes, and science education. Sixteen empirical studies published between 2017 and 2025 were selected based on predefined inclusion and exclusion criteria and analyzed using narrative thematic synthesis. The findings revealed four major themes. First, Ethno-STEAM-PjBL is characterized by authentic cultural contexts, interdisciplinary integration, project-based learning, and active student participation. Second, scientific literacy outcomes consistently improved, with reported N-gain values ranging from 0.20 to 0.71 and significant intervention effects ($p < 0.05$) in several studies. Third, environmental attitudes improved from moderate to high categories, with reported gains including n-Gain values of 0.38 and significant improvements in ecological attitude measures ($p < 0.001$). Fourth, the synthesis identified five SDGs-oriented instructional design principles: contextualization, interdisciplinary integration, project orientation, sustainability orientation, and student agency. Overall, the evidence suggests that Ethno-STEAM-PjBL provides a promising framework for contextual and sustainability-oriented science learning by simultaneously strengthening scientific literacy, environmental responsibility, and SDGs-related competencies.

Keywords: Environmental Attitudes; Ethno-STEAM; Project-Based Learning; Scientific Literacy; Science Education

Introduction

21st-century science education focuses on mastering concepts, but also on developing students' ability to solve complex problems, think critically, communicate, collaborate, and make evidence-based decisions in real-life situations (OECD, 2023). Science education is designed to be contextual, interdisciplinary, and meaningful so that students can connect scientific concepts to the technology, environment, culture, and social issues they encounter in their daily lives. Science education practices in schools still face various challenges, such as low student engagement, limited use of local contexts, and suboptimal integration of 21st-century skills into learning activities (Sumarni et al., 2025). Consequently, there remains a gap between the demands of 21st-century science education and classroom practices, which still need to be strengthened through contextual, collaborative, and project-based learning models relevant to students' lives (Rohman et al., 2024).

Science literacy is defined as a person's ability to engage in reasoned discussions about science, sustainability, and technology to support appropriate

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action (Ilisa-Gateway, 2025). The latest indicators of science literacy include the ability to explain phenomena scientifically, designing and evaluating scientific investigations and critically interpreting data and evidence, and researching, evaluating, and using scientific information for decision-making and action (Ilisa-Gateway, 2025). The PISA 2025 framework also emphasizes personal, local/national, and global contexts; content, procedural, and epistemological knowledge; and scientific identity, which encompasses awareness, concern, and active engagement with the environment (OECD, 2025). Based on this description, science literacy in science education is understood as the ability to answer test questions, but also as students' ability to apply science in interpreting real-world problems, including environmental and sustainability issues.

The 2022 PISA results indicate that Indonesia's science score increased to 383 compared to the 2018 cycle, although it remains below the OECD average (OECD, 2023). The Ministry of Education, Culture, Research, and Technology also reported that Indonesia's scientific literacy ranking improved by six positions; however, this improvement has not yet been accompanied by a substantial increase in overall science achievement (Kemendikbudristek, 2023). Nurjaman (2024) further noted that the score of 383 still reflects limitations in students' scientific reasoning, problem-solving, and evidence-based decision-making abilities. Similar concerns are reflected in national assessment data. According to the Indonesian Education Report Card derived from the National Assessment (Asesmen Nasional), only 70.34% of junior high school students achieved minimum literacy competency in 2024, while 68.10% achieved minimum numeracy competency, with considerable disparities across regions and schools still evident (Kemendikdasmen, 2025). These findings suggest that although improvements have occurred at both international and national levels, the development of scientific literacy remains a major challenge in Indonesian science education and requires more contextual, inquiry-based, and higher-order thinking-oriented learning approaches.

The focus on junior high school science education is based not only on developmental considerations, curricular and pedagogical reasons. At the junior high school level, students begin to engage with integrated science content that combines concepts from biology, physics, chemistry, and earth sciences, requiring higher levels of reasoning and conceptual integration than in elementary education (OECD, 2025). Learning nowadays need to go with the trend in globalization era, one of those is by integrating Science, Technology, Engineering, dan Mathematics (STEM). Relationship between sciences and technology or other knowledge can not be separated in sciences learning. STEM is science dicipline which is related each other (Afriana et al., 2016). By engaging diverse and active STEM learners to address current and future global challenges, authentic PjBL provides a promising path for the future of STEM education (Beier et al., 2019).

Ethnoscience is an interdisciplinary science that combines human and cultural anthropology with science education. The study of the scientific knowledge that is gained by examining the local knowledge that is contained in the culture of a community or ethnic group (Dewi et al., 2021) , previous studies have demonstrated that ethnoscience- and STEM-based learning interventions are predominantly implemented at the junior high school level because students at this stage are cognitively ready to connect scientific concepts with socio-cultural and environmental contexts through project-based activities (Prabawati et al., 2025). The STEAM approach makes students learn how to convey ideas in an attractive, persuasive way with the support of convincing data (Ellianawati et al., 2025). Therefore, junior high school represents a strategic educational stage for examining how the integration of Ethno-STEAM-PjBL can simultaneously promote scientific literacy, environmental awareness, and sustainability-oriented learning.

In addition to scientific literacy, science education plays a strategic role in developing environmental attitudes because students live amid various environmental challenges, including climate change, pollution, waste crises, biodiversity loss, and ecosystem degradation. Science learning should therefore help students understand environmental issues scientifically while fostering awareness, responsibility, and pro-environmental behavior in everyday life (Suryawati et al., 2020). Environmental attitudes are particularly important to develop during adolescence because this developmental stage strongly influences future values, habits, and ecological behaviors (Saputra et al., 2025). However, research on global warming topics indicates that junior high school students' environmental attitudes remain relatively low, with an average score of only 49.78% (Hillary et al., 2023). Furthermore, students in Adiwiyata schools demonstrate significantly higher environmental awareness than those in non-Adiwiyata schools, indicating that school culture and environmentally oriented instructional design play important roles in fostering ecological attitudes (Saputra et al., 2025). These findings suggest that environmental awareness cannot be adequately developed through conceptual instruction alone but must be cultivated through direct experiences, engagement in solving local environmental problems, and reflection on the impacts of human activities on nature (Suryawati et al., 2020).

One relevant approach for connecting scientific concepts with students' everyday lives is ethnoscience. Ethnoscience integrates scientific knowledge with local wisdom, cultural practices, and community experiences, helping students recognize that science is embedded within traditional technologies, environmental practices, local food systems, handicrafts, agriculture, natural resource management, and daily community activities (Chamdani et al., 2025). Empirical studies show that ethnoscience-based Project-Based Learning significantly improves scientific literacy, resulting in higher literacy levels among experimental groups compared to control groups. Similarly, Hidayah et al. (2024) reported that ethnoscience-based PjBL enhances science process skills, scientific attitudes, communication abilities, and students' awareness of socio-cultural contexts. Therefore, ethnoscience offers considerable potential for science education because it brings local contexts closer to students while reinforcing the relevance of science in real-life situations (Rayis et al., 2025).

The contribution of ethnoscience can be further strengthened when combined with STEAM and Project-Based Learning. Ethno-STEAM positions local wisdom as a context for interdisciplinary learning that encourages students to develop products, solutions, or creative works based on scientific concepts and cultural practices (Prabawati et al., 2025). Meanwhile, Project-Based Learning provides students with opportunities to design, investigate, make decisions, test ideas, create products, and communicate learning outcomes through meaningful projects (Fauziah et al., 2023). Imron et al. (2025) demonstrated that Ethno-STEM integrated with PjBL significantly improved junior high school students' scientific literacy on vibration and wave topics. Similarly, Prabawati et al. (2025) found that an Ethno-STEAM-based science module for ecology and biodiversity effectively promoted students' creative thinking skills. These findings suggest that Ethno-STEAM-PjBL provides a promising instructional approach for improving scientific literacy while simultaneously fostering environmental awareness through locally grounded learning experiences (Rohman et al., 2024).

The integration of local wisdom within Ethno-STEAM-PjBL is inherently connected to sustainability values, as the urgency to improve STEM education is driven by environmental and social impacts of the twenty-first century which in turn jeopardizes global security and economic stability (Kelley & Knowles, 2016). Many traditional practices developed by local communities represent long-established forms of environmental stewardship, responsible resource management, and community resilience. Such practices demonstrate how scientific knowledge, cultural values, and environmental responsibility can coexist and support sustainable living. Furthermore, many ethnoscience practices, including traditional resource management and environmentally responsible production systems, reflect values closely aligned with SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). Therefore, the integration of ethnoscience into science education naturally provides a pathway for connecting local knowledge with broader sustainability agendas.

Ethno-STEAM-PjBL-based science education should therefore be aligned with the Sustainable Development Goals (SDGs), because combining STEAM education with sustainable development prepares students for the complex challenges of a rapidly changing world (Rantanen et al., 2024). Melindawati et al. (2025) reported that SDGs-oriented project-based learning improves active learning, critical thinking, problem-solving, sustainability awareness, and pro-environmental behavior through projects focusing on waste management, biodiversity conservation, and environmental campaigns. The PISA 2025 framework further emphasizes sustainability-oriented learning by incorporating environmental awareness, responsibility, and agency as key components of scientific identity (OECD, 2025). Consequently, SDGs-oriented Ethno-STEAM-PjBL can function as a learning design principle that not only promotes project outcomes but also fosters scientific understanding, social responsibility, and meaningful engagement with environmental challenges.

Despite the growing number of studies on ethnoscience, STEAM, PjBL, scientific literacy, and environmental attitudes, existing research remains fragmented. Some studies focus primarily on scientific literacy, while others emphasize creative thinking, environmental awareness, instructional material development, or specific science topics. Furthermore, most studies investigate Ethno-STEAM-PjBL within isolated instructional contexts without examining its broader contribution to sustainability-oriented science education. To date, limited attention has been given to synthesizing empirical evidence that simultaneously addresses the characteristics of Ethno-STEAM-PjBL implementation, its effectiveness in improving scientific literacy and environmental attitudes, and its alignment with SDGs-oriented instructional design. Given the increasing demand for sustainability-oriented science education, understanding how Ethno-STEAM-PjBL can simultaneously promote scientific literacy, environmental responsibility, and SDGs-related competencies has become an important research priority. The novelty of this study lies in its comprehensive synthesis of empirical evidence on Ethno-STEAM-PjBL by integrating fragmented findings into a unified framework that connects local wisdom, interdisciplinary learning, scientific literacy, environmental attitudes, and SDGs-oriented science learning. Therefore, this study aims to conduct an integrative review of empirical evidence regarding the characteristics and effectiveness of Ethno-STEAM-PjBL in science education, particularly in improving scientific literacy and environmental attitudes among junior high school students, as well as to identify SDGs-oriented instructional design principles relevant for science learning.

Method

This study employed an Integrative Literature Review (ILR) approach. The ILR method was selected because it enables researchers to synthesize empirical and theoretical literature from diverse methodological traditions to provide a comprehensive understanding of a phenomenon (Whittemore & Knafl, 2005). Unlike systematic reviews that primarily focus on answering narrowly defined research questions through strict procedural protocols, ILR emphasizes the integration of heterogeneous evidence to generate conceptual insights and identify emerging patterns (Torraco, 2005).

The use of ILR is particularly appropriate for this study because research related to Ethno-STEAM, ethnoscience, Project-Based Learning (PjBL), scientific literacy, environmental attitudes, and sustainability-oriented science learning has developed across different educational contexts and research designs. Therefore, review is to synthesize fragmented findings into a coherent conceptual framework for understanding the potential of Ethno-STEAM-PjBL in junior high school science education (Snyder, 2019).

The literature search was conducted using an exploratory and iterative search strategy. In contrast to rigid systematic review procedures, ILR allows the search process to evolve as conceptual understanding develops throughout the review process (Booth et al., 2016). Consequently, the search strategy was progressively refined to identify studies that were conceptually relevant to the integration of ethnoscience, Ethno-STEAM, local wisdom-based learning, and Project-Based Learning in science education.

Literature sources were identified through academic databases and journal indexing systems, including Google Scholar, SINTA-indexed journals, Scopus-indexed journals, and ERIC. The search process employed combinations of keywords such as *ethnoscience, Ethno-STEAM, Ethno-STEM, local wisdom, Project-Based Learning, scientific literacy, environmental attitudes, science education, and sustainability*. The use of multiple databases was intended to enhance the breadth of literature coverage and ensure that the selected articles represented diverse yet relevant perspectives on the phenomenon under investigation (Whittemore & Knafl, 2005).

To ensure conceptual relevance and scientific quality, articles were selected based on predefined inclusion and exclusion criteria. Unlike systematic reviews that seek exhaustive coverage of all available studies, the criteria in this ILR were applied to identify studies that could contribute meaningfully to the development of the conceptual synthesis (Torraco, 2005).

Table 1. Inclusion and Exclusion Criteria of Studies

Aspect	Inclusion Criteria	Exclusion Criteria
Learning context	Studies involving ethnoscience, Ethno-STEM, Ethno-STEAM, local wisdom-based learning, Project-Based Learning (PjBL), sustainability-oriented science learning, or combinations of these approaches in science education	Studies unrelated to cultural context, ethnoscience, or science learning
Publication type	Articles published in peer-reviewed journals	Conference proceedings, books, websites, blogs, dissertations, and other non-journal sources
Research outcomes	Scientific literacy and/or environmental attitudes	Studies not examining scientific literacy or environmental attitudes
Article type	Empirical studies (experimental, quasi-experimental, R&D, mixed methods, and qualitative studies)	Opinion papers, essays, editorials, and non-systematic literature reviews
Field	Science education and closely related science learning contexts	Studies outside science education

The literature identification and selection process was conducted iteratively following the logic of integrative review inquiry. Initially, a broad search yielded a larger body of potentially relevant articles. Articles were then screened based on title, abstract, conceptual relevance, and compliance with the inclusion criteria. During this process, some studies were retained because they provided important evidence related to ethnoscience, Ethno-STEAM, PjBL, scientific literacy, environmental attitudes, or sustainability-oriented learning, even when not all components were simultaneously present in a single study. This approach is consistent with the purpose of ILR, which seeks conceptual integration rather than strict homogeneity of evidence (Whittemore & Knafl, 2005).

After the screening and evaluation process, 16 key articles were selected and used as the primary corpus for thematic analysis.

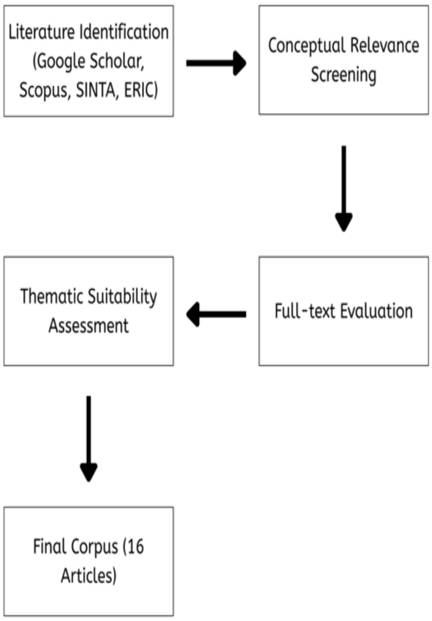

Figure 1. Integrative literature selection process used in this study

Data analysis was conducted using a narrative–thematic synthesis approach, which facilitates the identification of patterns, relationships, and conceptual themes across heterogeneous studies (Thomas & Harden, 2008). This process involved iterative reading, coding, categorization, and comparison of findings across studies to identify recurring themes relevant to the research objectives (Braun & Clarke, 2006).

The identified themes were developed inductively and organized according to four research objectives: Characteristics of Ethno-STEAM-PjBL implementation in science education; Its effectiveness in improving scientific literacy; Its influence on environmental attitudes; and SDGs-oriented instructional design principles. The thematic synthesis enabled the integration of empirical findings related to cultural context, interdisciplinary learning, project-based inquiry, and sustainability-oriented education. Through this process, a conceptual framework was developed to explain how Ethno-STEAM-PjBL can support contextual and sustainable science learning in junior high school settings (Melindawati et al., 2025). Therefore, the ILR approach in this study serves not only to summarize existing evidence but also to generate theoretical and practical implications for the development of innovative science learning approaches.

Result and Discussion

The analysis was conducted on 16 selected corpus articles that met the inclusion criteria and were considered relevant to the objectives of this review. Following the principles of integrative literature review, the selected studies were not analyzed as isolated findings but were examined collectively to identify recurring patterns, relationships, and conceptual connections across different educational contexts. Through iterative reading, coding, and thematic comparison, the findings were organized into four major themes: (1) the characteristics of Ethno-STEAM-PjBL integration, (2) scientific literacy outcomes, (3) environmental attitudes, and (4) SDGs-oriented instructional design principles. Several studies contributed to more than one theme, reflecting the interconnected nature of scientific literacy, environmental awareness, local wisdom, and sustainability-oriented science learning. The distribution of studies across themes also provides an overview of current research trends, showing that scientific literacy and instructional implementation have received greater attention than environmental attitudes and SDGs-oriented learning design. The distribution of the corpus articles across the four themes is presented in Table 2.

Table 2. Distribution of Corpus Articles Across Research Themes

Theme	Focus	Representative Studies
Theme 1	Characteristics of Ethno-STEAM-PjBL Integration	(Hidayah et al., 2024; Hikmawati et al., 2021) (Hanum et al., 2023; Imron et al., 2025; Prayogi et al., 2023; Rayis et al., 2025)
Theme 2	Scientific Literacy Outcomes	(Chamdani et al., 2025; Hindun et al., 2024; Imron et al., 2025; Setiawan et al., 2017)
Theme 3	Environmental Attitudes	(Agnafia & Anfa, 2025; Amelia et al., 2021; Nurmasitoh et al., 2025)
Theme 4	SDGs-Oriented Design Principles	(Melindawati et al., 2025; Prabawati et al., 2025; Sihombing et al., 2025)

Table 2 shows that the reviewed studies contributed unequally across the four research themes. Most studies focused on the implementation characteristics of Ethno-STEAM-PjBL and its influence on scientific literacy, indicating that these two areas have received the greatest empirical attention in the existing literature. In contrast, fewer studies explicitly examined environmental attitudes and SDGs-oriented instructional design, suggesting that these dimensions remain relatively underexplored. The overlap among themes also demonstrates that Ethno-STEAM-PjBL is a multidimensional approach that simultaneously addresses pedagogical design, cognitive development, environmental awareness, and sustainability-oriented learning. This thematic distribution provides the basis for the four thematic discussions presented in the following sections.

Theme 1. Characteristics of Ethno-STEAM-PjBL Integration

The results of the literature review indicate that the key feature of integrating Ethno-STEAM with Project-Based Learning (PjBL) lies not only in the use of cultural contexts in general, but specifically in the utilization of authentic local cultural practices as a source of science learning. (Hikmawati et al., 2021) facilitated the exploration of ecological concepts and the interactions of living organisms through the traditions of the Lombok community, such as nature-based tourism activities (Senggigi Beach, Sesaot Forest, and Mount Rinjani). This demonstrates that ethnoscience is not merely a "cultural illustration," but functions as an authentic context for understanding scientific phenomena. A similar approach is evident in the research by Setiawan et al. (2017), which utilized the context of Mount Kelud's eruption as a means to apply local wisdom in understanding concepts of disaster management and earth sciences. Based on this discussion, the main characteristic of Ethno-STEAM-PjBL lies in its ability to integrate scientific phenomena with the local realities directly experienced by students.

The local culture that is integrated encompasses not only the natural environment but also traditional technological practices and community wisdom. Imron et al. (2025) integrated traditional musical instruments (drums) into the teaching of vibrations and waves, so that students could understand physics concepts not only abstractly but also through cultural artifacts that were already familiar to them. Rayis et al. (2025) used the context of palm sugar production as a learning project, allowing students to examine the concepts of matter, energy, and chemical processes within the context of community life. Based on this description, Ethno-STEAM-PjBL places a strong emphasis on contextualizing scientific concepts through local technology and community economic practices, thereby making learning more socially and culturally relevant.

The use of real-world problem-based projects directly related to environmental issues and community life is also a hallmark of ethno-STEAM-PjBL learning. Research conducted by Nurmasitoh et al. (2025) involved students in developing projects based on the diversity of medicinal herbs, which not only integrated biological concepts but also local wisdom regarding plant utilization. This demonstrates that projects in ethno-STEAM-PjBL are not merely theoretical but rooted in real-world practices passed down from generation to generation within the community. Another study conducted by Agnafia & Anfa (2025) involved the development of worksheets based on the local wisdom of Ngawi addressing environmental issues; students were engaged in solving problems occurring in their environment. Thus, projects in this approach serve as a means to directly connect scientific knowledge with students' life experiences.

Another important characteristic of Ethno-STEAM-PjBL is its strong interdisciplinary nature combined with active student participation. Hanum et al. (2023) demonstrated that Ethno-STEAM-PjBL integrates science with experimental activities, product design, and cultural contexts, enabling students not only to understand scientific concepts but also to develop higher-order thinking skills. Similarly, Prabawati et al. (2025) emphasized that STEAM integration allows students to connect science with art and creativity through projects related to ecology and biodiversity. These findings suggest that Ethno-STEAM-PjBL promotes holistic and interdisciplinary learning experiences that transcend traditional subject boundaries.

At the same time, the approach positions students as active participants in the learning process rather than passive recipients of knowledge. Hidayah et al. (2024)

reported that students were actively involved in designing, implementing, and presenting ethnoscience-based projects, allowing them to act as knowledge constructors throughout the learning process. This finding is supported by Prayogi et al. (2023), who found that integrating ethnoscience with inquiry-based and digital learning approaches encourages students to think critically and reflectively about the phenomena under investigation. As a result, Ethno-STEAM-PjBL not only fosters interdisciplinary understanding but also strengthens student agency by empowering learners to take an active role in knowledge construction, problem-solving, and evidence-based decision-making.

Based on the synthesis of the reviewed studies, four recurrent characteristics were identified, namely authentic cultural contexts, project-based learning, interdisciplinary integration, and student-centered learning. These characteristics form the conceptual foundation of Ethno-STEAM-PjBL as illustrated in Figure 2.

While the preceding analysis highlights how Ethno-STEAM-PjBL is implemented in science learning, the next question concerns whether these characteristics translate into measurable educational outcomes. The reviewed studies most frequently evaluated scientific literacy, making it the dominant outcome variable across the corpus. Therefore, the following section discusses the effectiveness of Ethno-STEAM-PjBL in improving students' scientific literacy.

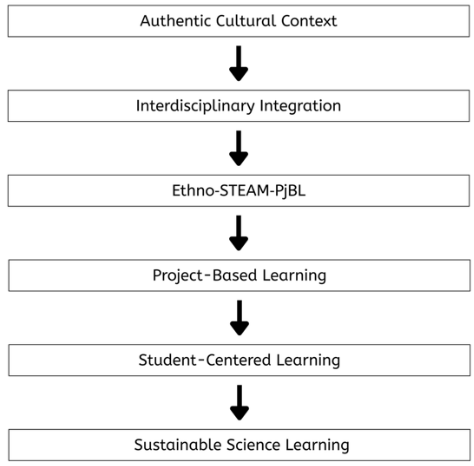

Figure 2. Conceptual framework of Ethno-STEAM-PjBL integration in science learning.

Theme 2: Effectiveness of Ethno-STEAM-PjBL on Scientific Literacy

As summarized in Table 4, scientific literacy was one of the most frequently investigated outcomes among the reviewed studies. Overall, the findings consistently indicate that Ethno-STEAM-PjBL contributes positively to the development of scientific literacy across various educational contexts. The reviewed studies provide both quantitative and qualitative evidence showing improvements in scientific reasoning, investigation skills, contextual understanding, and the application of scientific knowledge in authentic situations. These findings suggest that the integration of local cultural knowledge, interdisciplinary learning, and project-based activities creates meaningful opportunities for students to engage with science beyond conceptual memorization.

Table 3. Empirical Evidence of Ethno-STEAM-PjBL Effectiveness on Scientific Literacy

Author(s)	Educational Level	Quantitative Evidence	Main Scientific Literacy Contribution
(Setiawan et al., 2017)	Junior high school	N-gain = 0.2–0.4	Explaining scientific phenomena
(Chamdani et al., 2025)	Pre-service teachers	N-gain = 0.71; p = 0.003	Context, competence, and knowledge aspects
(Hindun et al., 2024)	Junior high school	77.78 vs 66.01; improvement = 33.15%	Scientific reasoning and collaboration
(Imron et al., 2025)	Junior high school	p = 0.047; η^2 = 0.21	Scientific investigation and data interpretation
(Hidayah et al., 2024)	Elementary school	Qualitative improvement	Science process skills and communication
(Rayis et al., 2025)	Junior high school	Qualitative improvement	Application of science in local practices
(Prayogi et al., 2023)	Pre-service teachers	N-gain = 0.89; p < 0.001	Critical evaluation and decision making

The strongest quantitative evidence is provided by Chamdani et al. (2025); Hindun et al. (2024); Imron et al. (2025); Setiawan et al. (2017). Quantitative outcomes ranged from low to high effectiveness. Setiawan et al. (2017) reported N-gain values between 0.2 and 0.4, indicating low to moderate improvement in scientific literacy through local wisdom-based science modules. Although conducted with pre-service elementary school teachers, Chamdani et al. (2025) reported a significant effect of ethnoscience-based PjBL on scientific literacy (p = 0.003), suggesting the potential transferability of ethnoscience-oriented project learning to broader science education contexts. Similarly, Hindun et al. (2024) reported substantially higher scientific literacy scores in the PjBL group (77.78) than in the control group (66.01), representing an improvement of 33.15%. Imron et al. (2025) also demonstrated a significant positive effect ($p = 0.047$) with a partial eta squared value of 0.21, indicating a large effect size. Collectively, these findings provide strong empirical evidence that Ethno-STEAM-PjBL can enhance scientific literacy across different learning settings.

When examined through the lens of the PISA scientific literacy framework, the reviewed studies indicate that Ethno-STEAM-PjBL supports the development of several key scientific competencies. Chamdani et al. (2025) found improvements in the dimensions of context, competence, and knowledge, suggesting that students become more capable of applying scientific understanding in meaningful situations. (Imron et al., 2025) reported improvements across all measured literacy dimensions, particularly in explaining scientific phenomena and interpreting data through investigations involving traditional musical instruments. Although Prayogi et al. (2023) primarily examined critical thinking, the reported gains in evaluation, inference, and decision-making skills are closely related to the competencies required for scientific literacy, particularly the ability to evaluate information and make evidence-based judgments. These findings indicate that Ethno-STEAM-PjBL contributes not only to scientific knowledge acquisition but also to higher-order scientific reasoning.

Beyond quantitative gains, several studies help explain the mechanisms through which scientific literacy improves. Hidayah et al. (2024) demonstrated that ethnoscience-based projects encouraged students to develop science process skills, scientific attitudes, and communication abilities through authentic problem-solving activities. Likewise, Rayis et al. (2025) showed that students learned scientific concepts such as crystallization and material transformation through the culturally relevant context of palm sugar production. Such learning experiences allow students to connect scientific concepts with familiar local practices, thereby strengthening contextual understanding and the relevance of science in daily life. These findings support the argument that the effectiveness of Ethno-STEAM-PjBL stems from its ability to situate scientific inquiry within students' socio-cultural environments.

Overall, the synthesis demonstrates that Ethno-STEAM-PjBL contributes positively to scientific literacy through both measurable learning gains and improvements in higher-order scientific competencies. Quantitative evidence ranges from low-to-moderate gains (N-gain = 0.2–0.4) to high gains (N-gain = 0.71), accompanied by statistically significant effects and improved literacy performance across experimental groups. At the same time, qualitative findings indicate that contextualized projects, ethnoscience integration, and interdisciplinary inquiry help students connect scientific knowledge with real-world situations. Therefore, Ethno-STEAM-PjBL not only improves scientific literacy outcomes but also supports the development of the competencies emphasized in the PISA 2025 framework, including scientific reasoning, investigation, evidence interpretation, and informed decision-making.

Theme 3. Impact of Ethno-STEAM-PjBL on Environmental Attitudes

Environmental attitudes emerged as another important outcome across the reviewed studies. As presented in Table 4, the findings consistently indicate that Ethno-STEAM-PjBL and related ethnoscience-based learning approaches contribute positively to students' environmental awareness, responsibility, and pro-environmental behavior. The reviewed studies provide both quantitative and qualitative evidence demonstrating that environmental attitudes develop more effectively when learning activities are connected to local environmental issues, cultural values, and authentic project experiences.

Table 4. Evidence of Environmental Attitude Development in Ethnoscience-, Ethno-STEAM-, and Project-Based Learning Studies

Author(s)	Educational Level	Quantitative Evidence	Main Scientific Literacy Contribution
(Amelia et al., 2021)	Junior high school	87% vs 84%; $t = 2.06$	Environmental awareness
(Agnafia & Anfa, 2025)	Junior high school	n-Gain = 0.3772; $p = 0.000$	Environmental concern
(Septianingsih et al., 2025)	Junior high school	ES = 0.30; $p = 0.000$	Ecological attitudes
(Nurmasitoh et al., 2025)	Junior high school	Qualitative improvement	Conservation awareness
(Hidayah et al., 2024)	Elementary school	Qualitative improvement	Environmental responsibility
(Sihombing et al., 2025)	Mixed levels	Qualitative synthesis	Pro-environmental behavior
(Melindawati et al., 2025)	Elementary school review	Qualitative synthesis	Sustainability awareness

Beyond the quantitative improvements reported across the reviewed studies, several recurring mechanisms explain how environmental attitudes are developed through Ethno-STEAM-PjBL. The findings suggest that environmental awareness grows more effectively when students engage directly with authentic environmental issues embedded in their local cultural context. Hidayah et al. (2024) demonstrated that ethnoscience-based projects encouraged students to participate actively in identifying, analyzing, and addressing environmental problems through project activities rooted in local practices. Similarly, Nurmasitoh et al. (2025) reported that learning activities centered on herbal plant biodiversity promoted environmental literacy and conservation awareness by connecting scientific concepts with local ecological knowledge. These findings indicate that environmental attitudes are strengthened when students experience environmental issues first-hand rather than learning about them as abstract concepts.

An important pattern emerging from the reviewed studies is the progression from environmental awareness toward pro-environmental behavior. Sihombing et al. (2025) found that the integration of ethnoscience into science education promotes environmental responsibility and sustainable behavior through the incorporation of local wisdom and traditional ecological practices. Likewise, Melindawati et al. (2025) reported that project-based learning aligned with sustainability goals encouraged students to engage in activities such as waste management, biodiversity conservation, and environmental campaigns. These activities allowed students to observe the real consequences of their actions and understand the practical relevance of environmental stewardship.

The findings suggest that project-based learning plays a crucial role in transforming environmental attitudes into observable actions. Rather than only discussing environmental problems, students are encouraged to investigate local issues, develop solutions, and implement environmental projects. As a result, environmental learning becomes action-oriented and participatory.

Overall, the reviewed studies indicate that Ethno-STEAM-PjBL contributes positively to the development of environmental attitudes across cognitive, affective, and behavioral domains. Quantitative evidence demonstrates improvements ranging from moderate to high levels, as reflected in attitude scores, n-Gain values, and significant intervention effects. At the same time, qualitative findings reveal that students become more environmentally aware, show greater concern for local ecological issues, and demonstrate stronger pro-environmental behaviors following participation in ethnoscience-based and project-oriented learning activities.

Across the reviewed studies, three recurring factors appear to explain these outcomes: the use of meaningful local contexts, active participation in project-based learning, and the integration of ecological values embedded in local wisdom. Together, these elements create learning experiences that help students understand environmental issues scientifically while simultaneously developing personal responsibility and sustainable behavioral intentions. Therefore, Ethno-STEAM-PjBL can be considered a promising approach for fostering environmental attitudes that support the broader goals of sustainability-oriented science education and provide a foundation for SDGs-oriented learning.

Theme 4. SDGs-Oriented Instructional Design Principles

Beyond learning outcomes, the reviewed studies reveal a set of instructional design principles that characterize Ethno-STEAM-PjBL and contribute to sustainability-oriented science learning. Although most studies do not explicitly refer to the Sustainable Development Goals (SDGs), recurring patterns across the reviewed literature indicate strong alignment with key sustainability principles. Through thematic synthesis, five major design principles were identified: contextualization, interdisciplinary integration, project orientation, sustainability orientation, and student agency. Together, these principles provide a conceptual framework for designing science learning experiences that connect local cultural knowledge with global sustainability challenges.

Table 5. SDGs-Oriented Design Principles Identified Across the Reviewed Studies

Design Principle	Supporting Studies	Main Contribution
Contextualization	Hidayah; Hikmawati; Setiawan; Rayis	Connecting scientific concepts with local culture and environment
Interdisciplinary Integration	Prabawati; Imron; Hanum	Integrating science, technology, engineering, arts, and mathematics
Project Orientation	Rayis; Hanum; Hidayah; Agnafia	Solving authentic real-world problems through projects
Sustainability Orientation	Nurmasitoh; Sihombing; Melindawati	Promoting environmental awareness and conservation values

Design Principle	Supporting Studies	Main Contribution
Student Agency	Prayogi; Hidayah; Hanum	Encouraging students to become active decision-makers and knowledge constructors

The first principle identified through the thematic synthesis is contextualization, which refers to the use of local cultural and environmental contexts as the foundation of science learning. Across the reviewed studies, local wisdom was not treated merely as supplementary content but functioned as an authentic learning resource that enabled students to connect scientific concepts with their everyday experiences. Hidayah et al. (2024); Hikmawati et al. (2021); Setiawan et al. (2017), demonstrated that culturally responsive learning contexts enhanced the relevance and meaningfulness of science instruction. Similarly, Rayis et al. (2025) showed that local practices such as palm sugar production provided opportunities for students to explore scientific concepts embedded within community activities. These findings suggest that contextualization serves as a bridge between scientific knowledge and students' lived experiences, thereby strengthening meaningful learning.

A second principle is interdisciplinary integration. The reviewed studies consistently demonstrate that Ethno-STEAM-PjBL combines multiple disciplines within a single learning experience. Prabawati et al. (2025) highlighted how Ethno-STEAM modules integrated scientific concepts with creativity and artistic expression, while Imron et al. (2025) connected physics concepts to traditional musical instruments. Hanum et al. (2023) likewise reported the integration of experimentation, product design, and local cultural knowledge within project activities. These examples suggest that Ethno-STEAM-PjBL moves beyond disciplinary boundaries and promotes a holistic understanding of complex real-world phenomena.

The third principle is project orientation. Across the reviewed studies, projects functioned as the central mechanism through which students explored scientific concepts and developed solutions to authentic problems. Rayis et al. (2025) demonstrated that students applied scientific knowledge through projects related to palm sugar production, while Hanum et al. (2023) emphasized experimentation and product development. (Agnafia & Anfa, 2025; Hidayah et al., 2024)similarly reported that project activities encouraged students to investigate environmental issues and propose locally relevant solutions. These findings indicate that project-based learning enables students to translate scientific understanding into action.

Sustainability orientation emerged as another recurring design principle. Several studies integrated environmental conservation, biodiversity, and resource management into learning activities. Nurmasitoh et al. (2025) demonstrated that local biodiversity exploration fostered conservation awareness, while Sihombing et al. (2025) emphasized the role of local wisdom in promoting sustainable environmental practices. Similarly, Melindawati et al. (2025) showed that project-based learning aligned with the SDGs encouraged students to engage in environmental campaigns, waste management, and biodiversity conservation activities. These findings indicate that sustainability is embedded within both the content and learning processes of Ethno-STEAM-PjBL.

The final principle identified is student agency. The reviewed studies emphasize that students are positioned as active participants who construct knowledge through investigation, collaboration, and reflection. Prayogi et al. (2023) reported that ethnoscience-integrated inquiry learning significantly strengthened students' critical thinking and decision-making skills. Hidayah et al. (2024) also found that students independently designed and implemented ethnoscience-based projects. Such findings suggest that Ethno-STEAM-PjBL empowers learners to take responsibility for their own learning and to make informed decisions based on scientific evidence.

Although most reviewed studies do not explicitly frame their interventions within the SDGs agenda, the identified design principles demonstrate substantial alignment with sustainability-oriented science education. Contextualization supports locally meaningful learning, interdisciplinary integration develops complex problem-solving competencies, project orientation enables authentic engagement with real-world challenges, sustainability orientation promotes environmental responsibility, and student agency empowers learners to participate actively in decision-making processes. Taken together, these principles suggest that Ethno-STEAM-PjBL functions not only as a pedagogical approach but also as a comprehensive instructional design framework capable of bridging local cultural knowledge and global sustainability goals. Furthermore, the framework aligns closely with SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land), highlighting its potential to support sustainability-oriented science education in the twenty-first century.

Conclusion

This integrative literature review demonstrates that Ethno-STEAM-PjBL is a promising approach for supporting contextual, transdisciplinary, and sustainability-oriented science education. The synthesis of sixteen studies reveals that the approach is characterized by authentic cultural contexts, interdisciplinary integration, project-based learning, and active student participation. The findings consistently indicate positive contributions to scientific literacy, with evidence of improved scientific reasoning, investigation skills, and the application of scientific knowledge in real-world contexts. In addition, Ethno-STEAM-PjBL promotes environmental attitudes through meaningful engagement with local environmental issues and cultural values. The review also identified five SDGs-oriented instructional design principles, namely contextualization, interdisciplinary integration, project orientation, sustainability orientation, and student agency. These findings suggest that Ethno-STEAM-PjBL can serve as a valuable framework for advancing sustainability-oriented science learning. Future research should examine the implementation of Ethno-STEAM-PjBL across different educational levels, cultural settings, and science topics to determine its broader applicability. More experimental and longitudinal studies are also needed to investigate the long-term effects of the approach on scientific literacy, environmental attitudes, and sustainability-related competencies. Furthermore, future studies may develop and validate SDGs-oriented instructional materials, particularly student worksheets (LKPD), based on the design principles identified in this review.

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