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FOSTERING ENVIRONMENTAL AWARENESS THROUGH SUSTAINABLE DEVELOPMENT GOAL-ORIENTED ETHNO-STEM APPROACH IN ELEMENTARY EDUCATION

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ABSTRACT

This study examines the effectiveness of a Sustainable Development Goals (SDGs)-oriented Ethno-STEM approach in promoting environmental awareness among elementary school students through natural and social science learning. Utilizing a quasi-experimental one-group pretest-posttest design, the research involved 60 students from an elementary school in Makassar, Indonesia. Environmental awareness was assessed before and after the implementation of Ethno-STEM-integrated lessons that incorporated culturally relevant and participatory activities such as eco-brick making, waste management simulations, and the "Zero Plastic Week" challenge. Data were analyzed using a paired t-test, which revealed a statistically significant improvement in students' environmental awareness scores ($p = 0.001$), with the mean increasing from $M = 61.06$ ($SD = 7.10$) to $M = 68.61$ ($SD = 6.63$). The findings demonstrate that integrating local cultural values and sustainability themes into science education fosters both cognitive understanding and behavioral engagement with environmental issues. This study contributes to the development of culturally contextualized and sustainability-focused pedagogy, reinforcing the relevance of SDG 4 (quality education) and SDG 13 (climate action). This study is novel in its integration of SDGs-oriented Ethno-STEM with elementary science education, demonstrating not only cognitive improvement but also fostering affective and behavioral engagement. Its contribution lies in bridging cultural relevance with sustainability pedagogy, thereby informing both theoretical discourse and practical applications in early education.

Keywords: elementary school; environmental awareness; ethno-STEM; natural and social science learning; sustainable development goals

INTRODUCTION

Environmental education plays a crucial role in shaping students' ecological awareness from a young age. The increasing severity of global issues such as climate change, biodiversity loss, resource depletion, and environmental injustice has intensified the demand for educational practices that not only transfer knowledge but also inspire environmentally responsible action (Ricoy & Sánchez-Martínez, 2022; Altassan, 2023; Punzalan, 2024). In the face of global challenges such as climate change, environmental degradation, and social inequality, there is a growing demand for educational approaches that foster a deeper understanding of the interconnectedness of science, technology, environment, and culture (Porter et al., 2020; Löfström et al., 2021; Nguyen et al., 2023).

At the same time, education systems globally are grappling with the need to connect science and technology learning with broader environmental and cultural issues. STEM (Scien-

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ce, Technology, Engineering, and Mathematics) education has been widely adopted as a forward-looking approach that equips students with the competencies required for the 21st century: scientific literacy, critical thinking, innovation, and problem-solving skills (Dare et al., 2021; Lavi et al., 2021; Xu & Zhou, 2022). However, while the cognitive benefits of STEM education are well-documented, its application in real-world, socially embedded contexts remains limited. Particularly in multicultural and Indigenous contexts, conventional STEM approaches often overlook local culture, values, and lived experiences, rendering learning less relevant and less impactful for students from diverse backgrounds (Putri et al., 2021). This cultural disconnect not only limits student engagement but also restricts the potential of STEM to foster meaningful understanding and behavioral change in sustainability education.

To bridge this gap, the Ethno-STEM approach has gained traction as a culturally responsive pedagogy that integrates indigenous knowledge systems, traditional ecological wisdom, and cultural heritage into STEM curricula (Sumarni & Kadarwati, 2020; Martawijaya et al., 2023). By situating scientific learning within students' cultural contexts, the Ethno-STEM approach enables a more meaningful and accessible understanding of science in everyday life. The strength of this approach lies in its potential to democratize science education by recognizing multiple ways of knowing and validating local knowledge systems.

Aligning this culturally responsive learning model with the Sustainable Development Goals (SDGs) further enhances its relevance and impact. Education aligned with SDG 4 (quality education) and SDG 13 (climate action) seeks to equip students with the knowledge, skills, and values that contribute to sustainable development from an early age. Integrating SDG into Ethno-STEM learning not only enhances the global relevance of education but also ensures that students are empowered with the knowledge, skills, and values required to contribute to sustainable development (Oláh et al., 2020; Rivera et al., 2020; Yamane & Kaneko, 2021; Bappenas, 2024b, 2024a). Furthermore, in Industry 4.0, where rapid technological advancements are reshaping society and the environment, there is a pressing need for education to foster both digital competencies and environmental ethics simultaneously (Hogan & O'Flaherty, 2022; Chen & Wu, 2024).

Despite the theoretical promise of SDG-oriented Ethno-STEM in natural and social science learning, empirical evidence regarding its effectiveness—particularly in early education settings—remains limited. Most existing studies focus primarily on cognitive outcomes, such as students' conceptual understanding and problem-solving skills. However, sustainability education necessitates a broader scope that includes affective outcomes such as environmental attitudes, values, and behaviors (Darvishmotevali & Altinay, 2022; Ahmad et al., 2022). Environmental awareness encompasses knowledge, attitudes, intentions, and actions related to environmental protection and sustainability. These dimensions are crucial for cultivating lifelong environmental stewardship, yet they are often underexplored in STEM-based educational models. Despite the growing recognition of sustainability education, few studies have empirically examined how SDGs-oriented Ethno-STEM learning simultaneously addresses both cognitive and affective domains of environmental awareness at the elementary level. This gap highlights the need to explore integrated models that not only enhance conceptual knowledge but also foster the values and behaviors essential for sustainable environmental stewardship. Addressing this gap is crucial for ensuring that early education makes a meaningful contribution to global sustainability goals.

Schools play a vital role in embedding environmental awareness through curricula that encourage participatory, contextual, and inquiry-based learning (Thor & Karlsudd, 2020; Ndzimbomvu et al., 2021). However, observations from both the field and large-scale assessments suggest that environmental awareness among students remains inadequate. Programme for International Student Assessment (PISA) revealed stagnation in environmental awareness levels among 15-year-olds from 2006 to 2015, despite increased attention to sustainability in policy discourse (List et al., 2020). Similarly, observational data from elementary classrooms indicate that younger students often struggle to connect abstract environmental concepts to their own experiences and communities, suggesting a failure of conventional, decontextualized teaching methods to promote meaningful learning (Liu et al., 2020; Uralovich et al., 2023).

Furthermore, while many educational interventions incorporate STEM or environmental education independently, few have integrated both culturally grounded content and explicit SDG alignment. Current approaches often fall short of promoting a holistic understanding of sustainability that combines scientific reasoning, cultural relevance, and environmental ethics

(Timm & Barth, 2021; Izzah et al., 2023). There is a clear research gap in studies that examine how integrated, contextualized learning models affect both the cognitive and affective domains of environmental awareness, particularly in the context of elementary education.

Addressing this gap is essential, as early education lays the foundation for lifelong learning and behavior development. Research has shown that learning becomes more meaningful when students can apply knowledge to real-life situations and recognize its relevance to their personal and cultural contexts (Cheung et al., 2021; Akour & Alenezi, 2022). Therefore, educational models that link socio-science learning with local cultures, community practices, and global sustainability goals hold significant promise for enhancing academic and ethical development.

To address these challenges, this study examines the effectiveness of an SDGs-oriented Ethno-STEM learning model in the context of elementary-level natural and social science education. The study aims to evaluate how this integrated approach enhances students' environmental awareness by fostering scientific understanding, cultural relevance, and sustainability-oriented values. Specifically, it seeks to measure both cognitive gains (such as knowledge of environmental concepts) and affective outcomes (such as attitudes and awareness of ecological responsibility). By embedding local wisdom into the learning process and aligning it with global goals, this study explores how Ethno-STEM can serve as a transformative educational approach to building sustainability awareness and competence from an early age.

This research contributes to the growing body of literature on contextual and culturally responsive science education by offering empirical evidence of how integrated Ethno-STEM learning supports sustainable outcomes in primary education. Its novelty lies in the holistic fusion of science, culture, and sustainability, addressing not only what students know but how they feel and act in relation to the environment. Ultimately, these findings aim to inform educators, curriculum developers, and policymakers in designing innovative, inclusive, and future-oriented education strategies that support environmental management in line with the SDGs.

METHODS

This study employed a quasi-experimental one-group pretest-posttest design (Reichardt, 2019) to examine the effectiveness of an SDGs-oriented Ethno-STEM approach in fostering environmental awareness among elementary school students through natural and social science learning. This design enabled the researchers to observe changes in students' knowledge, attitudes, and behaviors before and after the intervention, offering a comprehensive view of the program's impact. The use of a control group was not feasible due to practical constraints in the school setting, including limited access to comparable student populations and the school's policy restrictions on withholding innovative instructional approaches from certain groups of students. This decision was grounded not only in logistical challenges but also in ethical considerations, as withholding an innovative instructional approach from certain student groups could disadvantage them. Thus, the quasi-experimental one-group design was deemed the most appropriate and ethically responsible choice for this context. These conditions made it ethically and logistically challenging to implement a traditional control group design, thereby necessitating the use of a one-group approach.

The study involved 60 purposively selected students from grades four and five in an elementary school, chosen for their active engagement in science-related lessons. These participants were considered sufficiently representative to provide insight into the effects of the learning model on students' environmental awareness. The participants comprised 60 students (31 girls and 29 boys) aged between 9 and 11 years, representing the socio-cultural background of urban Makassar, which is characterized by strong community-based environmental practices.

The research was carried out in four main stages:

1. Preparation Stage

Ethno-STEM-based instructional materials were developed, focusing on key environmental topics such as the impact of plastic waste, the 3R principle (reduce, reuse, recycle) (Escario et al., 2020), and their alignment with the SDGs. Teachers were trained as facilitators, and a range of learning tools—such as educational posters, interactive media (Meilinda et al., 2017), and necessary technological supports—were prepared (Asri et al., 2020; Sholahuddin et al., 2021). A validated research instrument was administered as a pre-test to measure students' environmental awareness. Prior to its use, the instrument's reliability was tested using Cronbach's Alpha, which yielded a value of $\alpha > 0.60$, indicating high internal consistency. The instrument, based on the framework by Ham et al. (2016), captured three

key aspects: knowledge, attitudes, and behavior. These were categorized into pro-environmental and non-pro-environmental dimensions.

The structure of the environmental awareness measurement instrument is detailed in Table 1.

Table 1. Aspects of Environmental Awareness Measurement Instrument

No	Aspect	Indicator		
		Knowledge	**Attitude**	**Behavior**
1	Pro-environment	Knowing the classification of waste	Reminding not to litter	Throwing away trash by sorting it according to its classification
		Knowing things that can pollute the environment	Reminding to protect the environment from pollution	Implementing government regulations to prevent pollution of the environment
		Knowing the types of protected animals	Reminding people not to catch or even kill protected animals	Helping or supporting animal rehabilitation centers for release
		Knowing the function of reforestation	Reminding to always replant after cutting down trees	Not cutting down or damaging trees carelessly
2	Non-pro-environment	Knowing the classification of waste	Not reminding not to litter	Throwing trash carelessly
		Knowing things that can pollute the environment	Not reminding to protect the environment from pollution	Doing things that can pollute the environment
		Knowing the types of protected animals	Not reminding people not to catch or kill protected animals.	Hunting animals as desired
		Knowing the function of reforestation	Not reminding to always replant after cutting down trees.	Cutting down or damaging trees carelessly

2. Implementation Stage (8 Weeks):

The SDGs-oriented Ethno-STEM approach was implemented through structured, weekly activities:

Weeks 1–2: Socialization on plastic pollution and introduction to the 3R principle via interactive lectures and video demonstrations

Weeks 3–4: Engaging students in eco-brick making (Syamsahima et al., 2024) and organizing a technology-enhanced environmental poster competition (Pryshchenko, 2021).

Weeks 5–6: Conducting waste management simulations and launching a "Zero Plastic Week" challenge, where students committed to reducing single-use plastics.

Weeks 7–8: Promoting student-to-student sustainability communication through presentations, showcasing recycled projects, and delivering group messages advocating environmental stewardship.

3. Post-Implementation Stage:

After the learning cycle, a post-test was administered using the same environmental awareness instrument. Reflective discussions were facilitated to explore students' learning experiences, while participatory observation was conducted to document behavioral changes toward environmental issues during school activities.

Data were collected using a 5-point Likert scale questionnaire (Jebb et al., 2021), tested for reliability and validity (Cronbach's Alpha = 0.65). Quantitative data were analyzed using SPSS version 21 through the following methods:

Paired Sample t-Test: Employed to identify statistically significant changes between pre-test and post-test scores. A Shapiro-Wilk test was used to confirm the normality of the data. A p-value < 0.05 indicated a significant improvement in students' environmental awareness.

Cohen's d Effect Size: Calculated to measure the magnitude of the intervention's effect, where 0.2 is small, 0.5 is moderate, and ≥0.8 is large.

Normalized Gain (N-Gain): N-Gain values range from 0 to 1, with values near 1 indicating significant improvement (Coletta & Steinert, 2020). The categorization of N-Gain levels is outlined in Table 2.

Table 2. N-Gain Criteria

N-Gain	Interpretation
0.70 ≤G ≤100	High
0.30 ≤G<0,70	Medium
G<0.30	Low

Thematic Analysis: Conducted on qualitative reflection data and observation notes to identify emerging themes related to students' attitudes, experiences, and behavioral changes. Visual representations of overall N-Gain results are shown in Figures 1 and 2 to support interpretation.

This mixed-methods approach, combining quantitative and qualitative data, enabled the triangulation of findings, ensuring the validity and depth of insights regarding the effectiveness of SDG-oriented Ethno-STEM learning in raising environmental awareness and reducing plastic waste among elementary school students. The paired t-test was selected due to its suitability for detecting pre-test–post-test differences within the same group. While this approach provides strong evidence of change, it does not eliminate all potential confounding factors, and results should therefore be interpreted with caution.

RESULTS AND DISCUSSION

The results of this study began with a Shapiro–Wilk normality test as a prerequisite for conducting a paired t-test on the pre-test and post-test scores of students' environmental awareness.

Table 3. Shapiro-Wilk Normality Test

	Group	Shapiro-Wilk		
		Statistic	df	Sig.
Score	Pre-test	.980	60	.426
	Post-test	.988	60	.826

As presented in Table 3, the normality test indicated that the distribution of both pre-test and post-test data met the assumption of normality ($p > 0.05$), aligning with the findings of Fiandini et al. (2024). Therefore, the data were suitable for further analysis using a paired t-test.

Descriptive and inferential statistical analyses were conducted to assess the effect of the SDGs-oriented Ethno-STEM approach on students' environmental awareness. The mean pre-test score was M = 61.06 (SD = 7.10), while the mean post-test score increased to M = 68.61 (SD = 6.63), reflecting a positive change. A paired t-test confirmed this increase as statistically significant ($p = 0.001$), as shown in Table 4. Furthermore, the effect size analysis yielded a Cohen's d of 2.84, which is categorized as a large effect. This suggests that the intervention had a substantial practical impact on enhancing students' environmental awareness.

Table 4. Paired t-Test Pretest-Posttest

Variable	Mean Difference	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	Sig. (2-tailed)	Cohen's d
Pre-test – Post-test	-7.750	2.730	0.352	-8.455	-7.044	-21.982	59	0.001	2.84

To further analyze the degree of improvement, a Normalized Gain (N-Gain) analysis was performed. The findings indicate that the Ethno-STEM approach—characterized by hands-on, culturally grounded, and participatory activities such as eco-brick creation, waste management simulations, and the "Zero Plastic Week" challenge—played a crucial role in deepening students' understanding of environmental issues while promoting sustainable behavior.

Figure 1 presents the distribution of students' overall environmental awareness based on N-Gain scores, while Figure 2 provides disaggregated results by knowledge, attitudes, and behaviors.

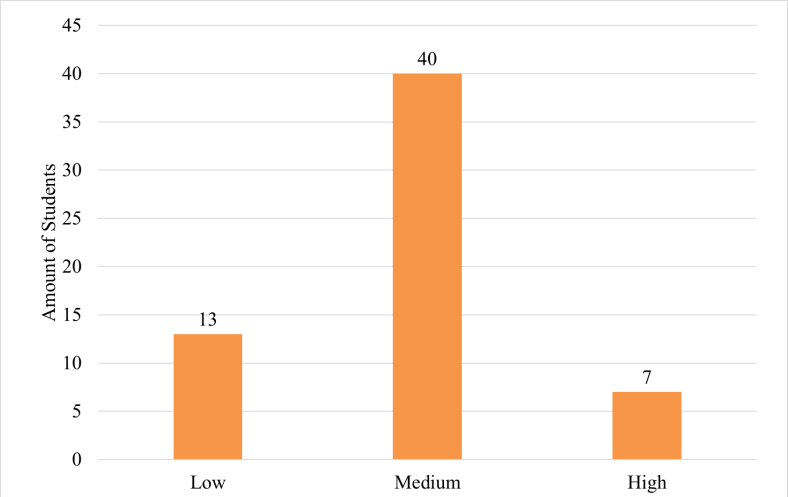

Figure 1. N-Gain Category of Students' Overall Environmental Awareness

As depicted in Figure 1, 13 students exhibited low improvement, 40 showed moderate improvement, and 7 demonstrated high improvement in overall N-Gain scores.

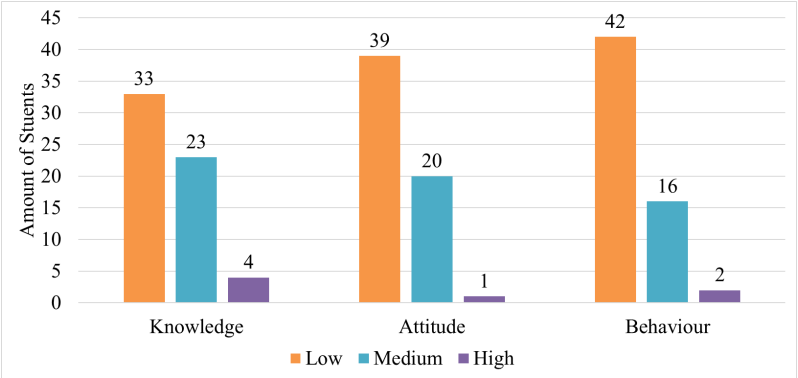

Figure 2. N-Gain Category of Students' Environmental Awareness on Knowledge, Attitudes, And Behavior

As depicted in Figure 1, 13 students exhibited low improvement, 40 showed moderate improvement, and 7 demonstrated high improvement in overall N-Gain scores.

A disaggregated analysis of N-Gain across the dimensions of knowledge, attitudes, and behavior revealed varied outcomes:

Knowledge (Science): 33 students showed low improvement, 23 showed moderate improvement, and 4 achieved high improvement.

Social Attitudes: 39 students fell into the low improvement category, 20 into the moderate, and one into the high category.

Behavior (Action): 42 students demonstrated low improvement, 16 showed moderate improvement, and 2 demonstrated high improvement.

These results confirm the effectiveness of the Ethno-STEM approach in fostering environmental awareness, especially in the cognitive domain, while also highlighting areas where affective and behavioral change may require further reinforcement.

The findings support the view that Ethno-STEM integration significantly enhances elementary students' environmental awareness. The statistically significant increase from pre- to post-intervention ($p = 0.001$) reinforces the potential of culturally contextualized, interdisciplinary learning in shaping sustainable mindsets. According to English (2017), embedding cultural context in STEM education bridges abstract science concepts with students' lived realities. Similarly, Struyf et al. (2019) and Le et al. (2023) emphasize that integrative STEM approaches encourage student-centered learning and real-world problem solving, both of which are central to this study's design. These findings extend previous works (e.g., Wahono et al., 2021; Izzah et al., 2023) by demonstrating that the Ethno-STEM approach

not only enhances cognitive learning but also cultivates the affective and behavioral aspects of environmental awareness—dimensions that have remained underexplored in prior research. This highlights the distinctive contribution of the present study.

This research aligns with contextual learning theory, which advocates for learning experiences grounded in students' socio-cultural contexts. The Ethno-STEM approach leverages local knowledge to promote relevance, engagement, and higher-order thinking. Martín-Páez et al. (2019) suggest that contextualized STEM learning fosters deeper conceptual understanding. Moreover, the present findings affirm the value of combining STEM with local cultural narratives, encouraging students to view environmental stewardship as both a scientific responsibility and a cultural imperative.

In line with Wahono et al. (2020, 2021), integrating STEM with socio-scientific issues not only enhances academic outcomes but also improves motivation, creativity, and prosocial behavior. The novelty of this study lies in demonstrating how SDGs-oriented Ethno-STEM pedagogy can directly foster environmental awareness, particularly addressing SDG 4 (quality education) and SDG 13 (climate action) (Campbell et al., 2018; Wahono & Chang, 2019; Thapa et al., 2023). These figures illustrate that while most students achieved moderate cognitive improvement, affective and behavioral domains require more targeted reinforcement. Beyond theoretical implications, the findings provide empirical support for integrating culture-based learning into elementary education. The instruments and measurement criteria used captured changes across cognitive, affective, and behavioral domains. These findings resonate with the work of Onowugbeda et al. (2024) and Polman et al. (2021), who argue that culturally grounded and technologically enriched learning fosters meaningful, participatory experiences. Aarto-Pesonen & Piirainen (2020) define meaningful learning as the restructuring of cognitive frameworks, where new knowledge is integrated with prior understanding—an outcome clearly evident in the students' evolving environmental awareness.

Furthermore, the Ethno-STEM model underscores the interconnectedness of environmental education and cultural preservation. As noted by Achille and Fiorillo (2022), cultural heritage education can make a meaningful contribution to the 2030 SDGs agenda. By engaging students with their own cultural context, the approach promotes environmental responsibility as both a scientific and moral obligation.

From a theoretical standpoint, this study advances the Ethno-STEM discourse by empirically validating its role in fostering environmental awareness. Culturally contextualized STEM learning not only enhances conceptual understanding but also fosters students' emotional and ethical engagement with sustainability issues (Huang et al., 2019; Zidny et al., 2020). Grounded in contextual learning theory and social constructivism, the results affirm that learning outcomes—spanning cognitive, affective, and psychomotor domains—are enhanced when cultural relevance is integrated into pedagogy.

Practically, the SDGs-oriented Ethno-STEM framework offers a viable alternative learning model for primary education. It allows educators to anchor science instruction in local realities, making abstract environmental concepts more accessible and actionable. This has implications for curriculum design and policy, particularly for embedding sustainability-focused competencies in early education. Policymakers may consider adopting this approach better to align elementary education with national and global sustainability agendas.

Despite its promising outcomes, this study has limitations. First, the relatively small and culturally specific sample constrains the generalizability of findings. Further research is needed to assess the model's effectiveness across diverse cultural and geographic contexts. Moreover, variables such as family background, peer influence, and socio-economic conditions were not fully accounted for, though these likely impact students' environmental attitudes and behaviors outside the classroom. External factors, such as parental modeling, home practices, and exposure to environmental messages through the media, may have also played a role in shaping students' responses during the intervention. Future studies should consider these influences to more accurately isolate the effect of the instructional model.

The study's eight-week duration also limits the ability to conclude the long-term impact of the intervention. While short-term gains were evident, the persistence of these changes over time remains uncertain. Future longitudinal studies are needed to assess whether improvements in awareness and behavior are sustained beyond the intervention period.

In addition, while quantitative methods effectively demonstrated statistical change, they did not capture students' subjective experiences in depth. A mixed-methods approach that includes interviews, observations, and reflective narratives would provide richer insights into how students interpret and internalize their learning. Based

on these findings and limitations, future research should expand the participant pool to include students from various socio-cultural backgrounds and explore the role of external environmental factors (e.g., family and community support). Longitudinal and mixed-methods research designs are recommended to capture both the durability and depth of learning outcomes.

Lastly, the study carries significant ethical and social implications. It highlights the importance of designing inclusive, culturally respectful, and scientifically sound curricula. Integrating local wisdom into environmental education not only strengthens community identity but also fosters collective responsibility for ecological stewardship. Ethno-STEM, when implemented thoughtfully, harmonizes traditional and modern scientific paradigms, supporting a more holistic and justice-oriented approach to sustainability education. In summary, this study demonstrates that SDG-oriented Ethno-STEM learning is a powerful pedagogical tool for fostering environmental awareness among elementary students, especially when grounded in culturally relevant practices. The results inform educators, curriculum developers, and policymakers on how to design more contextual, inclusive, and sustainability-driven educational interventions.

This study demonstrates that integrating an SDGs-oriented Ethno-STEM approach in natural and social science education significantly enhances elementary students' environmental awareness. The findings highlight notable improvements in students' environmental knowledge, attitudes, and behaviors, affirming the effectiveness of combining science education with culturally relevant and participatory learning experiences. Grounded in the theoretical frameworks of social constructivism and contextual learning, the results highlight the importance of connecting curriculum content with students' socio-cultural realities to foster meaningful and enduring engagement. This approach also contributes directly to the achievement of Sustainable Development Goal 4 (quality education) by fostering inclusive, relevant, and transformative learning and Sustainable Development Goal 13 (climate action) by cultivating early awareness and responsibility toward environmental issues.

In addition to its theoretical contributions, the study offers practical implications for educators, curriculum developers, and policymakers. The Ethno-STEM model—through localized, hands-on activities such as eco-brick production, waste management simulations, and the "Zero Plastic Week" challenge—proves effective in helping students internalize environmental concepts and apply them in real-life contexts. However, several limitations must be acknowledged. The research involved a limited sample from a specific cultural setting, which may restrict the generalizability of the results. Moreover, the short duration of the intervention limits the ability to assess the long-term impact of the approach on students' behavior and environmental consciousness.

Given these limitations, future research is recommended to expand the scope by involving more diverse populations across different cultural and geographical contexts to test the consistency and adaptability of the Ethno-STEM approach. Longitudinal studies should be conducted to evaluate the sustainability of environmental awareness over time, and a mixed-methods approach is encouraged to gain deeper insights into students' subjective learning experiences. It is also essential to consider external influences such as family background, community engagement, and socio-economic factors that may shape students' environmental attitudes beyond the classroom. Furthermore, educational policies should support the integration of the Ethno-STEM model into national curricula to institutionalize sustainability-oriented, culturally grounded learning practices at the primary and secondary education levels. Teacher training programs should also be developed to equip educators with the necessary pedagogical and cultural competencies to implement this approach effectively.

CONCLUSION

This study demonstrates that the SDGs-oriented Ethno-STEM approach in natural and social science learning significantly enhances elementary students' environmental awareness. This approach not only improves students' understanding and concern for ecological issues but also aligns with social constructivist and contextual learning theories. Practically, it fosters meaningful learning experiences linked to SDG 4 (quality education) and SDG 13 (climate action). Teachers are encouraged to incorporate local cultural elements and real-world issues into STEM lessons, while policymakers should consider integrating Ethno-STEM into curricula to promote inclusive, sustainability-focused education. Strengthening teacher training programs is crucial for developing culturally responsive pedagogical skills. However, the study's limitations include a small sample size and a narrow cultural context. Future research should involve more diverse

populations to test generalizability and explore adaptability. Longitudinal studies are also necessary to evaluate long-term behavioral outcomes, and mixed-method designs could provide deeper insights into students' internalization of environmental values.

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