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The Application of Ethno-ESD as a Strategy to Strengthen Sustainable Environmental Attitudes in Chemistry Education Students

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Abstract

This study aims to analyze the effectiveness of the Engineering Design Project learning model based on Ethno-ESD in actualizing sustainable environmental literacy in Chemistry Education students. The method used was a quasi-experiment with the design of the One-Shot Case Study involving 46 fifth-semester students. The environmental literacy measurement instrument which includes the aspects of Sustainability Environmental, Sustainability Social, and Sustainability Economic was validated using Aiken's V analysis. After Ethno-ESD learning was applied, the test result data was analyzed through normality, homogeneity, and one-way ANOVA tests to determine the effectiveness of the treatment. The results show that all data are distributed normally and homogeneously, thus qualifying parametric analysis. The ANOVA test produced a value of F = 20.365 with a significance of 0.000, which indicates that the Ethno-ESD learning model has a significant effect on improving students' sustainable environmental literacy. This finding confirms that the integration of local wisdom with the principles of Education for Sustainable Development is able to improve students' knowledge, attitudes, and sustainable behaviors in the context of environmental chemistry learning. The Ethno-ESD model is recommended as an innovative approach to strengthen sustainable environmental literacy in higher education.

Keywords: ESD; ethnoscience; environmental chemistry; sustainability attitude

Abstrak

Penelitian ini bertujuan untuk menganalisis efektivitas model pembelajaran Proyek Desain Teknik berbasis Ethno-ESD dalam mengaktualisasikan literasi lingkungan berkelanjutan pada mahasiswa Pendidikan Kimia. Metode yang digunakan adalah quasi-eksperimen dengan desain Studi Kasus Satu Kali (One-Shot Case Study) yang melibatkan 46 mahasiswa semester lima. Instrumen pengukuran literasi lingkungan yang mencakup aspek Keberlanjutan Lingkungan, Keberlanjutan Sosial, dan Keberlanjutan Ekonomi divalidasi menggunakan analisis Aiken's V. Setelah pembelajaran Ethno-ESD diterapkan, data hasil pengujian dianalisis melalui uji normalitas, homogenitas, dan ANOVA satu arah untuk menentukan efektivitas perlakuan. Hasil menunjukkan bahwa seluruh data terdistribusi normal dan homogen, sehingga memenuhi syarat analisis parametrik. Uji ANOVA menghasilkan nilai F = 20,365 dengan signifikansi 0,000, yang menunjukkan bahwa model pembelajaran Ethno-ESD memiliki pengaruh signifikan dalam meningkatkan literasi lingkungan berkelanjutan mahasiswa. Temuan ini menegaskan bahwa integrasi kearifan lokal dengan prinsip-prinsip Pendidikan untuk Pembangunan Berkelanjutan mampu meningkatkan pengetahuan, sikap, dan perilaku berkelanjutan siswa dalam konteks pembelajaran kimia lingkungan. Model Ethno-ESD direkomendasikan sebagai pendekatan inovatif untuk memperkuat literasi lingkungan berkelanjutan di pendidikan tinggi.

Keywords: ESD; etnosains; kimia lingkungan; sikap berkelanjutan

Introduction

The importance of environmental education in Indonesia has been recognized since the 1990s (Nomura, 2009). Learning materials containing knowledge about the environment and the importance of environmentally friendly behavior have been taught in schools, both public and private schools as part of the national curriculum. Environmental awareness has long been a topic of teaching in schools, but it has not provided certainty whether environmental education has positive results in Indonesian society (Ardan, 2016). Previous research shows that Indonesian society is low in supporting earth conservation (Susilastri & Rustaman, 2015). Attitude-focused education provides an understanding of global issues, but also teaches practical skills that can be applied in daily life to support sustainability (Sasa et al., 2022). Student involvement in practical projects, such as on-campus waste management programs or the construction of green areas, can provide hands-on experience and increase awareness of students' responsibilities towards the surrounding environment (Kuruppuarachchi et al., 2021). A holistic approach in the curriculum can integrate courses such as environmental chemistry so that students can understand the complex relationships between humans, nature, and the economy.

Environmental Chemistry courses can be a foundation for understanding the impact of chemical substances on sustainable attitudes and solutions. Integration of sustainable environmental attitudes in environmental chemistry courses can broaden students' understanding of the relationship between chemistry and global environmental issues and form the attitudes and skills needed to create a more sustainable and environmentally conscious society (Zuin et al., 2021). Environmental chemistry courses can emphasize the importance of applying sustainability principles in chemical practice, including in the context of chemical waste treatment and disposal. The integration between environmental chemistry courses and local wisdom creates a deeper understanding of the impact of chemistry on the environment and how local communities can play a role in sustainable solutions (Marfai, 2019). Students can see that the application of chemistry can be in line with local wisdom, creating solutions that preserve the local cultural and natural richness and develop an appreciation for local knowledge and sustainability values that have been passed down from generation to generation (Izzah et al., 2020). This can motivate students to incorporate the principles of local wisdom in their approach to chemical research and practice.

However, preliminary observations in three Chemistry Education programs in Semarang show that current teaching strategies in Environmental Chemistry have not optimally met their intended outcomes. Although the instructional goals are formally achieved, they fall short in strengthening students' deeper understanding of chemical mechanisms in the environment, pollution analysis, and the development of chemistry-based solutions for environmental protection. This indicates a need for more innovative pedagogical designs that integrate scientific, cultural, and sustainability perspectives. A multidisciplinary approach has been promoted as one way to enrich Environmental Chemistry by integrating insights from ecology, sociology, economics, and environmental science (Hardy et al., 2021). Beyond multidisciplinary integration, ethnoscience-based learning has also shown positive impacts on students' scientific thinking, literacy, chemical understanding, and attitudes toward science (Strachan et al., 2021). Ethnoscience allows local cultural practices to serve as learning stimuli and encourages students to construct scientific understanding while appreciating local ecological knowledge (Erman & Suyatno, 2022; Sudarmin et al., 2020; Sumarni et al., 2021).

Ethnoscience-based learning today not only aims to improve critical thinking skills (Sudarmin et al., 2018), but is able to improve various thinking skills, namely science thinking and science literacy (Hastuti et al., 2019), chemical literacy (Sumarni,

2018; Ariyatun et al., 2020), attitudes towards science (Fasasi, 2017a; Wibowo & Ariyatun, 2020) and has an impact on efforts to preserve local wisdom or community culture. Ethnoscience-based learning is able to increase the participation of students in maintaining and preserving the potential of local wisdom in the community (Erman & Suyatno, 2022). The reorientation of sustainability education confirms that program developers need to balance looking ahead for a more sustainable society with looking back to traditional ecological or cultural knowledge. The quality of learning can be done by integrating local culture into science learning (ethnoscience) (Sudarmin et al., 2020; Sumarni et al., 2021). Local culture can function as a learning stimulus to motivate and assist students in constructing knowledge (Sudarmin et al., 2020; Sudarmin et al., 2023).

Local cultural practices such as natural dye processing, traditional water purification, or organic waste handling reflect chemical principles embedded in community traditions (Febrianty et al., 2023). These practices align with sustainability values and can help students see how chemistry operates within real environmental systems (Li et al., 2016). Because many Indigenous practices inherently promote conservation and ecological balance (Sulaiman et al., 2022), they resonate with the broader goals of Education for Sustainable Development (ESD) (Batoro et al., 2017). Ethnoscience-based learning has a strategic role in preserving indigenous knowledge which is included in the ESD (Educational for Sustainable Development) category. With these characteristics, it can be said that ESD has long grown and developed in the local community environment that has always consistently maintained the preservation of the environment and nature (Erman et al., 2023). The implementation of the ESD integrated ethnoscience approach is expected to be able to actualize the objectives of environmental chemistry lectures.

Despite the growth of ethnoscience-based approaches and widespread promotion of ESD, there is still limited empirical evidence demonstrating how an integrated Ethno-ESD approach improves measurable outcomes in chemistry education, particularly environmental literacy, understanding of environmental chemistry concepts, and sustainable attitudes. Most previous studies have examined ethnoscience to enhance scientific literacy or cultural appreciation, and ESD research has largely focused on attitudes or sustainability awareness but the direct linkage between culturally grounded practices, ESD principles, and chemistry-specific learning outcomes remains underexplored.

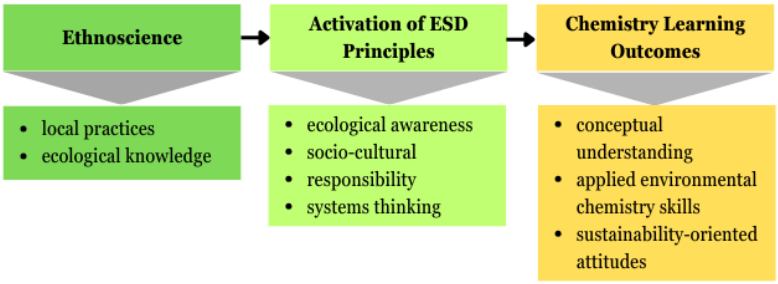
While ethnoscience, ethno-STEM, and ESD have each contributed valuable perspectives to science education, Ethno-ESD represents a distinct pedagogical integration (Gupta et al., 2024; Sumarni et al., 2022; Ariyatun et al., 2025). Ethnoscience foregrounds Indigenous knowledge and local cultural practices as meaningful contexts for understanding scientific ideas (Sudarmin, Ariyatun, et al., 2025). Ethno-STEM emphasizes the blending of cultural knowledge with STEM disciplines to enhance creativity, technological relevance, and problem-solving skills. ESD, on the other hand, prioritizes sustainability principles such as ecological awareness, socio-cultural responsibility, and systems thinking.

Ethno-ESD uniquely merges these three traditions into a coherent transdisciplinary framework, in which local cultural practices act not only as contextual examples but also as pathways for applying sustainability principles directly to chemistry learning (Misseyanni et al., 2020). Through this integration, Ethno-ESD seeks to strengthen students' understanding of environmental chemistry concepts such as reaction processes, pollutants, and waste transformation while simultaneously cultivating measurable gains in sustainable environmental attitudes (Ariyatun et al., 2024). Given this positioning, Ethno-ESD addresses a critical gap in chemistry education, namely the limited empirical evidence showing how culturally grounded sustainability education can enhance both

environmental literacy and conceptual understanding in environmental chemistry. Thus, Ethno-ESD offers strong potential to actualize the goals of Environmental Chemistry courses by bridging chemical concepts, local ecological knowledge, and sustainability competencies within a unified instructional model.

The concept of ESD includes ecological awareness, attitudes, human relations with nature, interaction between science and social sciences, and exploration of social issues about the environment (Juntunen & Aksela, 2014). Judging from the concept of ESD, ethnoscience-based learning is very relevant to ESD which not only focuses on mastering learning materials but also the environment and social life. The context in ESD is then elaborated with the ethnoscience context so that it becomes an Ethno-ESD learning approach. Thus, Ethno-ESD is a learning approach that involves various scientific or transdisciplinary disciplines, including economic, environmental, social and cultural aspects. To illustrate how these components interact in shaping students' environmental chemistry understanding and sustainable attitudes, the conceptual framework of the Ethno-ESD pathway is presented in Figure 1.

Figure 1.
Conceptual Framework



Method

The method used in the application of Ethno-ESD learning is a quasi-experiment with the design of The One Shoot Case Study. The subjects involved were 46 students of Chemistry Education in the 5th semester. The design of The One-Shot Case Study used in this study allows researchers to provide treatment in the form of the application of the Ethno-ESD learning model, then measure the ability of students' sustainable attitudes after the treatment is given. In this design, there are no control groups or pretests, so the focus of measurement is directed to the final achievement of students after going through a series of learning activities based on local wisdom and sustainability principles. At the implementation stage, students are divided into several small groups and given environmental problems relevant to the local context as a basis for designing solutions that are in line with the principles of Education for Sustainable Development (ESD). Each group is asked to integrate elements of local culture (ethnography) into the solution design developed, both in the form of material selection, processes, and approaches to solving environmental problems.

The data analysis technique in this study uses Analysis of Variance (ANOVA) to test the effectiveness of the Ethno-ESD learning model on students' sustainable environmental literacy. Before ANOVA is implemented, a prerequisite test is carried out in the form of normality and homogeneity tests to ensure that the data meets the basic assumptions of parametric statistics. The normality test was carried out to determine whether the data distribution was under normal conditions, while the homogeneity test was used to ensure the similarity of variance between the literacy components. Once both prerequisite tests were met, the analysis was followed by One-

Way ANOVA to determine if there was a significant difference in sustainable environmental literacy scores between the three components. The significance value (p-value) generated from ANOVA is the basis for determining the effectiveness of treatment; If $p \leq 0.05$, it is stated that there is a significant difference so that the treatment of Ethno-ESD has a meaningful influence on improving students' sustainable environmental literacy. Thus, ANOVA was chosen as the main analysis technique to comprehensively test the effects of treatment and ensure that the results of the study have a strong statistical basis.

Results and Discussion

Results of Validation of Expert Judgment of Sustainable Environmental Attitude Instruments

This type of validity is the validity of the content of several items or items of the Sustainability Environmental Attitude (SEA) instrument. The data from filling out the validity sheet by experts is used as a reference in conducting data analysis. Validity data was analyzed using Aiken's V validity analysis technique (Aikens, 1985). Aiken (1985) formulated Aiken's V formula to calculate the content-validity coefficient which is based on the results of an assessment by a panel of experts of n people on an item in terms of the extent to which the item represents the construct being measured. The validity of the content is carried out by five validators. The validator's assessment data is obtained after the validator provides an assessment by filling in the validity instrument that has been provided. The filling of this instrument is carried out by the validator after observing a set of SEA instruments. The validation results were then analyzed using Aiken's V analysis and presented in Table 1.

Table 1.
Results of Aiken's V Sustainability Environmental Attitude analysis

No	Aspects/components	V	Criterion	Interpretation
1	Sustainability Environmental	0.85	Relevant	Valid
2	Sustainability Social	0.85	Relevant	Valid
3	Sustainability Economic	0.75	Quite Relevant	Valid (Revision)
	Average	0.81	Relevant	Valid

The results of the content validity analysis using Aiken's V were obtained that the value of the validity coefficient for the three main aspects of the Sustainability Environmental Attitude (SEA) instrument was in the range of 0.75 to 0.85. This value shows that all aspects are judged to meet the relevance criteria by the validators. Two aspects, namely Environmental Sustainability and Social Sustainability, each received a V value of 0.85, which is in the relevant category, so that both aspects can be declared valid without revision. Meanwhile, the Sustainability Economic aspect obtained a V value of 0.75, which is in the category of quite relevant, so it is still declared valid but needs revision to improve the instrument items. Aiken's V mean value of 0.81 indicates that overall the SEA instrument has good content validity and meets the eligibility criteria for use in the study. These findings indicate that experts agree that the instrument represents the construct of sustainable environmental literacy to be measured, although some improvements to the economic aspect are still needed to improve the accuracy and clarity of the question points. Thus, this instrument is suitable for use at the next stage of data collection after minor revisions are made according to the validator's input.

Effectiveness of the Implementation of the Ethno-ESD Learning Model

After the Sustainability Environmental Attitude (SEA) instrument is declared valid through Aiken's V analysis, the next stage is to test the effectiveness of the

application of the Ethno-ESD learning model in improving students' sustainable environmental literacy. Learning effectiveness is measured based on the results of environmental literacy tests after students participate in a series of learning activities based on local wisdom and the principles of Education for Sustainable Development (ESD). Environmental, Social Sustainability and Economic Sustainability data students were then subjected to prerequisite tests to see the normality and homogeneity of the data group. The calculation of the normality test can be seen in Table 2.

Table 2.
SEA Normality-Homogeneity Test Results

Indicators	N	Average	Sig. Normalitas	Sig. Homogenitas
Sustainability Knowledge	46	86.33	0.542	0.093
Sustainability Attitude	46	81.71	0.456	0.073
Self-report sustainable behavior	46	83.76	0.318	0.184

The results of the prerequisite test, which included normality and homogeneity tests for the three components of sustainable environmental literacy, Sustainability Knowledge, Sustainability Attitude, and Self-report Sustainable Behavior, were obtained that all data met the normal distribution criteria. The significance value of the normality test in the three components was above the limit of α = 0.05, 0.542 each; 0,456; and 0.318. This shows that the distribution of the data is in a normal state, so it can be used for advanced analysis using parametric statistical techniques. This condition also indicates that students' responses to the SEA instrument tend to be stable and do not show extreme deviations in the answer pattern.

In addition, the results of the homogeneity test with a significance value of 0.093 each; 0,073; and 0.184 is also above the value of α = 0.05, which means that all three data groups have homogeneous variance. The homogeneity of variance is important to ensure that the difference in achievement between aspects is not caused by irregularities in data dissemination, so that the results of the analysis can be interpreted more accurately. This condition strengthens the validity of the evaluation process for the effectiveness of the implementation of Ethno-ESD learning, because the data analyzed has stable and accountable statistical characteristics.

Overall, the fulfillment of the assumptions of normality and homogeneity shows that students' sustainable environmental literacy data is ready to be analyzed further to determine the effectiveness of the Ethno-ESD learning model. This supports the inference that changes in student achievement after treatment are actually a reflection of the influence of the learning model, rather than an artifact of inappropriate data distribution or inhomogeneous variance. Thus, the results of this prerequisite test strengthen the methodological basis to assess how much the Ethno-ESD approach contributes in improving aspects of knowledge, attitudes, and sustainable behavior in students.

After the prerequisite test is met, the analysis is continued using one-way ANOVA to assess the effectiveness of the application of the Ethno-ESD learning model to students' sustainable environmental literacy. The results of the ANOVA test are presented in Table 3.

Based on the results of the ANOVA test presented in Table 3, it can be seen that the value of the Sum of Squares between groups is 5229.736 with a mean square of 2036.478, while the Sum of Squares in the group is 11927.010. The comparison of these two values results in an F value of 20.365. This high F value indicates that the variation caused by the Ethno-ESD learning treatment is much greater than the variation that arises naturally between individual students in the group. Furthermore, a significance value of 0.000, which is well below the α = 0.05 limit, indicates that the difference is statistically

significant. This means that the application of the Ethno-ESD learning model has a real influence on improving students' sustainable environmental literacy.

Table 3.
ANOVA Test

Ethno-ESD Use					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	5229.736	1	2036.478	20.365	.000
Within Groups	11927.010	45	101.765		
Total	18366.746	46			

In other words, students' final achievements do not happen by chance, but are the result of their involvement in learning based on local wisdom integrated with the principles of Education for Sustainable Development (ESD). These results confirm that the Ethno-ESD model is effective in developing students' understanding, attitudes, and sustainable behavior tendencies, making it worthy of being recommended as an innovative approach in environmental chemistry learning in higher education. From an educational perspective, the statistical significance suggests that Ethno-ESD may offer promising potential for enriching students' understanding of sustainability-oriented chemistry concepts, particularly through learning experiences grounded in local ecological knowledge. However, stronger research designs such as pretest–posttest control group studies, longitudinal tracking, or mixed-methods approaches are needed in future work to more confidently determine the extent to which Ethno-ESD contributes to the development of knowledge, attitudes, and environmentally responsible behaviors in chemistry education.

Changes in sustainability environmental attitudes illustrate a shift in students' attitudes towards environmental and sustainability issues. The Ethno-ESD learning design successfully creates an environment that supports the development of positive attitudes towards sustainability, involving ethnographic aspects to explore local and cultural values that support sustainability. Improved sustainability behavior shows that Ethno-ESD learning design not only provides knowledge and attitude change, but also encourages real, sustainable actions from students (Horvath et al., 2013). The ability of students to report their own sustainable behaviour demonstrates the integration of sustainability values into their daily practices.

The Ethno-ESD learning model is able to provide opportunities for students to collaborate with the local community, strengthening community involvement in learning projects. As a result, students can directly experience the impact of the technological innovations they design in the context of sustainability, which can stimulate positive attitudes and actions towards the environment (Winarno et al., 2020). Thus, the Ethno-ESD learning model not only shapes students' technical expertise, but also encourages the development of deep and sustainable environmental literacy.

Ethno-ESD strengthens students' understanding of environmental chemistry by linking core chemical principles such as reaction processes, pollutant behavior, and waste-management mechanisms with culturally rooted practices that students can observe directly (Marouli, 2021). When learners analyze real environmental phenomena embedded in local traditions, abstract chemical ideas become concrete and meaningful (Sudarmin et al., 2025). Through this approach, students examine how natural reactions occur in everyday cultural activities, how certain materials act as pollutants or environmental stressors, and how communities traditionally manage waste or purify water. This contextual grounding helps students develop a deeper

conceptual grasp of environmental chemistry while recognizing the ecological logic embedded in Indigenous knowledge systems.

A central learning activity in the intervention involved a project on producing natural batik dyes using mangrove extracts, sappan wood, and indigo leaves. Students engaged in hands-on chemical processes: extracting pigments, observing oxidation reduction reactions, identifying functional groups in natural colorants, and analyzing how pH, temperature, or mordants influence dye fixation. Through this project, they documented each stage in a final report that integrated environmental chemistry concepts including the environmental impact of synthetic versus natural dyes, the biodegradability of organic compounds, and the potential for chemical waste reduction in traditional dyeing practices. This experiential learning allowed students to internalize chemical concepts not as isolated theories but as processes directly observable in culturally meaningful activities.

Ethnoscience practices are closely tied to chemical phenomena (Sudarmin et al., 2025). Natural dyeing traditions embody principles of organic chemistry and reaction kinetics, such as pigment extraction, molecular bonding between dyes and fibers, and the role of metal salts as catalysts or mordants. Local water purification practices, such as using charcoal, crushed seeds, or plant fibers, reflect adsorption, coagulation, and filtration mechanisms recognized in environmental chemistry.

Composting traditions reveal biochemical and thermochemical processes microbial degradation, heat-release reactions, and nutrient cycling that parallel topics commonly covered in environmental chemistry courses. By engaging with these culturally embedded practices, students learn to see chemistry not as abstract formulas but as a living system intertwined with community knowledge, ecological stewardship, and sustainable resource management.

Conclusion

The findings from the validation and effectiveness testing demonstrate that the Sustainability Environmental Attitude (SEA) instrument possesses strong content validity, with Aiken's V values ranging from 0.75–0.85, indicating that the items largely capture the intended constructs despite minor refinement needs in the sustainability economic dimension. The ANOVA results further show that the Ethno-ESD learning model significantly enhances students' sustainable environmental literacy, supported by fulfilled normality and homogeneity assumptions and an F value of 20.365 ($p < 0.001$). These results confirm the effectiveness of Ethno-ESD in integrating local wisdom with ESD principles to strengthen knowledge, attitudes, and environmentally responsible behavior in environmental chemistry learning. However, this study is limited by its quasi-experimental design, relatively small and localized sample, and reliance on self-report measures, which may restrict generalizability. Future research should involve comparative or longitudinal studies, incorporate laboratory-based modules, and expand participant diversity to examine long-term conceptual and behavioral impacts. Theoretically, this study contributes to chemistry education by clarifying the mechanistic pathway through which ethnoscience-based cultural practices interact with sustainability principles to produce measurable gains in environmental literacy, thereby positioning Ethno-ESD as a coherent and context-responsive pedagogical framework for higher education.

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