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Sustainability Literacy: What is its Impact on Pro-Environmental Behavior and Students' Ecological Competence?

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ABSTRACT

The urgent need for environmental preservation requires a fundamental shift in human behavior, which can be achieved through education focused on sustainable development. This study is aimed at analyzing the effect of understanding the concept of sustainable development on pro-environmental behavior and ecological competence among students at MA Al-Islam Joresan. This research employed a quantitative approach with a causal-associative design. Data were gathered through standardized test instruments and structured questionnaires. The target population comprised 11th-grade science students, from which the sample was drawn in two distinct phases. Initially, 23 students participated in a preliminary assessment, followed by the selection of the 20 highest-scoring individuals for the subsequent questionnaire phase. Purposive sampling was utilized based on practical constraints of time and accessibility, ensuring that participants' age, cognitive level, and existing knowledge were aligned with the research objectives. Data analysis used descriptive statistics to identify low scores and the Partial Least Squares - Structural Equation Modeling (PLS-SEM) approach for inferential testing.The PLS-SEM analysis indicates that conceptual understanding has a significant positive effect on pro-environmental behavior ($R^2 = 0.780$) and ecological competence ($R^2 = 0.646$). These findings demonstrate that strengthening cognitive literacy fosters concrete environmental action in schools. The implication is that educational institutions should reposition their curricula by integrating digital technology to transform students into agents of environmental change.

Keywords: *ecological competence, sustainable development, pro-environmental behavior, PLS-SEM*

INTRODUCTION

The world today faces a serious global environmental crisis, with challenges such as global warming, ecosystem destruction, air pollution, and the decline in the quality of natural resources continuing to threaten the survival of humans and the planet (Putro, 2024). Human activities are the main factor in increasing greenhouse gas emissions. Other factors contributing to global warming include waste, transportation, agriculture, and deforestation. Rahmani & Ahmadi (2024) also revealed that global temperature rise results from several factors, including fluctuations in the concentrations of greenhouse gases and particulates in Earth's atmosphere, as well as black carbon, methane, nitrous oxide, and chlorofluorocarbons.

Human behavior is the basis of all aspects. In their existence, humans must always monitor and guide, especially the younger generation. Guidance and supervision regarding the environmental economy and the role of human activities in global warming are essential to reduce the adverse effects of its spread. Human activities have a far greater impact on the climate than

natural phenomena such as solar fluctuations and volcanic eruptions (Liputo, 2025). Sustainable Development has emerged as an essential framework that aims to meet the needs of the current generation without compromising the ability of future generations (Rahmat, 2024). The concept of Sustainable Development integrates three main pillars, namely economy, society, and environment. Climate change has become a global challenge that disrupts the balance of ecosystems, requiring teaching materials to comprehensively improve students' climate literacy (Mutmainah & Norsaputra, 2023). The environmental awareness of the younger generation is also strengthened by digital interactions and by social media's role as a medium of advocacy in disseminating sustainable practices, making the integration of the green economy concept into the curriculum a key to building an educational ecosystem (Tass & Malik, 2025).

Education for Sustainable Development represents a deliberate and ongoing process, serving as a fundamental pillar for community advancement while fostering pro-environmental conduct and ecological competencies among students (Utami et al., 2025). The Ministry of Education and Culture has demonstrated a steadfast commitment to the institutionalization of Education for Sustainable Development (ESD). Through this framework, students are empowered with the requisite attitudes, skills, and cognitive insights necessary for informed and responsible decision-making. Consequently, the integration of sustainability principles into the core curriculum is regarded as a strategic imperative. Extensive literature suggests that the proficiency of educators in applying Technology Pedagogical Content Knowledge (TPACK) within an ESD context remains the cornerstone of effective instructional delivery (Purwianingsih et al., 2022).

The implementation of sustainable development at MA Al-Islam Joresan does not stop at theoretical studies of Green Islamic Schools in national forums; it is realized through concrete actions through the P2RA program, one of which is organic fertilizer processing. Based on a preliminary study conducted by researchers using an integrative test instrument, there is a significant gap in students' understanding. The study found that the lowest scores were in the range of 36-49, indicating misconceptions about the systemic relationships among physical and chemical phenomena and ecological impacts, such as acid rain and the carbon cycle. As in the research conducted by Mustika et al. (2025), students have a basic understanding of sustainability issues, but their capacity to analyze risks and make smart decisions on complex issues is still limited.

Students' inability to connect scientific concepts with environmental realities shows that conventional evaluation tools often fail to capture the depth of systemic thinking. The development of integrative testing tools in this study is key to assessing the extent to which students can synthesize multidisciplinary information into practical, sustainable solutions for their ecosystems. In this rapidly evolving digital age, environmental education faces challenges not only in traditional teaching methods but also in how technology can transform abstract concepts into meaningful learning experiences. The use of virtual simulations and artificial intelligence (AI)-powered platforms allows students to see the effects of carbon emissions firsthand. Hence, it is particularly important because preliminary research indicates barriers to understanding systemic phenomena such as the carbon cycle. With the right visualizations, misunderstandings about its relationship to physical stress, chemical reactions, and environmental damage can be significantly reduced.

Although there is a positive and significant correlation between environmental awareness and pro-environmental behavior, implementing sustainable development faces challenges due to the gap between awareness and action (the knowledge-action gap) (Wang & Mangmeechai, 2021). Individuals with high environmental knowledge do not necessarily exhibit pro-environmental behavior due to the many barriers in this gap (Ringle et al., 2021). In fact, research shows that environmental knowledge does not always correlate positively with pro-environmental behavior, suggesting that relying solely on the cognitive aspect is insufficient (Simanjuntak et al., 2023). Pro-environmental behavior is behavior that stems from a person's awareness of how to minimize the negative impact of their actions on the sustainability of natural resources.

The crucial aspect of this study is ecological competence. This variable is defined as the capacity of students to conduct critical analysis and systemic evaluation of the complexity of environmental phenomena in an integrated manner, based on test instruments developed by researchers, the ability to integrate the concept of water pressure physics with geological risks in dam construction (Ardiansyah & Khurtumi, 2022), or the chemical process of photosynthesis with carbon emission management. Given the knowledge-action gap and misconceptions in preliminary studies, statistical analysis capable of modeling complex relationships is required (Shobah, 2025).

Therefore, educational transformation is not merely about adding material, but about repositioning students from consumers of information to agents of change capable of designing innovative solutions to environmental crises. Through an integrated understanding of science, technology, and ethics, it is hoped that pro-environmental behavior will be formed not through curriculum coercion, but through deep critical reasoning about future sustainability.

Previous research has highlighted that the Adiwiyata program can positively impact students' environmental literacy through descriptive analysis (Aprilianti, 2023). Similarly, Yulinda et al. (2024) demonstrated that the higher the level of environmental awareness, the more pro-environmental the behavior. Furthermore, research conducted by Husban (2025) emphasizes that understanding the concept of sustainable development can be measured through students' understanding of the dimensions of the SDGs. However, most of these studies remain descriptive and have not tested complex causal relationships. Therefore, the Author conducted this study to address this gap by using a PLS-SEM approach to model the simultaneous influence of conceptual understanding on students' ecological competencies and behaviors. Consequently, it provides a more in-depth empirical contribution to the effectiveness of Education for Sustainable Development at the high school level. Thus, it aligns with the research objective of analyzing the influence of conceptual understanding of sustainable development on pro-environmental behavior and ecological competencies among students at MA Al-Islam Joresan.

METHODOLOGY

The study used a quantitative research with a causal associative design. According to Sugiyono, associative research is a research problem formulation that asks about the relationship between two or more variables. The method used in this study is the survey method, where the Author distributed questionnaires for data collection (Siagian, 2024). This method was chosen to empirically test whether the independent variable has a significant effect on the dependent variable. The research sample was determined using saturated sampling to obtain maximum accuracy and full representation of the group being studied. The research population consisted of all 11th-grade students at MA Al-Islam Joresan. From this population, class XI A was selected as the research sample, with 23 students in the first phase and 20 in the second phase. This sample was selected based on specific considerations, such as time, access, and students. Characteristics relevant to the research needs, such as age, level of understanding, and initial abilities, were considered relevant. By selecting this class, the researchers hoped to minimize bias and enhance the validity of the research results.

The study measured understanding of the systemic concept, pro-environmental behavior, and ecological competence. The study was conducted by giving test questions to students in the first stage, followed by a questionnaire in the second stage, which was completed by the sample with the highest scores on the previous test. The first stage consisted of a test comprising 9 multiple-choice questions, 9 multiple-choice questions with dilemma cases, and 3 integrative essay questions. The questions were based on decision-making indicators: integrated and multidisciplinary cognition, multidisciplinary understanding, and absence of misunderstanding. This instrument is designed to examine how an understanding of the concept of sustainable development can transform students' pro-environmental behavior and ecological competencies

through an integrated cognitive framework. Specifically, this approach measures the extent to which mastery of classroom material goes beyond mere memorization. Instead, it serves as a foundation for students to conduct systemic analyses of complex environmental phenomena. The second stage consisted of a questionnaire using a 5-point Likert scale with the following scores: score 5 = Strongly Agree (SA), score 4 = Agree (S), score 3 = Neutral (N), score 2 = Disagree (D), and score 1 = Strongly Disagree (SD). The questionnaire was based on the following research variables: sustainable development (X), consisting of 3 questionnaires; pro-environmental behavior (Y_1), consisting of 4 questionnaires; and ecological competence (Y_2), consisting of 4 questionnaires.

Data analysis was conducted in two stages. The first stage was descriptive analysis of the integrative test instrument to map low scores (range 36-40). The second stage was an inferential analysis using the Partial Least Squares - Structural Equation Modeling (PLS-SEM) approach with SmartPLS software. Hair et al. (2022) stated that the data analysis method using Partial Least Squares - Structural Equation Modeling (PLS-SEM) has high statistical power and remains stable even when used on limited sample sizes, especially for causal relationships in small populations. The Partial Least Squares Structural Equation Modeling (PLS-SEM) method was chosen because it can handle complex structural models and is flexible regarding data assumptions(Babatunde et al., 2024).

The Partial Least Squares: Structural Equation Modeling (PLS-SEM) analysis was conducted in two main steps. First, an evaluation of the Measurement Model (Outer Model) is conducted to test the validity and reliability of the Likert-scale questionnaire instrument, including convergent validity (factor loadings and AVEs), discriminant validity, and composite reliability. Second, an evaluation of the Structural Model (Inner Model) is conducted to test the research hypothesis through the bootstrapping procedure. This analysis aims to measure the strength of the influence of independent variables on dependent variables through path coefficient values, significance levels (P-values), and R^2 (R-square) values to see the contribution of Understanding the Concept of Sustainable Development (X) to Pro-Environmental Behavior (Y_1) and Ecological Competence (Y_2) of students.

RESULT AND DISCUSSION

Initial assessments involving 23 respondents revealed a notable dispersion in performance, as illustrated in Figure 1. The mapping results found that 3 respondents had very low scores in the range of 36-49, and 20 respondents scored in the range of 69-100.

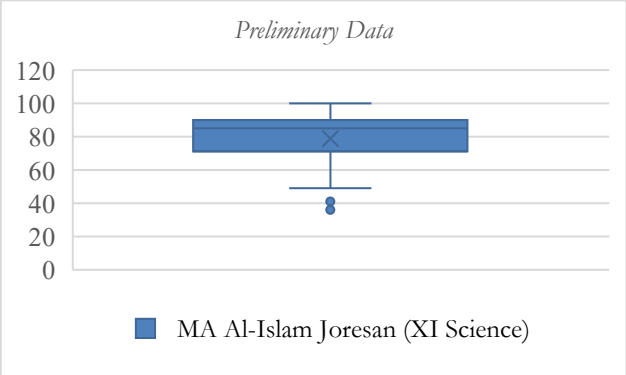

Figure 1. Preliminary Data

To maintain data quality and model accuracy in Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis, researchers conducted sample reduction. Of the initial 23 respondents, 3 were excluded because they were categorized as outliers that could distort construct validity results. Therefore, in the second stage of the study, only 20 respondents who met the data

consistency criteria were included. This step was taken to ensure that the relationships between the variables tested had high precision, in accordance with structural model analysis standards. The next stage was a questionnaire assessing students' understanding of development, sustainability, pro-environmental behavior, and ecological literacy. For this questionnaire, subjects were selected based on the highest scores from the previous test.

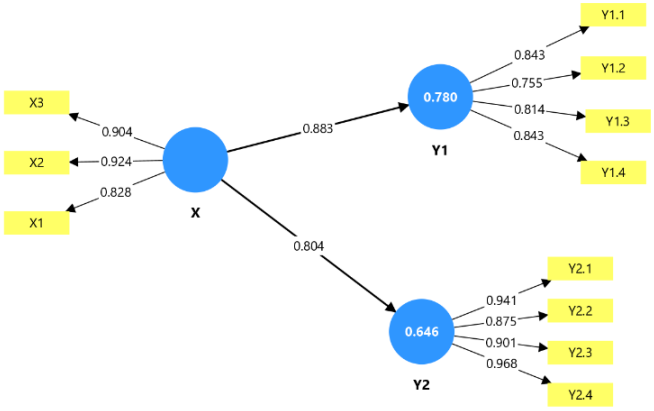

Figure 2. Path Diagram

Based on the highest-value path diagram for students' ecological abilities, the strongest indicator is the integrated cognition indicator, with a value of 0.968. The lowest value for the pro-environmental behavior variable and the weakest indicator is the pro-environmental behavior and action indicator, which is 0.755. The high scores on these indicators demonstrate that students have not only achieved a level of theoretical understanding but also have mature, integrated cognition (the ability to explain water conservation/biopori techniques) in connecting interdisciplinary scientific concepts, such as water infiltration physics and soil biology, to produce real environmental solutions. The low score on this indicator indicates that energy-saving behaviors, such as turning off lights or fans, are less consistent than other pro-environmental actions, as they are often considered trivial. To increase pro-environmentalism, teachers need to strengthen learning focused on transformative, participatory innovation, such as the Environmental Ambassador group formation program. Through this program, students with the highest ecological ability scores can educate their friends about the importance of pro-environmental behavior using language that is more easily accepted.

Table 1. Loading Factor Table

Description of Specific Statements	The Concept of Sustainable Development	Pro-Environmental Behavior	Students' Ecological Competence
Awareness of the concept of sustainability for the future	0.828		
Understanding the impact of plastic waste on soil ecosystems	0.924		
The belief that protecting nature is a religious obligation (Islam)	0.904		
The habit of separating waste types at school		0.843	
Concrete actions to save energy (lights/fans)		0.755	
Awareness of saving water when performing ablution		0.814	

Description of Specific Statements	The Concept of Sustainable Development	Pro-Environmental Behavior	Students' Ecological Competence
Commitment to reducing plastic by bringing a water bottle		0.843	
Practical skills in making organic fertilizer			0.941
Ability to educate others about reforestation			0.875
Sensitivity to identifying environmental issues at school			0.901
Mastery of biopore hole maintenance techniques			0.968

As illustrated in Table 1, cognitive reinforcement of the concept of sustainable development at MA Al-Islam Joresan is key to motivating students to take concrete action. The significant influence on pro-environmental behavior shows that a good understanding can transform awareness into action, such as waste management and energy conservation, which are part of the P2RA program at the school.

Hence, it supports the theory that sound scientific reasoning leads to accurate decision-making regarding environmental issues (Mustika et al., 2025). Compared to a 2023 study by Aprilianti (2023), which used a Partial Least Square - Structural Equation Modeling (PLS-SEM) model, this study shows that students' ecological competence does not stem from habits but rather depends on their conceptual understanding of systemic ecosystems.

Table 2. Construct Reliability and Validity Table

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
X	0.863	0.874	0.916	0.786
Y1	0.831	0.841	0.887	0.663
Y2	0.941	0.945	0.958	0.850

Based on the results of hypothesis testing (Inner Model) through bootstrapping in Table 1, variable X has a path coefficient of 0.900 with a T-statistic value of 23.043 (> 1.96) and a P-value of 0.000 (< 0.05) on variable Y_1. It indicates that understanding the concept of sustainable development significantly affects pro-environmental behavior. Hence, it is in line with the research procedure conducted by Sutrisno, Siregar, Putra, and Akmal (2024) on "Construct Analysis of AMDA Model Syntax Using the SEM-PLS Method" which found that SEM-PLS is effective for measuring the causal relationship between learning model syntax and student learning outcomes or competencies (Siregar et al., 2024). The coefficient value of 0.900 indicates a very strong relationship. It indicates that a noticeable increase in student understanding will follow the level of student behavior. In this context, students know that littering with plastic waste can damage the soil ecosystem in the long term, so students actually separate organic and inorganic waste when disposing of waste in the school environment. Moreover, it is in line with the theory that knowledge or understanding is the most important domain in shaping a person's overt behavior (Alfajri et al., 2025).

The results of the analysis indicate that understanding the concept of sustainable development has a positive and significant influence on students' ecological competence, as evidenced by a path coefficient of 0.820, a T-statistic of 10.313 (> 1.96), and a P-value of 0.000 (< 0.05). A high path coefficient value represents a very strong relationship, meaning that a significant improvement will follow every increase in conceptual understanding in students' ecological

competence. It proves that mastery of classroom material is not merely rote memorization but rather serves as the primary foundation for students to conduct systematic analysis of complex environmental phenomena. Theoretically, these findings align with the research by Ardiansyah & Khurtumi (2022), which indicates that ecological competence is highly dependent on students' ability to integrate their understanding of scientific concepts with real-world environmental risks. Furthermore, Mustika et al. (2025) emphasize that well-developed scientific reasoning is key for students to conduct systemic analysis and make accurate decisions regarding complex environmental issues (Mustika et al., 2025). Thus, the enhancement of cognitive literacy at MA Al-Islam Joresan has proven to be a determining factor in transforming theoretical knowledge into practical ecological competence.

Based on the analysis results, the pro-environmental behavior variable (Y1) has an R-square of 0.780, which is considered strong. It shows that the variable of understanding the concept of sustainable development (X) plays a dominant role, accounting for 78%, in shaping the actual actions of MA Al-Islam Joresan students. Moreover, it is supported by research by Saputra et al. (2025), which found that students' pro-environmental attitudes and behaviors do not develop overnight but result from the implementation of a structured environmental program at school, namely GPBLHS. At MA Al-Islam Joresan, the P2RA (Projek Penguatan Profil Pelajar Rahmatan Lil Alamin) program plays a role similar to GPBLHS in creating an ecosystem that supports the transformation of knowledge into concrete action.

The high figure of 78% is influenced by the integration of environmental values into the school curriculum, which is application-oriented. Other variables outside the scope of this study explain the remaining 22%. The R^2 of 0.780 is effective for mapping the interaction of latent variables in the field of education. In addition, the finding that conceptual understanding encourages real action supports the argument (Mutmainah & Norsaputra, 2023) regarding the importance of comprehensive literacy in changing students' perspectives on ecosystem issues.

Variable Y_2 obtained an R-square value of 0.646, which is in the moderate category. It indicates that the variable measuring understanding of the concept of sustainable development (X) explains 64.6% of the variation in the ability variable. Although conceptual understanding accounts for 64.6%, there remains a 35.4% gap, influenced by factors outside the scope of this study. Therefore, it suggests the influence of external variables, such as the intensity of field experience and higher-order thinking skills, which have not yet been fully measured. This finding aligns with the theory proposed by Putri et al. (2023), which states that systemic ecological competencies require more than theoretical understanding; they necessitate deeper pedagogical interventions to sharpen students' critical thinking. Thus, these results underscore the importance of schools not only focusing on classroom content but also strengthening practical activities to bridge the remaining gap.

This study provides a crucial insight: although practical programs such as P2RA at MA Al-Islam Joresan have succeeded in shaping students' daily habits, there are major challenges in transforming these habits into systemic ecological competencies. The moderate score on the ecological competency variable (64.6%) indicates that students still tend to perform pro-environmental actions procedurally without a deep understanding of the long-term scientific consequences of these actions. For example, students may routinely separate waste because of school rules. However, they may not necessarily be able to chemically analyze how the decomposition of this waste affects the nitrogen cycle or methane emissions in the atmosphere.

To improve systemic (ecological) analysis skills, students need more than just theory; they also need critical thinking skills and more intensive field experience. In line with the research study by Putri, Hidayat, and Supriatno (2023) on Senior High School Students' Perception of Sustainability Literacy in Biology Learning, it was revealed that although students have a positive perception and basic awareness of sustainability, they often still struggle with more complex and

systemic aspects of ecological literacy. It reinforces the study's findings at MA Al-Islam Joresan that students find it easier to practice daily habits but require more intensive pedagogical intervention to master comprehensive ecological reasoning (Putri et al., 2023).

The analysis results show that the variable measuring understanding of the concept of sustainable development (X) explains 78% of the variation in pro-environmental behavior (Y_1). This figure is very high and shows that students' knowledge at MA Al-Islam Joresan is not only theoretical. In line with the integration of Islamic education and environmental programs, this integration effectively shapes students' sustainable character (Malik et al., 2025). Thus, it is evidenced by students' concrete actions in separating organic and inorganic waste to protect the soil ecosystem. This condition is supported by the application of the Green Islamic School concept and the P2RA program through organic fertilizer processing. An evaluation study demonstrated its ability to increase the effectiveness of environment-based character education in Islamic schools (Wahjusaputri & Nazhif, 2025). This implementation helps Students Bridge the knowledge-action gap that often becomes an obstacle in environmental education. Through the P2RA program, students' understanding of the Sustainable Development Goals (SDGs) can be strengthened, and they can be influenced by learning media and a supportive school social environment (Baga et al., 2022).

One factor that caused the analysis results to differ was that students at the school quickly imitated the good behavior of teachers and the P2RA program. However, students' ecological abilities required more critical thinking training. The strong influence of conceptual understanding on pro-environmental behavior in this study aligns with Dalam and Abad (2020), who argue that environmental literacy is not merely a mastery of theory but rather an individual's capacity to take concrete actions to solve environmental problems. The awareness that grows from a mature understanding of concepts will shape students' personal responsibility for ecosystem sustainability. This study confirms that the gap between ecological behavior and ability can be bridged through the development of socio-scientific reasoning. As emphasized by Mustika et al. (2025), strengthening scientific reasoning will equip students with more mature decision-making skills, so that they not only behave in a pro-environmental manner procedurally, but also have sharp systemic analysis capabilities.

Although the results are promising, this study has limitations due to the relatively small sample size and the use of a saturated sampling technique, which limits the generalizability of the findings to a broader population. The primary focus of this study is also limited to the influence of conceptual understanding, so it has not yet thoroughly explored other external variables. Factors such as the intensity of field experience, the specific influence of social media, and the level of higher-order thinking skills which can affect the gap between knowledge and action have not been fully accounted for in this model.

For future research, it is recommended to expand the sample to include a broader range of educational institutions to enhance the external validity of the findings. It is strongly recommended to integrate problem-based learning strategies and digital technology to enhance students' systemic ecological competencies more effectively. Furthermore, strengthening critical thinking training is crucial so that the pro-environmental behaviors that are formed are not merely procedural or simply following school rules, but are grounded in deep scientific reasoning regarding global sustainability issues.

CONCLUSION

The study conducted at MA Al-Islam Joresan highlights the importance of having a strong conceptual understanding of environmental issues. This understanding accounts for up to 78% of the variation in students' pro-environmental behavior. Thus, the findings emphasize that ecological

awareness cannot be developed solely through the habitual practices encouraged by the P2RA program. Instead, it must be anchored in critical reasoning about the core principles of sustainability. These findings have significant implications for educational practice. Institutions should realign their curricula, embed digital technology, and adopt problem-based learning models. These approaches empower students as agents of change, connecting Islamic ethical values with practical environmental solutions. For future research, attention should be given to developing and implementing strategies that enhance higher-order thinking skills and address the current shortfall in ecological competencies. Strengthening these skills will help forge a stronger connection between scientific literacy and sustainable action in real-world contexts.

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