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Research Article

Ecopedagogy-based experiential learning model: An effective effort in shaping environmentally concerned attitudes

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Higher education holds a strategic role in supporting the goals of Education for Sustainable Development, particularly in strengthening students' environmental care attitudes. This study investigates the effectiveness of an ecopedagogy-based experiential learning model in fostering environmental care among elementary school teacher education students in the Surakarta Residency, Indonesia. Employing a quantitative approach with a quasi-experimental design, data were analyzed using SmartPLS 4. The measurement model demonstrated strong validity and reliability. Structural model analysis using SmartPLS 4 indicated that all constructs—biocentrism, ecoconsciousness, humanism, and sustainability significantly influenced students' environmental care attitudes. Syntax analysis further revealed that experiencing and continuing dimensions consistently exerted the strongest influence across constructs. These findings confirm that the ecopedagogy-based experiential learning model effectively cultivates environmental awareness through contextual, reflective, and action-oriented learning. The study highlights the need for lecturers to develop transformative ecological learning strategies and recommends broader application of the model across educational levels.

Keywords: Ecopedagogy; Environmental care attitudes; Experiential learning; Higher education; PLS-SEM

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1. Introduction

The Industrial Revolution 4.0 has transformed the scope and complexity of human activities, contributing to the emergence of global social and ecological crises marked by pollution, climate change, and other socio-scientific problems (Oliveira et al., 2023). In facing these challenges, basic environmental knowledge becomes essential for fostering ecological awareness and supporting problem-solving efforts (Fadjarajani & As'ari, 2021). In line with the goals of environmental education, individuals with awareness, values, and skills are needed for future sustainability (Curren, 2009). This is in line with the statement of Mazman Akar et al. (2025), revealing that technological developments in the 21st century have brought major changes to the world of education and significantly influenced the learning environment. Therefore, transformative

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learning characterized by cross-disciplinary, experiential, and participatory approaches is needed to cultivate systemic thinking, empathy, and sustainability-oriented competencies, enabling students to become active agents of social and ecological change (Bryant et al., 2023; Mian et al., 2020; Varela-Losada et al., 2022)

The implementation of learning in higher education should also align with the goals of Education for Sustainable Development [ESD] to teach how actions in terms of 'development' have positive and negative impacts on society and the entire natural world, and then determine how these actions can be 'sustainable' without causing adverse impacts or future socio-environmental oppression (Misiaszek, 2020). An ESD-based curriculum not only delivers content but also applies participatory, reflective, and interdisciplinary pedagogy to encourage transformative learning (Howell, 2021; Price et al., 2021). The framework of ESD emphasizes the need for learning processes that cultivate awareness, foster responsibility, and encourage sustainable behavior to address global challenges (Arifin et al., 2025). The integration of ESD in educational institutions supports the formation of critical, reflective professionals committed to positive socio-ecological changes (Price et al., 2021). However, at the higher education level, particularly in education study programs such as the Elementary School Teacher Education, ESD integration is still not fully reflected in the applied learning approaches. This creates a gap between the competencies required by 21st-century teachers and the provisions they obtain during their studies in colleges. In the 21st century, access to information is vast and easily reachable. Having the knowledge alone is no longer sufficient; 21st-century education must equip children with skills such as critical thinking, problem-solving, communication, collaboration, creativity, and adaptability. In this era, individuals are required to master a wider range of skills and competencies, which are, of course, influenced by brain development (Ezmeci, 2023).

One real form of this integration is strengthening environmentally conscious behavior, which is essential for every individual to maintain and pass on environmental sustainability to future generations (Ichsan et al., 2019). According to UNESCO (2017), to encourage human concern for the environment, educational institutions must provide an understanding of the importance of preserving it. Phan Hoang and Kato (2016) found that through environmental awareness education, previously less environmentally conscious human behavior can be changed and directed to a more positive direction. Such environmental education will be effective if it can have a real impact not only on daily lifestyles and consumption behavior but also increases environmental awareness to an equal or even greater extent (Szeberenyi et al., 2022).

Environmental awareness is crucial for 21st-century students, particularly in the Natural Sciences curriculum. Science, particularly in the context of natural science, is a dynamic process shaped by human actions, yet this human influence often leads to science being misunderstood or improperly learned. In practice, many people argue that we still lack clarity about what it truly means to engage with “real” science. As science develops over time, its explanations and conclusions may change, even when addressing the same phenomena, reflecting advances in evidence, methods, and theoretical perspectives (Lederman, 2007). The nature of science instruction requires lecturers to possess strong competencies in subject-matter mastery, understanding student characteristics, instructional strategies, assessment, and general pedagogical knowledge (Landolfi, 2023; Natsiopoulos & Angelakeris, 2023; Ojetunde & Ramnarain, 2025). These competencies are essential, as the quality of science teaching greatly influences students’ learning outcomes, including their achievement and motivation. Climate change education is effective in fostering environmental awareness and preparing students to become agents of change in society (Filho et al., 2023).

In universities, natural science courses aim to equip students with a basic understanding of science concepts relevant to everyday life, including material on waste management, including issues of environmental pollution due to human activities, industrialization, and urbanization (Özer-Keskin & Aksakal, 2020). Environmental pollution becomes a global threat primarily caused by humans, so environmental awareness and behavior are important steps to prevent it (Güler &

Ürey, 2022). Data from Badan Pusat Statistik [BPS] (2018) shows that the level of apathy of the Indonesian people towards waste management is still high: 72% are neglectful, 53% do waste-burning, 5% throw waste into rivers or gutters, and 2.7% do littering. In addition, as many as 81.4% of households still rarely bring their own shopping bags to reduce plastic waste.

Observations conducted in Elementary School Teacher Education study Programs show a low level of environmental awareness among students, with around 68% displaying insufficient concern, as seen from poor plant care, the absence of proper waste management, and the continued use of single-use plastics in daily activities. Most students also show limited interest in environmental issues and have not taken responsibility for environmental preservation. This condition highlights the need for learning strategies that go beyond content delivery and actively build environmental awareness. Experiential learning, as emphasized by (Kolb, 1984), offers meaningful knowledge construction through real experiences and reflection, and lecturers hold a key role in shaping students' environmental values as future teachers. To equip them with 21st-century competencies, learning models incorporating experiential approaches and environmental issues are essential, aligning with (Muangasame & Wongkit, 2023) view that environmentally focused curricula can effectively address ecological challenges and foster active participation in improving environmental quality.

The experiential learning model views knowledge as the result of transforming real experiences through cycles of reflection and action (Dewey, 1997; Kolb et al., 2014). This approach enables students to apply classroom concepts to real-life contexts, promotes active learning, and improves retention, as supported by findings showing its effectiveness in enhancing prospective teachers' skills. However, its current application often overlooks broader social and ecological dimensions. To address this gap, integrating ecopedagogy into experiential learning is essential, as ecopedagogical practices have been shown to increase ecological awareness and participation through active engagement with sustainability issues (Desfandi et al., 2017). Ecopedagogy emphasizes transformative action by connecting social and environmental perspectives and responds to the urgency of the current ecological crisis in alignment with sustainable education goals (Misiaszek, 2022; Muangasame & Wongkit, 2023)

Therefore, learning models that combine experiential learning with ecopedagogy are needed to support transformative education. An ecopedagogy-based experiential model enables students to explore environmental issues and helps transform campus perspectives and lifestyles toward more sustainable practices. Although previous studies have developed experiential learning in various contexts, none have specifically focused on strengthening environmental awareness among pre-service teachers. This study addresses that gap by empowering elementary school teacher education students through direct experience integrated with ecopedagogy, a crucial effort given their strategic role in shaping future students' character. The findings of Aribowo et al. (2025), and Mulyanie and Setiawan (2024) also support the effectiveness of experiential and ecopedagogical approaches in fostering ecological knowledge and action-oriented awareness. Although ecopedagogy and experiential learning have been widely examined, most previous studies investigate them separately, resulting in the absence of a comprehensive instructional model that integrates both approaches to strengthen environmental care attitudes among pre-service elementary teachers. Research on ecopedagogy within teacher education programs, particularly Elementary School Teacher Education, remains limited, even though future teachers play a crucial role in shaping students' ecological character.

However, research using an ecopedagogy-based experiential learning model has not yet been implemented in higher education. The researchers implemented a syntax developed from a combination of experiential learning models consisting of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Dewey, 1997; Kolb et al., 2014) with the principles of ecopedagogy, which include teaching about the social and natural environment, teaching in the social and natural environment, teaching through the social and natural environment, and teaching about the sustainable relationships between living things

(Gaard, 2008). The results of the researchers' syntax modifications formed an experiential learning model based on ecopedagogy, which consists of 1). experiencing, 2) reflecting, 3) constructing, 4) performing, and 5) continuing. No prior studies have specifically combined experiential learning with ecopedagogical principles in the context of elementary teacher preparation.

Thus, this study offers novelty by developing an ecopedagogy-based experiential learning model designed to provide authentic, reflective, and transformative learning experiences that foster environmental care attitudes among pre-service teachers. Therefore, this study aims to analyze the implementation of an ecopedagogy-based experiential learning model for elementary school teacher education students in the former Surakarta Residency to build knowledge through experience and cultivate sustainable environmental concern.

2. Theoretical Framework

2.1. Experiential Learning Model

The Experiential Learning [EL] model is a learning model based on experience. This model enables directed learning because it is based on field or contextual experiences. The contextual concept is a learning concept that helps education connect to real-world conditions. This contextual concept directs learning conditions to address learning problems. EL is a process that creates knowledge through the transformation of experience (Kolb, 1984). Experiential learning is defined by (Kolb, 2014) as the process by which knowledge is created through the transformation of experience.

EL enables students to gain practical experience, reflect on the process and results of activities, develop new theoretical understandings, and reapply them in more complex contexts (Bogas, 2023). Experiential learning is a learning approach that emphasizes direct experience as the basis for developing knowledge, skills, and understanding (Ahdhianto et al., 2025). Experiential learning is simply defined as hands-on learning, and can encompass various types of activities such as service-based learning, application of knowledge in specific fields of study, cooperative education, internships, study abroad, and other experimental activities (Austin & Rust, 2015). This learning model involves four main components in a cyclical process: concrete experience (ce), reflective observation (ro), abstract conceptualization (ac), and active experimentation (ae) (Chan et al., 2021). Kolb's (1984) EL stages consist of Concrete Experience-CO (concrete experience), Reflective Observation-RO (reflective observation), Abstract Conceptualization-AC (abstract conceptualization), and Active Experimentation-AE (active experimentation) (Ahdhianto et al., 2025; Holman et al., 1997).

The strength of experiential learning include: (1) facilitating the development of participants' soft skills such as critical thinking, higher-order thinking, curiosity, intrinsic motivation, and reflection skills (Shammas, 2021) (2) allowing for group learning, exchanging information, managing different perspectives, and being in a position to ask questions and face real problems (Alves & Putnik, 2019). Prospective educators benefit from experiential learning, developing well-designed literacy through meaningful experiences (DeGraff et al., 2015).

2.2. Ecopedagogy Approach

Ecopedagogy can be defined as an academic movement to educate students into individuals with an understanding, awareness, and life skills aligned with environmental conservation (Kahn, 2010). In a different sense, (Gadotti, 2010; Payne, 2018) argue that ecopedagogy is an approach to learning that empowers independent, autonomous learners to be capable of developing their learning potential based on experiences gained outside the classroom, and be aware that every action impacts them and their environment. Kahn (2010) defines ecopedagogy as an academic movement to foster students' awareness of understanding and life skills aligned with the principles of environmental sustainability, encompassing social, economic, humanitarian, policy, and other aspects. Ecopedagogy is also defined as a learning approach based on the reciprocal relationship between living things and their environment, the natural and social environments, or both. Agreeing with this, Payne (2015) argues that ecopedagogy is a development of critical theory and pedagogy integrated with ecological principles, placing social justice at the core of its approach. It can be seen as a form of critical theory that is relevant to the current context.

Kahn (2010) emphasized that ecopedagogy represents a critical pedagogical approach capable of educating learners about their relationships with both natural and social environmental issues, while fostering ecological awareness, social justice, and transformative action. Kinyota (2021) argued that critical pedagogy is a key to transforming environmental education, particularly in the application of transformative models such as ecopedagogy. In out-of-school learning environments [OSLE], students can apply what they learn in the classroom to real situations in their natural surroundings (Filiz & Güneş, 2023). This approach helps them connect academic concepts to everyday life, making learning more meaningful. Therefore, school-based learning and OSLE should be designed to complement one another. In line with this, Misiaszek (2016) stated that ecopedagogy is both a critical environmental education approach and a movement aimed at building a sustainable world. This approach has developed as a progressive form of environmental education, critically and dialectically examining the relationship between social conflict and environmental degradation.

2.3. Ecopedagogy-Based Experiential Learning

The ecopedagogy-based experiential learning model has five syntaxes. The steps of ecopedagogy-based experiential learning consist of: 1) experiencing, 2) reflecting, 3) constructing, 4) performing, and 5) continuing. The following is the theoretical basis for the ecopedagogy-based experiential learning syntax.

Based on Table 1, it can be illustrated that the relationship between the syntax of the experiential learning model and the principles of the ecopedagogy approach is integrated into learning. This series of stages is then structured into a syntax model, a conceptually formulated learning flow that serves as a reference for implementing the ecopedagogy-based experiential learning model.

2.4. Environmental Awareness Attitude

Understanding of environmental attitudes is essential to see how individuals respond to ecological issues (Milfont & Schultz, 2018). Güler and Ürey (2022) defines environmental awareness as attitudes and actions aimed at repairing damage and preventing further damage to the environment. Environmental awareness can also be interpreted as an attitude of respect carried out to create a balance between humans and their environment. Environmental attitude can be defined as an individual’s positive evaluation of behaviors and actions that are considered necessary to prevent or reduce negative impacts on the environment (Milfont & Duckitt, 2010). Simanjuntak et al. (2023) define environmental awareness as an individual's concern, awareness, and sense of responsibility for preserving and protecting the environment in everyday life. "Environmental attitude and ecological behavior" view environmental attitude as a strong predictor of ecological behavior, consisting of environmental knowledge, environmental values, and ecological behavioral intentions (Metin, 2010). Environmental education impacts ecological behavior "based on environmental attitude," implying that environmental attitude is a mediator between ecological knowledge and behavior (Larashati et al., 2022).

Research conducted by De la Vega-Rivera and Merino-Pérez (2021) shows that environmental awareness is positively related to natural resource conservation behavior, including flora, fauna, water, soil, and air. Environmental awareness and concern are the most influential factors in encouraging water and air conservation and waste reduction behavior, both in urban and rural communities. Biospheric values and environmentally grounded social norms play a significant role in strengthening individuals’ pro-recycling attitudes and behavioral intentions, which in turn contribute to positive outcomes for soil, water, and air quality (Steg et al., 2014).

Table 1
The foundation used for developing the ecopedagogy-based experiential learning model

Ecopedagogy-Based Experiential Learning Syntax (Kolb, 1984)	*Ecopedagogy Approach Principles (Gaard, 2008)*	*Integration into Learning*
Experiencing	Principle 1: Teaching about the social and natural environment.	Students gain concrete experiences through direct observation of the social and natural environment to identify current environmental issues. The learning activities foster ecological awareness through real-world experiences.
Reflecting	Principle 2: Teaching in the social and natural environment.	Students reflect on their observations of the social and natural environment, fostering awareness of the interconnectedness of human behavior and its impact on ecosystems. The reflection fosters empathy and socio-ecological responsibility.
Constructing	Principles 1 and 2: Teaching about and in the social and natural environment.	Students construct knowledge by analyzing environmental issues based on observations and learning resources. The learning activities foster critical thinking skills in understanding the roots of ecological problems.
Performing	Principle 3: Teaching through the social and natural environment.	Students apply their learning outcomes through social action and real-world activities such as environmental projects, community collaborations, and sustainability campaigns. The knowledge is translated into concrete actions.
Continuing	Principle 4: The continuity of relationships among living things.	Students develop follow-up plans and sustainable programs to maintain harmonious relationships among humans, animals, and nature. The learning activities instill the values of sustainability and long-term ecological responsibility.

Another study confirmed that environmental awareness encourages reforestation and reforestation behavior in response to land degradation (Rhead et al., 2015). Pivetti et al. (2020) showed that environmental awareness and knowledge positively influence environmentally friendly attitudes, including waste management and the consumption of environmentally friendly products. Furthermore, positive attitudes toward environmental issues such as water, air, and waste also correlate with a willingness to take concrete action to reduce negative environmental impacts. These findings confirm that environmental awareness is an important foundation for comprehensive environmental attitudes and behavior.

3. Method

3.1. Research Design

This is quasi-experimental, nonequivalent control group research. The research design was chosen because the researchers did not fully control external variables that might influence the research results. Besides, this study provided a rigorous, yet practical approach to evaluate the impact of the experiential learning based ecopedagogy to improve environmental awareness. In educational contexts, random assignment is often not feasible due to intact classroom settings. Therefore, quasi-experimental methods such as the nonequivalent control group design are widely used to assess the effectiveness of instructional models (Shadish et al., 2002). This design enables comparison between experimental and control classes without disrupting the natural learning process, while pretests and posttests help control external variables and strengthen causal inferences.

3.2. Participants

The sample was selected purposively by considering the accreditation status of the study program, the availability of students taking courses, and the readiness of the institution in implementing learning experiments. The sample size was justified based on the guidelines proposed by Hair et al. (2006), which recommend a minimum sample size of 100 to 150. Byrne (2001) recommends a minimum acceptable sample for SEM estimation of 100. The research sample consisted of 157 students from the elementary school teacher education program who took the natural science course in 2023 (age 21-22 years). The participants included 37 students from Universitas Sebelas Maret, 40 from Universitas Muhammadiyah Surakarta, 40 from Universitas Veteran Bangun Nusantara, and 40 from Universitas Slamet Riyadi. The research sample consisted of classes representing each university, both as experimental and control classes, with the total number of students adjusted to field conditions. Figure 1 summarizes the research process.

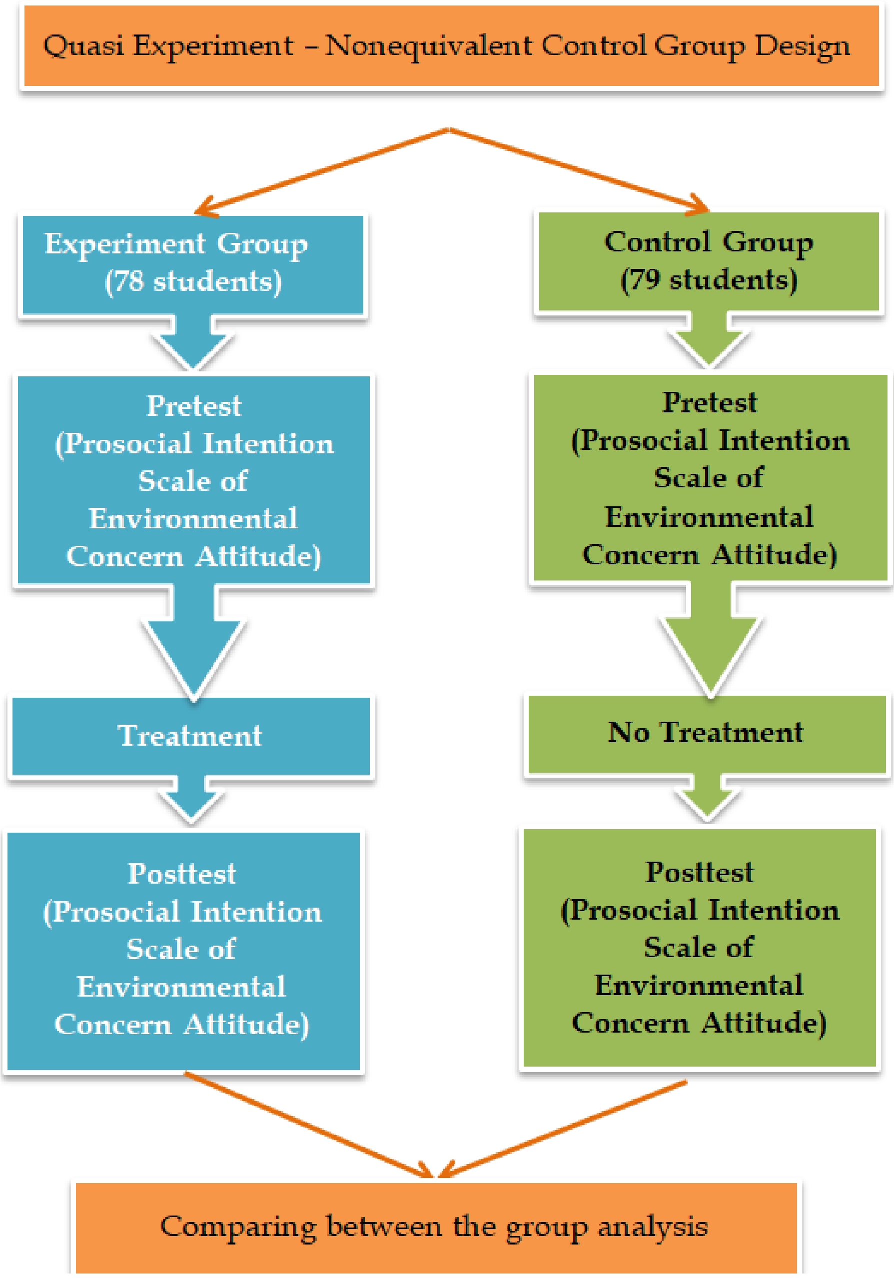
This research has also been approved by the Elementary School Teacher Program Study Program at Universitas Muhammadiyah Surakarta, Universitas Sebelas Maret, Universitas Slamet Riyadi, and Universitas Bangun Veteran Sukoharjo. In addition, written consent to participate was obtained from the students. Respondents gave their consent without coercion from anyone. All data obtained remained confidential to protect respondents' rights and privacy.

3.3. Data Collection

In order to evaluate participants' environmental care levels and to examine the effectiveness of the ecopedagogy-based experiential learning model, this study employed the Environmental Care Attitudes Scale as the primary data collection instrument. The Environmental Care Attitudes Scale enables the systematic assessment of individuals' environmental care-related attitudes through its multidimensional structure. To ensure the methodological rigor of the measurement process, validity and reliability analyses of the scale were conducted based on the data collected in this research. The findings regarding the validity and reliability of the Environmental Care Attitudes Scale are presented in the following section.

Figure 1

The Quasi-Experimental Nonequivalent Control Group Research Design



Content validation was carried out on the developed instrument to determine the level of feasibility of the created construct. The criteria for validators of the environmental attitude instrument are one lecturer of an environmental expert, and three lecturers of the evaluation tools. To determine the level of feasibility, the researchers used Aiken's V formula. The content validity coefficient was calculated using Aiken's V based on the experts' ratings. In this method, each expert assigns a score (r) to each item, and the Aiken's V value is obtained by subtracting the lowest possible score (l_0) from each rating, summing these values, and dividing the result by $n(c-1)$ where n represents the number of experts and c represents the highest possible score on the rating scale.

The description of the indicators for each aspect of environmental care attitudes can be seen in Table 2. Based on the aforementioned components of aspects and indicators of environmental care attitudes, the researchers describe the instrument details for each item in Appendix 1.

Table 2
Components of Aspects and Indicators of Environmental Care Attitudes

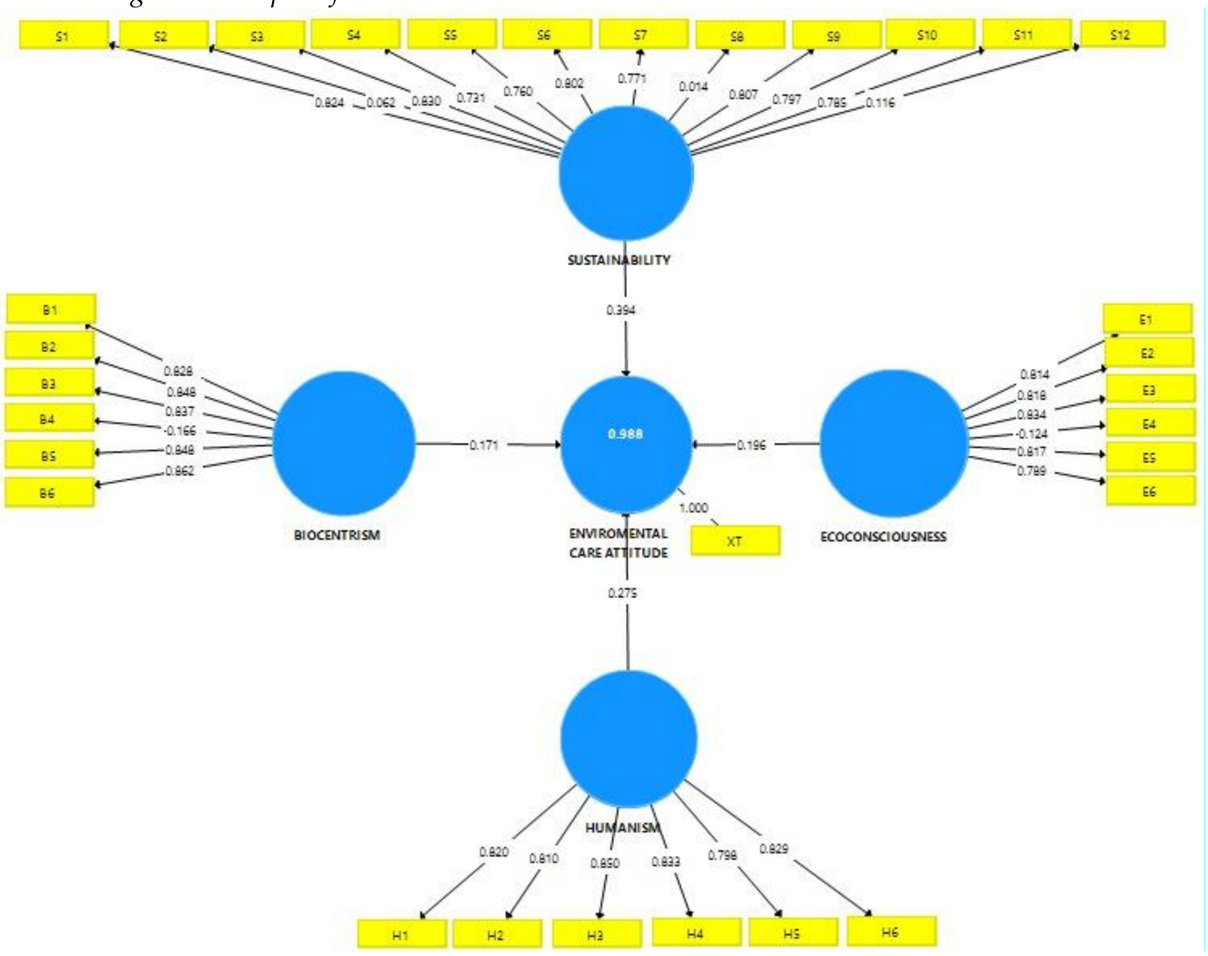
Aspects	*Symbols*	*Indicators*	*Number*
Biocentrism	B1, B2	Changing the natural environment to suit their needs	1,2
	B3, B4	Keeping the environment clean and tidy	3,4
	B5, B6	Attitudes toward flora and fauna	5,6
Ecoconsciousness	E1, E2	Approaching the limit to growth	7,8
	E3, E4	Rejection of exemptionalism	9,10
	E5, E6	Actively participating in reducing air pollution and water use	11, 12
Sustainability	S1, S2	Attitudes toward garbage	13, 14
	S3, S4	Human-related environmental damage	15, 16
	S5, S6, S7, S8	Activity for greening	17, 18, 19, 20
	S9, S10, S11, S12	The fragility of nature balance	21, 22, 23, 24
Humanism	H1, H2	Human intelligence makes the Earth uninhabitable	25, 26
	H3, H4	Care for people and the social environment	27, 28
	H5, H6	A caring attitude toward the sustainable use of the environment	29, 30

Note. Adapted from NEP (New Ecological Paradigm) (Dunlap et al., 2000; "Guidelines for Adiwiyata: School Which Care and Environment Cultured," 2011; Munandar, 2016).

Validity and reliability of measuring instruments on the construct of environmental care attitude employed the outer model in Partial Least Squares [PLS] from the SmartPLS 4 application. The outer model is a measurement model to assess the validity and reliability of the model. Validity in PLS functions to analyze the construct of environmental care attitude, namely, through convergent validity and discriminant validity. According to (Sarstedt et al., 2021), the rule of thumb used to test convergent validity is the loading factor value> 0.5, which is considered practically significant, and the average variance extracted (AVE)> 0.5. Discriminant validity value can be seen by comparing the root of the AVE; an aspect/component must be higher compared to the correlation between other aspects/components. Reliability in PLS functions to analyze the construct of environmental care attitude by looking at Cronbach's alpha and composite reliability values. The expected Cronbach's alpha and composite reliability values are > 0.7.

Convergent validity can be seen by observing the loading factor and AVE values. Items that were validated in the construct of environmental care attitudes can be seen in Figure 1. Based on the results of the analysis using SMART PLS, there were 25 out of 30 items of the construct of environmental care attitudes considered to be valid because the 25 items had a loading factor value> 0.7 and an AVE value> 0.7. The loading factor and AVE values of the environmental care attitude construct can be seen in Figure 2.

Figure 2
The PLS algorithm output of the environmental care attitude construct



Based on Figure 2, it can be understood that the four components of the environmental care attitude construct have items that can reflect each component in the environmental care attitude construct. The most dominant component contributing to reflecting the environmental care attitude construct is the humanism component. The item loading factor value showing the largest value was located in item H_3 with a value of 0.850. The item lappenoading factor value showing the smallest value was in the sustainability component, which was located in item S8, with a value of 0.014. The discriminant validity of the components of the environmental care attitude construct can be seen in Table 3.

Table 3
The discriminant validity of components in the construct

Components	*Biocentrism*	*Ecoconsciousness*	*Humanism*	*Sustainability*
Biocentrism	**0.774**	0.746	0.972	0.863
Ecoconsciousness	0.845	**0.865**	0.824	0.887
Humanism	0.972	0.929	**0.961**	0.888
Sustainability	0.863	0.887	0.888	**0.743**

Note. Diagonal elements (bold) represent √AVE. Off-diagonal elements represent inter-construct correlations. Discriminant validity is supported when each construct's √AVE is greater than its highest correlation with any other construct.

3.4. Data Analysis

Data analysis was conducted using SmartPLS 4 with the Partial Least Squares approach to examine the relationship between the ecopedagogy-based experiential learning model (independent variable) and environmental care attitudes (dependent variable). The analytical procedure consisted of three stages. First, discriminant validity was assessed using the cross-loading technique to ensure that each indicator accurately distinguished its construct from others. Second, construct reliability and validity were evaluated to confirm measurement consistency and accuracy. Third, hypothesis testing was carried out through the structural model to determine the effect of the experiential learning model on environmental care attitudes. Although PLS is appropriate for exploratory models and complex relationships, potential biases may arise, such as sensitivity to sample size, loading inflation, and model overfitting; thus, interpretation of results must consider these limitations.

4. Results

Figure 3 shows that the outer loadings value of each syntax implementation observation item is greater than 0.70, with 0.706 as the smallest value and 1.000 as the largest value. The rule used to determine whether each syntax implementation observation item is valid or not is if the item value is > 0.70. Because the value of each syntax implementation observation item is > 0.70, it indicates that each syntax implementation observation item is valid.

The initial criterion assessed in the measurement model is internal consistency reliability, which is evaluated using Cronbach's alpha (α), rho_A, and Composite Reliability (CR); values above .70 indicate acceptable reliability, as shown in Table 2. Table analysis reveals that all constructs range from 0.725 to 0.913 for (α), 0.733 to 0.928 for rho_A, and 0.844 to 0.945 for CR, indicating that each construct measurement exceeds the threshold of 0.7. This indicates the use of a reliable model for Environmental Care Attitudes. The next evaluation focuses on convergent validity, which aims to determine the validity of the relationship between each indicator and its latent variable. This was measured using the AVE, with indicators meeting convergent validity criteria if the AVE was ≥ 0.50. Table analysis revealed that all constructs ranged from 0.645 to 0.852 for AVE, indicating that each construct measurement exceeded the 0.5 threshold.

The second approach for assessing discriminant validity is the heterotrait–monotrait ratio [HTMT]. Henseler et al. (2015) state that HTMT is evaluated by examining the correlations between different constructs (heterotrait–heteromethod) in relation to the geometric mean of the correlations among indicators measuring the same construct. In simpler terms, HTMT represents the average of all correlations among indicators across all constructs. Henseler further explains that an HTMT value below 0.90 indicates adequate discriminant validity between constructs. Based on the analysis results, all indicators demonstrated HTMT values below 0.90; therefore, discriminant validity is considered to be established.

Figure 3
The Outer Loading

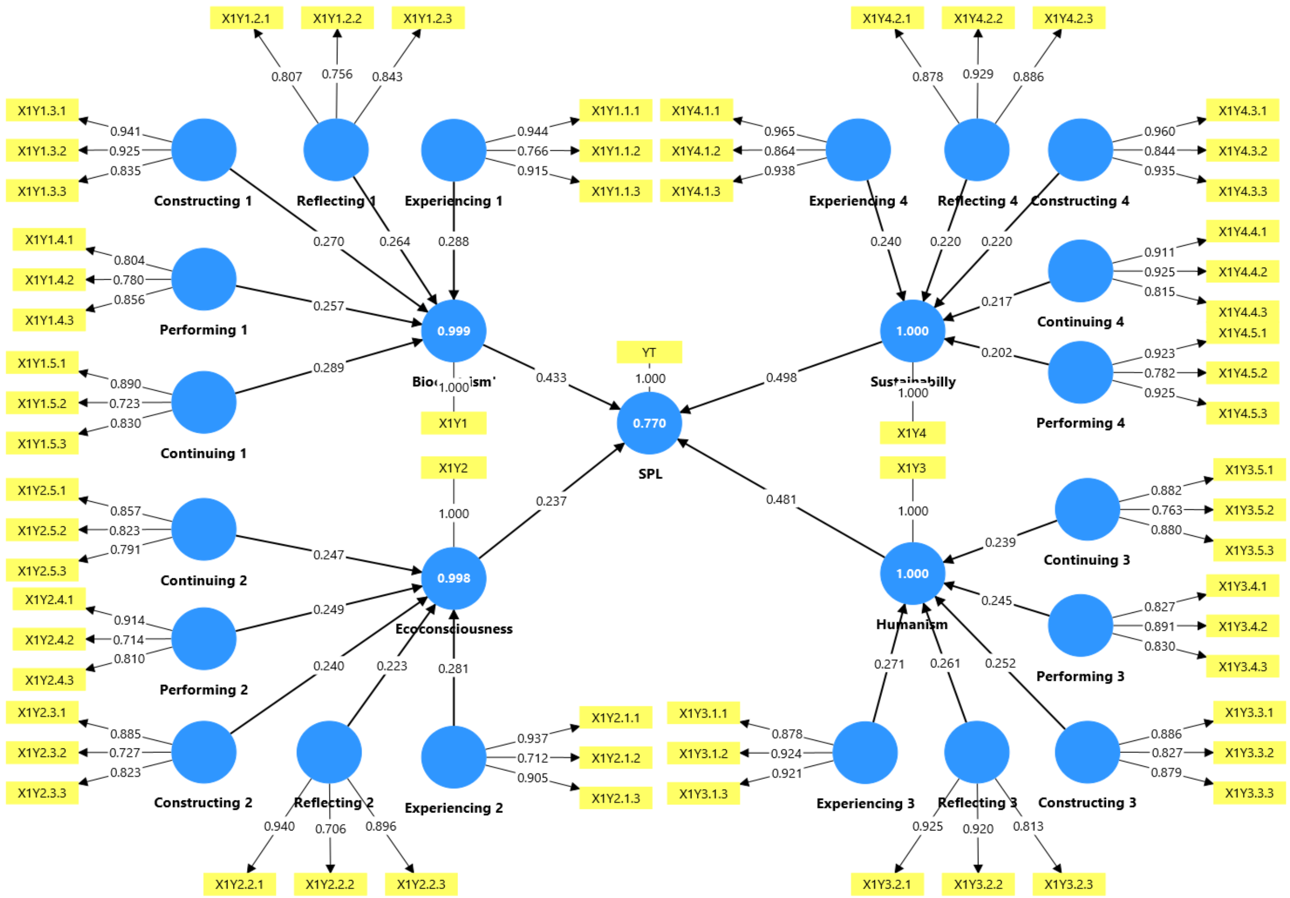


Table 4 presents the results of the reliability test conducted on all measurement indicators used in this study. The reliability assessment was carried out using four criteria—Cronbach's Alpha (α), rho_A, Composite Reliability, and Average Variance Extracted—with the recommended threshold values of $\alpha \geq 0.70$, rho_A ≥ 0.70, CR ≥ 0.70, and AVE ≥ 0.50. All indicators for the four dimensions (Constructing, Continuing, Experiencing, and Performing) meet the minimum criteria, demonstrating that each construct exhibits satisfactory internal consistency and convergent validity. The consistently high CR and AVE values further confirm the stability and accuracy of the measurement model in capturing the intended latent constructs.

Table 4
The Reliability Test

	α ≥0.70	rho_A≥0.7	CR ≥0.70	AVE≥0.50
Constructing 1	0.884	0.885	0.929	0.813
Constructing 2	0.742	0.752	0.854	0.663
Constructing 3	0.830	0.830	0.899	0.747
Constructing 4	0.900	0.903	0.938	0.836
Continuing 1	0.752	0.781	0.857	0.668
Continuing 2	0.763	0.766	0.864	0.679
Continuing 3	0.794	0.796	0.880	0.711
Continuing 4	0.860	0.866	0.915	0.783
Experiencing 1	0.848	0.857	0.910	0.772
Experiencing 2	0.811	0.822	0.891	0.735
Experiencing 3	0.893	0.899	0.933	0.824
Experiencing 4	0.913	0.928	0.945	0.852

Table 4 continued

	α ≥0.70	rho_A≥0.7	CR ≥0.70	AVE≥0.50
Performing 1	0.745	0.749	0.855	0.663
Performing 2	0.745	0,765	0.856	0.667
Performing 3	0.807	0.807	0.886	0.722
Performing 4	0.850	0.851	0.911	0.773
Reflecting 1	0.725	0.733	0.844	0.645
Reflecting 2	0.805	0.821	0.888	0.729
Reflecting 3	0.863	0.863	0.917	0.788
Reflecting 4	0.879	0.881	0.926	0.806

Model fit testing is conducted to determine the suitability of the model and data for testing the influence of variables. The Standardized Root Mean Squared Residual [SRMR] requirement is less than 0.10. Table 5 shows that the SRMR value was 0.082<0.10, indicating that the model and data were suitable for testing the influence of variables.

Table 5
The Model Fit Test

	Saturated model	*Estimated model*	*Criteria*
SRMR	0.080	0.082	< 0.10
d_ULS	13.891	14.257	≥ 0.05
d_G	3.790	3.790	≥ 0.05
Chi-square	2042.032	2042.032	χ^2 statistic ≥ χ^2 table
NFI	0.555	0.555	Approaching 1 (good values 0.9/0.8)

Table 6 shows the Q^2 (predictive relevance) values for each endogenous construct in the model. The Q^2 values are used to assess the extent to which the structural model can predict data that were not used in the estimation process. In general, a Q^2 value greater than 0 indicates predictive relevance, whereas a Q^2 value ≥ 0.50 signifies strong predictive capability.

Table 6
Q^2 predict results

	Q^2predict	*Interpretation*
Biocentrism	0.998	Strong
Ecoconsciousness	0.988	Strong
Humanism	0.949	Strong
Sustainabilly	0.995	Strong
Environmental Care Attitudes	0.731	Strong

Based on Table 6, the Q^2 values indicate the model's predictive capacity for the endogenous indicators or variables. The Q^2 values obtained for all endogenous variables in the model exceed 0.50. This confirms that the model possesses high predictive relevance, in accordance with the Stone–Geisser criterion, which states that Q^2 ≥ 0.50 reflects strong predictive ability. Therefore, this research model is capable of providing good predictions for the analyzed variables and demonstrates that the constructed structural relationships have high predictive reliability.

In this study, anlysis was conducted using Smart PLS 4 software with an inner model test. The inner model testing stage was conducted to determine the significance of the influence of exogenous variables on endogenous variables. The criteria used to determine the influence of the model were a *p*-value < .05 or a t-value > 1.96. Table 7 shows that the *p*-value for each syntax was 0.000, and all *t*-values were >1.96. Therefore, it can be concluded that the ecopedagogy-based experiential learning model has an effect on environmental awareness.

Table 7
The Inner Model Test

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	p-values
Biocentrism → Environmental Care Attitudes	0.433	0.436	0.052	8.283	<.001
Constructing 1 → Biocentrism	0.270	0.269	0.032	8.459	<.001
Constructing 2 → Ecoconsciousness	0.240	0.244	0.034	7.080	<.001
Constructing 3 → Humanism	0.252	0.252	0.014	17.619	<.001
Constructing 4 → Sustainability	0.220	0.218	0.010	22.457	<.001
Continuing 1 → Biocentrism	0.289	0.290	0.028	10.221	<.001
Continuing 2 → Ecoconsciousness	0.247	0.244	0.019	12.696	<.001
Continuing 3 → Humanism	0.239	0.238	0.013	17.872	<.001
Continuing 4 → Sustainability	0.217	0.219	0.010	20.857	<.001
Ecoconsciousness → Environmental Care Attitudes	0.237	0.239	0.065	3.664	<.001
Experiencing 1 → Biocentrism	0.288	0.289	0.024	11.812	<.001
Experiencing 2 → Ecoconsciousness	0.281	0.280	0.029	9.632	<.001
Experiencing 3 → Humanism	0.271	0.271	0.019	14.155	<.001
Experiencing 4 → Sustainability	0.240	0.241	0.013	18.946	<.001
Humanism → Environmental Care Attitudes	0.481	0.481	0.062	7.787	<.001
Performing 1 → Biocentrism	0.257	0.263	0.041	6.190	<.001
Performing 2 → Ecoconsciousness	0.249	0.245	0.029	8.453	<.001
Performing 3 → Humanism	0.245	0.246	0.013	18.940	<.001
Performing 4 → Sustainability	0.202	0.201	0.009	23.085	<.001
Reflecting 1 → Biocentrism	0.264	0.257	0.041	6.369	<.001
Reflecting 2 → Ecoconsciousness	0.223	0.220	0.032	6.943	<.001
Reflecting 3 → Humanism	0.261	0.262	0.014	19.157	<.001
Reflecting 4 → Sustainability	0.220	0.220	0.009	25.640	<.001
Sustainability → Environmental Care Attitudes	0.498	0.498	0.060	8.243	<.001

To evaluate the explanatory power of the structural model, the R-square (R^2) values for each endogenous construct were examined. R^2 serves as an essential indicator in Partial Least Squares Structural Equation Modeling [PLS-SEM], as it reflects the proportion of variance in an endogenous variable that can be explained by its predictor constructs. Higher R^2 values indicate stronger explanatory capability and greater model robustness. The following table presents the R-square results for all endogenous variables in the model.

Table 8
R-square Analysis Results

	R-square	R-square adjusted
Biocentrism	0.999	0.999
Ecoconsciousness	0.998	0.998
Humanism	1.000	1.000
Environmental Care Attitudes	0.770	0.759
Sustainabilly	1.000	1.000

Table 8 shows the obtained R-square values indicate that the model has an exceptionally high explanatory power for the endogenous variables. Biocentrism, Ecoconsciousness, Humanism, and Sustainability each show R-square values ranging from 0.998 to 1.000, meaning that more than 99% to 100% of the variability in these constructs can be explained by their predictor variables. These values reflect a remarkably strong and stable explanatory capacity, as evidenced by the consistently high adjusted R-square values across all constructs.

Meanwhile, the environmental care attitudes construct has an R-square of 0.770 with an adjusted R-square of 0.759, which still demonstrates strong explanatory power, as more than 75%

of its variance is accounted for by the model. Overall, these results indicate that the structural model possesses very high and reliable explanatory strength in describing the relationships among the variables.

To assess the magnitude of influence exerted by each predictor construct on the endogenous variables, an analysis of the effect size, or F-square (f^2), was conducted. In PLS-SEM, the F-square statistic is used to determine the contribution of each construct to the increase in the R-square value of an endogenous variable when the construct is included in the model. Accordingly, the F-square analysis provides an indication of the strength of influence for each structural relationship within the model. Table 9 presents the calculated F-square values for all relationships among the constructs.

Table 9
F-square results

Relationship	*F-square (f^2)*	*Interpretation*
Biocentrism → Environmental care attitudes	0.789	Large
Constructing 1 → Biocentrism	0.878	Large
Constructing 2 → Ecoconsciousness	0.389	Large
Constructing 3 → Humanism	0.759	Large
Constructing 4 → Sustainability	0.799	Large
Continuing 1 → Biocentrism	0.793	Large
Continuing 2 → Ecoconsciousness	0.341	Medium
Continuing 3 → Humanism	0.471	Large
Continuing 4 → Sustainability	0.284	Medium
Ecoconsciousness → Environmental care attitudes	0.227	Medium
Experiencing 1 → Biocentrism	0.461	Large
Experiencing 2 → Ecoconsciousness	0.836	Large
Experiencing 3 → Humanism	0.578	Large
Experiencing 4 → Sustainability	0.533	Large
Humanism → Environmental care attitudes	0.959	Large
Performing 1 → Biocentrism	0.522	Large
Performing 2 → Ecoconsciousness	0.549	Large
Performing 3 → Humanism	0.385	Large
Performing 4 → Sustainability	0.413	Large
Reflecting 1 → Biocentrism	0.530	Large
Reflecting 2 → Ecoconsciousness	0.262	Medium
Reflecting 3 → Humanism	0.667	Large
Reflecting 4 → Sustainability	0.846	Large
Sustainability → Environmental care attitudes	0.991	Large

Based on the analysis Table 9 the obtained F-square values indicate that most of the relationships among variables in the model exhibit large effect sizes according to Cohen's criteria, where f^2 values above 0.35 are categorized as large effects. Overall, this pattern of results suggests that the majority of construct relationships within the model have substantial effects, indicating that the structural model is robust and highly capable of explaining the influence among variables.

Path coefficients were used to assess the contribution of each environmental attitude. Table 10 shows that the path coefficients for each environmental attitude ranged from 0.237 to 0.498. These results indicate that sustainability contributed the most, at 0.498, or 49%.

Table 10
The Inner Model Test Environmental Care Attitudes

	Path coefficients
Biocentrism → Environmental Care Attitudes	0.433
Ecoconsciousness → Environmental Care Attitudes	0.237
Humanism → Environmental Care Attitudes	0.481
Sustainability → Environmental Care Attitudes	0.498

Table 10 shows path coefficients were used to assess the contribution of each syntax element to the ecopedagogy-based experiential learning model. Table 11 shows that the path coefficients for each syntax element ranged from 0.257 to 0.289. These results indicate that the contributions between each syntax element were approximately equal, with the Continuing syntax element contributing the most, at 0.289, or 28%.

Table 11
The Inner Model Test of Biocentrism Indicators

	Path coefficients
Constructing 1 → Biocentrism	0.270
Continuing 1 → Biocentrism	0.289
Experiencing 1 → Biocentrism	0.288
Performing 1 → Biocentrism	0.257
Reflecting 1 → Biocentrism	0.264

Path coefficients were used to assess the contribution of each syntax to the ecopedagogy-based experiential learning model. Table 12 shows that the path coefficients for each syntax ranged from 0.223 to 0.281. These results indicate that the contributions between each syntax were approximately equal, with the Experiencing syntax providing the largest contribution, at 0.281, or 28%.

Table 12
The Inner Model Test of Ecoconsciousness Indicators

	Path coefficients
Constructing 2 → Ecoconsciousness	0.240
Continuing 2 → Ecoconsciousness	0.247
Experiencing 2 → Ecoconsciousness	0.281
Performing 2 → Ecoconsciousness	0.249
Reflecting 2 → Ecoconsciousness	0.223

Path coefficients were used to assess the contribution of each syntax to the ecopedagogy-based experiential learning model. Table 13 shows that the path coefficients for each syntax ranged from 0.239 to 0.271. These results indicate that the contribution of each syntax was approximately the same, with the Experiencing syntax providing the largest contribution, at 0.271 or 27%.

Table 13
The Inner Model Test of Humanism Indicators

	Path coefficients
Constructing 3 → Humanism	0.252
Continuing 3 → Humanism	0.239
Experiencing 3 → Humanism	0.271
Performing 3 → Humanism	0.245
Reflecting 3 → Humanism	0.261

Path coefficients were used to assess the contribution of each syntax to the ecopedagogy-based experiential learning model. Table 14 shows that the path coefficients for each syntax ranged from 0.202 to 0.240. These results indicate that the contributions between each syntax were approximately equal, with the experiencing syntax providing the largest contribution, at 0.240, or 24%.

Table 14
Inner Model Test for Sustainability Indicators

	Path coefficients
Constructing 4 → Sustainability	0.220
Continuing 4 → Sustainability	0.217
Experiencing 4 → Sustainability	0.240
Performing 4 → Sustainability	0.202
Reflecting 4 → Sustainability	0.220

5. Discussion

The results of statistical tests show that the application of the ecopedagogy-based experiential learning model has a significant impact on increasing students' environmental awareness in natural science learning, which can be detailed based on the five model syntaxes developed as follows:

5.1. Experiencing Syntax

In the experiencing syntax, students gain concrete experiences through direct observation in the social and natural environment to identify current environmental degradation issues. Such learning activities can foster ecological awareness through real-life experiences. The experiencing stage in experiential learning plays a crucial role in fostering biocentric awareness, ecoconsciousness, and sustainability. Direct engagement with nature enables individuals to recognize that all living things have intrinsic value that deserves respect, thus strengthening a biocentric orientation (Francuz, 2020). Besides, concrete experiences in addressing ecological issues such as pollution and environmental degradation foster a deeper ecoconsciousness. This process helps students internalize ecological awareness not only cognitively but also through sustained emotional engagement (Stevenson et al., 2013). Research in sustainability-oriented education indicates that experiential and practice-based learning approaches help learners translate abstract sustainability concepts into actionable strategies by engaging with real-world environmental challenges (Magtibay, 2024).

Furthermore, experiencing also provides a space for strengthening humanistic values that expand empathy, solidarity, and a sense of responsibility from fellow humans to the environment as a shared living space. Direct experience facing the impact of environmental damage on community well-being encourages the emergence of environmental awareness based on humanistic values (Garrison, 2015). Thus, the experiencing stage becomes an important foundation in integrating the four dimensions of these values: biocentrism, ecoconsciousness, sustainability, and humanism to form more complete and sustainable pro-environmental behavior.

5.2. Reflection Syntax

Students reflect on their observations of the social and natural environment, fostering awareness of the interconnectedness of human behavior and its impact on ecosystems. Reflection fosters empathy and socio-ecological responsibility. The stage also plays a crucial role in strengthening the internalization of the values of biocentrism, ecoconsciousness, sustainability, and humanism. Through reflection, individuals not only recall experiences but also analyze, evaluate, and relate them to ecological values and social responsibility (Kalsoom et al., 2022). In the context of biocentrism, reflection after observing biodiversity, for example, in an urban forest, fosters an awareness that all living things have intrinsic value that should be respected. For example, in the online program “Backyard Biodiversity” at the University of Tasmania, students reflect on the species they encounter in their surroundings, deepening their connection to nature and fostering a strong ecological awareness, reflecting the biocentric view of valuing every living organism equally (Douglas et al., 2024). In addition, hands-on learning experiences in protected areas such as biosphere reserves foster transformational learning through active engagement with nature, which not only enriches knowledge but also internalizes the value of respect for all living things (Cano-Ortiz et al., 2025). Likewise, the wild pedagogies approach, enacted in natural learning spaces such as forests or community gardens, enables the formation of a "multi-species relational classroom" in which learners engage with and through nature, thereby reinforcing a biocentric orientation within experience-based learning (Jickling et al., 2018; Taylor, 2017).

In the ecoconsciousness dimension, writing a reflective journal about experiences witnessing river pollution can foster ecological awareness by connecting it to everyday plastic consumption. Meanwhile, reflection on renewable energy practices, such as observing solar panels at school, helps individuals understand the urgency of sustainability and the negative impacts of fossil fuels on the climate. Furthermore, in the humanism aspect, reflection after a visit to a village affected by flooding due to deforestation can foster empathy and solidarity, as students recognize the close relationship between environmental damage and human well-being. In the context of ecoconsciousness, activities such as creative journaling or local reflection journals, for example, document human-environment interactions around homes or schools, facilitate a deeper understanding of the interconnectedness of socio-ecological systems, and build a sense of responsibility for sustainability (Post, 2019).

The reflection stage plays a crucial role in strengthening the internalization of sustainability and humanistic values. Deep reflection practices can foster emotional resilience and ecological commitment, and help understand the interconnectedness of social and environmental issues (Post, 2019). Furthermore, a humanistic approach expands empathy and moral responsibility, fostering creativity in action solutions (Kohl et al., 2024). Individual and collective reflection have also been shown to enhance self-awareness and collaboration, strengthening the ethical foundations of sustainability (Ayers et al., 2020). Within the context of experiential learning at Living Labs, contemplation fosters personal exploration of ecological values and responsibilities.

Thus, the reflective stage is not merely a cognitive activity, but rather a process that integrates the emotional, moral, and social dimensions of experience. Reflective activities such as group discussions, journal writing, and field evaluations help students connect real-life experiences with ecological and humanitarian values. This makes reflective practice a crucial stage in fostering a deeper environmental awareness, ecological awareness, humanism, and long-term sustainability orientation.

5.3. Constructing Syntax

Students construct knowledge by analyzing environmental issues based on observations and learning resources. Such a learning activity can foster critical thinking skills in understanding the roots of ecological problems through a literature review from reliable sources. The constructing stage in experiential learning focuses on the process of building new knowledge, understanding, and meaning from the experiences that have been gained. Within the biocentrism dimension, knowledge construction enables individuals to develop the understanding that all living beings possess intrinsic value, for instance through the design of projects or research reports that examine the role of biodiversity in sustaining ecosystem balance (Næss, 1973; Tilbury, 1995). In the context of ecoconsciousness, the construction process helps students formulate a more systematic ecological awareness. For example, by developing solutions based on field experience to local environmental problems, such as water pollution or waste management, they can link real experiences with critical knowledge about ecological issues (Evans et al., 2017).

Furthermore, from a sustainability perspective, experiential and design-based learning approaches enable learners to develop practical strategies that address real-world environmental challenges, such as creating energy-efficient solutions or recycling-oriented innovations that emphasize long-term resource utilization (Fikri et al., 2026). Through the experiential learning approach in Living Labs, students not only acquire theory but also develop practical understanding by engaging in applied research projects. These activities can be in the form of experiments with sustainable innovations, such as the application of environmentally friendly transportation technology in urban areas or concrete actions to maintain a clean environment. The results of this learning process are then presented to professional practitioners and the public as a tangible contribution and social validation of the solutions they design.

Finally, in humanism, the construction stage directs individuals to build an understanding of the interconnectedness between humans and the environment, for example, by integrating the values of solidarity, empathy, and social responsibility into the design of community-based environmental activities. This is in line with Ely's research (2018), which suggests the importance of experiential education that not only develops ecological awareness but also intercultural skills, empathy, and an understanding of sustainability values in a global context. Thus, the construction stage not only emphasizes conceptual understanding but also develops critical and creative abilities to produce real solutions based on the values of biocentrism, ecoconsciousness, sustainability, and humanism. This process makes learning more meaningful because the experience gained does not stop at mere reflection, but is transformed into new, applicable knowledge oriented towards changing environmentally conscious behavior.

5.4. Performing Syntax

Performing stage is the culmination of the model's application, where individuals implement the understanding and knowledge they have developed into concrete actions. The performing stage is a critical moment where the constructed knowledge is realized through concrete actions. In the realm of biocentrism, actions such as planting trees, caring for local flora and fauna, or participating in animal conservation reflect an appreciation for the intrinsic value of all living things (Naess, 1973). Meanwhile, at the ecoconsciousness level, concrete actions such as reducing the use of single-use plastics, sorting community waste, or environmental awareness campaigns demonstrate the translation of ecological understanding into sustainable habits (Hedlund-de Witt et al., 2014). Furthermore, in the sustainability dimension, students engage in sustainable lifestyles through the use of environmentally friendly transportation, renewable energy, or the development of circular economy-based products that support the ecological transition (Friman et al., 2024). In the humanism realm, performing reflects concrete ecological solidarity, such as the initiation of green community movements, community participation in environmental projects, and the development of social networks to strengthen empathy and collective responsibility for the earth (Martusewicz et al., 2014). Thus, the performing stage becomes the peak of actualization of pro-environmental and humanitarian values in daily actions.

5.5. Continuing Syntax

Learning instills the values of sustainability and long-term ecological responsibility. At this stage, students develop follow-up plans and sustainable programs to maintain harmonious relationships between humans, animals, and nature. Learning instills the values of sustainability and long-term ecological responsibility. The continuing stage emphasizes the continuity of environmental practices and attitudes after formal experiences end. In terms of biocentrism, individuals demonstrate consistent respect for and protection of living things through ongoing involvement in conservation programs or the maintenance of natural habitats (Naess, 1973). In the realm of ecoconsciousness, daily habits such as energy conservation, waste reduction, and environmentally friendly consumption patterns are evidence of the internalization of long-term ecological awareness (Urien-Lefranc, 2020). For sustainability, continuing is manifested in a commitment to an environmentally friendly lifestyle, such as regular use of public transportation and the application of the principles of reduce, reuse, and recycle in consumption and production activities (Friman et al., 2024). Meanwhile, from a humanist perspective, continuing demonstrates the importance of sustainable ecological solidarity through the establishment of green communities, education of future generations, and strengthening a sense of collective responsibility towards the earth (Lowenstein et al., 2010). This stage ensures that actions taken do not stop temporarily, but develop into a collective ecological culture centered on moral values and sustainability.

In the context of ecopedagogy, the experiential learning model enables students to develop critical awareness of the social and economic structures underlying environmental crises. Ecopedagogy aims to cultivate global citizens committed to ecological justice (Payne, 2018). Through real-life experiences and reflection, students learn not only as individuals who understand concepts but as socially and ecologically responsible actors. This aligns with Vygotsky's sociocultural theory, which emphasizes that learning is strengthened through social interaction and collaborative activities (Vygotsky, 1978). Group discussions, cooperation, and shared reflection help internalize environmental values and build collective responsibility toward ecosystems. Ecopedagogy also provides an ethical and political foundation for experiential learning (Misiaszek, 2020), ensuring that students' experiences are directed toward ecological awareness and sustainability. Integrating sustainability values and critical consciousness helps foster eco-empathy care grounded in emotional and moral connection to nature. Empirical evidence supports this integration: experiential environmental education has been shown to significantly improve pro-environmental attitudes (Evcimen et al., 2025), and ecopedagogical curriculum approaches in higher education also strengthen students' sustainability orientations (Amaliati et al., 2024).

The results of this study confirm that the integration of ecopedagogy and experiential learning works synergistically in forming a comprehensive ecological awareness, encompassing cognitive, affective, and behavioral aspects. Ecopedagogy, rooted in Freirean critical pedagogy, encourages the formation of critical awareness of environmental issues as issues of ethics, politics, and ecological justice, as emphasized in the study of Misiaszek (2022), which shows that ecopedagogy can build critical ecological consciousness. When this principle is combined with experiential learning, the process of internalizing ecological values becomes stronger because students directly experience the ecological realities they are learning about. This is consistent with the findings of Nisbet et al. (2008) which demonstrate that direct and meaningful experiences with nature significantly enhance individuals' nature relatedness and ecological empathy. In the experiencing and reflection stages, students develop biocentric values and eco-consciousness through critical reflection, in line with the findings of Tryggvason et al. (2023), who emphasize the role of reflection in the formation of ecological morals. The constructing and performing stages support Kolb's constructivist theory that the transformation of experience into action occurs through a cycle of reflection–conceptualization–action, which is confirmed by recent research on Living Labs as spaces for co-creation of sustainability solutions (Hadfield et al., 2025). Meanwhile, the continuing stage confirms the theory of sustainable ecological behavior that environmental habits are formed through consistent action and internalization of values, as reported by Linder et al. (2022). Thus, this study not only strengthens the theories of ecopedagogy and experiential learning but also provides empirical evidence that both are capable of internalizing the values of biocentrism, ecoconsciousness, sustainability, and humanism, resulting in meaningful, lasting ecological behavioral changes that align with the demands of 21st-century sustainability education.

6. Conclusion and Future Perspectives

The results of this study show that the experiential learning model significantly influences students' environmental care attitudes. SmartPLS 4 analysis revealed that all constructs—biocentrism, ecoconsciousness, humanism, and sustainability—significantly affected environmental care attitudes. Sustainability and humanism contributed the most, followed by biocentrism and ecoconsciousness, with experiencing and continuing syntaxes showing the strongest indicator-level effects.

These findings provide theoretical contributions by strengthening the evidence that experiential learning combined with ecopedagogy can shape ecological attitudes through cognitive, affective, social, and action-oriented dimensions. Empirically, the study demonstrates that this model can be effectively implemented in Elementary School Teacher Education programs to enhance pre-service teachers' environmental awareness. However, the study has limitations, including the use of a cross-sectional design, reliance on self-reported data, and a sample limited to one regional context, which may introduce bias and limit generalizability. Therefore, future research is recommended to employ longitudinal designs, incorporate behavioral or observational measures, compare multiple institutional contexts, and explore additional mediating or moderating variables to further strengthen the model's explanatory power.

Author contributions: All authors contributed substantially to the conception, design, data collection, analysis, and writing of this study.

Data availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable requests.

Declaration of generative AI: During the preparation of this work, the authors used ChatGPT to check the grammar of the text and Sci-Space for the purpose of looking for quality literature that can support our research results. The entire manuscript was also reviewed and revised to ensure a consistent academic tone and clarity. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of interest: The authors declare no conflict of interest.

Ethical Approval and Consent to Participate: This study was approved by the Research Ethics Committee of Fakultas Keguruan Dan Ilmupendidikan on December 27, 2024 (No. 009/ETH/II.3.AU/F/2024) and was conducted with the utmost adherence to ethical standards (uns.id/ethicalexemption). Before the research, approval was obtained from the relevant educational ethics committee to ensure the study adhered to ethical guidelines. Informed consent was obtained from the teachers and participating students, and the confidentiality of participants was strictly maintained. The study ensured that participation was voluntary and that students could withdraw at any time without any consequence.

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Appendix 1. The relationship among aspects, indicators, and items of the environmental care attitude instrument

Aspects and indicators	*No*	*Statements*
Biocentrism		
Changing the natural environment to suit human needs	1	Students are provided with a case of a protected forest converted into modern housing due to human housing; they have to select the trends in actions taken to alter the natural environment for human benefits.
	2	Students are provided with a case study concerning a river normalized and concreted to facilitate infrastructure development. Students have to select the actions taken to support structural interventions in nature for human convenience.
Keeping the environment clean and tidy	3	Students are provided with a case of residual waste in a classroom/canteen after use. Students have to choose the actions they will take to keep the classroom clean before leaving.
	4	Students are provided with a case concerning campus public areas that are dirty despite the presence of janitors. Students are asked to demonstrate a willingness to take the initiative to clean up the trash.
Attitudes toward flora and fauna	5	Students are provided with a case concerning a proposal to violently expel a wild animal nuisance. Students have to choose the tendency of actions taken against acts of violence or abuse against animals.
	6	Students are provided with a case concerning someone damaging plants in a public facility. They have to choose the actions they will take to reprimand or report the person.
Ecoconsciousness		
Approaching the limit to growth	7	Students are provided with a case concerning natural resources (water, fertile soil) in their area that are possibly depleted and damaged. They are asked to demonstrate their belief that nature has a limited carrying capacity.
	8	Students are provided with a case study concerning the increasing exploitation of fossil fuels due to energy needs. They are asked to demonstrate their belief that these resources will eventually run out.
Rejection of exemptionalism	9	Students are provided with a case concerning a severe drought. Students are asked to believe that this problem will soon be completely resolved only through artificial rain technology.
	10	Students are provided with a case study concerning a city hit by an extreme heat wave. Students are asked to choose a technology that can make humans immune to all the impacts of climate change.
Actively participating in reducing air pollution and using water	11	Students are provided with a case study concerning daily activities involving short-distance travel. Students are asked to demonstrate a tendency to choose transportation that does not cause pollution.
	12	Students are provided with a case study concerning water use in everyday life. They have to choose the tendencies of action taken against these wasteful water habits.

Appendix 1 continued

Aspects and indicators	*No*	*Statements*
Sustainability		
Attitudes toward garbage	13	Students are provided with a case study concerning organic and inorganic waste management. Students are asked to demonstrate a tendency to sort waste and dispose of it in the correct containers.
	14	Students are provided with a case study concerning an obligation to independently sort waste on campus without supervision. They are asked to demonstrate their level of personal compliance with this waste sorting obligation.
Human-related environmental damage	15	Students are provided with a case study concerning factory dumping waste that pollutes a river. They are asked to demonstrate their level of concern about the impact of human-caused damage.
	16	Students are provided with a case study concerning destructive fishing practices (e.g., trawling). They are asked to demonstrate a willingness to participate in efforts to prevent these destructive practices.
Activity for greening	17	Students are provided with a case study concerning a voluntary tree-planting activity along a highway. They are asked to indicate their level of inclination to participate in the reforestation activity.
	18	Students are provided with a case study concerning a small vacant lot in a house/apartment. Students are asked to demonstrate the tendency of greening methods on the land.
	19	Students are provided with a case study concerning an organization raising funds for a reforestation program. They are asked to indicate their level of inclination to provide financial support or other resources for reforestation activities.
	20	Students are provided with a case study concerning students who are invited to recycle used cloth into shopping bags. They are asked to demonstrate an interest in learning creative recycling methods.
Fragility of nature's balance	21	Students are provided with a case study concerning a situation where minor damage to a forest can lead to major disasters elsewhere. They are asked to believe that the balance of nature is fragile and vulnerable to disruption.
	22	Students are provided with a case study concerning the disappearance of a single pollinator species disrupting an ecosystem. They are asked to believe that the loss of a single natural element will disrupt the entire food chain.
	23	Students are provided with a case study concerning a selection of actions that can impact the environment in the future. They are asked to demonstrate awareness that every individual action must be considered carefully due to the fragile balance of nature.
	24	Students are provided with a case study concerning minor damage to a mangrove ecosystem due to large-scale development. Students are asked to believe that minor damage can disrupt the entire balance of nature.

Appendix 1 continued

Aspects and indicators	*No*	*Statements*
Humanism		
Human intelligence makes the Earth uninhabitable	25	Students are provided with a case study concerning technological development that creates unknown long-term environmental risks. They are asked to indicate their level of concern that human intelligence can jeopardize the planet's survival.
	26	Students are provided with a case study concerning technological innovation being pursued without considering possible pollution. They are asked to agree that human intelligence must be limited in its use for the sake of environmental sustainability.
Care for people and the social environment	27	Students are provided with a case study concerning a natural disaster in a remote area. They are asked to demonstrate a tendency to gather and provide aid to disaster victims.
	28	Students are provided with a case study concerning their social environment that is experiencing a minor conflict. They are asked to demonstrate a tendency to strive to maintain harmony and resolve social problems.
A caring attitude towards the sustainable use of the environment	29	Students are provided with a case study concerning a company that chooses to dump waste due to high processing costs. They are asked to agree with the view that the current generation is responsible for protecting the environment for future generations.
	30	Students are provided with a case study concerning a factory that has been proven to pollute the environment. They are asked to support the factory's responsibility to cover the full costs of repairing the damage.