



Improving Environmental Literacy and Creative Attitudes of High School Students on Pollution Material: The Influence of *Ecopreneurship* -Based *Project-Based Learning*

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ABSTRACT. The problem of low environmental literacy and creative attitudes of students on environmental pollution of materials is a challenge that is still often encountered in schools, especially because learning tends to be theoretical and does not involve direct experience. This study aims to determine the effect of the Ecopreneurship-based Project Based Learning (PjBL) model in improving environmental literacy and creative attitudes of grade X high school students. The study used a quasi-experimental method with a pretest–posttest control group design, involving one experimental class implementing Ecopreneurship-based PjBL and one control class with conventional learning. The research instruments were an environmental literacy test and a creative attitude questionnaire. The results showed that the experimental class experienced a much higher increase than the control class, with post-test environmental literacy achievements of 75%–82% and N-Gain of 45%–100%, as well as an increase in creative attitudes from 32%–42% to 82%–86% with N-Gain of 35%–44%. Hypothesis testing through an independent t-test produced a significance value of 0.000, which confirmed that there was a significant difference between the two groups. The conclusion of this study is that the Ecopreneurship-based PjBL model is effective in improving environmental literacy and creative attitudes through authentic project activities that encourage students to deeply understand environmental issues while generating innovative solutions based on green entrepreneurship. This model is suitable as an alternative learning method for biology materials that requires the integration of concepts, practice, and creativity.

Keywords: Creative Attitude, Ecopreneurship, Environmental Literacy, PjBL.

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INTRODUCTION

Environmental pollution has become a pressing global problem and requires serious attention from all countries in the world (Hery Susanto, Achi Rinaldi, 2024) . This condition is characterized by increasing levels of pollutants in the air, water, and soil caused by industrial activities, transportation, and uncontrolled consumption (Maulidiyah, 2025) . The impact of this pollution not only threatens the sustainability of the ecosystem, but also causes various human

health problems such as respiratory diseases, reproductive disorders, and climate change that triggers natural disasters (Munandar, 2024) . In facing these challenges, Indonesia has demonstrated its commitment by signing the Sustainable Development Goals (SDGs), specifically goal 12 on responsible consumption and production, goal 13 on addressing climate change, and goal 15 on terrestrial ecosystems (Munandar, 2024) .

Education plays a fundamental role in shaping the environmental literacy of the younger generation as a preparation for facing future ecological problems (Krishnan, 2024) . In the context of Indonesian education, environmental literacy has been integrated into the Independent Curriculum, which provides broader space for the holistic development of student competencies, including environmental awareness (Pusparadi et al., 2024) . Environmental pollution material taught in biology lessons at the high school level is a strategic topic because it provides a comprehensive understanding of the types of pollution, their impacts, and possible control and mitigation efforts (Baderan, 2024) . Environmental literacy in this case is not merely understood as the cognitive ability to memorize pollution concepts, but rather the ability to understand environmental phenomena in depth, critically analyze their causes and impacts, and take concrete actions in everyday life to address these problems (Azizah & Wulandari, 2024) .

However, the reality on the ground shows a significant gap between students' conceptual understanding and their actual actions on environmental issues. This gap indicates that current environmental education has not been able to transform students' knowledge into consistent, environmentally conscious attitudes and behaviors. This situation demonstrates the need for a transformation in learning approaches that focus not only on conceptual mastery but also on character development and skills for action in addressing environmental issues concretely.

Environmental learning in most high schools currently tends to be theoretical and *teacher-centered* , placing the teacher as the sole source of information (Y. Rahmawati, 2023) . Conventional learning methods such as lectures and note-taking still dominate the learning process, leaving students passive recipients of information without the opportunity to explore and construct their own understanding (Anak & Dini, 2024) . The lack of student involvement in active and contextual learning results in environmental pollution being understood as an abstract concept separate from their real lives (Nurhidayati et al., 2025) .

This situation is exacerbated by students' limited direct experience in observing, analyzing, and finding solutions to environmental problems that occur around them. Initial observations at SMA Negeri 1 Tanjung Bintang showed that most students were able to explain the definition and types of pollution, but they struggled when asked to identify sources of pollution in the school environment or formulate applicable alternative solutions. This data confirms that students' environmental literacy remains at a basic cognitive level and has not yet reached the application and evaluation stages that are the true learning objectives. This low level of environmental literacy is also reflected in students' lack of concern for the cleanliness of the school environment, such as the abundance of scattered trash, minimal participation in waste management programs, and a lack of initiative to take concrete action in environmental conservation.

The 21st century presents complex challenges that require the younger generation to master critical, creative, collaborative, and communicative thinking skills, known as the 4C skills (Munandar, 2024) . Among these four skills, a creative attitude plays an essential role in the context of solving environmental problems because it enables students to find innovative solutions that have never existed before (Munandar, 2024) . A creative attitude is not only related to the ability to generate new ideas, but also includes the courage to think differently, flexibility in dealing with problems, and perseverance in realizing ideas into real products or actions (Azizah & Wulandari, 2024) .

In the context of environmental conservation, this creative attitude is essential for developing a green entrepreneurship approach or *Ecopreneurship* that integrates environmental awareness with

economic innovation (Avinni Achmad et al., 2024). *Ecopreneurship* offers a new paradigm that does not view environmental conservation as a burden or barrier to economic development, but rather as an opportunity to create added value through environmentally friendly products and services (Sulfikah et al., 2024). This approach teaches students that environmental awareness can be realized through productive activities that not only benefit the ecosystem but also provide economic benefits (Iberahim et al., 2025). Therefore, the world of education has a responsibility to cultivate a young generation that not only has knowledge and awareness of the environment, but also has a creative attitude and entrepreneurial spirit to create sustainable solutions that can be implemented in real life.

Project Based Learning (PjBL) has emerged as a promising alternative learning solution to address various weaknesses of conventional learning in developing environmental literacy and students' creative attitudes (Purba et al., 2025). As a constructivist learning approach, PjBL positions students as active subjects who construct their own knowledge through direct experience in completing authentic and meaningful projects. The main characteristics of PjBL, which include student-centered learning, contextual problem-based, requiring in-depth investigation, collaborative nature, and producing tangible products, are very suitable for the needs of environmental learning that demands active student involvement (Nandifa et al., 2025). Through PjBL, students not only learn the concept of pollution theoretically, but also are directly involved in identifying pollution problems in the surrounding environment, formulating research questions, seeking information from various sources, designing solutions, and implementing projects to address these problems (Maulidiyah, 2025).

This comprehensive learning process provides meaningful experiences that facilitate the development of students' environmental literacy holistically, starting from knowledge, skills, attitudes, to environmentally conscious behavior (Iberahim et al., 2025). The advantages of PjBL in developing creative attitudes are also very prominent because students are required to produce innovative solutions that have not existed before, think divergently in exploring various alternative problem-solving, and have autonomy in determining the direction of their projects (Purba et al., 2025). The effectiveness of PjBL in science learning has been supported by various previous studies that show that this approach is able to improve cognitive learning outcomes, science process skills, critical thinking skills, creativity, and student learning motivation. However, the implementation of PjBL in biology learning, especially on environmental pollution material, still requires further development to optimize its potential in forming environmental literacy and creative attitudes simultaneously (Rahayu et al., 2025) (Faediyah et al., 2024).

the Ecopreneurship concept into *Project Based Learning* offers a new dimension that enriches students' learning experience in understanding and addressing environmental pollution problems (Purwati et al., 2023). *Ecopreneurship* or environmental conservation-based entrepreneurship is an approach that combines entrepreneurial principles with a commitment to environmental sustainability. When the *Ecopreneurship* concept is integrated into PjBL, students are not only required to identify and understand pollution problems, but also to design innovative solutions that have economic value and can be implemented sustainably.

The synergy between PjBL and *Ecopreneurship* creates highly meaningful learning because students learn through direct experience in developing environmentally friendly products or services that can address pollution problems while providing economic benefits to the community. This approach facilitates the development of students' environmental literacy because they must have a deep understanding of the causes, impacts, and ways to address pollution to be able to design appropriate solutions. At the same time, the integration of *Ecopreneurship* also hones students' creative attitudes because they are encouraged to think innovatively in creating products or services that do not yet exist, seek opportunities from environmental problems, and develop sustainable business models.

Ecopreneurship- based PjBL in developing environmental literacy and creative attitudes simultaneously makes it a highly relevant approach to the demands of 21st-century education that emphasizes holistic and meaningful learning. The novelty of the *Ecopreneurship -based PjBL approach* in the context of biology learning in Indonesia lies in its systematic integration of biology content (especially pollution material), constructivist pedagogy (PjBL), and green entrepreneurship values that have rarely been combined in a coherent learning design.

Based on the description above, there is a significant gap between the expectations for environmental learning that can form an environmentally literate and creative generation and the reality on the ground that shows learning is still conventional and less meaningful. This gap shows the urgency to develop and test the effectiveness of learning innovations that not only focus on knowledge transfer, but also on the formation of student attitudes, skills, and behaviors in solving environmental problems creatively. Research on the effect of *Ecopreneurship -based Project Based Learning* on environmental literacy and creative attitudes of students is very important because it offers a comprehensive solution that integrates learning content, innovative pedagogical approaches, and sustainable entrepreneurial values in a coherent whole.

The uniqueness of this research lies in its attempt to improve two important variables simultaneously. environmental literacy and creative attitudes which has often been developed separately in previous studies. The contribution of this research to the development of biology learning in Indonesia is very significant because it can provide an alternative learning model that is evidence-based for environmental pollution material, as well as enrich the treasure of biology education research in Indonesia which is still limited in exploring the integration of *Ecopreneurship* . The results of this study are expected to provide practical benefits for teachers in designing more meaningful learning, for students in developing 21st-century competencies, for schools in implementing effective environmental education programs, and for educational policy makers in formulating strategies for developing curriculum and sustainability-based learning.

METHOD

1. Research Time

This research was conducted at SMA Negeri 1 Tanjung Bintang from September until the end of the odd semester of the 2024/2025 academic year.

2. Research location

The location that will be used for the research is State Senior High School 1 Tanjung Bintang which is located at Jl. Antara No. 1, Jatibaru Subdistrict, Tanjung Bintang District, South Lampung Regency, Lampung Province.

3. Types of research

The type of research used in this study is a *Quasi-Experiment* . The research design is presented in the following table.

Table 1. Research Design

Class	Pre-test	Treatment	Post-test
Experiment	O ₁	X ₁	O ₂
Control	O ₃	X ₂	O ₄

4. Population

The population that will be used in this study is all class X students at SMA Negeri 1 Tanjung Bintang in the 2024/2025 academic year, distributed into 10 classes, namely 10-1 – 10-10, with each class having 35 students, and a total of 350 students.

5. Sample

The sampling technique used for this study was Probability sampling, which provides the opportunity for the entire population to be selected as sample members. Then, the sampling technique used was simple random sampling, which is a sampling technique by randomly selecting students to be sampled. So, the samples obtained in this study were classes 10-3 and 10-2. Class 10-3, consisting of 36 students using the *Ecopreneurship learning approach*, was the experimental class, while class 10-2, consisting of 33 students, was the control class.

6. Research Instruments

In the study, the research instrument was used to measure the "Influence of the *Ecopreneurship Approach* on Environmental Literacy and Creative Attitudes on Environmental Pollution Material for Class X in High School".

Table 1 Research Instruments and Research Objectives

No	Research Variables	Variable Indicator	Instrument Type	Instrument's Shape	Data source
1	Environmental Literacy	Ecological knowledge, cognitive skills, attitudes towards the environment, and environmental behavior	Test	Multiple choice test (25 questions)	Student
2	Creative Attitude	Curiosity, imagination, originality and the courage to take risks	Questionnaire	Student questionnaire (Likert scale statements)	Student and Teacher Observers

7. Research Data Analysis Techniques

The research data analysis is presented in Table 3.

Table 3. Analysis of Research Data

Analysis Techniques	Purpose of Analysis
Environmental Literacy Test Analysis	<ol style="list-style-type: none"> 1. Assessing the increase in environmental literacy from pretest to posttest. 2. Knowing the effectiveness of learning through comparing increases in student learning outcomes. 3. Provides a measure of improvement that can be compared across groups.
Analysis of Creative Attitude Questionnaire	<ol style="list-style-type: none"> 1. Measuring changes in students' creative attitudes after learning treatment

Analysis Techniques	Purpose of Analysis
	<ol style="list-style-type: none"> 2. <i>the Ecopreneurship</i> -based PjBL model impacts student creativity. 3. Produces improvement values that can be analyzed along with other indicators.
Normality Test	<ol style="list-style-type: none"> 1. Determine whether the data is normally distributed. 2. It is the basis for selecting the next statistical test (parametric or nonparametric).
Homogeneity Test	<ol style="list-style-type: none"> 1. Knowing the similarity of variance between the experimental and control groups. 2. Ensure that both groups are comparable using parametric tests.
Hypothesis Testing with Independent t-test)	<ol style="list-style-type: none"> 1. Testing whether there is a significant difference between the experimental and control groups after learning. 2. Determine whether the applied learning model has a significant influence on environmental literacy and creative attitudes.

RESULTS AND DISCUSSION

1. Research Test and Questionnaire Results

This research was conducted in August, involving a series of activities including observation, implementation of learning models, and measurement of student abilities. After the entire process, data from environmental literacy tests and a creative attitude questionnaire were obtained, reflecting the condition and development of student abilities during the intervention. These findings serve as an important basis for analyzing the extent of the implementation of *Project-Based Learning based on the Ecopreneurship* approach . contribute to improving environmental literacy and creative attitudes of students, which will be further described in detail in the following section.

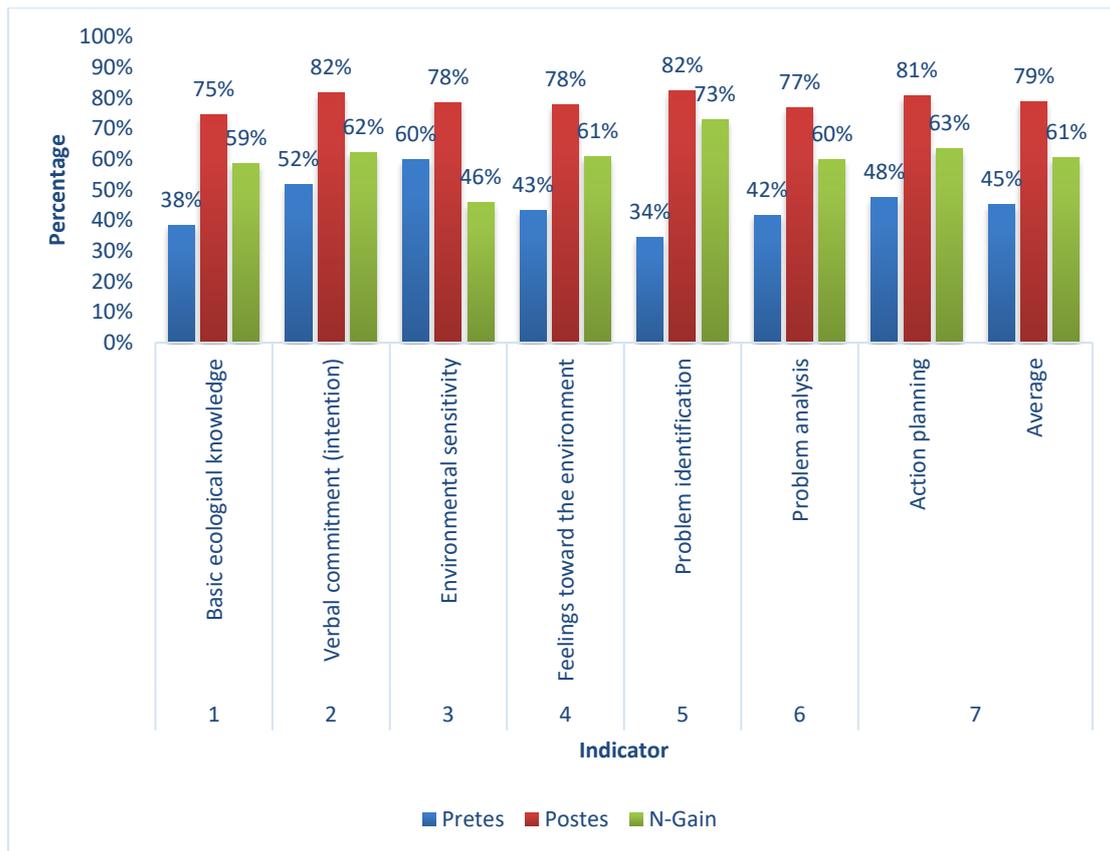


Figure 1. Results of the Experimental Class Environmental Literacy Test

The results of the environmental literacy assessment of the experimental class in Figure 1 show a diverse achievement profile across the seven measurement indicators, with percentage scores ranging from 45% to 82%. For the first indicator, "Knowledge of basic ecology," the experimental class demonstrated a post-test achievement of 75% with an N-Gain of 100%, indicating a significant increase in understanding of fundamental ecological concepts such as the interactions of organisms with their environment, biogeochemical cycles, and ecosystem dynamics. The second indicator, "Ability to analyze environmental issues," demonstrated a post-test achievement of 82% and an N-Gain of 78%, indicating that students have developed the ability to critically identify, analyze, and evaluate environmental issues. Cognitive abilities in environmental literacy are crucial aspects that often pose challenges in learning.

The third and fourth indicators, which measure "Sensitivity to Environmental Issues" and "Knowledge of Environmental Action," recorded a posttest score of 78% with an N-Gain of 49% and 76% with an N-Gain of 45%, respectively. These results indicate that although students have developed sensitivity to environmental issues and an understanding of various proactive action alternatives, the improvement from the pretest to the posttest was relatively moderate compared to the other indicators. This indicates the need for further strengthening of the affective and procedural knowledge aspects related to concrete environmental conservation actions.

The fifth indicator, "Quality of Action," achieved a posttest score of 82% with an N-Gain of 77%, indicating that students not only understood the actions needed to be taken but were also able to evaluate the effectiveness and quality of those actions. Meanwhile, the sixth indicator, "Individual Participation," recorded a posttest score of 81% with an N-Gain of 45%, indicating that students' level of active engagement in environment-based activities has increased, although ongoing facilitation is still needed to optimize their participation.

The final indicator, "Ability to analyze environmental behavior," showed a post-test achievement of 79% with an N-Gain of 51%, indicating that students have been able to reflect on and analyze behaviors that impact the environment, both destructive and constructive. Environmental literacy research shows that domains such as ecological knowledge, environmental

awareness, and environmentally responsible behavior need to be measured comprehensively to obtain a holistic picture of students' environmental literacy abilities.

High increase in verbal commitment indicators and problem analysis in the experimental class showed that the implementation of *Ecopreneurship -based Project Based Learning (PjBL)* was able to develop environmental literacy aspects related to students' ability to express environmental attitudes verbally and describe environmental issues more critically. In the PjBL model, students are directly involved in the process of identifying problems, group discussions, and compiling solutions that are expressed in the form of projects. This activity requires them to express opinions, arguments, and decisions verbally, thereby strengthening the *verbal commitment indicator*. This is in line with research stating that PjBL encourages students to actively communicate and express their understanding during the project completion process.

Indicator Problem analysis also experienced significant improvements because the *Ecopreneurship approach* not only allows students to understand environmental pollution theoretically but also to analyze the causes, impacts, and opportunities for utilizing waste as an economically valuable product. This activity requires high-level critical thinking skills. According to research, *Ecopreneurship -based PjBL* effectively improves analytical skills because students are directly involved in solving environmental problems through the development of environmentally friendly products.

The significant increase in these two indicators indicates that the research title emphasizing *the influence of Ecopreneurship-based PjBL* is truly relevant. This model not only improves ecological knowledge, but also strengthens students' critical thinking skills (problem analysis) *and verbal attitudes towards the environment (verbal commitment)*, in accordance with the main character of PjBL which is oriented towards collaboration, communication, and solving real problems. As a comparison, the control class was given the same test and obtained the following results.

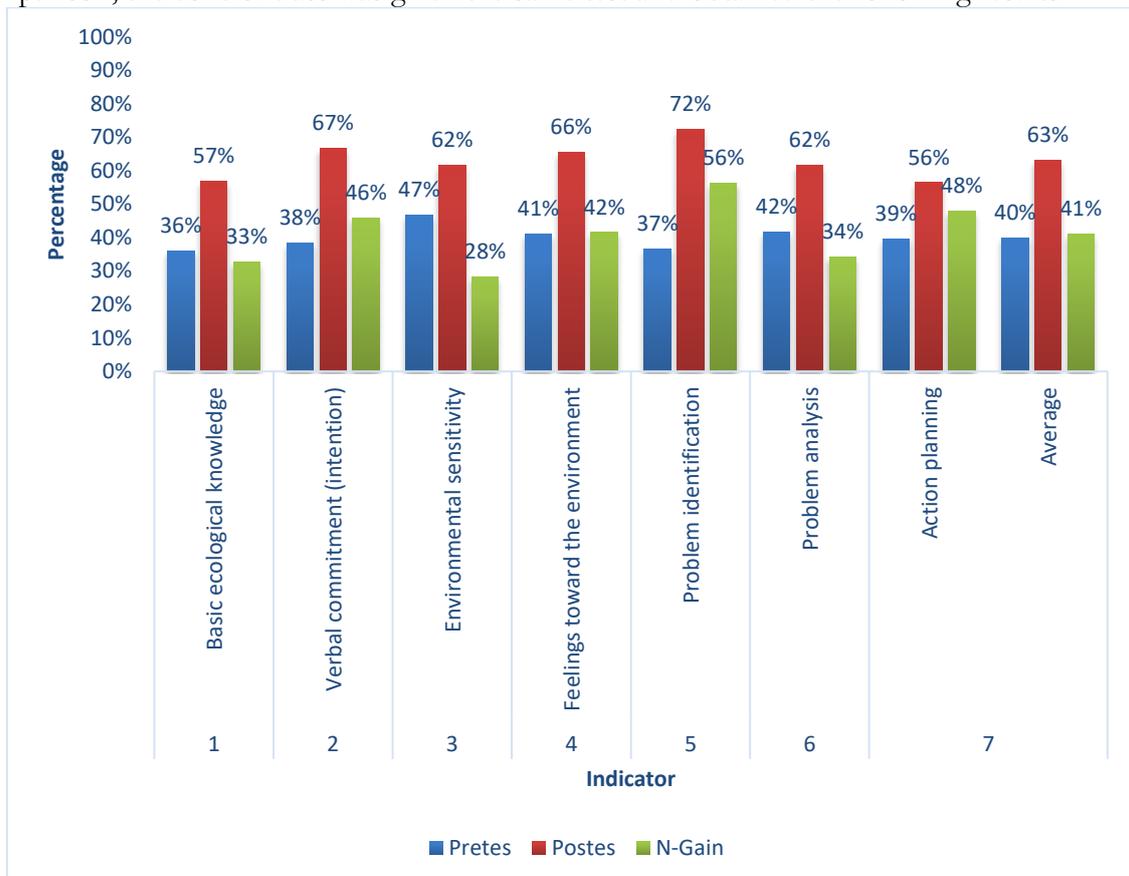


Figure 2. Results of the Environmental Literacy Test for the Control Class

Figure 2 presents a comprehensive portrait of the environmental literacy capacity of control class students as measured through seven indicator dimensions, with post-test scores ranging from

56% to 72%. The first indicator, which explores "Knowledge of basic ecology," showed a post-test achievement of 57% with a coefficient of improvement of 31%, indicating that progress in understanding the conceptual foundations of ecology is taking place at a moderate intensity. In the second indicator, which tests "Ability to analyze environmental issues," a post-test gain of 67% was recorded with an N-Gain of 57%. Exploration of the third indicator, "Sensitivity to environmental issues," resulted in a post-test score of 62% with an N-Gain of 49%, indicating that the construction of emotional sensitivity and critical awareness of environmental degradation has experienced sufficient but not comprehensive development.

indicators, which examine "Knowledge of environmental action" and "Problem-solving skills," showed post-test gains of 66% (N-Gain 41%) and 72% (N-Gain 62%), respectively. These data reveal that students' knowledge repertoire of pro-environmental action options and their capacity for contextual problem-solving have accumulated, with problem-solving skills registering the highest performance across all indicators. On the sixth indicator which measures "Individual participation," a post-test score of 62% was obtained with an N-Gain of 56%, a manifestation of the complexity of the translation between knowledge and attitudes into behavioral practice. The terminal indicator, "Behavioral analysis ability related to the environment," recorded a posttest score of 63% with an N-Gain of 51%, demonstrating that students' reflective capacity to evaluate the ecological implications of human actions has been developed at an intermediate level.

The results of this study are supported by various previous studies which show that the *Project Based Learning model based on the Ecopreneurship* approach consistently provides a greater impact than conventional learning models and *Discovery Learning*, in developing environmental literacy and creative attitudes of students. The study revealed that PjBL is able to improve the ability to analyze environmental issues and pro-environmental participation because students are directly involved in the process of identifying problems and creating project-based solutions. Furthermore, other studies show that the integration of *Ecopreneurship elements* in learning provides an authentic experience that encourages creativity, courage to take risks, and innovation in designing environmentally friendly products.

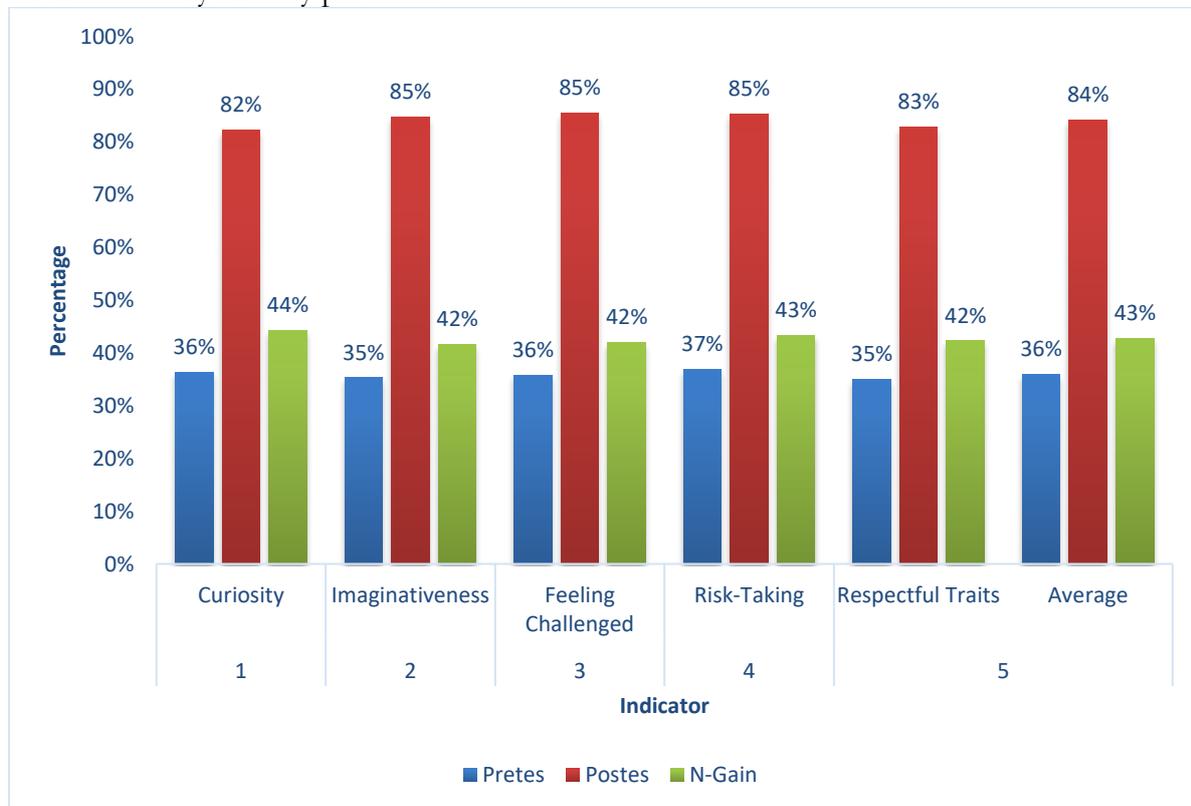


Figure 3. Results of the Experimental Class Creative Attitude Questionnaire

Figure 3 shows that the creative attitudes of students in the experimental class show a very significant increase after the implementation of the *Project Based Learning model based on the Ecopreneurship* approach .

In the pretest stage, the percentage of students' creative attitudes was in the range of 32%–42%, which reflects that before the learning, students' abilities to show curiosity, generate imaginative ideas, try new things, and solve problems were still relatively low. After the learning was implemented, posttest scores increased sharply to 82%–86% across all indicators. The indicator with the highest increase was seen in the ability to try new challenges (indicators 3 and 4) with a posttest achievement of 85%, while the indicator with the lowest achievement was still high in the nature of appreciating ideas (indicator 5) with an achievement of 83%.

The N-gain value reaching 35%–44% for each indicator indicates an increase in the medium to high category. This shows that project-based learning combined with the *Ecopreneurship approach* is able to facilitate students to be actively involved in the process of exploration, product creation, and creatively solving environmental problems. The average achievement of creative attitudes increased from 36% in the pretest to 84% in the posttest, demonstrating the success of learning in encouraging students to be more innovative, imaginative, and responsive to learning challenges. Overall, these results indicate that the *Ecopreneurship -based PjBL model* is very effective in improving students' creative attitudes.

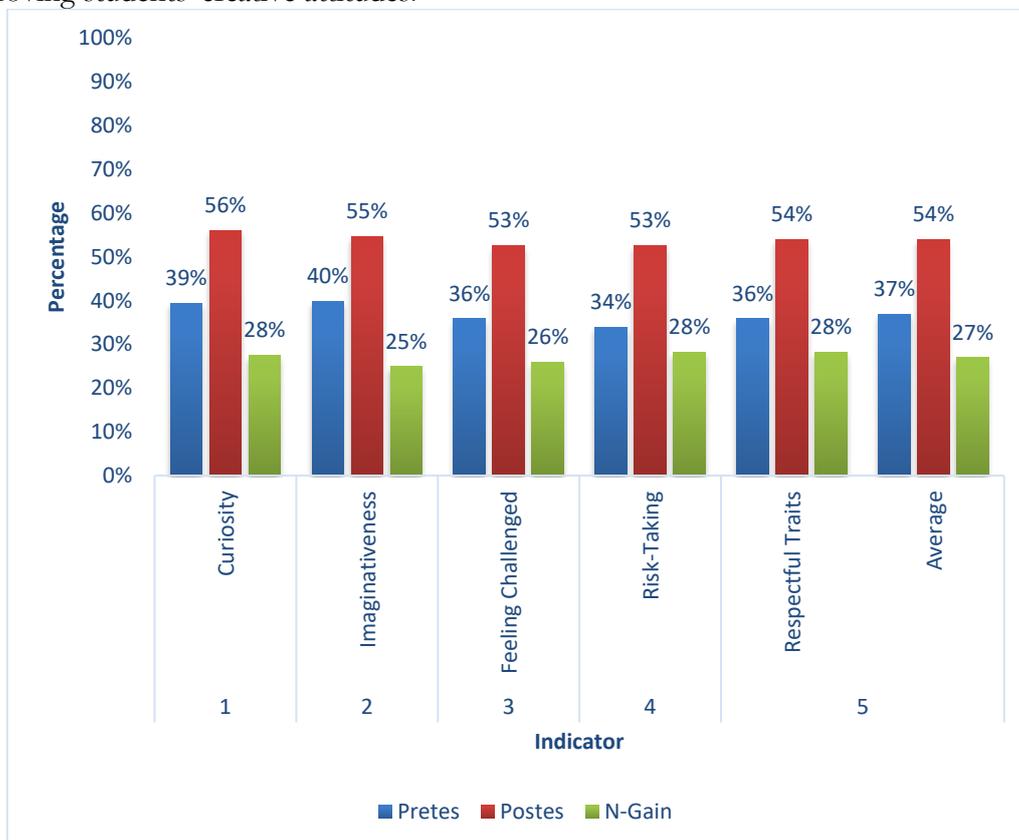


Figure 4. Results of the Creative Attitude Questionnaire for the Control Class

Figure 4 displays the results of the creative attitudes questionnaire for the control class, measured using six indicators. The data show that post-test scores ranged from 53% to 56%, with a relatively uniform level of improvement (N-Gain) ranging from 27% to 35%. These results indicate that control class students who participated in regular learning experienced a relatively limited increase in environmental literacy compared to their baseline. The first indicator is "Specific Gravity of Issues," with a post-test score of 56% and an N-Gain of 32%. This indicates that control class students have a sufficient understanding of the importance of various environmental issues, although the improvement is not significant. They are able to distinguish which environmental issues are more urgent to address, but this understanding has not yet developed optimally.

The second indicator, "Ecology and Humans," achieved a posttest score of 55% with an N-Gain of 28%. This achievement indicates that students have a basic understanding of the relationship between humans and the natural environment, such as how human activities affect ecosystems and vice versa. However, the improvement from pretest to posttest was relatively low, indicating that conventional learning is less effective in deepening understanding of human-environmental interactions. The third indicator, "Problem Solving," recorded a posttest score of 53% with an N-Gain of 35%. Although the N-Gain for this indicator is relatively higher than the other indicators, the posttest score of only 53% indicates that students' ability to solve environmental problems is still limited. Students may know how to solve environmental problems theoretically, but are not yet able to apply them well in real situations.

The fourth and fifth indicators, "Thinking from an Ecological Perspective" and "Attitudes Toward Ecology," both showed a post-test score of 53% with an N-Gain of 34% and 35%, respectively. These results indicate that students in the control class have limited ability to view problems from a holistic ecological perspective. Similarly, their attitudes toward the environment, while positive, have not developed significantly.

The final indicator, "Specific Gravity," recorded a post-test score of 54% with an N-Gain of 27%, the lowest among all indicators. This indicates that students' understanding of the gravity or severity of environmental impacts experienced minimal improvement. Overall, the environmental literacy profile of the control class showed consistent results across all indicators, with post-test scores ranging from 53-56% and an N-Gain of 27-35%. This pattern suggests that conventional learning has had a limited and uneven impact on various aspects of environmental literacy. No indicator showed a significant increase, and conversely, none showed a decrease. This indicates that conventional learning methods are sufficient to provide basic understanding, but not effective enough to develop a deep and comprehensive creative attitude.

2. Research Prerequisite Test Results

Before presenting the main research results, a series of prerequisite tests were conducted to ensure that the data obtained met the requirements for the statistical analysis to be used. These prerequisite tests are a crucial initial step in ensuring accurate and valid interpretation of the research results. Therefore, this section briefly presents the test results, including an examination of the data distribution characteristics and the appropriateness of variance, as a basis for determining the analysis techniques used in the next stage.

Table 4. Results of Data Normality Test

Variables	Class	Kolmogorov-Smirnov Sig.	Shapiro-Wilk Sig.	Information
Environmental Literacy Test	Experiment	0.345	0.104	Normal
	Control	0.145	0.232	Normal
Creative Attitude Questionnaire	Experiment	0.256	0.222	Normal
	Control	0.321	0.123	Normal

Table 5. Results of Data Homogeneity Test

Variables	Levene Statistics	df1	df2	Sig.	Information
Environmental Literacy Test	0.486	1	58	0.489	Homogeneous
Creative Attitude Questionnaire	0.161	1	58	0.689	Homogeneous

3. Research Hypothesis Test Results

After all prerequisite tests have been met, the next step is to conduct a hypothesis test to determine the extent to which the *Ecopreneurship* -based *Project-Based Learning* model significantly impacts students' environmental literacy and creative attitudes. This hypothesis test is a key step in answering the research question, and the results are presented in Table 6.

Table 6. Results of Research Hypothesis Testing

Variable Pairs	Mean Difference	t	df	Sig. (2- tailed)	Information
Pair 1: Environmental Literacy Test	-66.92	-	59	0.000	Significant
		37,347			
Pair 2: Creative Attitude Questionnaire	-67.33	-	59	0.000	Significant
		32,494			

The results of the study indicate that the implementation of the *Ecopreneurship* -based *Project Based Learning model* has a significant impact on improving students' environmental literacy. This is evident from the striking differences in achievement between the experimental and control classes on all measured environmental literacy indicators. The experimental class implementing *Ecopreneurship* -based *Project Based Learning (PjBL)* recorded post-test scores ranging from 75% to 82% with N-Gain values varying from 45% to 100%, while the control class using conventional learning only achieved post-test scores of 57% to 72% with N-Gain values of 31% to 62%. This difference indicates that the learning model that integrates a constructivist approach with green entrepreneurship values is able to optimize students' understanding of environmental issues in a deeper and more comprehensive manner.

Discussion

The highest increase in the experimental class occurred in the basic ecological knowledge indicator with N-Gain reaching 100%, which shows that through *Ecopreneurship* -based *PjBL* , students do not simply memorize ecological concepts but build a solid understanding through direct experience in projects. The characteristics of *PjBL* which are student-centered and contextual problem-based facilitate students to explore ecological concepts in real situations, such as when they identify types of pollution in the school environment, analyze their impact on the ecosystem, and design *Ecopreneurship* -based *solutions* . This process is in line with the theory of constructivism which states that knowledge is actively constructed by learners through interaction with the environment and concrete experiences, not through passive information transfer from teachers.

The environmental issue analysis ability indicator also showed a very high increase with a post-test score of 82% and an N-Gain of 78% in the experimental class. This achievement confirms that *Ecopreneurship* -based *PjBL* is effective in developing students' higher-order thinking skills, especially in the analysis and evaluation aspects. When students are required to identify pollution problems, investigate their causes and impacts, and design environmentally friendly products as solutions, they simultaneously train their critical and analytical thinking skills. This finding is supported by previous research showing that project-based learning can improve analytical skills because students are involved in a complex and authentic problem-solving process.

Interestingly, although the experimental class showed significant improvements in all indicators, some indicators such as sensitivity to environmental issues and knowledge of environmental actions showed a relatively lower N-Gain of 49% and 45%. This indicates that although *Ecopreneurship* -based *PjBL* is very effective in developing cognitive aspects and skills, the formation of affective aspects such as sensitivity and awareness requires a longer time and a more intensive value internalization process. This finding is in line with Bloom's taxonomy which shows that the affective domain involves a tiered value internalization process starting from receiving, responding, appreciating, organizing, to characterization that requires continuous habituation and reinforcement.

Comparison with the control class further clarifies the effectiveness of *Ecopreneurship* -based *PjBL* . The control class, which implemented conventional learning, showed a much more moderate increase, with the highest N-Gain of only 62% in the problem-solving skills indicator.

Conventional learning patterns, which tend to be teacher-centered and focus on knowledge transfer through lectures, result in students being less actively involved in the knowledge construction process (Munandar, 2024d). They understand the concept of pollution theoretically but lack direct experience in applying that knowledge to solve real-life problems. This condition causes their understanding to be superficial and less meaningful, making it difficult to transfer into everyday life contexts (Munandar, 2024).

the Ecopreneurship concept into PjBL provides an additional dimension that enriches the students' learning experience. Through the *Ecopreneurship approach*, students not only learn about environmental pollution problems but are also encouraged to view waste and pollutants as resources that have economic potential if managed creatively (Batubara et al., 2025). This green entrepreneurial mindset shifts students' perspectives from simply understanding the problem to actively seeking innovative, sustainable solutions (Pusparadi et al., 2024). For example, when students develop a project to process plastic waste into economically valuable craft products, they simultaneously learn about the impact of plastic pollution, recycling principles, creativity in product design, and marketing and entrepreneurial skills.

Ecopreneurship-based PjBL in improving environmental literacy is also inseparable from its collaborative learning characteristics. During the project completion process, students work in groups to discuss, share ideas, solve problems together, and provide feedback to each other (Muhiddin, 2024). This social interaction facilitates scaffolding and the zone of proximal development as conceptualized by Vygotsky, where students with different abilities support each other to achieve higher understanding. Collaborative learning also trains communication and cooperation skills, which are important competencies in the 21st century (Hery Susanto, Achi Rinaldi, 2024).

The results of the hypothesis test with the Independent t-test showed a significance value of 0.000 ($p < 0.05$) with a mean difference of -66.92 and a t-value of -37.347, which confirmed that there was a very significant difference between the environmental literacy of the experimental class and the control class. These statistical data strengthen the empirical evidence that *Ecopreneurship -based PjBL* not only increases environmental literacy moderately, but also provides a substantial and consistent impact across all aspects of environmental literacy. These findings provide an important contribution to the development of biology learning, especially on environmental pollution material, and show that learning innovations that integrate a constructivist approach with sustainable entrepreneurship values are an effective strategy for achieving holistic learning objectives.

The research findings on creative attitudes show a pattern consistent with the results of environmental literacy, where the experimental class experienced a significantly higher increase compared to the control class. The experimental class that implemented *Ecopreneurship -based PjBL* recorded an increase in creative attitudes from 32-42% in the pretest to 82-86% in the posttest with an N-Gain ranging from 35-44%, while the control class only achieved an increase from pretest to posttest of 53-56% with an N-Gain of 27-35%. This significant difference indicates that the characteristics of PjBL learning that provide freedom for students to explore, experiment, and produce innovative solutions are very conducive to the development of creativity.

The high increase in creative attitudes in the experimental class can be explained through several learning mechanisms that occurred during the implementation of *Ecopreneurship -based PjBL*. First, the characteristics of PjBL which are based on open-ended problems (ill-structured problems) provide space for students to think divergently and explore various alternative solutions. Unlike conventional learning which often presents problems with one correct answer, PjBL encourages students to produce multiple creative and innovative solutions. When students are asked to design *Ecopreneurship products* from waste or recycled materials, they must think outside the box to produce products that are not only environmentally friendly but also have aesthetic and economic value.

The iterative process in PjBL involving planning, implementation, evaluation, and revision stages provides an opportunity for students to develop persistence and courage to take risks, which are important dimensions of a creative attitude (Nurhidayati et al., 2025) (Munandar, 2024a) . In *Ecopreneurship* projects , students often face failure or results that do not meet expectations in their initial attempts. However, the PjBL learning culture that values the process and makes failure part of learning encourages students to not give up easily, continue experimenting, and trying new approaches until finding the optimal solution (Munandar, 2024) . This attitude of not being afraid of failure and daring to try is a fundamental characteristic of creative individuals (Baderan, 2024) .

The integration of *Ecopreneurship* in PjBL adds a practical and contextual dimension that allows students' creativity to not stop at the level of abstract ideas but is realized in the form of real, functional products (Rochmawati et al., 2025) . The process of transforming ideas into real products involves various skills such as designing, prototyping, testing products, and improving based on feedback (Munandar, 2024) . These stages train not only creativity in thinking (creative thinking) but also creativity in acting (creative doing). Students learn that creativity is not only about having brilliant ideas but also about the ability to realize those ideas into something concrete and useful.

The creative attitude indicator that showed the highest improvement in the experimental class was the ability to try new challenges, with a post-test score of 85%. This finding confirms that project-based learning, which requires students to step out of their comfort zones, confront complex problems, and find solutions independently, is effective in building the courage to take risks. In the context of the *Ecopreneurship project* , students were challenged not only to produce environmentally friendly products but also to consider aspects of marketing, branding, and business sustainability. This multidimensional challenge encouraged them to continue innovating and trying new approaches they had never tried before.

In contrast, the control class, which implemented conventional learning, showed a much more limited increase in creative attitudes. Teacher-centered learning, using lectures and practice exercises, tends to promote convergent thinking, where students search for a single correct answer determined by the teacher or textbook. This learning pattern does not provide sufficient space for students to explore, ask critical questions, or generate original ideas. As a result, students' creativity does not develop optimally because they are accustomed to passively receiving information and following established procedures without being given the opportunity to innovate.

The collaborative aspect of PjBL also contributes to the development of creative attitudes through the process of brainstorming and exchanging ideas among group members. When students work in teams, they are exposed to different perspectives and ideas from their peers (Rifky, S., Suhirman, L., Kurniawati, I., & Fihrisid et al., 2024) . This interaction stimulates creative thinking because students learn to consider multiple viewpoints, combine ideas from various sources, and produce more creative syntheses (Munandar Aris, Ahmad Sahroni, 2024) . This process of cross-pollination of ideas is one of the important mechanisms in the development of creativity as explained in creativity theory which emphasizes the importance of social interaction and a supportive environment (Utami, 2024) .

The role of teachers as facilitators in PjBL is also crucial in developing attitudes. The results of the hypothesis test showed a significance value of 0.000 ($p < 0.05$) with a mean difference of -67.33 and a t-value of -32.494 for creative attitudes, which confirmed that the difference between the experimental and control classes was statistically significant. These data provide strong empirical evidence that *Ecopreneurship -based PjBL* is an effective learning approach to develop students' creative attitudes. These findings have important implications for learning practices in schools, especially in the context of 21st-century education that demands the development of higher-order thinking skills including creativity.

One interesting finding from this study is that improvements in environmental literacy and creative attitudes occur simultaneously and reinforce each other. This indicates a synergy between the two variables in the context of *Ecopreneurship -based PjBL learning* . When students develop better

environmental literacy, they have a more solid foundation of knowledge and understanding to generate creative solutions to environmental problems. Conversely, a strong creative attitude allows students to explore new dimensions of environmental issues and discover alternative perspectives that enrich their environmental literacy.

This synergy is facilitated by the characteristics of *Ecopreneurship-based PjBL*, which integrates conceptual learning with practical application (RF Rahmawati, 2024). Students not only learn theories about environmental pollution but also directly apply this knowledge in designing and implementing *Ecopreneurship projects*. This application process requires them to think creatively in connecting theoretical concepts with practical realities, while deepening their understanding of the complexity of environmental issues. Thus, environmental literacy and creativity do not develop separately but are intertwined in a holistic learning process.

The Ecopreneurship dimension also plays a crucial role in creating this synergy because it provides an authentic and meaningful context for the development of both competencies (Sutoyo Putri, 2024). When students are asked to develop products or services that are not only environmentally friendly but also have economic value, they must integrate ecological understanding with innovative and entrepreneurial thinking. This context demands in-depth environmental literacy to understand the principles of sustainability and environmental impact, as well as high creativity to produce innovative and marketable solutions. This integration makes learning more relevant and meaningful for students because they see that environmental awareness can be realized through productive activities that provide economic benefits.

The findings of this study provide a theoretical contribution to understanding how project-based learning integrated with sustainable entrepreneurship values can simultaneously develop complex competencies. This aligns with the 21st-century educational paradigm that emphasizes holistic and integrative learning, where various competencies are not developed in isolation but through authentic and contextual learning experiences. *Ecopreneurship-based PjBL* offers a learning model that can integrate learning content (environmental pollution), cognitive skills (environmental literacy), and creative skills into a coherent and meaningful learning environment.

Based on the findings of this study, there are several practical implications that can be drawn. This study also has limitations that need to be acknowledged. First, the study was conducted over a relatively limited period of one semester, so it cannot yet describe the long-term impact of the implementation of *Ecopreneurship-based PjBL* on students' environmental literacy and creative attitudes. Longitudinal research that tracks student development over a longer period is needed to understand the sustainability of this learning impact. Second, this study was conducted in a single school with a specific context, so generalizing the findings to different contexts requires caution. Replication research in various school settings with diverse characteristics will strengthen the external validity of this study's findings.

For further research, several aspects that can be explored further include: first, analyzing in depth the learning process that occurs during the implementation of *Ecopreneurship-based PjBL* through a qualitative approach to understand the psychological and pedagogical mechanisms underlying the improvement of environmental literacy and creative attitudes. Second, testing the effectiveness of *Ecopreneurship-based PjBL* on other biology materials to see whether the findings of this study can be generalized to different content contexts. Third, exploring contextual factors that influence the successful implementation of *Ecopreneurship-based PjBL* such as teacher characteristics, school culture, and management support. Fourth, developing and testing variations of *Ecopreneurship-based PjBL designs* with a focus on specific aspects such as the use of technology, collaboration with the community, or integration with other school programs.

CONCLUSION

This study concludes that the implementation of the *Ecopreneurship-based Project Based Learning* (PjBL) model has been proven to have a very significant influence on increasing

environmental literacy and creative attitudes of class X students on environmental pollution material at SMA Negeri 1 Tanjung Bintang, where this approach is able to overcome the weaknesses of conventional learning which is still theoretical and teacher-centered. Through authentic, contextual, and problem-solving-oriented project activities, students not only understand the concept of ecology and pollution issues more deeply but are also directly involved in designing creative solutions in the form of environmentally friendly products that have economic value. This is reflected in the achievements of the experimental class which showed an increase in environmental literacy post-test reaching 75%–82% with an N-Gain value of 45%–100%, much higher than the control class which only reached 57%–72% with an N-Gain of 31%–62%. Similarly, students' creative attitudes increased drastically from 32%–42% in the pretest to 82%–86% in the posttest with an N-Gain of 35%–44%, while the control class only increased moderately in the range of 53%–56%. The results of the hypothesis test through the independent t-test which showed a significance value of 0.000 for both variables further strengthens that *Ecopreneurship -based PjBL* is consistently and significantly able to develop critical thinking skills, sensitivity to environmental issues, courage to take risks, flexibility of thinking, and the ability to generate innovative ideas.

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