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The effectiveness of green entrepreneurship-oriented project-based learning in improving students' creative thinking skills in organic waste processing

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Abstract. Creative thinking is a 21st-century competency that must be developed through contextual learning. This study aims to analyze the effectiveness of Project-Based Learning (PjBL) oriented toward green entrepreneurship through processing organic domestic waste on high school students' creative thinking ability in environmental change material. The study used a quantitative approach with a quasi-experimental method and a Nonequivalent Control Group Design. The research sample included 43 students: 23 from the experimental class and 20 from the control class, selected through purposive sampling. Data were analyzed using the Mann–Whitney test, N-Gain, effect size, and ANCOVA as supporting analyses. The results showed that the experimental class had a higher average N-Gain of 0.6256 (medium category) than the control class. The Mann–Whitney test showed a significant difference between the two classes ($p < 0.05$), while the ANCOVA results confirmed that the learning model remained significant after controlling for initial abilities. The large effect size indicated that implementing PjBL oriented toward green entrepreneurship had a strong practical influence on improving students' creative thinking ability. The results of this study have implications for developing contextual Biology learning by using organic domestic waste as a project source to develop students' creative thinking skills while integrating the values of sustainability and entrepreneurship.
Keywords: Creative thinking skills, Environmental change, Green entrepreneurship, Organic domestic waste, Project-based learning

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INTRODUCTION

Educational developments in the 21st century require students to master not only knowledge but also higher-order thinking skills, including creative thinking. According to the OECD (2023), creative thinking is a competency that enables students to generate diverse and original ideas, evaluate and refine ideas, and generate solutions to problems. UNEP (2022) also emphasizes the importance of developing creative thinking skills in education to prepare students to face global challenges and support sustainable development. Therefore, learning needs to provide experiences that encourage students to generate ideas, explore alternatives, and generate solutions to real-world problems.

One real-world problem that can serve as a learning context is managing organic domestic waste. According to the 2024 National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry, approximately 50.8% of waste generated comes from households, while 39.36% of the waste composition consists of food scraps or organic waste. Poorly managed organic domestic waste can cause environmental problems. On the other hand, this waste can be utilized to create various useful products with potential economic value. This makes processing organic domestic waste a relevant context for Biology learning, particularly in the area of environmental change.

Learning that addresses organic domestic waste requires active student involvement in identifying problems and developing solutions (Bang et al., 2025). However, interviews with Biology teachers indicate that lecture and discussion still dominate learning. Students are rarely

involved in project activities that utilize organic domestic waste to solve environmental problems. This situation limits students' opportunities to explore ideas, generate alternative solutions, and develop products based on real-world problems. Therefore, students need a learning model that provides direct experience designing and producing solutions to environmental problems.

One learning model relevant to these needs is Project-Based Learning (PjBL). PjBL engages students in investigating real-world problems by planning, implementing, and evaluating projects (Abas et al., 2024). These activities give students opportunities to develop ideas, make decisions, solve problems, and produce products (Anazifa & Djukri, 2017). In the topic of environmental change, PjBL can connect the concept of pollution with the problem of organic domestic waste encountered in everyday life (Apriani & Sudrajat, 2025). Thus, learning is not only oriented towards conceptual understanding but also provides hands-on experience in solving environmental problems.

Applying PjBL to organic domestic waste processing can be strengthened through a green entrepreneurship approach (Angraeni et al., 2024). Green entrepreneurship is an entrepreneurial approach that integrates economic goals with environmental protection and sustainability by developing products or services that provide environmental benefits (Schaltegger & Wagner, 2011; Belz & Binder, 2017). This approach emphasizes identifying business opportunities that can generate economic value while reducing negative environmental impacts. In an educational context, green entrepreneurship can be implemented through activities such as identifying environmental problems, developing product ideas, using resources responsibly, and considering the resulting product's utility and economic value (Syifa'uliyah et al., 2023).

Integrating green entrepreneurship into Project-Based Learning (PjBL) provides clearer direction for project implementation. Students are directed not only to solve problems through a product but also to consider the product's environmental benefits and potential economic value. In this study, this integration was carried out through activities such as identifying organic domestic waste, designing a project, processing waste into a useful product, evaluating environmental benefits, and identifying the product's economic opportunities. This process gives students space to generate ideas, develop alternative solutions, create original products, and elaborate on their ideas (Bianchi et al., 2022). Thus, integrating PjBL and green entrepreneurship can support the development of creative thinking skills in the context of environmental issues.

Various studies have shown that Project-Based Learning (PjBL) can support the development of students' creative thinking skills. Laksmi et al. (2018) reported that implementing Project-Based Learning (PjBL) can improve creative thinking skills, particularly fluency, flexibility, and originality. Weng et al. (2022) also demonstrated that integrating entrepreneurial elements into project-based learning can encourage students to generate creative solutions to real-world problems. Furthermore, Komodiki et al. (2021) explained that implementing environmental entrepreneurship increases environmental awareness and student engagement in learning. Fauzi et al. (2022) also reported that a green entrepreneurship approach can support creativity and innovation by developing environmentally friendly products.

However, previous research has shown limitations in systematically integrating green entrepreneurship into each stage of Project-Based Learning (PjBL). Some studies have focused on implementing Project-Based Learning (PjBL) or green entrepreneurship separately. Research that specifically integrates green entrepreneurship principles into the PjBL stages through organic domestic waste processing in environmental change topics at the high school level remains limited. Furthermore, studies on the contribution of this integration to each indicator of creative thinking ability, namely fluency, flexibility, originality, and elaboration,

also need to be expanded (Elisondo & Melgar, 2021). This gap formed the basis for researching the application of green entrepreneurship-oriented Project-Based Learning (PjBL) in the context of organic domestic waste processing.

This research is novel in integrating green entrepreneurship principles into each stage of PjBL, using organic domestic waste as a learning context for environmental change. This integration not only directs students to produce products from waste but also considers the environmental benefits and potential economic value of the products. This approach provides a learning experience that connects environmental problem-solving, product development, and creative thinking skills. Based on this description, this study aims to analyze the effectiveness of green entrepreneurship-oriented Project-Based Learning (PjBL) through organic domestic waste processing in improving high school students' creative thinking skills in environmental change.

METHOD

This study employed a quantitative approach with a quasi-experimental method using a nonequivalent control group design (pretest–posttest control group design). The study was conducted in the even semester of the 2025/2026 academic year at a high school in Majalengka Regency. The study included 43 tenth-grade students selected through purposive sampling. The sample selection was based on the relatively homogeneous academic characteristics of both classes, as recommended by their biology teacher, who taught both classes and delivered the environmental change material in the same semester. The sample consisted of 23 students in the experimental class and 20 students in the control class.

The experimental class participated in Project-Based Learning (PjBL) with a green entrepreneurship orientation through organic domestic waste processing activities. Meanwhile, the control class participated in PjBL learning without integrating green entrepreneurship principles. Both groups received learning in three meetings and followed the same PjBL syntax. The differences in treatment were the project context, waste processing activities, and the integration of environmental sustainability and economic value aspects in the experimental class. Table 1 compares the treatments for the two groups.

Table 1. Comparison of experimental class and control class treatments

PjBL syntax	Experimental class	Control class
Essential Question	Identify problems with organic domestic waste and opportunities to utilize it to create useful and economically valuable products.	Identify environmental pollution problems and their impacts on the environment.
Design a Plan for the Project	Design environmentally friendly products from organic domestic waste, considering its utility and potential economic value.	Design a project in the form of a poster or educational video about environmental pollution.
Create a Schedule	Develop a schedule for material preparation, waste processing, product completion, and a simple marketing plan.	Develop a schedule for completing the poster or educational video.
Monitor the Students and the Progress of the Project	Teachers monitor the waste-processing process and guide creativity, environmental benefits, and green entrepreneurship.	The teacher monitors the poster or video creation process and guides understanding of environmental pollution.
Assess the Outcome	Evaluate products based on creativity, usefulness, innovation, environmental benefits, and potential economic value.	Evaluate the poster or video based on the content's relevance to environmental pollution, creativity, and presentation quality.
Evaluate the Experience	Reflect on the waste processing process, environmental benefits, project constraints, and product development opportunities.	Reflect on the project creation process, understanding of the concept, and challenges encountered during poster or video development.

The instruments used in this study included a creative thinking ability test, a teacher activity observation sheet, a student activity observation sheet, and a student response questionnaire. The creative thinking ability test consisted of 11 essay questions that were declared valid and reliable. The instrument was designed based on Torrance's (1974) four indicators of creative thinking ability: fluency, flexibility, originality, and elaboration. The observation sheet evaluated the teacher's implementation of the lesson and student activities during the learning process. In contrast, the student response questionnaire gathered information on students' responses to the implementation of green entrepreneurship-oriented PjBL.

Data were collected through a pretest before the lesson and a posttest after the entire learning series was completed in both groups. Data were analyzed using descriptive statistics to illustrate the research results. Prerequisite tests included a normality test using the Shapiro–Wilk test and a homogeneity test using Levene's Test. The results showed that the data did not meet the assumptions of normality and homogeneity, so hypothesis testing continued using the nonparametric Mann–Whitney U test. The effectiveness of implementing green entrepreneurship-oriented PjBL in improving creative thinking skills was analyzed using N-Gain. The entire data analysis process was carried out using IBM SPSS Statistics software.

RESULTS AND DISCUSSION

This section presents the results of the research data analysis, which includes descriptive analysis of students' creative thinking abilities, creative thinking ability achievement based on each indicator, N-Gain analysis, normality test, homogeneity test, and hypothesis testing. The research findings are discussed and interpreted with reference to theory and previous research results.

Results

Descriptive analysis results

The descriptive analysis showed that students' creative thinking skills increased in both groups, with a greater increase in the experimental class. The average pretest score in the experimental class increased from 46.83 to 80.35 in the posttest. The average score in the control class also increased from 40.45 to 48.10. These findings indicate that implementing Project-Based Learning (PjBL) integrated with a green entrepreneurship approach is more effective in improving students' creative thinking skills than implementing PjBL without a green entrepreneurship orientation.

Pretest and posttest results of creative thinking ability based on indicators

The analysis of creative thinking skills was conducted based on four indicators: fluency, flexibility, originality, and elaboration. The results showed improvements in all indicators in both the experimental and control classes after the learning process (Table 2). However, the increase in creative thinking skills was greater in the experimental class than in the control class.

Table 2. Pretest and posttest creative thinking ability based on indicators

Indicator	Pretest experiment	Posttest experiment	Pretest control	Posttest control
Fluency	49	79	39	46
Flexibility	48	74	32	40
Originality	50	80	42	54
Elaboration	40	84	40	42

Based on Table 2, implementing Project-Based Learning (PjBL) oriented toward green entrepreneurship was more effective at improving all indicators of students' creative thinking

abilities than learning in the control class. The greatest increase in the experimental class was in the elaboration indicator, indicating that project activities encouraged students to develop ideas in more detail during the design and manufacturing of products from organic domestic waste. The increase in the originality and fluency indicators shows that learning gives students opportunities to produce more diverse, original, and relevant ideas for solving environmental problems (Table 3).

Table 3. Descriptive analysis results

Class	N	*Pretest* (Mean ± SD)	*Posttest* ((Mean ± SD)
Experiment	23	46.83 ± 11.38	80.35 ± 5.65
Control	20	40.45 ± 10.17	48.10 ± 14.90

Normality test

The results of the normality test using the Shapiro–Wilk method showed that the pretest data in the experimental class (Sig. = 0.332), the pretest in the control class (Sig. = 0.650), and the posttest in the control class (Sig. = 0.730) were normally distributed, as each had a significance value greater than 0.05. The posttest data in the experimental class obtained a significance value of 0.016 ($p < 0.05$), thus failing to meet the assumption of normal distribution.

Homogeneity test

Based on the results of the homogeneity test using Levene's Test, a significance value of 0.002 ($p < 0.05$) was obtained. These results indicate that the data from both research groups did not meet the assumption of homogeneity of variance.

Hypothesis testing

Based on the prerequisite test results, the data did not meet the assumptions of normality and homogeneity, so hypothesis testing was continued using the nonparametric Mann–Whitney U test. The analysis results showed a U-value of 2.500, a Z-value of -5.563, and an Asymp. Sig. (2-tailed) of 0.000. A significance value less than 0.05 indicates that H_0 is rejected and H_1 is accepted. There was a significant difference between the creative thinking abilities of students in the experimental and control classes after the learning process. These findings indicate that implementing Project-Based Learning (PjBL) oriented toward green entrepreneurship effectively improves high school students' creative thinking abilities. To determine the learning model's effect on creative thinking abilities, we used an Analysis of Covariance (ANCOVA), with pretest scores as a covariate. This analysis aimed to control for students' initial abilities so we could evaluate differences in posttest scores after accounting for these factors. Table 4 presents the results.

Table 4. ANCOVA test results

Source	F	Sig.
Pretest	8.670	0.005
Learning Model	84.632	0.000

Table 4 shows that pretest scores significantly influenced posttest scores ($F = 8.670$; $p = 0.005$). The learning model remained significantly influential on creative thinking skills after controlling for pretest scores ($F = 84.632$; $p < 0.001$). This finding corroborates previous results showing that increased creative thinking skills were related to implementing green entrepreneurship-oriented Project-Based Learning, not solely to differences in students' initial abilities.

Effect size

The magnitude of the effect of green entrepreneurship-oriented Project-Based Learning (PjBL) on creative thinking skills was analyzed using effect size. Based on the Mann–Whitney test, the Z-value was -5.563, the sample size was 43 students, and the effect size was 0.85. Based on Cohen's criteria, this value is considered large, indicating that implementing green entrepreneurship-oriented Project-Based Learning (PjBL) strongly influences students' creative thinking skills.

Discussion

The results indicate that implementing Project-Based Learning (PjBL) integrated with a green entrepreneurship approach effectively improves high school students' creative thinking skills on environmental change. This effectiveness is shown by a higher average posttest score in the experimental class than in the control class, an average N-Gain of 0.6256 (moderate), a Mann–Whitney test with a significance value of 0.000 ($p < 0.05$), and a large effect size. These findings indicate a significant difference in creative thinking skills between students who participated in PjBL learning with a green entrepreneurship orientation and those who participated in PjBL learning without green entrepreneurship integration. Integrating environmental sustainability and entrepreneurship principles into the PjBL model had a significant impact, both statistically and practically, on improving students' creative thinking skills. The improvement in creative thinking skills in the experimental class is likely influenced by the different treatments given to the two groups. In the experimental class, each Project-Based Learning syntax was integrated with green entrepreneurship principles.

Learning begins with identifying the problem of organic domestic waste in the surrounding environment. Students then design solutions in the form of environmentally friendly products, process waste, evaluate product quality, and consider their benefits and economic value. In contrast, the control class implemented the Project-Based Learning (PjBL) model without integrating green entrepreneurship principles. Therefore, the project focused more on conveying environmental change concepts through posters or videos, without involving the process of processing waste into useful products. This difference in learning experiences gave students in the experimental class broader opportunities to explore ideas, develop innovations, evaluate alternative solutions, and connect biology concepts with real-world problems in the surrounding environment. This condition is suspected to be one factor contributing to increased creative thinking skills in the experimental class compared to the control class. The findings support the theory that Project-Based Learning is a learning model that can develop higher-order thinking skills through authentic problem solving. According to Krajcik and Shin (2021), Project-Based Learning (PjBL) gives students opportunities to build knowledge through investigation, collaboration, and the completion of contextual projects. Similarly, Guo et al. (2020) explained that PjBL can enhance creativity, problem-solving skills, communication, and collaboration because students are actively involved in every stage of learning. However, the results indicate that improvements in creative thinking skills are influenced not only by the characteristics of PjBL but also by integrating a green entrepreneurship approach.

This integration adds an orientation toward environmental sustainability and economic value, requiring students not only to produce products as project outputs but also to consider the product's benefits for the environment and society. Thus, combining PjBL and green entrepreneurship creates a more complex learning experience than PjBL without integrating these approaches. In this study, green entrepreneurship was implemented through activities that processed organic domestic waste into products such as potato peel chips, orange peel candy, eggshell fertilizer, eggshell decorations, and garlic peel powder broth. These activities required students to identify waste's potential as a raw material, determine appropriate product

alternatives, select appropriate processing procedures, and consider the benefits and economic value of the resulting products. This process not only strengthened students' understanding of environmental change but also raised awareness that organic domestic waste can be a valuable resource when managed creatively. These findings support green entrepreneurship, which emphasizes environmentally based innovation and creating economic value through sustainable resource use (Benjamin et al., 2022).

Based on the analysis of each indicator of creative thinking ability, all indicators improved in the experimental class. The fluency indicator increased from 49 in the pretest to 79 in the posttest. This improvement is thought to be influenced by the Start with the Essential Question stage, when students were asked to identify various types of organic domestic waste and generate as many alternative uses as possible before deciding on a product to be made. This brainstorming activity enabled students to engage in divergent thinking, thus developing their ability to generate numerous ideas. These findings indicate that increased fluency is influenced not only by the characteristics of PjBL but also by the green entrepreneurship context, which encourages exploration of various waste-utilization opportunities (Runco & Jaeger, 2019). These results align with Torrance's (1974) concept, which states that fluency is the ability to generate many ideas in a certain time. The flexibility indicator also increased, indicating that students could generate more alternative solutions to a problem. This ability developed through the Design a Plan for the Project stage, when each group was given the freedom to choose the type of organic domestic waste, determine the product to be developed, and discuss various alternative processing methods. Group discussion activities encourage students to view a problem from multiple perspectives, enabling them to generate more diverse solutions. This finding aligns with Guilford's (1950) view that creative thinking is characterized by divergent thinking that generates multiple possible solutions to a problem.

The originality indicator increased from 50 to 80. This improvement indicates that students can generate more unique and distinctive ideas than other groups. The resulting products vary in characteristics depending on the type of waste used and each group's creativity. The elaboration indicator showed the highest increase, from 40 to 84. This increase likely reflects the Monitor the Progress of the Project, Assess the Outcome, and Evaluate the Experience stages, where students refine product designs through discussions, teacher feedback, and presentations (Sari et al., 2023). Unlike fluency, which only requires students to generate numerous ideas in the initial stages of learning, elaboration develops throughout the entire PjBL syntax. Throughout the project process, students continuously refine their products through group discussions, teacher monitoring, presentations, and evaluation. This process requires students to develop initial ideas into increasingly complete products, thereby enhancing their elaboration skills more effectively than other indicators. According to Torrance (1974), elaboration is the ability to develop an idea in greater detail and systematically. The results indicate that the revision and evaluation process during project implementation contributes to developing students' elaboration skills. The results indicate that integrating Project-Based Learning (PjBL) with green entrepreneurship provides a more complex learning experience than implementing PjBL without such integration. In the experimental class, students not only completed the project but also identified problems with organic domestic waste, selected alternative products, considered environmental benefits, and assessed the economic potential of the resulting product.

Based on several previous studies, the improvement of creative thinking skills in project-based learning occurs because students are involved in solving authentic problems, have the opportunity to generate various alternative solutions (Laksmi et al., 2018), develop a concern for environmental sustainability (Komodiki et al., 2021), and produce innovative products with economic value (Fauzi et al., 2022). This study shows a similar mechanism, but it also shows that creativity develops not only through project activities but also through integrating green

entrepreneurship principles into each PjBL syntax. As a result, students consider both environmental aspects and the product's economic value. The results of this study strengthen these findings by processing organic domestic waste into various products that not only serve as learning media but also have potential use and sales value. This study not only implements PjBL as a project-based learning model but also integrates green entrepreneurship principles into each PjBL syntax, from problem identification and project planning to implementation, product evaluation, and learning reflection. This integration ensures that the project does not stop at completing the task, but directs students to consider both environmental sustainability and the economic value of the resulting product. The increase in creative thinking skills in this study was influenced by the combination of project activities and green entrepreneurship orientation, which has not been widely studied in learning environmental change material at the high school level.

CONCLUSION

Based on the research results, it can be concluded that implementing Project-Based Learning (PjBL) integrated with a green entrepreneurship approach through processing organic domestic waste effectively improves high school students' creative thinking skills in environmental change material. This effectiveness is shown by the average posttest score of the experimental class, which is higher than that of the control class; the average N-Gain value of 0.6256, which is included in the moderate category; and the results of the Mann–Whitney U test, which show a significant difference between the two classes (Asymp. Sig. = 0.000 < 0.05). The increase in creative thinking skills is seen in all indicators, namely fluency, flexibility, originality, and elaboration, with the highest achievement in the elaboration indicator. These findings indicate that implementing projects that integrate green entrepreneurship principles through organic domestic waste can encourage students to produce more diverse ideas, develop alternative solutions, create original ideas, and elaborate ideas in more detail. PjBL oriented towards green entrepreneurship can be an alternative contextual Biology learning approach to develop creative thinking skills while fostering concern for the environment and an entrepreneurial spirit oriented towards sustainability. In practice, teachers can use this learning model when designing biology lessons that link environmental change material to waste issues around students and produce useful products. Future research should apply this model to different materials, levels, and types of waste, and develop more comprehensive measures of green entrepreneurship, environmental awareness, and students' entrepreneurial skills.

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