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Integrated environmental education physics project to enhance student creativity

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Abstract: This study aims to describe the results of research on physics education integrated with environmental issues, especially related to climate change, through literature review and its implementation in schools. The aspects observed include the feasibility, effectiveness, and student responses to the implementation of integrated physics learning with environmental education related to climate change to enhance creativity. The research method used was quantitative research with a true experimental design involving pretest and posttest control groups. The subjects of the study were science students in public secondary schools in Jombang, divided into experimental and control groups. The research data were processed using observation sheets for the feasibility of learning, prerequisite tests including tests for data normality and homogeneity, paired t-tests, two-tailed t-tests, one-tailed t-tests, n-gain tests, effect size, and student response questionnaires. Based on the research findings, it can be concluded that (1) there is a significant difference in students' creativity before and after the implementation of integrated physics learning with environmental education related to climate change, with the experimental group experiencing a higher increase compared to the control group, indicating the effectiveness of integrated physics learning with environmental education. (2) Student responses after the implementation of integrated physics learning with environmental education related to climate change were categorized as excellent. Therefore, as an initial study, it can be stated that climate change education can be implemented in the form of project performance and has an impact on student creativity.
Keywords: physics education; environmental learning; climate change; creativity

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Introduction

Climate change has led to global temperature rise, changes in rainfall patterns, increased extreme weather events, and rising sea levels over the past century (Mikhaylov et al., 2020; Griggs & Reguero, 2021). One of the threats to the Earth's safety due to global warming is the irregular population growth accompanied by various environmentally damaging activities (Santos & Bakhshoodeh, 2021; Kurup et al., 2021). This can be minimized through educating the public about the importance of safeguarding the Earth. Environmental Education (EE) can provide such education. Environmental Education is a form of learning that incorporates the environment as a teaching resource. Environmental Education serves as a solution to learning that allows students to interact directly with their surroundings (Perdiawan, 2021). Environmental Education in the 21st century has transformed the pattern of learning from teacher-centered to student-centered (Ichsan et al., 2019). Environmental education requires students not only to memorize formulas but also to gain experience in analyzing environmental issues relevant to the material they are studying (Chalkiadaki, 2018; Saputri et al., 2019).

Learning experiences can be provided through the application of challenging and enjoyable teaching models (Marzuki, 2017). The success of learning is not only measured by learning outcomes but also by the meaningfulness of the learning process (Chen & Yang, 2019). One student-centered teaching model that involves activity and creativity is the project-based learning model (Sumarni & Kadarwati, 2020; Santyasa et al., 2020). Project-based learning can also be integrated with other teaching models, such as integrating project-based learning with inquiry-based learning, known as PjBI-Science (Project Based Inquiry Science). The inclusion of projects in PjBI-Science can enhance students' creativity (Lestari et al., 2022).

Creativity in students can lead to the generation of ideas that can be developed (Siburian et al., 2019; Suyidno et al, 2019). Creativity arises from the ability to think creatively, which can be assessed through components such as fluency, flexibility, elaboration, and originality. Creative thinking abilities in individuals are considered present when they can synthesize and establish connections between different elements spontaneously, which may not be obvious to others. Supported by preliminary research conducted in Jombang's secondary schools, the level of creative thinking ability indicated that students fell into the category of being not creative. This was because the problem-solving solutions provided by students were limited to a single solution and did not consider alternative perspectives. Additionally, the solutions provided by students were not detailed, resulting in ideas that were too brief and not comprehensive.

Research conducted by Liliawati & Rusnayati (2021) on enhancing creativity through physics education with a STEAM approach found that involving students in the creation of projects can enhance creativity. Perdiawan (2021) in his research argued that creative outcomes significantly influence students' achievements and learning interest. This indicates that creativity is essential to support the success of learning (Bulut et al., 2022).

Creativity is required to generate creative ideas to address issues such as environmental degradation. Therefore, creative ideas are needed as solutions to these problems. Efforts to mitigate environmental damage can be channeled through Environmental Education. Environmental Education is necessary to ensure the preservation of the environment and make learning more meaningful. This aligns with research by Samsudin (2020) which states that physics education using social and environmental-based teaching models can increase students' activity levels (Samsudin et al., 2020). Furthermore, another study by Satriawan (2021) also explains that to address technological and scientific advancements, there is a need for educational planning that can enhance 21st-century knowledge and skills simultaneously (Satriawan et al., 2021).

Method

The research was conducted by combining a literature review and observing the implementation of learning in schools. The research falls into the category of quantitative research with a True Experiment with Randomized Subject Control Group Pretest and Posttest Design (Jatmiko et al., 2018). It was conducted in public secondary schools in Jombang, East Java. The sample for this study consisted of students from two science classes selected through random sampling. The instruments used in this research were a test of creative thinking abilities with indicators of fluency, flexibility, elaboration, and originality, which were validated by three expert professors and deemed valid, and a questionnaire for student responses.

Subsequently, an analysis was performed using prerequisite tests (normality and homogeneity tests), paired t-tests, two-tailed t-tests, and n-gain analysis to determine the improvement in scores after implementing integrated physics learning with Environmental Education related to climate change, with n-gain criteria based on Table 1.

Table 1. Normalized N-Gain Criteria

Value <g>	Criteria
$\langle g \rangle \geq 0{,}7$	High
$0{,}7 > \langle g \rangle \geq 0{,}3$	Moderate
$\langle g \rangle < 0{,}3$	Low

The research process is illustrated in **Figure 1.**

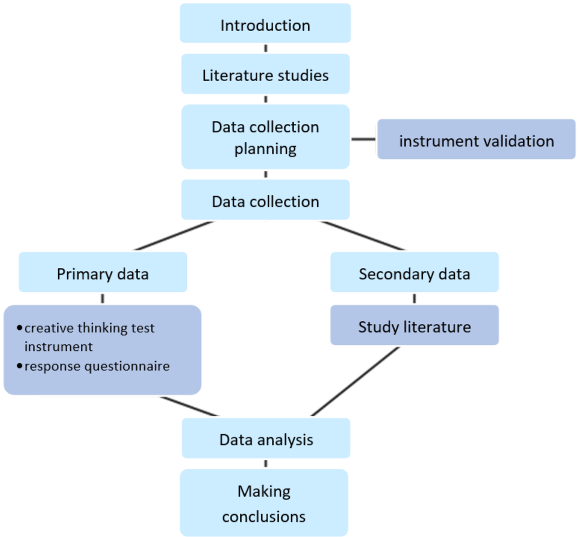

Figure 1. Research Flow

Results and Discussion

The data and analysis in this study include the improvement in creative thinking abilities and student responses to integrated physics project learning with Environmental Education related to climate change.

Improvement in Student Creative Thinking Abilities

The analysis of the improvement between pretest and posttest scores began with prerequisite tests, which included normality and homogeneity tests, and the results showed that the data were normally distributed, and both samples were homogeneous. Subsequently, a paired t-test was conducted, as shown in Table 2.

Table 2. Results of the Paired T-Test Calculation

Class	T_{value}	t_{table}	Conclusion
Control	9,678	1,694	H_0 Rejected
Experiment	22,353		

Based on Table 2, the t-value is larger than the t-table for each class, which means that H_0 is rejected, and it is concluded that there is a difference in the average scores between the pretest and posttest in both classes. The second test is a two-tailed t-test, as shown in Table 3.

Table 3. Results of the Two-Tailed T-Test Calculation

Test Class	Comparison Class	t-value	t-table	Conclusion
Experimental class	Control class	-6,06	2	H_0 Rejected

Based on Table 3, the t-value is not between -t-table and t-table. Therefore, it can be concluded that H_0 is rejected, and H_1 is accepted, indicating a difference in the average scores between the control class and the experiment class. The third test is the n-gain analysis. The results of the n-gain analysis are shown in Table 4.

Table 4. N-gain Analysis Results

Class	<g>	Category
Control	0,37	Moderate
Experiment	0,62	Moderate

Based on the hypothesis testing conducted, it was found that the implementation of integrated physics learning with Environmental Education has an impact on creative thinking abilities. This is supported by the n-gain value, with the experimental class achieving a score of 0.62, categorized as moderate. The improvement occurred due to the direct involvement of students, leading to meaningful experiences related to real-life situations. This is in line with the perspective of (Hsbollah & Hassan, 2022), who suggested that meaningful learning is a process of connecting new knowledge with one's real life.

Based on the test results and analyses performed, it can be said that the experimental class exhibited higher improvements than the control class in each indicator. The improvement in pretest and posttest scores in each class can be seen in Figure 2.

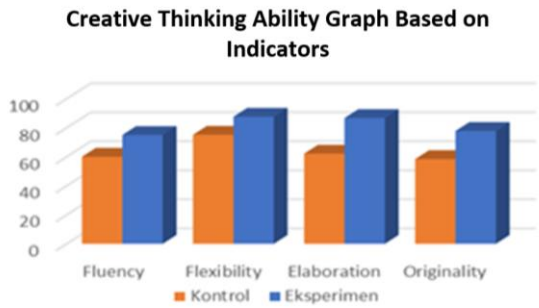

Figure 2. Graph of Creative Thinking Ability Based on Indicators

Based on Figure 2, the experimental class showed a higher increase in posttest scores compared to the control class. The first indicator is fluency or thinking fluently. There were differences in responses between the control and experimental classes. In the control class, students' responses were still in line with the available infographics. In contrast, the experimental class provided answers by linking the information from the infographics to the arid and dry conditions of the African region as evidence of severe climate change in the African region. Examples of posttest answers from the control class are shown in point 1), and those from the experimental class are shown in point 2).

1. *"Africa is experiencing significant impacts due to climate change because Africa contributes less than 4% of greenhouse gas emissions, but it is estimated to be severely affected by climate change."*
2. *"Because Africa contributes less than 4% of greenhouse gas emissions, it is estimated to be severely affected. The condition of African countries, which are arid and lack trees, as well as the impact of countries that contribute to greenhouse gas emissions, where Africa does not have the latest/efficient methods to address global warming in their country due to poverty."*

The students' responses represent their fluency indicator abilities, which involve providing a large number of answers and processing information more quickly to find the expected answers to the questions. This aligns with the perspective of Hadar (2019), who stated that fluency is the ability to generate numerous answers to a problem.

The second indicator is flexibility. Students were asked to mention the causes of CO2 emissions. There were differences in responses between the control and experimental classes. The control class provided general answers as the causes of CO2, while the experimental class provided unique answers involving a biological process, namely the respiration of living organisms. Examples of responses from each class can be seen in point 1) for the control class and point 2) for the experimental class.

1. *"CO2 comes from the residue of fossil fuel combustion, the combustion/use of petroleum."*
2. *"CO2 comes from the respiration process of animals and humans (respiration result)."*

Based on the students' answers, it is evident that the experimental class provided unique answers from a different perspective. This corresponds with the perspective of Bryndin (2019), who suggested that flexibility in creative thinking abilities allows for generating ideas from different directions.

The third indicator is elaboration. In the elaboration indicator, students were given questions about the relationship between climate change and the use of fertilizers in the agricultural sector. There were differences between the control class and the experimental class. The control class provided answers that climate change is caused by the production of chemical fertilizers in factories. In contrast, the experimental class provided comprehensive answers regarding the relationship between fertilizers and climate change, along with the phenomena and gases responsible for climate change. Examples of answers from both classes can be seen in point 1) for the control class and point 2) for the experimental class.

1. *"Climate change occurs because of the process of burning/producing chemical fertilizers that contribute to greenhouse gas emissions."*
2. *"Climate change occurs due to the use of chemical fertilizers in agriculture. Chemical fertilizers are made of chemicals that can cause pollution in both soil and air. Chemical fertilizers also produce N2O, which can be more harmful to living organisms as it can lead to acid rain that is dangerous for respiration and skin. Excessive N2O accumulating in the Earth's atmosphere (troposphere) can lead to the greenhouse effect, trapping solar heat on Earth's surface and causing a temperature rise."*

This indicates that students in the experimental class were able to provide detailed and comprehensive explanations. This aligns with the perspective of (Yaniawati et al., 2020), who stated that the elaboration indicator encourages students to elaborate on a solution to a problem.

The fourth indicator is originality. In the originality indicator, students were asked to provide ideas needed to address the issue of the ozone layer depletion. Based on the students' responses, there were differences in ideas between the two classes. Examples of answers from both classes can be seen in point 1) for the control class and point 2) for the experimental class.

1. *"By finding ways for an industry to manage its waste, especially smoke, properly, reducing the use of personal vehicles and replacing them with bicycles or public transportation, and managing waste properly."*
2. *"To reduce it, a solution is to organize environmental activities, such as a day without motorized vehicles each month. This is because if each student brings their own bicycle, it will lead to increased CO2 emissions."*

This shows that students provided ideas or suggestions that stemmed from environmental issues in their own school, resulting in unique ideas of their own. This corresponds with the perspective of Yustina et al., (2020), who state that the originality indicator encourages students to express personal ideas or suggestions.

Based on the overall results of the posttest for students, they achieved a 78% percentage, indicating a "good" category. This is because the integration of Environmental Education can enhance students' interest in learning by reducing the level of classroom monotony, making the learning experience comfortable. This is in line with the viewpoint of Valtonen et al., (2021), who state that the environment as a medium creates a comfortable learning atmosphere and allows students to express their potential.

A comfortable environment reduces stress on students who often have classroom-based learning, thus making students more creative in problem-solving. This corresponds with the perspective of Conradty (2020) who states that excessive focus on specific individuals can hinder individual creativity in terms of flexibility. Creativity in this learning is developed through project-based learning resulting from the environmental action program, BKB (*Berburu Kertas Basyasaka*). Environmental action activities and the results of students' projects can be seen in **Figure 3.**

The Activity of Environmental Action

Results of the Environmental Action Project

Figure 3. Process of Activities and Results of Environmental Action Projects

Before being able to create a project, students need to design a project, which can be further evaluated to be realized as an action. One of the stages in project-based inquiry science learning facilitates the process of students finding projects through the design and build phase. An example of the design stage created by students is shown in Figure 4.

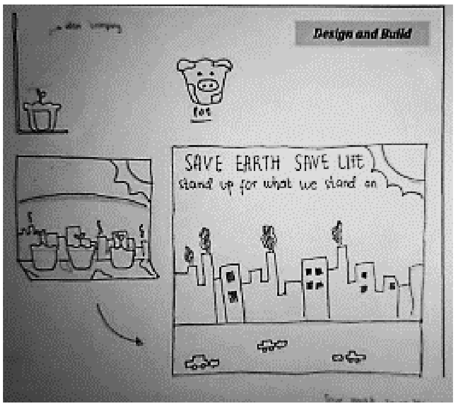

Figure 4. Design Results in the Initial Stage of Project Creation

With the presence of these projects and environmental actions, students can directly increase their awareness of reducing the risks of global warming by reducing waste. This aligns with Debrah (2021) view that issues related to waste require special attention and awareness from individuals towards the environment.

Student Response

Student response data was obtained through the distribution of response questionnaires to students regarding project-based learning integrated with Environmental Education (EE) that was conducted. The results of the student response analysis are summarized in Table 5.

Table 5. Summary of Student Response

No	Statement	Percentage (%)
1	Integrated physics education with EE is able to increase my interest in learning physics	75.00%
2	Physics learning activities integrated with EE have increased my environmental awareness	93.75%
3	Integrated physics education with EE makes it easier for me to understand the lessons	87.50%
4	Integrated physics education with EE eliminates boredom in the classroom	88.13%
5	Integrated physics education with EE can enhance creative thinking	88.13%
6	Integrated physics education with EE makes it easier for me to generate unique ideas	87.50%
7	Integrated physics education with EE makes it easier for me to provide a variety of ideas	85.00%
8	The experimentation of the greenhouse effect model has improved my understanding of the greenhouse effect phenomenon	91.25%
9	The presence of projects in learning has increased creativity	91.88%
10	Integrated physics education with EE has made me more aware of climate change phenomena	88.75%

Student responses represent the feedback of students regarding the learning that was conducted. Students agree that Environmental Education enhances their environmental awareness, as demonstrated by the positive response percentage of 93.75%. This is in line with the views of (Nkoana, 2020; Moody-Marshall, 2023) who stated that environmental education instills environmental awareness in the younger generation, who are the inheritors of the Earth's natural resources.

Based on the overall summary of student responses, an average percentage of 87.68% was obtained, categorized as "very good." The environmental action carried out is one of the character education programs that can be implemented in schools. This is because it can enhance environmental care so that individuals can coexist harmoniously with the environment. This corresponds with Debrah (2021) view that environmental care is a good character value, involving concern for the environment, society, and the economy above individual or group interests.

Conclusion

Based on the research results, the following conclusions were obtained: (1) There is a significant difference in students' creativity before and after the implementation of physics learning integrated with environmental learning related to climate change, with the experimental class showing a higher increase compared to the control class, indicating the effectiveness of physics learning integrated with environmental learning. (2) Student responses after the implementation of physics learning integrated with Environmental Education related to climate change are categorized as "very good." Therefore, as an initial study, it can be stated that learning about climate change can be implemented in the form of project performance and has an impact on students' creativity.

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