

## **Integrating Project-Based Learning and Place-Based Education on Renewable Energy to Enhance Students' Creativity and Environmental Awareness**

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### **ARTICLE INFO**

**Keywords:**

Creativity;  
Environmental Awareness;  
Place-Based Education;  
Project-Based Learning;  
Renewable Energy

**Article history:**

Received 2021-08-14  
Revised 2021-11-12  
Accepted 2022-01-17

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### **ABSTRACT**

This research aims to produce a project learning model on the theme of renewable energy with a place-based education framework and assess its effectiveness in increasing students' creativity and environmental awareness. The method used was quasi-experimental with Pretest-Posttest Control Group Design. The research sample consisted of 35 students of SMPN 19 Bogor City as the control class and 39 students of Sekolah Alam Bogor, who were randomly selected from the available population. The instruments used were creative thinking skills test questions, environmental awareness questionnaires, learning observation formats, as well as student, teacher and community response questionnaires to learning. The instruments have been tested and have been tested with 30 respondents. The results showed that project learning on renewable energy material based on PjBL-PBE syntax by inserting communication/questioning/discussion steps with the source of the problem/solution maker was very implementable. Learning shows high effectiveness as indicated by an increase in creative thinking scores with an N-Gain of 56.18% in the experimental class, higher than the N-Gain in the control class. Environmental awareness also improved, with a score of 13.62% in the control class and 67.15% in the experimental class (good category). Student, parent and community responses to the learning reached 91.60% (excellent category), indicating strong support for the method.

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**Corresponding Author:**

Anna Permanasari

Science Education, SPs Universitas Pakuan 1, Bogor, Indonesia; [anna.permanasari@unpak.ac.id](mailto:anna.permanasari@unpak.ac.id)

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## 1. INTRODUCTION

The Merdeka Belajar Curriculum provides flexibility to educators in designing learning that suits the needs and learning environment of students in order to create meaningful and quality learning experiences (Kemdikbud, 2023). However, the implementation of this curriculum still faces challenges, especially in terms of learning flexibility that includes the materials and learning spaces available in education units. The school environment plays an important role as a formal education facility that supports the teaching and learning process and contributes to producing quality, healthy and intelligent human resources. Therefore, creating a comfortable and safe school environment is the shared responsibility of all school members so that the learning process can take place optimally (Jumirah, Sari, Kusnadi, & Oktaviani, 2021). In the field, the reality shows that not all schools in Indonesia have adequate access and facilities to optimize the implementation of Merdeka Curriculum. This limitation can hinder the achievement of the main objective of the curriculum, which is to form students with character in accordance with the Pancasila Student Profile. Therefore, innovative strategies and approaches are needed so that curriculum flexibility can be applied effectively in various conditions of education units, so that quality and inclusive education can be achieved.

One of the innovative approaches offered is learning using the place-based education (PBE) framework, which aims to improve students' creative thinking skills and environmental awareness through direct involvement in the learning process with the community (Littrell et al., 2020). PBE facilitates contextualized learning, enables learners to solve real problems and builds awareness of the surrounding environment (Deringer, Hodges, & Griffin, 2020). This approach can be collaborated with a project-based learning model, which provides greater space for students to develop creativity and build environmental awareness. Project-based learning is a learning model that focuses on problem solving through real projects that involve critical thinking and contextual investigation (Retnowati, Istiana, & Nadiroh, 2020), (Siti Dwi Amriani et al., 2024). This model supports science learning outcomes that aim to improve critical thinking, communication and problem-solving skills.

Creative thinking skills are one of the important competencies that need to be trained to students, as stated by (Yamin, Permanasari, Redjeki, & Sopandi, 2020), (Sumarni & Kadarwati, 2020), (Wijaya, Zhou, Ware, & Hermita, 2021), (Yustina, 2020), because in reality these skills have not been fully developed optimally. Similarly, environmental awareness is very relevant to the principle of sustainable education. A preliminary study conducted at a junior high school in Bogor showed that students' creative thinking skills were still relatively low, with a percentage of flexible thinking of 40.77%, original thinking of 51.37%, and elaborative thinking of 46.43%. In addition, the results of questionnaire analysis showed that 32% of students had low environmental awareness, which was caused by a lack of sensitivity to school environmental conditions. These findings indicate the importance of implementing innovative learning models such as PBE integrated with project-based learning to improve these skills and awareness more effectively.

Place-based education (PBE) is a learning framework that is now increasingly popular because it provides space for students to learn directly from the community as a source of problems or solutions. Interviews with science teachers showed that 68% of them have never implemented PBE in the classroom. Some teachers are familiar with the concept, but have not implemented it due to various obstacles, such as lack of understanding, communication and negotiation barriers with external parties, transportation problems, student safety during visits, and the accuracy of the subject matter. Meanwhile, 32% of teachers have recognized and implemented PBE in materials such as ecology, biodiversity, local wisdom, and growth and reproduction. These findings suggest that place-based learning is feasible if these constraints can be overcome through appropriate science learning approaches.

Based on this description, project-based science learning will be more meaningful if designed using a place-based education framework to increase students' creativity and environmental awareness. Renewable energy materials are seen as potential to be implemented because they are closely related to technological developments that encourage industrial progress, but also have an impact on increasing emissions and extreme climate change (Noviani, 2020). Renewable energy is part of the green technology concept that utilizes natural resources such as sun, wind, water, and biomass to produce environmentally friendly energy and reduce greenhouse gas emissions (Zainal, 2023). Therefore, through this material, students are expected to become agents of change by presenting creative, innovative and efficient solutions to global problems through project-based learning with a place-based education framework.

This research aims to produce an implementative model of project-based learning with a place-based education framework on the theme of Renewable Energy. The problem formulation in this research is: "How can project-based learning with a place-based education framework on the theme of Renewable Energy increase students' creativity and environmental awareness?". This problem formulation is derived in several research questions:

1. How is the implementation of project-based learning with place-based education framework?
2. How is the improvement of students' creativity after project-based learning with place-based education framework is implemented?
3. How is the improvement of students' environmental awareness after project-based learning with place-based education framework is implemented?
4. How do students respond to project-based learning with place-based education framework?

## 2. METHODS

This research has been designed using quasi experimental method with Pretest-Posttest Control Group Design (Abraham & Supriyati, 2022), (Anshori & Iswati, 2017). The experimental group received Project-Based Learning (PjBL) treatment with PBE framework, while the control group received Project-Based Learning without PBE framework. The research design is shown in the following table:

Table 1. Quantitative Research Design

Group	Pretest	Treatment	Posttest
Control Class	O <sub>1</sub>	X	O <sub>2</sub>
Experiment Class	O <sub>3</sub>	Y	O <sub>4</sub>

Description:

O<sub>1</sub> : Pretest of control group

O<sub>2</sub> : Posttest of control group

O<sub>3</sub> : Pretest of experimental group

O<sub>4</sub> : Posttest of the experimental group

X : Project Learning (control)

Y : Implementation of the Project using the Place-based education framework (experiment).

This research was conducted in October 2024, odd semester of the 2024/2025 school year. Population is a group of individuals who have the same characteristics and the sample is a subgroup of the target population that will be studied by researchers to generalize about the target population (Creswell, 2012). The research sample consisted of 74 students of SMP N 19 Bogor City and Sekolah Alam Bogor, who were selected using random sampling technique. Data collection was carried out using a random sampling technique, namely random selection of classes from two schools that both

implemented project-based learning. The control class came from SMP Negeri 19, which has implemented Merdeka Curriculum and is accustomed to using projects, while the experimental class came from Sekolah Alam Bogor, which also applies a similar approach. All students from the randomly selected classes were used as research samples. The population of this study is presented in Table 2.

Table 2. Research Population

No	Name of School	Number of Grades	Respondents
1.	SMP Sekolah Alam Bogor (Private School)	IX-A	20
		IX-B	19
2.	SMP Negeri 19 Kota Bogor (Public School)	IX-B	35
<b>Total number of respondents</b>			<b>74</b>

The data collection technique used an essay question instrument and a questionnaire instrument. The instrument is calibrated through expert judgment to analyze content and construct validity. In the validity test, researchers will ask for advice and input from lecturers (experts) to make judgments on the instruments that have been made, then test the validity using the Pearson correlation formula and reliability with Cronbach Alpha. Data analysis is carried out descriptively inferentially, including prerequisite tests (homogeneity and normality analysis). Comparative testing used an independent t-test to compare two independent groups to see if their means were significantly different. Meanwhile, the N-Gain formula was used to measure the improvement of learning outcomes, revealing the improvement of creative thinking skills (Hake, 1999). The following table categorizes the effectiveness of N-Gain.

$$N - gain = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Max score} - \text{Pretest score}}$$

Table 3. N-Gain Effectiveness Interpretation Categories

Percentage (%)	Interpretation
< 40	Ineffective
40-55	Less Effective
56-75	Effective Enough
>75	Effective

(Hake, 1999)

### 3. FINDINGS AND DISCUSSION

The implementation of project-based renewable energy learning with the Place-based education framework shows a significant increase in student creativity and environmental awareness variables. Learning is carried out with the PjBL-PBE syntax, the learning steps are briefly shown in the following figure.

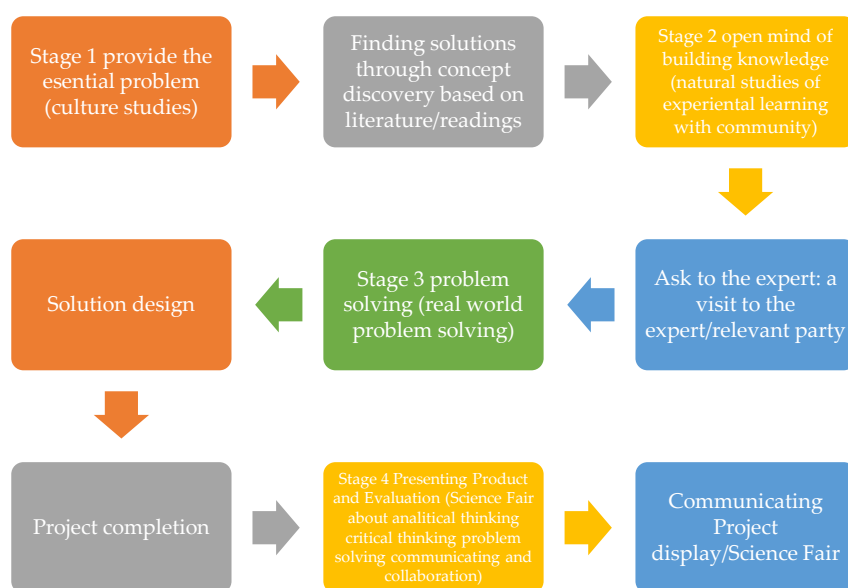


Figure 1. Syntax of PjBL with Place-based education framework

After the statement of the problem, which can be done by teacher or student initiative, students search for relevant concepts through searches to library sources such as books and internet searches. The concept is then used as the basis for finding a solution in the form of a prototype project. To ensure the steps, students are directed to communicate through visits to the source of the solution, discussing with experts. Sources of information can be related industry partners, the community, or community communities such as NGOs (Non-Governmental Organizations). The results of the visit are then assessed for suitability with the concept, and used as a basis for designing biogas, solar panel, and waterwheel projects. In its implementation, students are very enthusiastic in following every stage of learning. Students in their groups seemed active in expressing ideas, thoughts, helping each other find the most appropriate solution. More enthusiasm was seen when discussing with experts in the field.



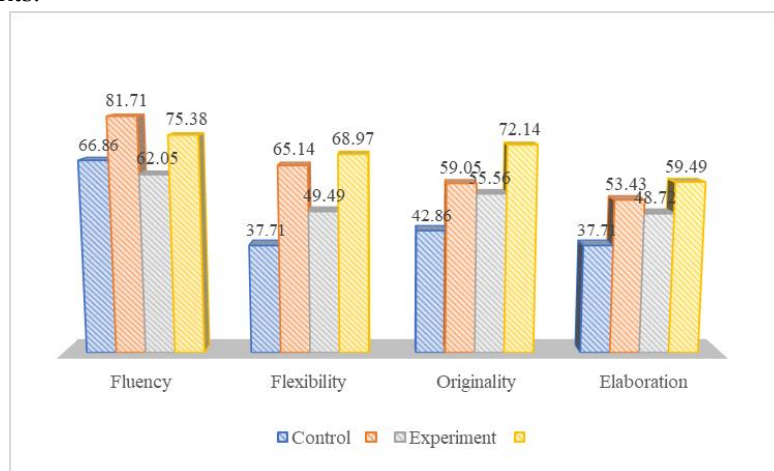
**Figure 2.** Explains the process of project-based learning with the PBE framework. The following information; a) Ask the expert, b) Visit the community, c) Product planning and d) Presentation of product results / science fair

Based on the observation of the lesson, it can be concluded that basically student activeness is very dependent on how the teacher facilitates student interaction. If a lot of space is given for discussion, and while being directed by the teacher, then students will totally collaborate in their groups to produce their best projects. Thus, the hope for the growth of students' creative thinking skills becomes a necessity. The use of environmental issues as a trigger also led to the development of students' environmental awareness to be better. Both of these are evidenced by the analysis of students' creative thinking test results before and after learning, as well as how students' environmental awareness grows during learning.

### 3.1 Results

#### 3.1.1 Creativity

Student creativity is measured by creative thinking instruments and creative products produced during the learning process. The creative thinking instrument includes students' ability to generate innovative ideas, problem solving, and flexibility in designing renewable energy solutions. Creative thinking indicators include fluency, flexibility, originality and elaboration. The results of students' creative thinking are listed in the following graph. Meanwhile, creative products include real projects that are implemented, such as mini solar panel models, hydropower plants and simple biogas systems made by students.



**Figure 3.** Results of students' creative thinking skills

Based on the data from the pretest and posttest results of students' creative thinking skills in the two groups, namely control and experimental, there was a significant increase in each aspect of creative thinking, namely Fluency, Flexibility, Originality, and Elaboration. In the Fluency indicator, there was an increase from 66.86 in the pretest to 81.71 in the posttest in the control group, while in the experimental group it increased from 62.05 in the pretest to 75.38 in the posttest. This increase shows that students' ability to generate many diverse ideas and ideas is growing. Furthermore, in the Flexibility indicator, the score in the control group increased from 37.71 in the pretest to 65.14 in the posttest, while in the experimental group it increased from 49.49 in the pretest to 68.97 in the posttest. This shows that students are increasingly able to think from various points of view and produce diverse solutions. In the Originality of Ideas indicator, the control group experienced an increase from 42.86 in

the pretest to 59.05 in the posttest, while the experimental group increased from 55.56 in the pretest to 72.14 in the posttest. This increase reflects students' ability to generate unique and original ideas is increasing. Finally, in the Elaboration indicator, the score in the control group increased from 37.71 in the pretest to 53.43 in the posttest, while in the experimental group it increased from 48.72 in the pretest to 59.49 in the posttest. This shows that students are increasingly able to develop ideas with detail and depth.

Overall, these results show that the implementation of project-based learning with the Place-based education framework is able to improve students' creative thinking skills in both groups. Based on the pretest and posttest data from the two groups, namely the control group and the experimental group, the Originality of Ideas indicator in the experimental group showed the highest result with a score of 72.14 on the posttest, which is a significant increase from the pretest score of 55.56. Originality refers to the ability of students to generate ideas that are unique, innovative, and have never been thought of before. In the context of renewable energy learning, this indicator is very important because it encourages students to find creative and sustainable solutions related to environmentally friendly energy utilization. The increase in scores from 55.56 to 72.14 indicates that the project-based learning approach with the Place-based education (PBE) framework successfully stimulates students' ability to create original and innovative ideas.

The improvement of pretest and posttest learning in the control and experimental classes can be seen through the N-Gain scores listed in the table below.

Table 4. Mean Value of Pretest Posttest and N-Gain Score

Kelas	Pretest	Posttest	N-Gain Score	N-Gain Persen (%)
Eksperimen	53.95	69.00	0.56	56.18
Kontrol	46.29	64.83	0.49	49.28

The figure above displays a comparison of pretest, posttest, and N-Gain results between the control group and the experimental group. In the control group, the average pretest score of 46.29 increased to 64.83 during the posttest, resulting in an N-Gain value of 49.28. Meanwhile, the experimental group showed an average pretest score of 53.95 which increased to 69.00 at posttest, with an N-Gain value of 56.18. Although the numerical increase in scores from pretest to posttest was greater in the control group, the N-Gain results showed that the increase in the experimental group was proportionally more significant. Based on the interpretation of N-Gain values, the control group fell into the medium effectiveness category, while the experimental group approached the medium-high category. This indicates that the learning method or treatment applied to the experimental group was more effective in improving learning outcomes compared to the method used in the control group.

Normality and homogeneity testing of data is done after knowing the N-Gain score test. Normality testing using the Kolmogorov-Smirnov formula and homogeneity test whose purpose is to determine the distribution of the resulting data is normal or not and the resulting data is homogeneous or not in each class. The data can be seen in the figure below;

Table 5. Statistical Test Results to Prove the Research Hypothesis

Class	Number of Students	Normality Test		Homogeneity Test		Hypothesis Test Sig (2- Tailed)	
		Sig Value	Description	Sig Value	Description	Sig Value	Description
Control (Pretest)	35	0,200	Normal	0,470	Homogen		Significant
Control (Posttest)	35	0,026	Abnormal	0,511		0,000	

Experiment (Pretest)	39	0,038	Abnormal	0,511	Homogen
Experiment (Posttest)	39	0,002	Abnormal	0,446	

This study aims to compare creative thinking skills between the control class of 35 students and the experimental class of 39 students on renewable energy material. Based on the Kolmogorov-Smirnov normality test, only the pretest data in the control class was normally distributed with a significance value of 0.200, while the other data showed an abnormal distribution (significance value  $<0.05$ ). Therefore, the analysis continued using the Mann-Whitney non-parametric statistical test. The homogeneity test of the pretest data showed that both groups had homogeneous variances, with a significance value of 0.470 for the control class and 0.511 for the experimental class, respectively. The results of hypothesis testing with Mann-Whitney resulted in a U value of 338.500 and a significance (Asymp. Sig. 2-tailed) of 0.000, which means there is a significant difference between the control and experimental groups in improving creative thinking skills. Thus, the null hypothesis ( $H_0$ ) is rejected and the alternative hypothesis ( $H_1$ ) is accepted. This finding indicates that the treatment or learning method given to the experimental group has a significant effect on improving students' creative thinking skills compared to the control group.

The table above presents the results of the normality test of creative thinking data in the control group and experimental group, both at the pretest and posttest stages, using the Kolmogorov-Smirnov method. Based on the data analyzed, the study involved two groups: a control class with 35 students and an experimental class with 39 students. The results of the normality test showed that only the pretest data of the control class was normally distributed (sig. 0.200), while the other data was not normally distributed with a significance value below 0.05. Therefore, in further analysis, the Mann-Whitney non-parametric statistical test with the aim of knowing the increase in N-Gain obtained is meaningful or not in both classes.

Based on the analysis results, the homogeneity test on the pretest showed that both groups had homogeneous variances with a significance value of 0.470 for the control class and 0.511 for the experimental class. Hypothesis testing resulted in a significance value of 0.000 (sig  $< 0.05$ ) which showed a significant difference in the control class. In addition, analysis using the Mann-Whitney U test with a U value of 338.500 and a significance value (Asymp. Sig. 2-tailed) of 0.000 confirmed a significant difference between the creative thinking scores of control and experimental group participants. Overall, this finding indicates a significant difference in the research related to the creative thinking ability of the two groups.

Based on the results of the Mann-Whitney test,  $H_0$  is rejected and  $H_1$  is accepted, meaning that there is a significant difference in the increase in the value of creative thinking in renewable energy material in the control class and the experimental class, as evidenced by the 2-tailed sig value of 0.000. Data is said to have a significant difference if the 2-tailed sig  $< 0, 05$ . Thus, the treatment or learning method applied to the experimental group has a significant effect on improving creative thinking skills compared to the control group.

### 3.1.2 Creative Product Assessment

The results of the creative product assessment between the control class and the experimental class are based on several aspects in three stages of the main aspects, namely the preparation stage, the product manufacturing stage, and the assessment stage of the resulting product. The results of the product assessment are listed in the figure below;

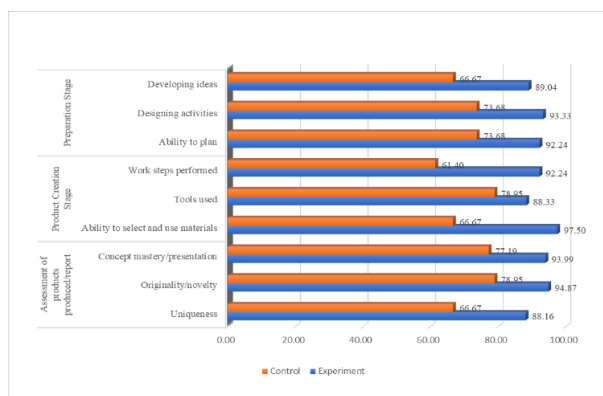


Figure 4. Creative Product Assessment

Based on figure 4, it generally shows that the experimental class obtained higher scores than the control class in each aspect assessed. In the preparation stage, the experimental class excelled in developing ideas (89.04), designing activities (93.33), and planning skills (92.24) compared to the control class which obtained 66.67, 73.68, and 73.68 respectively. In the product manufacturing stage, the experimental class showed better results in work steps (92.24), tool utilization (88.33), and the ability to select and use materials (97.50), while the control class only obtained 61.40, 78.95, and 66.67. As for the product assessment stage, the experimental class again excelled in concept mastery and presentation (93.99), originality and novelty (94.87), and uniqueness (88.16) compared to the control class which obtained 77.19, 78.95, and 66.67 respectively. This significant difference in assessment indicates that the approach applied in the experimental class was more effective in improving students' creativity and skills in producing creative products. The indicator that can reflect students' enthusiasm in the creative process is "Mastery of concepts/presentation". In this aspect, the experimental class obtained a score of 93.99, while the control class only reached 77.19. This difference indicates that students in the experimental class had a better understanding of the concepts presented and showed more effective presentation skills than students in the control class. It can also indicate that the learning method applied in the experimental class was able to increase students' confidence and enthusiasm in conveying their ideas and work.

### 3.1.3 Environmental Awareness

The renewable energy learning interaction between students and the community has also been proven to increase students' environmental awareness. Through direct observation of energy conservation efforts and the application of environmentally friendly technology carried out by the community, students become more sensitive to environmental issues and are motivated to play an active role in preserving nature. This Place-based education approach that emphasizes real experiences and direct involvement allows students to understand the impact of their actions on the environment, thus forming a more responsible and sustainable attitude. This can be seen from the following figure.

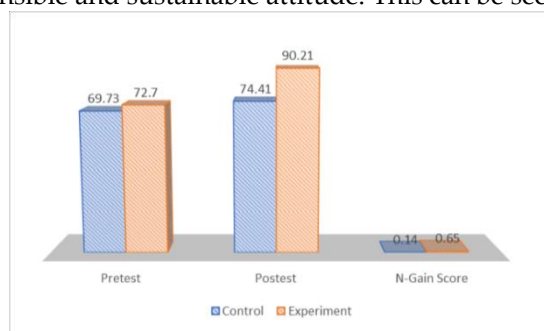


Figure 5. Results of Improvement in Environmental Awareness Instrument

Based on the data obtained, there is a significant increase in students' environmental awareness in two different groups, namely the control group and the experimental group, after the implementation of Place-based education-based learning. In the control group, the pretest score showed 69.73, which then increased to 72.90 in the posttest, with an overall average of 71.315. Meanwhile, in the experimental group, the pretest score reached 72.71 and experienced a higher increase in the posttest with a score of 80.15, resulting in an overall average of 76.43. The greater increase in the experimental group indicates that the learning approach involving the community and the surrounding environment is able to increase students' environmental awareness more effectively. This could be due to more intensive interaction between students and the community, as well as direct experience in observing and practicing environmental conservation efforts. Thus, place-based learning is proven to have a positive impact in increasing students' environmental awareness in both groups. Positive responses to the implementation of Place-based education learning were also shown by students, parents, and teachers. Based on the data obtained, 91.60% of them fully support this place-based learning. The support reflects the awareness of the importance of an approach that involves the surrounding community and environment in the learning process, which not only enhances students' creativity but also builds higher environmental awareness.

### 3.2 Discussion

In figure 3, it can be illustrated that there is an increase in the four indicators of creative thinking. The findings are in line with previous research which states that a project-based learning approach can encourage students' creative thinking, especially with regard to fluency and flexibility (Chen, Lai, Lai, & Su, 2022), (H. -C. Kuo, Y. -T. C. Yang, J. -S. Chen, 2022). Project-based learning can also improve students' creative thinking and learning outcomes (Mursid, Saragih, & Hartono, 2022) dan (Saputri, Syukri, & Elisa, 2022). The results showed a significant increase in creative thinking skills in students in both control and experimental classes. This increase indicates that students are able to express ideas fluently and diversely in various aspects of learning. However, there was a noticeable difference in the level of enthusiasm between the two classes during the learning process. Students in the experimental class showed a higher level of activeness, especially in terms of asking questions to the expert (community). They were able to interact well and showed great curiosity during the learning session. This interactive questioning ability indicates that students are not only passively receiving information, but also actively digging deeper knowledge to enrich their understanding. In addition, collaborative work skills were also more prominent in the experimental class, especially during the presentation of creative products in the Science Fair event. At the event, which was attended by parents, students, the community, and the general public, students in the experimental class were able to display their project results well. They explained the process of making the product systematically and confidently, showing a deep understanding of the project they were working on. This active participation in the Science Fair was an important factor in increasing the enthusiasm and motivation of students in the experimental class, this can be seen in graph 2 which shows the enthusiasm and presentation skills of students. Support and appreciation from various parties encouraged them to be more confident in communicating their ideas and improving the quality of the work presented. Thus, the learning approach applied in the experimental class proved to be able to improve students' creative thinking skills more optimally compared to the control class.

The increase in students' original thinking illustrated in figure 3 can also be attributed to the interaction during learning with the community involved. This is in line with the main feature of Place-based education, where the community is used as an authentic and relevant learning resource. Through this approach, students get the opportunity to discuss, collaborate and directly observe the practices implemented by the community in the context of renewable energy. This experience encourages

students to explore new ideas, connect theoretical concepts with real-world applications, and develop innovative solutions that fit the needs of the local environment (Dorji, Kinley, & Sivitskis, 2021). Thus, interaction with the community is one of the key factors in improving students' original thinking skills. The supporting factors for increasing originality are direct involvement of students in renewable energy projects, exploration of the local environment as a source of inspiration to create solutions that suit the needs of the community and collaboration with communities and renewable energy experts that encourage critical and innovative thinking.

Community involvement in learning with a place-based education framework can affect the beginning and end of the learning process in a contextualized way (Takano, 2022),(Gallay, Pykett, Smallwood, & Flanagan, 2020) and (Wright, 2021). Interaction between students and the community on the other hand is able to increase student awareness of the environment, this is also in line with research conducted by (Khadka, Li, Stanis, & Morgan, 2021). Place-based education can increase awareness of the environment so that learning is more meaningful and creative (Deringer et al., 2020).

This study has several limitations that need to be examined. The relatively small sample size of 74 students from two schools in Bogor - SMP Negeri 19 and Sekolah Alam Bogor - limits the generalizability of the results to a wider population. In addition, differences in characteristics between public schools and nature schools, such as learning approaches, facilities, and school culture, have the potential to cause bias that can affect the results of the study. Although the research instruments have been validated through expert tests and statistically tested, the use of essay questions and questionnaires still allows for subjectivity in filling out answers, both from students and assessors. The research findings show that the Place-Based Education-based Project-Based Learning (PjBL-PBE) learning model is able to significantly improve students' creative thinking skills and environmental awareness compared to conventional learning methods. This approach is proven to encourage students to be more active in designing, developing, and presenting projects that are directly related to the surrounding environment. This result is also reinforced by the increase in creative thinking indicators such as fluency, flexibility, originality, and idea development in the experimental group, as well as increased skills in making unique and meaningful products.

The PjBL-PBE model has great potential to be adopted in national and regional curriculum development. This approach is in line with the spirit of the Merdeka Curriculum which emphasizes contextual, independent, and collaborative learning. By integrating local potential and community involvement, this model is able to foster character and 21st century skills in students, including creativity, critical thinking, communication, and collaboration. Therefore, the application of PjBL-PBE can be an effective strategy in developing a curriculum that is relevant to local needs and global challenges. For future research directions, it is recommended to expand the scope of the study by involving more schools from various regions and diverse backgrounds. In addition, further research can explore the effectiveness of the PjBL-PBE model in various subjects and levels of education. A mixed-method approach can also be used to understand more deeply the learning process and the impact of this model on students' socio-emotional aspects, including motivation, empathy, and confidence in conveying ideas.

#### 4. CONCLUSION

The implementation of the Project-Based Learning model based on Place-Based Education (PjBL-PBE) has important implications for strengthening a more contextual, collaborative and meaningful learning process. Through direct involvement of students with the surrounding community and environment, this approach not only enriches the learning experience, but also builds character and creative thinking skills. Students' activeness in digging up information, interacting with experts, and displaying project results in public spaces such as Science Fair reflects the transformation

of a more participatory and reflective learning attitude. More than just improving grades, this model creates space for students to build a sense of ownership of the ideas and solutions they create. However, the generalizability of these findings is still limited by the small sample size and the context of the study which only includes two schools with different characteristics. These factors may affect the results and need to be taken into account in further interpretation. For this reason, future research is recommended to be conducted on a wider scale with the involvement of schools from different backgrounds. Further research could also expand the focus on socio-emotional aspects as well as the long-term influence of the PjBL-PBE model on student engagement in environmental issues and the development of community-based solutions. As such, this approach has the potential to be an important foundation in the development of an adaptive and future-oriented curriculum.

## ACKNOWLEDGEMENT

Thanks are expressed to the Directorate of Research, Technology and Community Service; Directorate General of Higher Education, Research and Technology, Ministry of Education, Culture, Research and Technology of the Republic of Indonesia through funding for Master's Thesis Research Grants for Fiscal Year 2025. SK No 7928/LL4/PG/2025.

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