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Project-Based Learning: Improving Scientific Writing Skills with the Integration of Ecological Literacy among Students

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Research Article

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Abstract

Background/purpose. This study examines the influence of project-based learning on the writing of scientific papers that have ecological literacy. This research is important because ecological literacy is a key competency in facing the environmental challenges of the 21st century.

Materials/methods. This study uses an experimental method. The main data is students. Experimental and control groups were selected based on the average score of students in each class. The analysis used data from the experimental group and the control group, with data normality, data homogeneity, and t-test. Data were analyzed with the Kolmogorov-Smirnov test.

Results. The results showed that there was a significant difference between the results of the post-experimental and control groups. Project-based learning is effective in improving students' ability to write scientific papers that contain ecological literacy. The experimental group showed a more consistent improvement in the structure of the writing and the depth of the ecological content. In addition, students in the experimental group were better able to integrate local environmental issues into their scientific work.

Conclusion. This research underscores an epistemic transformation in which students are not only involved in the acquisition of knowledge but also participate in creating an understanding of ecological consciousness as the ethical foundation of their intelligence. The implication of this research is that project-based learning can help students improve ecological literacy.

1. Introduction

Environmental issues have become an urgent global agenda, along with increasing awareness of the destructive impact caused by the uncontrolled exploitation of natural resources. In many parts of the world, human activities that depend on economic growth often neglect the ecological balance, creating complex environmental crises that have the potential to threaten the sustainability of life on earth (Filiz & Hablemitoglu, 2013; Hall et al., 2018; Illes, 2019; Tauro et al., 2021). Indonesia, as a country within the Ring of Fire region, faces unique but significant ecological challenges. The region, which is geologically vulnerable to natural disasters, also has to face the consequences of unsustainable anthropogenic actions, such as deforestation and rapid urbanization. These phenomena exacerbate ecosystem damage, increase the frequency of natural disasters such as floods and landslides, and worsen the overall quality of the environment (Asteria et al., 2016; Isnanda & Rinaldi, 2021; Pamungkas, 2021; Samudro et al., 2015). Thus, the urgency to develop sustainable mitigation strategies is increasingly real, one of which is through education that focuses on increasing ecological literacy. This literacy is expected to be able to instill awareness and responsibility for the environment in individuals, so that it can encourage the creation of more sustainable behavior.

In this regard, environmental education occupies a strategic position in global efforts to build deep ecological awareness and collective responsibility for environmental sustainability. Through a structured and holistic approach, environmental education can form individuals who are not only aware of environmental issues but also able to act as proactive agents of change (Gobster & Rickenbach, 2004; Odlerova et al., 2010; Verma et al., 2016). The project-based learning model has proven to be one of the effective pedagogical approaches in creating an immersive and meaningful learning experience for students. In the context of ecological literacy, this model provides space for students to participate directly in projects related to real environmental challenges (Gobster et al., 2019; Wafula & Ongunya, 2016). This participation not only enriches their theoretical knowledge but also develops the critical skills necessary to analyze and address environmental problems effectively. This empirical experience is the basis for strengthening students' commitment to environmental sustainability, which in turn can encourage them to take an active role in ecosystem conservation efforts. Furthermore, this model also stimulates the development of creativity and innovation, which is crucial in finding solutions to various increasingly complex ecological challenges.

For this problem, this study aims to investigate the effectiveness of the project-based learning model in improving students' writing skills, especially those with ecological literacy. Based on the assumption that the integration of theoretical knowledge and practical experience can enrich the learning process, this study seeks to investigate in depth how a project-based approach can contribute to the development of higher academic competence. Using an experimental research design involving control groups and experiments, this study will evaluate the differences in scientific writing ability between students who follow a project-based learning model and those who adopt conventional approaches. In addition, this study will also investigate specific elements in the learning process that have the potential to affect the effectiveness of the method. The findings are expected to make a substantial contribution to the development of a more adaptive and responsive educational model to the needs of the times, especially in an effort to instill a deeper ecological awareness in the younger generation. This research is expected to make a new contribution by directly linking the project-based learning model with the ability to write scientific papers oriented towards ecological literacy. Different from previous research that generally only emphasized improving knowledge or attitudes towards the environment, as this study highlights, real projects can encourage students to internalize ecological issues into the structure and content of scientific writing. Thus, this approach not only shapes ecological awareness, but also improves the quality of academic expression based on contextual experience.

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2. Literature Review

The Literature Review section constitutes the scholarly cornerstone of this research endeavor, meticulously surveying and synthesizing a diverse array of academic works, theories, and empirical studies germane to the subject matter. Within this section, the narrative unfolds as a tapestry woven from the threads of various scholarly contributions, each thread representing a unique perspective, theory, or empirical evidence pertinent to the overarching research inquiry. Through a rigorous examination and critical evaluation of these scholarly dialogues, this section aims not only to elucidate the historical and theoretical underpinnings but also to discern the gaps, discrepancies, and nuances within the existing body of knowledge. By dissecting and synthesizing the multifaceted discourse, this review serves as a compass, guiding the trajectory of this study while illuminating uncharted territories and delineating the path towards deeper understanding and novel insights. In essence, the Literature Review functions as the intellectual bedrock upon which the subsequent analyses and interpretations are constructed, providing a comprehensive context and foundation for the present investigation.

a. Scientific Work

Scientific work is scientific knowledge for scientific circles or others with certain branches of science forming new knowledge through the process of analyzing the problem and how to overcome it (Björk et al., 2003; Yousuf, 2024). The purpose of writing scientific papers is to make scientific papers based on the needs created in the form of scientific knowledge. The scientific thinking process is the act of finding, analyzing, and thinking critically about different solutions to different problems in life. Grouping of scientific papers in writings related to work, writings about research, narrative writings, and writings for academic assignments (Barau et al., 2016; Miller, 2005). For this matter, the type of scientific work can be in the form of conceptual papers, empirical papers, short reports, scientific articles, theses, dissertations, and others, which are characterized by scientific concepts and methodologies (Rabbianty, 2023; Taufik & Pamungkas, 2025).

For this character, according to Ricards & Miller (2006), there are five components in writing, namely the use of language, grammar, content, style, speaking, and the skill of making appearances. In the context of writing skill development, understanding these components is very important to achieve the desired results. In addition, each component has a complementary role in creating scientific work that is not only informative but also well-structured and easy for readers to understand. A good mastery of grammar and speaking style, for example, can increase clarity and precision in the delivery of complex ideas. Therefore, scholarly writers must continue to hone their skills to ensure that the resulting writing is able to meet the quality standards expected by the global academic community.

b. Project-Based Learning

Project-based learning is an educational model that allows students to solve interesting problems that ultimately create original products. In project-based learning, it is important to follow relevant steps carefully, including this approach, in order to achieve the desired level of behavior (Bekiryazıcı, 2015; DeVries, 2000; Piaget, 1995). Grant (2017) states that in project-based learning, gifted students are responsible for the duration of the project, either individually or in groups. Teachers assign complex tasks to students, ask them to make designs, and solve problems to help students make decisions and develop questioning skills through difficult questions and problems (Akili, 2014; Davis & Schaeffer, 2019; Tsybulsky et al., 2020).

Project-based learning is considered a variation of other constructivist learning models, such as research, problem-based development, and collaborative learning (Alotaibi, 2020; Wafula & Ongunya, 2016). This understanding shows that PBJL is characterized by a constructivist approach

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consisting of the activation of prior knowledge, exploration, and study-en-centricity. The questions are given to direct students to go through the learning process. In parallel, Wurdinger et al. (2007) describe the sequence of project work that begins with sharing and discussion to gain existing knowledge about a particular topic and arouse students' curiosity. Given that most activities are carried out individually and collectively by students, we can find another type of constructivism in project-based learning: students as active actors in learning (Bell, 2010; Wafula & Ongunya, 2016). The idea of project-based learning starts with the development of the desired learning outcomes and continues with an understanding of material concepts, training the required skills, designing project themes, making project proposals, and implementing.

The project-based learning model is rooted in constructivist theory, which emphasizes that knowledge is actively built by students through direct experience and reflection. In this context, project-based learning is a concrete form of active learning in which students engage independently in solving real-life problems relevant to their lives, including ecological issues. Similar research has been conducted in countries such as Saudi Arabia (Alotaibi, 2020), the United States (Bell, 2010), and Kenya (Wafula & Ongunya, 2016), which shows that this approach is effective in improving students' critical thinking skills and scientific communication skills, thus supporting the application of this model in a global context.

c. Ecological Literacy

Ecological literacy is a concept that integrates understanding of the relationship between humans and the natural environment to achieve ecosystem sustainability (Vital, 2008) This literacy not only achieves scientific knowledge about ecology and natural dynamics but also ethical awareness and social responsibility towards environmental sustainability (Ha & Dong, 2023; Tong, 2014) According to Palmer (2019), ecological literacy is an important component in education that aims to create a society that is able to interact harmoniously with the natural environment. In this case, ecological literacy involves a deep understanding of natural cycles, the mutual relationships between living things, and the impact of human activities on the balance of ecosystems. In addition, ecological literacy also emphasizes the importance of practical actions that support environmental conservation and protection, including policy development (Kapan & GÜREL, 2022; Rosdiana et al., 2020). Thus, ideological literacy plays a role as a foundation in building critical awareness and pro-environmental behavior that supports global ecological well-being.

3. Methodology

This research is an effort to explore project-based learning in improving Scientific Writing skills with the Integration of Ecological Literacy among students. For this, the development of research methods is locked into two parts. This research uses various materials and measuring tools to collect data relevant to students' scientific writing skills. The main tools used are essay tests and rubrics for the assessment of scientific writing skills. The essay test is designed to measure five important aspects in scientific writing, namely systematic, creativity of ideas, topic, use of data, and analysis (Creswell, 2014; Payne, 2018) Each of these aspects is covered with a rubric that has been validated to ensure the realism and validity of the measurement. In addition, the data collected were in the form of pretest and posttest scores that described students' abilities before and after the implementation of the learning model (Gall et al., 2003, 2007; Payne, 2018) This data was then analyzed using parametric and non-parametric statistical methods with the help of spss, to ensure the accuracy and precision of the research results.

The research procedure began with the selection of participants, consisting of even semester students at the University of Pekalongan and University of Peradaban. Sample selection was carried out using a purposive sampling technique based on the results of the Mid-Semester Exam (UTS) for the Indonesian course. The classes with the highest and lowest average scores are not selected to

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avoid extreme bias. Two classes with balanced average scores, namely classes B and C, were selected as control and experimental groups, respectively. The group is randomly assigned from the two selected classes to ensure a fair distribution without any particular preferences. Participants were divided into two groups based on the average score of the midterm exam, namely class B as the control group and class C as the experimental group. The experimental group used a project-based learning model (PJBL), while the control group used a conventional learning model. After the division of groups, a pretest was conducted to assess students' initial skills in writing scientific papers (Gall et al., 2003; Lee et al., 2016; Payne, 2018). In the experimental group, students participated in Project-Based Learning (PJBL), which was designed in five stages: identification of environmental problems, preparation of project proposals, implementation of field projects, writing scientific reports, and presentation of project results. Each stage is guided by lecturers with group discussions and written reflections to delve into ecological concepts associated with real practice. In contrast, the control group underwent conventional lecture-based learning and writing exercises without involvement in real projects, where material was presented theoretically and writing exercises were carried out based on topics that the lecturer had determined.

The initial level of students' scientific writing ability is measured through a pretest designed in the form of an essay with an ecological theme. The assessment is conducted using a standardized rubric that covers five main aspects: writing structure, clarity of ideas, relevance of topics, use of data, and depth of analysis. This rubric has been validated by language education experts to ensure the reliability and validity of the instrument. During the research period, the experimental group received learning using PJBL, which is designed to improve writing skills through relevant projects. At the end of the study, a posttest was carried out to measure the development of students' writing skills (Creswell, 2012; Lochmiller & Lester, 2015). The data obtained were analyzed using the Kolmogorov-Smirnov normality test. If the data is normally distributed, the analysis continues with parametric statistics; otherwise, non-parametric statistical analysis statistics are used.

The statistical analysis techniques used in this study include: (1) Normality test using Kolmogorov-Smirnov to ensure normal data distribution; (2) Homogeneity test of variance to verify the similarity of variance between groups; and (3) independent t-tests to analyze significant differences between the pretest and posttest results of the experimental and control groups. All analyses are carried out with the help of SPSS software to ensure the accuracy of the results. The selection of statistical methods takes into account the characteristics of the data and the purpose of testing the hypothesis. The normality test ensures that the data meets the parametric assumptions, while the homogeneity test verifies the equivalence of the variance so that the comparison results are valid. The use of independent t-tests aimed to objectively measure the effectiveness of treatment by considering the mean differences between groups.

4. Results

Research data was obtained from pretest data and posttest data. Data analysis on the effectiveness test of the PJBL model was carried out to measure students' scientific writing skills. Of the 60 students, there were two groups, namely the control group and the experimental group. Each group has 30 students. The following is the average pretest and posttest scores of the experiment and control groups, visualized in Diagram 1.

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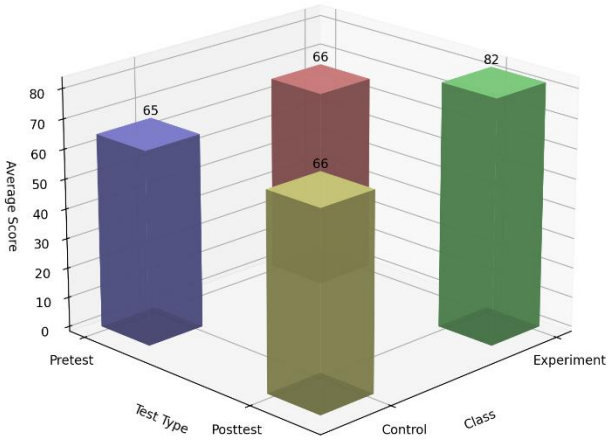

Diagram 1. The Scores of the Experimental and Control Groups

Diagram 1 shows the average, highest score, and lowest score of the results during the pretest and posttest. After that, a normality and homogeneity test was carried out with a Kolmogorov-Smirov before the t-test. Before performing the t-test. An initial analysis of compliance with the normal distribution of data can be carried out using the Kolmogorov-Smirov test. The results of this test, in the post-test, the control class had a significance value (Sig.) of 0.245, while the experimental class had a Sig. value of 0.612. Similarly, in the pre-test, the control class showed a Sig. value of 0.368, and the experimental class had a Sig. value of 0.724. Since the total value of Sig. is greater than 0.05, it can be concluded that the pre-test and post-test data in both the control class and the experimental class are normally distributed. This allows the use of parametric statistical methods that are more sensitive to the assumption of normality in the next stage of analysis (Lee et al., 2016; Mendeş & Pala, 2003)

Furthermore, homogeneity tests are carried out to ensure that the variance between the test groups, both the experimental group and the control group, is uniform before treatment. This uniformity of variance is important for the validity of the t-test results, which will be used to compare the mean of the experimental and control groups. This homogeneity test shows that Fcal is greater than Ftabel, indicating that the data has uniform or homogeneous variance. This situation strengthens the validity to continue with the parametric t-test in testing the differences between the control group and the experiment. This analysis provides a solid basis that the data used in this study have met the main prerequisites for further statistical analysis. For this, the next is the data homogeneity test, as shown in Figure 1.

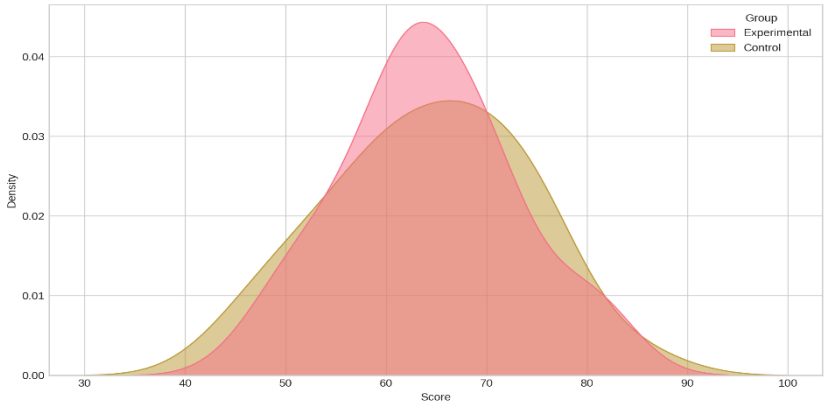

Figure 1. Homogeneity Test of Data

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The homogeneity test carried out gave an Fcal of of 0.518, which is a value greater than the Ftabel at α=0.05/alpha = 0.05α=0.05 of 0.442. These results show that the variance between the experimental and control groups before being given the pretest is homogeneous. This homogeneity of variance is important because it indicates that both groups had similar response variableities before the intervention was applied, which allows for fair and valid comparisons between the groups in subsequent analyses (Wafula & Ongunya, 2016). After verifying that the initial data were homogeneous, the study proceeded with a balance test. This test is essential to determine whether the two groups had a comparable starting point before treatment was given. In this case, the balance test uses a t-test to compare the mean of the experimental group and the control group in the prettest phase. It is important to ensure that there are no statistically significant differences between these two groups before the treatment is applied so that the differences found after the treatment can be better attributed to the effects of the treatment itself.

In interpreting the t-test results, the tcount value was compared with the ttablet critical value at a significance level of 0.05 if the tcount was smaller than the tablet then we can conclude that there was no significant difference between the two groups at the beginning of the study, which means that the preliminary data were balanced. This forms a solid basis for applying the treatment and then testing the effects of the treatment using a post-test t-test. The results of the pretest t-test in the control and experimental groups will be detailed to provide a clearer picture of how balanced the two groups are before the intervention is given. After the homogeneity test is carried out is a t-test pretest. Figure 2 below is the results of the pretest t-test in the control and experimental groups.

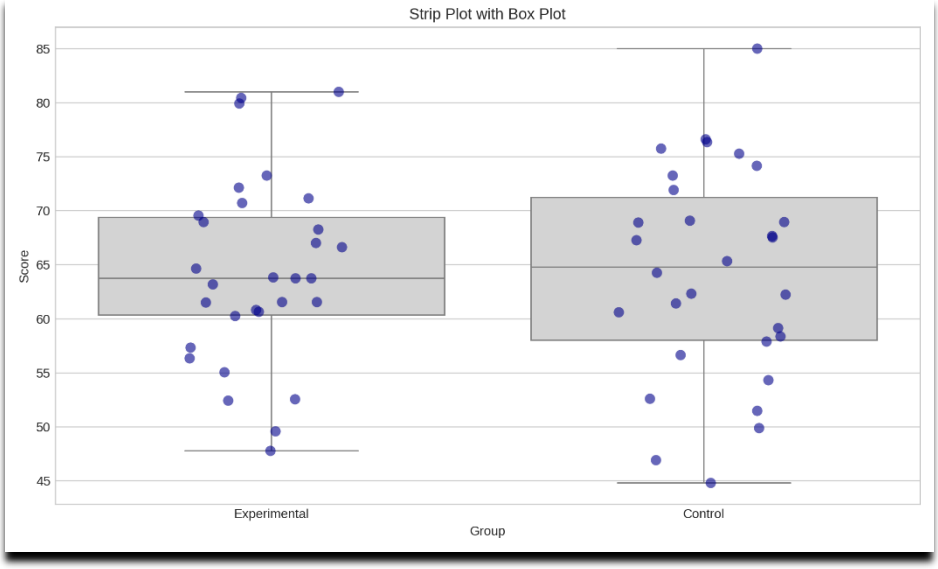

Figure 2. T-Test Pretest Test

Figure two shows that the tcount is 0.480 and the table is 2.0.it is stated that the group Therefore, the tcount is smaller than the value of α 0.05, which is 0.480 < 0,959.. The results of the data, it was stated that the experiment and control groups before the treatment were declared to be similar, after which the effectiveness of the model was tested by comparing the results of the posttest of the experimental group and the controversy on the ability to write scientific papers of students. After confirming that the initial data of the two groups were balanced, the study then proceeded with the effectiveness test of the model. The effectiveness test was carried out by comparing the post-test results of the experimental group and the control group to test the impact of the learning model applied on the students' scientific writing ability. The t-test was used in this stage to test the hypothesis that there was a significant difference between the performance of the posttests of the two groups which could be related to the application of the project-based learning model in the group

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which could be related to the application of the project-based learning model in the experimental group (Alotaibi, 2020; Kokotsaki et al., 2016; Sudigdo et al., 2024)

The details of the t-test results will provide important insights into the effectiveness of the project-based learning model. The difference between the posttest scores of the experimental and control groups will be displayed and the statistical interpretation of this data will show whether the learning model tested has a significant impact on improving the ability to write scientific papers. As such, this analysis not only tests the theoretical effectiveness of the model, but also provides strong empirical evidence that supports or discourages the application of the model in a broader educational context. After the t-test pretest, the next is the t-test posttest. This is the result of the details of the t-test results, which show the difference between the posttest scores of the experimental and control groups.

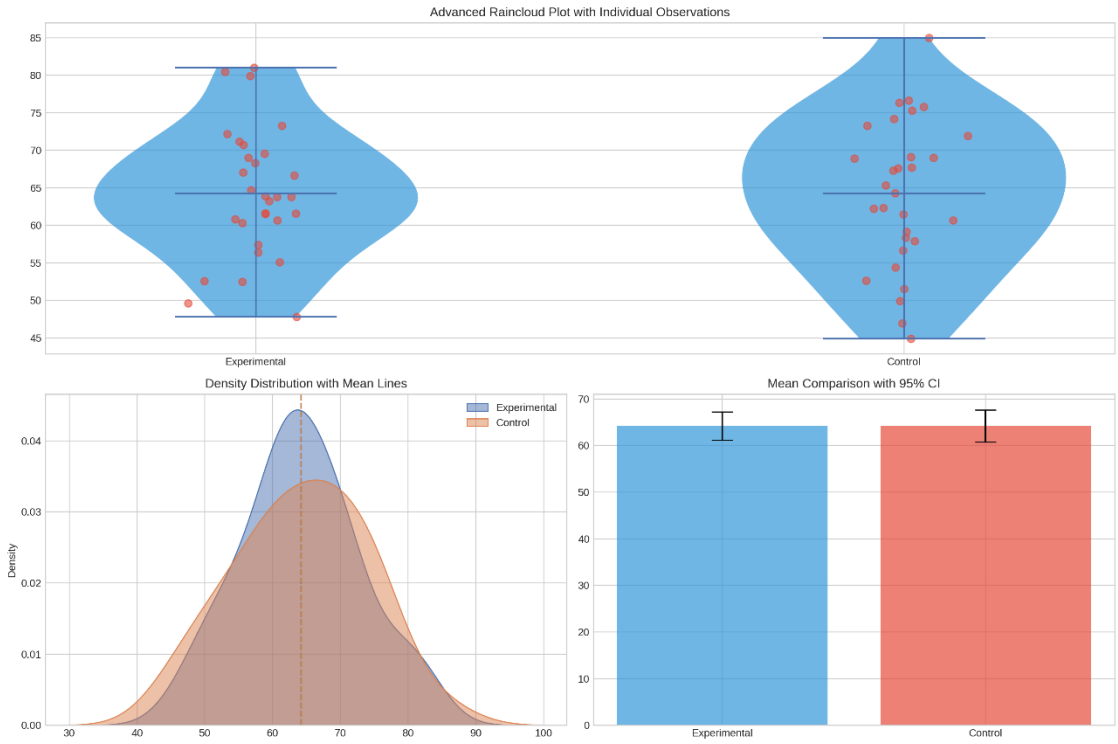

Figure 3. Posttest T-Test

From the data presented in Figure 2. It was obtained that the significant Thitung value of 11.672 far exceeded the ttable of 1.672 at the 95% confidence level (α=0.05/alpha = 0.05α=0.05). This condition statistically indicates that there is a very significant difference between the experimental group, which applies a project-based learning model, and the control group, which uses conventional learning approaches related to their skills in writing scientific papers that are ecologically literate. This striking difference shows that the project-based learning model is effective in improving scientific writing skills among students. The pretest results showed that the two groups had relatively balanced initial abilities, as shown by the absence of statistically significant differences. After treatment, the experimental group showed significant improvements in various aspects of scientific writing, such as the structure of arguments, the integration of ecological issues, and the depth of data analysis and interpretation. In contrast, the control group experienced only limited improvements, especially in technical aspects of writing such as grammar and paragraph organization, but did not show significant progress in understanding and decoding environmental issues in their scientific work.

This observation is further strengthened by the data presented in Figure 1, which shows the difference in the mean post-test scores between the experimental group and the control group. The increase in the average score in the experimental group not only indicates the success of the

implementation of project-based learning but also confirms that this type of approach can significantly improve student learning outcomes in the aspect of writing scientific papers with ecological literacy content. This difference reflects the positive impact of the application of more interactive and practical methods in environmental education, which not only teaches theory but also encourages the practical application of knowledge in concrete academic tasks (Kokotsaki et al., 2016; Mergendoller & Thomas, 2000; Wafula & Ongunya, 2016) This analysis is important because it shows that the integration of ecological literacy into a project-based learning framework can be an effective educational strategy. It illustrates the importance of adapting teaching methods at universities to include interactive components that promote better analytical and synthetic skills among students. Thus, this result can be a valuable reference for educational institutions that want to reform the curriculum and teaching methods, especially in increasing students' ecological awareness and skills. Sran for further research includes applying similar models in the context of other disciplines as well as measuring the long-term impact of project-based learning on knowledge retention and practical applications in the real world. In addition to improving scientific writing skills, project-based learning also encourages students to develop high-level thinking skills. During the project implementation process, students are trained to analyze environmental problems in depth, design solutions, and organize ideas logically in the form of scientific writing. This activity not only fosters analytical thinking and problem-solving skills but also improves critical thinking skills as students are required to evaluate information, develop data-backed arguments, and reflect on the impact of proposed solutions.

5. Conclusion

This study explicitly shows that the project-based learning model has a significant impact on improving students' ability to write scientific papers, especially those oriented to ecological literacy. Through this approach, students not only become passive recipients of knowledge but also become key actors in the process of forming and constructing knowledge. The integration of theory and practice presented by projects related to environmental issues allows students to understand the concept of ecology in depth and apply it in real contexts. Significant differences between the experimental and control groups confirm the effectiveness of PJBL in shaping scientific intelligence that is more critical and responsive to real-world complexity. These findings indicate that students' involvement in project-based learning not only improves the technical abilities of scientific writing but also strengthens their understanding of complex ecological issues. This improvement shows the effectiveness of contextual and participatory learning approaches in building academic skills as well as environmental awareness. Thus, the results of this study support and expand the previous understanding of the benefits of active learning for the development of scientific and ecological literacy. In addition, this study shows that the project-based learning approach is able to improve students' analytical and synthesis skills, which are crucial in writing quality scientific papers that are relevant to contemporary ecological challenges.

The implications of this study underscore the importance of adopting the PJBL method in higher education institutions, especially in the context of ecological literacy. This method not only improves academic skills but also forms an ethical awareness of the environment, which can ultimately encourage pro-environmental behavior among students. However, the study had some limitations, such as a limited number of participants and the scope of the study involving only one higher education institution, which may not be broadly generalized. In addition, this research tends to be dominant in a quantitative approach, so it has not been able to explore qualitative aspects in depth, such as student motivation and learning experience. Therefore, further research is recommended to involve a broader and diverse example, as well as to use a qualitative approach to gain a more holistic insight into the effectiveness of PJBL. Cross-disciplinary studies are also needed to explore the

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application of this model in a more varied context in order to enrich insights on the integration of ecological literacy across various disciplines.

6. Suggestion

The Project-Based Learning approach, combined with ecological literacy, can play an important function not only in improving students' division and composing skills but also in forming a deeper ecological awareness. It has provided students with practical knowledge and experience in real environment-related projects, which allows them to not only acquire certain theoretical knowledge but also generate analytical, critical, and solution-solving skills in addressing global ecological challenges. In addition, the model by changing the learning environment to be more interactive, where students become active contributors to the knowledge creation process. The guidance assistance reflected in this method, as evidenced by the differences between the training group and the control group, highlights the urgent need to expand Problem-Based Learning (PBL) at all levels of higher education, especially in disciplines related to environmental sustainability. However, to ensure the impact, further outreach is needed with a larger scope and multidisciplinary approach, not only aimed at measuring the effect on the academic context but also assessing the extent to which environmental skills and sensitivity can be applied in students' professional and social lives in the future.

This study has several limitations, including the limited number of participants in two classes in one institution, as well as the relatively short duration of the intervention. In addition, the research approach used is quantitative, so it has not been able to explore in depth the affective aspects or subjective experiences of students during the learning process. For future research, it is recommended that the scope of participants be expanded to include a variety of different educational institutions and levels to improve the generalization of the findings. Follow-up research can also use a mixed-method approach to explore more deeply the impact of CHD on motivation, emotional engagement, and cooperative dynamics between students. In addition, it is necessary to explore the long-term impact of PJBL on the application of ecological literacy values in students' real lives.

Declarations

Author Contributions. Hera Septriana: Conceptualization, methodology, formal analysis, resources, data curation, funding acquisition Sarwiji Suwandi: Conceptualization, software, validation, supervision Sumarwati: Visualization, validation, investigation, writing—original draft preparation, writing—review and editing, visualization, project administration

Conflicts of Interest. The authors declare no conflicts of interest.

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