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ESD-Oriented PBL to Enhance Vocational Students' Critical Thinking Skills

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ABSTRACT: The paradigm shift in global education demands learning processes that emphasize not only cognitive outcomes but also the development of critical thinking skills, environmental awareness, and social responsibility. This study aims to analyze the effect of implementing a Problem-Based Learning (PBL) model oriented toward Education for Sustainable Development (ESD) on students' critical thinking skills. The research employed a quasi-experimental method with a pretest–posttest control group design. Samples were selected using purposive sampling based on class characteristics. Class X DKV 1 (36 students) was assigned as the experimental group, and Class X DKV 2 (36 students) as the control group. The experimental group received instruction through the PBL-ESD model, while the control group was taught using conventional methods. Data were collected through multiple-choice tests covering five indicators of critical thinking and analyzed using t-tests and effect size calculations to determine the significance and magnitude of the treatment effect. The results showed that the experimental group achieved a higher average score in critical thinking than the control group. The N-Gain value in the experimental class was 0.59 (moderate category), while the control class obtained 0.24 (low category). The normality tests yielded Sig. 0.41 > 0.05 and Sig. 0.38 > 0.05 for the experimental and control groups, respectively, indicating normal data distribution. The homogeneity test resulted in Sig. 0.17 > 0.05, showing homogeneous variance. The independent t-test revealed Sig. (2-tailed) 0.002 < 0.05, indicating a significant difference between the two groups. Furthermore, the effect size value of 1.25 was categorized as high, demonstrating a strong influence of the PBL-ESD model on improving students' critical thinking skills. In conclusion, the implementation of the PBL model oriented toward ESD is proven effective in enhancing students' critical thinking abilities while fostering ecological awareness and social responsibility. The findings are expected to serve as a reference for educators in developing innovative learning strategies aligned with 21st-century education demands and sustainable development goals.

KEYWORDS - *Problem-based learning, education for sustainable development, critical thinking skills*

I. INTRODUCTION

The development of the digital era brings fundamental changes in the educational paradigm, including for Vocational High Schools (SMK) which are required to adapt to technological advances and the demands of the global job market [1]. As an educational institution that focuses on the formation of a professional workforce, SMK has a big responsibility in producing graduates who are not only superior in theoretical knowledge, but also capable of critical thinking, independent in acting, and flexible to the dynamics of changing times [2]. SMK graduates are expected to have skilled skills and be able to easily adapt to the environment and technological developments. In addition, they are also encouraged to continue to develop themselves to meet the needs of the industrial world which continues to change over time [3], [4].

One of the subjects that contributes to the formation of student competencies is the Natural and Social Sciences Project (IPAS Project) [5]. This subject is an integrated learning that combines the concepts of Natural Sciences (IPA) and Social Sciences (IPS) to help students understand the relationship between natural, social, and technological phenomena in everyday life [6]. In IPAS Project learning, student competencies are reflected when they can achieve learning outcomes, namely being able to explain phenomena in the surrounding environment and connect them with technical skills relevant to their field of expertise [7].

To achieve this, students are required to have critical thinking skills, students need to be trained to be able to explore ideas, put forward logical arguments, and solve problems creatively, while also fostering sensitivity to developing social, economic, and environmental issues [8]. Critical thinking skills are seen as an essential competency of the 21st century, which determines an individual's readiness to face the complexities of

modern life [9]. However, a number of findings reveal that the learning process in vocational schools, especially in the Science Project subject, still faces serious obstacles. The dominance of conventional teacher-centered methods results in low active student participation, weak critical thinking skills, and minimal awareness of sustainability issues [10].

Observation results at SMK Negeri Tanjung Sari, South Lampung revealed low achievement of students' critical thinking skills. Of the 72 students sampled in the study, more than half showed results below the sufficient category. A total of 58.34% of students (42 people) obtained scores below 50, consisting of 18.06% (13 students) in the very low category (0–25) and 40.28% (29 students) in the low category (26–50). Meanwhile, 29.17% (21 students) were in the sufficient category (51–75), and only 12.50% (9 students) managed to reach the high category (76–100). These data illustrate that almost two-thirds of students have not met the minimum competency standards, while only a small portion of around one in eight students actually demonstrate optimal mastery of critical thinking skills.

This condition has direct implications for students' low ability to analyze problems, formulate creative solutions, and connect theory with practice. Low critical thinking skills also impact students' lack of awareness of sustainable lifestyles, which is evident in their daily lives such as wasteful energy use, lack of concern for environmental cleanliness, and the absence of systematic waste management efforts in schools. In fact, the formation of character and a sustainable lifestyle can only be achieved if students have the concern and reflective ability to solve environmental problems constructively [11]. Sustainability-based education is very important in equipping students with insight into the ecological, social, and economic impacts of various phenomena in their environment [12].

In line with this, various studies confirm that critical thinking skills are one of the key competencies of the 21st century that are essential for students to be able to face uncertainty and global change [13]. Critical thinking skills are even included in the category of global competencies that are essential for students to be able to face future challenges and uncertainties [14]. In line with this, UNESCO emphasizes the importance of Education for Sustainable Development (ESD) as an approach to equip students with awareness, skills, and sustainability values that are relevant to global issues, such as the climate crisis, environmental degradation, and socio-economic disparities [15]. Several international studies also confirm that the integration of problem-based education with sustainability issues can encourage critical thinking skills, creativity, and social responsibility [16], [17].

In response to these conditions, learning innovations are needed that are able to encourage the development of 21st century skills in students, one approach that is relevant to the demands of the increasingly dynamic world of work and has been proven effective is the Problem-Based Learning (PBL) model [18]. In its application, the PBL model will be combined with ESD principles so that learning does not only focus on critical thinking and problem-solving skills, but also instills awareness of the importance of sustainability and responsibility towards the environment.

However, empirical studies that integrate the PBL model with ESD principles in Science Project learning in vocational schools are still very limited and most previous studies have focused more on the application of PBL in developing general cognitive aspects, and studies that specifically examine the influence of ESD-oriented PBL integration on critical thinking skills and the formation of students' sustainability awareness are still rare.

Thus, the novelty of this research lies in the integration of the PBL model with ESD principles in the context of Science Project learning in vocational high schools, which has not been widely studied in the vocational education literature in Indonesia. The purpose of this study is to analyze the effect of the implementation of the ESD-oriented PBL model on students' critical thinking skills in the Science Project subject at SMK Negeri Tanjung Sari, South Lampung.

This research is expected to provide theoretical contributions to the development of innovative learning strategies in vocational schools, while also offering practical benefits for teachers in developing more interactive, contextual learning models that are aligned with the demands of the workplace and sustainability issues. Based on this description, the hypothesis of this research is that there is a significant influence of the implementation of the ESD-oriented PBL model on students' critical thinking skills in the Science Project learning in vocational schools.

II. METHOD

This research method applies a quasi-experimental approach with a pretest-posttest control group design [19]. This method involves two classes, namely the experimental class that received treatment using the ESD-oriented PBL model and the control class that did not receive the same treatment. Data were collected through an initial test (pretest) and a final test (posttest) to measure differences in abilities before and after the treatment was given. The choice of this design was based on the consideration that researchers could compare critical thinking abilities between the experimental class that implemented the ESD-oriented PBL model and the

control class that used the conventional model. The quasi-experimental research design can be seen in the following table:

TABLE 2.1. Quasi-Experiment Research

Class	Pretest	Treatment	Postest
Experiment	THE_1	X_1	THE_2
Control	THE_1	X_2	THE_2

Information: THE_1 = Pretest; THE_2 = Posttest; X1 = Treatment with ESD-oriented PBL model teaching modules; X2 = Treatment with conventional model teaching modules.

The population subjects in this study included all grade X students of SMK Negeri Tanjung Sari, South Lampung in the 2025/2026 Academic Year. The research sample was taken by purposive sampling by considering the equality of class characteristics [20]. With this consideration, two classes were determined as samples with a total of 72 students, namely class X DKV 1 with 36 students as the experimental class and class X DKV 2 with 36 students as the control class.

The critical thinking skills test was given after the treatment to both classes, namely the experimental class and the control class. The test instrument used was in the form of multiple-choice questions based on problem context, which was arranged based on the sustainability issue in the environmental pollution sub-theme in the Science Project subject. There are five indicators of critical thinking skills measured in this study, namely: (1) providing simple explanations, (2) building basic skills, (3) making inferences or conclusions, (4) providing further explanations, and (5) developing strategies and tactics [21].

Based on these five indicators, 20 multiple-choice questions were developed to comprehensively measure students' critical thinking skills. Each question item underwent validity and reliability testing to ensure the instrument was truly appropriate and accurately measured the desired aspects. After the instrument was declared valid and reliable, the test data were analyzed using a t-test to determine the extent to which the implementation of the ESD-oriented PBL model influenced students' critical thinking skills in learning.

To maintain internal validity, the learning treatment between the two classes was carried out at the same time, with the same allocation of hours and materials, with the only difference being the learning model used. External validity was considered through the selection of a representative sample and one that was appropriate to the vocational school context. The reliability of the results was strengthened by the use of standardized instruments and the implementation of consistent data collection procedures [22].

The ESD-oriented PBL model is implemented through five main stages of learning, namely (1) problem orientation, (2) organizing learning activities, (3) independent and group investigations, (4) development and presentation of work results, and (5) analysis and reflection. Each stage is linked to critical thinking activities and sustainability values so that students are able to understand environmental issues scientifically, reflectively, and responsibly. The following is the ESD-oriented PBL learning framework:

TABLE 2.2. ESD-oriented PBL syntax

PBL steps	Learning Activities	ESD Integration
Problem orientation	The teacher presents a video/current news story about environmental pollution in their area or a global issue. Students are invited to discuss real-life problems occurring in their environment.	Raising awareness of global and local environmental issues, and the importance of sustainability.
Organizing students	Students were divided into project groups. Each group chose an environmental issue (waste, clean water, pollution, land conversion, etc.) that existed in their area.	Cultivate cooperation, social awareness, and active participation in solving real problems.
Guiding individual/group investigations	The teacher facilitates groups to conduct investigations (interviews, observations, and literature reviews) on the selected problem. They collect data, analyze the root cause, and design solutions.	Encourage critical thinking skills and cause-and-effect analysis by taking into account economic, social, and ecological aspects.
Develop and present work results	Groups present the results of their projects in the form of posters, videos, environmental campaigns, or mock-ups of appropriate technology solutions.	Encourage creativity, communication and the delivery of ideas that support sustainability.
Analyze and evaluate the problem-solving process	A joint reflection on what has been learned, their role in protecting the environment, and what concrete actions	Forming reflective awareness and long-term commitment to environmental sustainability.

can be taken in the future.

III. RESULT AND DISCUSSION

Based on the results of research conducted at SMK Negeri Tanjung Sari, South Lampung, as shown in Table 3.1, it was found that students' critical thinking skills in the experimental class were higher than those in the control class. This difference occurred because the experimental class implemented an ESD-oriented PBL model that emphasized student involvement in analyzing environmental issues and sustainable development. Through this approach, students not only focused on cognitive achievement but also were trained to think critically, solve real-world problems, and foster awareness of social and environmental responsibility.

TABLE 3.1. Critical Thinking Skills Results

Class	X	Normality Test	Homogeneity Test	Independent Samples t-Test
Experiment	0.64	Sig. 0.41 > 0.05	Katakanlah 0.17 > 0.05	Sig. (2-tailed) 0.002 < 0.05 (SD)
Control	0.29	Sig. 0.38 > 0.05		

Description: Experimental Class = with ESD-oriented PBL model; Control Class = with conventional model; SD = Significantly Different

Based on Table 3.1, the results of the normality test show that the data are normally distributed (Sig. > 0.05), and the homogeneity test also shows homogeneous variance (Sig. > 0.05). Furthermore, the results of the independent sample t-test show a Sig. (2-tailed) value = 0.001 < 0.05, which means there is a significant difference between the experimental class and the control class. This indicates that the implementation of the ESD-oriented PBL model has a significant effect on improving students' critical thinking skills.

Thus, the implementation of PBL enables students to develop critical thinking skills, while the integration of ESD principles in the Science Project learning helps students understand the relationship between social, economic, and environmental aspects, thereby fostering critical awareness of sustainability issues around them.

TABLE 3.2. N-Gain Results Analysis

Indikator	Kelas Eksperimen	Kelas Kontrol
Basic Clarification	0.62 (Medium)	0.25 (Low)
Basic Support	0.68 (Medium)	0.28 (Low)
Conclusion	0.55 (Medium)	0.23 (Low)
Further Clarification	0.64 (Medium)	0.27 (Low)
Strategy and Tactics	0.81 (High)	0.22 (Low)

Table 3 shows that all indicators of students' critical thinking skills in the experimental class experienced higher improvements than those in the control class. The indicator with the highest improvement in the experimental class was strategy and tactics, with an N-Gain value of 0.81 (high category). This finding indicates that students have been able to identify real problems related to sustainability issues, formulate various alternative solutions, select the best solution, and determine concrete steps to be implemented in the Science Project subject.

The significant improvement in the strategy and tactics aspects reflects that ESD-oriented PBL learning encourages students to think more critically, reflectively, and systematically in solving real-world problems, such as waste management, the use of environmentally friendly energy, and natural resource conservation. This is in line with the concept of 21st Century Learning (P21), which emphasizes the development of critical thinking, problem solving, collaboration, and sustainability awareness as students' core competencies [23].

The essence of ESD is to develop student competencies through holistic, interdisciplinary, and action-oriented learning, so that students are able to understand the relationship between social, economic, and environmental aspects in a sustainable manner [12]. Thus, the implementation of ESD-oriented PBL not only improves cognitive critical thinking skills, but also strengthens students' reflective character and ecological responsibility.

Table 4 presents the results of the effect size calculation of the implementation of the ESD-oriented PBL model on improving students' critical thinking skills in the Science Project learning at SMK Negeri Tanjung Sari, South Lampung. This effect size calculation aims to determine the extent of the influence of the implementation of the ESD-oriented PBL model in the experimental class compared to conventional learning in the control class.

TABLE 3.3. The Effect Size Calculation Result

Class	Average N-Gain	Std. Deviation	Effect Size	Criteria
Experiment	0.59	0.12	1.25	High
Control	0.24	0.10		

Based on Table 3.3, the effect size value was 1.25, which is considered high. These results indicate that the implementation of the ESD-oriented PBL model has a strong influence on improving students' critical thinking skills in grade X of SMK Negeri Tanjung Sari, South Lampung. This finding reinforces the analysis results in Tables 3.1 and 3.2, where the experimental class showed a more significant increase in critical thinking skills compared to the control class.

The application of the PBL model in learning the Science Project effectively improves critical thinking skills because it actively involves students in the process of analyzing and solving contextual problems [24]. Meanwhile, the integration of ESD principles in learning helps students understand the relationship between social, economic, and environmental aspects, as well as fostering awareness of the importance of sustainability [25].

The improvement in students' critical thinking skills is inseparable from the characteristics of PBL, which emphasizes real-world problem-based learning, particularly those related to environmental, social, and economic sustainability issues. Students not only understand the concept of environmental pollution theoretically but also actively engage in the process of finding solutions to contextual problems around them. ESD-oriented materials encourage students to read more broadly, critique emerging phenomena, analyze them in depth, and develop applicable solutions to environmental issues. This learning process creates a meaningful and action-oriented learning experience.

The ESD concept integrated into the PBL model further strengthens the effectiveness of the learning process, as it is able to link environmental issues with social, economic, and educational dimensions holistically [15]. Through this approach, students not only focus on understanding the theory, but are also invited to see the relationship between human actions and their impact on environmental sustainability [26]. Thus, the implementation of ESD-oriented PBL not only contributes to improving students' critical thinking skills, but also fosters ecological awareness and a sense of responsibility towards the sustainability of life.

However, the improvement in critical thinking skills in the experimental class can also be influenced by external factors beyond the implementation of the model, such as high learning motivation, teacher support, and group work dynamics. These factors contribute to creating an active and collaborative learning environment that positively influences learning outcomes. Therefore, the success of ESD-oriented PBL implementation also depends heavily on teacher readiness, a supportive learning environment, and the characteristics of students in each class.

The implications of this research indicate that the implementation of an ESD-oriented PBL model can be a relevant learning alternative for the Science Project subject and other social studies subjects. This model not only improves critical thinking skills but also fosters ecological awareness and social responsibility in students. Teachers are expected to systematically integrate an ESD-oriented PBL approach into the curriculum to foster 21st-century competencies, particularly in scientific literacy, social literacy, and environmental sustainability.

This study has limitations because it was conducted at only one school, SMK Negeri Tanjung Sari, South Lampung. Therefore, the generalizability of the results is limited. Furthermore, the study only measured cognitive aspects of critical thinking skills without examining changes in students' attitudes and behaviors toward sustainability issues. Learning environment factors and teachers' teaching styles may also influence the results.

Therefore, further research is recommended to involve more schools with diverse characteristics and use mixed methods to obtain more comprehensive results. Further research could also explore the long-term impact of ESD-oriented PBL implementation on the development of students' attitudes toward sustainability, self-reflection, and social responsibility.

IV. CONCLUSION

The results of this study indicate that the implementation of the ESD-oriented PBL model significantly improves students' critical thinking skills in the Science Project subject at SMK Negeri Tanjung Sari, South Lampung. The effect size value of 1.25 indicates a high influence, which confirms the effectiveness of the integration of PBL and ESD in creating active, reflective, and action-oriented learning.

The findings provide empirical evidence that problem-based learning contextualized with sustainability issues can develop 21st-century competencies, particularly critical thinking skills. This model also fosters ecological awareness and social responsibility in students, which are highly relevant to the needs of vocational education in the era of globalization and green industry.

However, this study's limitations lie in its sample size, which included only one school, and its limited focus on the cognitive domain. Therefore, further research is recommended, involving more schools with diverse characteristics and using a mixed methods approach to examine the long-term impact of ESD-oriented PBL on students' attitudes, behaviors, and awareness of sustainability.

Practically, the results of this study confirm that the ESD-oriented PBL model is worthy of being used as an alternative learning strategy in the Science Project subject and other Social Studies fields to build a generation that is critical, has an ecological character, and is ready to face the challenges of sustainable development.

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