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Application of The Problem-Based Learning (PBL) Model Using The Education for Sustainable Development (ESD) Approach to Students' Critical Thinking Ability in Global Warming Material

Mochamad Raihan Ahnaf Rizqulloh*, Heni Rusnayati, and Agus Danawan
Physics Education Study Program, Universitas Pendidikan Indonesia, Bandung, Indonesia
*raihanahnaf@gmail.com

Abstract

The rapid development of the Industrial Revolution 4.0 era requires humans to withstand rapid changes. Mastery of 21st-century skills and sustainability awareness becomes crucial as society in this era is required to sustain Natural Resources (NR) and develop Human Resources (HR) preparedness to adapt. Critical thinking is one of the competencies that students must possess in the 21st century and is also a key competency in ESD that can help students realize the concept of sustainability awareness in the Industrial Revolution 4.0 era. A learning model that can develop students' critical thinking skills is the PBL model because thinking and problem-solving skills can be developed when students do it themselves, explore, and transfer the complexity of existing knowledge. Therefore, this study aims to determine the application of the PBL model with an ESD approach to students' critical thinking skills on global warming material. This research uses the quantitative method of pre-experimental designs with the One Group Pre-test-posttest design. The subjects of this study were 38 students at a public high school in Bandung. The sample was taken using the convenience sampling method on 11th-grade science students in the even semester of the 2022/2023 academic year. The instruments used in this study were a critical thinking skills test and a sustainability awareness questionnaire using the Guttman scale. The data obtained were processed using the Normalized Gain (N-Gain) test for critical thinking skills and the response percentage for the sustainability awareness questionnaire. The results showed increased students' critical thinking skills N-Gain of 0.524 in the medium category. Meanwhile, the sustainability awareness questionnaire profile after learning activities showed a total percentage of 73.94% in the high category.

Keywords: critical thinking; education for sustainable development; sustainability awareness; problem-based learning model

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INTRODUCTION

The world is currently in the era of the Fourth Industrial Revolution, which is characterized by increased connectivity, interaction, and advancements in digital systems, artificial intelligence, and virtual technology. The boundaries between humans, machines, and other resources are becoming increasingly blurred. Information and communication technology significantly impact various aspects of life, including the education system in Indonesia.

Lase (2019) stated that changes in this era are unavoidable by anyone. Therefore, proper HR preparation is necessary so that every individual is ready to adapt and compete globally. Improving the quality of human resources through education, from elementary to secondary to higher education, is key to facing the development of the Fourth Industrial Revolution.

The rapid development of the times demands that humans survive by anticipating changes through mastering 21st-century skills. Mastering these skills is crucial because people in this era must develop soft and life skills. One of the essential 21st-century skills is critical thinking ability.

According to Johnson (2009), critical thinking is a directed and clear process used in mental activities such as problem-solving, decision-making, persuasion, assumption analysis, and scientific research. Critical thinking ability includes organized reasoning and systematic evaluation of one's own and others' opinions.

According to Dewey & Fisher (2009), critical thinking is fundamentally an active process of deep thinking about various matters, questioning oneself, and seeking relevant information independently rather than accepting something from others. Johnson (2009) states that critical thinking aims to achieve deep understanding. Faiz (2012) explains that the simple goal of critical thinking is to ensure that our thoughts are valid and correct. With critical thinking skills, students will be able to solve the problems they face.

However, the reality is that students' critical thinking skills in Indonesia could be significantly improved. This is evidenced by interviews conducted at a public high school in Bandung with a physics teacher, who stated that students' critical thinking skills are still lacking due to several factors, such as internal factors, external factors, behaviour, and the learning process, which generally focuses on developing memory and comprehension aspects. This is also reflected in the 2015 Programme for International Student Assessment (PISA) survey, which showed that Indonesian students' scores in solving problems requiring critical thinking were still low, ranking 69th out of 76 countries.

Students' low critical thinking ability indicates a gap between expectations and reality. Susilowati (2018) mentioned several factors influencing this, including teacher factors, student factors, and other supporting factors in the learning process. Redhana (2013) identified one cause as the teacher-centred learning condition, where teachers must utilize the environment in the learning process, preventing students from mastering 21st-century skills optimally. Another factor Hidjrawan (2016) mentioned is the need for more effort to connect students with their environment, resulting in low student interest and attention during the learning process, especially in knowledge based on local wisdom. Yunita et al. (2018) added that many students only see and know the given material without understanding it, as they feel the material cannot be applied in everyday life. As a result, students need help applying knowledge and understanding information when solving problems. Prasetyowati (2016) also stated that the teaching methods used do

not target higher-order thinking processes and only focus on conceptual understanding.

One effort to improve students' critical thinking and problem-solving abilities is to expose them to ill-structured or ill-defined problems (Rutherford & Ahlgren, 1990). A learning model believed to develop students' critical thinking skills is the PBL model (Redhana, 2009; Redhana & Sudiatmika, 2010). Additionally, according to Almasarweh and Khudairat (2021), the PBL model is an application-based learning that combines behavioural logic and ethical treatment, thus emphasizing critical thinking characteristics.

The rapid development in the era of the Fourth Industrial Revolution requires humans to survive and find ways to preserve the environment and natural resources while developing prosperity and well-being for the growing population. To support this, the United Nations (UN) declared the Sustainable Development Goals (SDGs) at the 70th General Assembly in New York, USA, in 2015. This significant task is explained in the concept of sustainable development. The global community under the UN agreed to work together in sustainable development. In response, ESD was launched as one of the main solutions for sustainability.

The main concept of ESD is to empower students with sustainable skills through a holistic, interdisciplinary approach and democratic, pluralistic, and learner-centred teaching strategies. As a result of the UN Decade of Education for Sustainable Development, ESD has been adopted worldwide (DESD; 2005–2014). Despite a global commitment to ESD as a teaching method, empirical evidence on (1) the extent to which ESD is implemented in classrooms and (2) its impact on student learning outcomes (such as knowledge, attitudes, and behaviours related to sustainable development) remains limited.

According to Mahat and Idrus (2017), addressing this issue requires the application of the ESD concept at various school levels. The implementation of ESD at the school level is considered effective in increasing the awareness of the current generation to appreciate the environment for future generations. To achieve this goal, teachers' roles as effective agents of change in implementing the concept of education for sustainable development are crucial (Liu, 2009). One way to implement the ESD concept is through learning activities integrated with sustainable development goals.

However, many schools still need to implement the concept of ESD. This is evidenced by an interview at a public high school in Bandung, where a physics teacher stated that many teachers still need to integrate the ESD concept into their teaching. For example, the learning materials have not been linked to sustainable development goals, so students' awareness of sustainable development has not been formed, and the materials and concepts studied still need to implement ESD.

UNESCO (2017) states that eight key competencies are essential for supporting sustainable development. These competencies include systematic thinking, anticipatory thinking, normative thinking, strategic thinking, collaborative skills, critical thinking, self-awareness, and integrated problem-solving. Students must develop these competencies through experiential and reflective actions. Critical thinking is also considered important in promoting sustainable development among these competencies. Experience and action-based reflection can be achieved through the ESD approach and PBL processes. Applying the ESD approach in the PBL model is expected to be an educational

innovation that can enhance students' critical thinking skills.

Therefore, based on the issues previously discussed, a learning model that can improve students' critical thinking skills is needed. Among the many learning models, the PBL model with the ESD approach is a model that can develop critical thinking skills and train students to care about aspects of sustainable development. This is because students explore existing problems and can connect these problems with environmental, economic, and social aspects. One of the physics subjects that can incorporate the ESD approach is global warming. The subject of global warming also supports future life, and it is hoped that students will become more aware of issues surrounding global warming. Based on the explanations outlined above, the researcher feels the need for a study on "The Application of the Problem-Based Learning (PBL) Model with the Education for Sustainable Development (ESD) Approach to Enhance Students' Critical Thinking Skills on Global Warming Material in Grade XI."

METHOD

The research method used in this study is quantitative and pre-experimental, using a One-Group Pretest-Posttest design. Campbell and Stanley (2015) explain that this design involves one group of subjects measured before and after a treatment (intervention). It has three basic stages: pretest, treatment, and posttest. The One Group Pretest-Posttest design uses only one experimental class, generally illustrated by Table 1.

Tabel 1 One group pretest – posttest design

O_1	X	O_2

Information:

X = treatment; O_1 = Pretest; O_2 = Posttest

In practice, the researchers formed a group, which was then given an initial test (pretest) as a baseline to measure the effect of the treatment to be tested. After the pretest, the group was given the treatment of problem-based learning with the ESD approach. The group was then given another test (posttest) as a subsequent reference. After the treatment, students were given a sustainability awareness questionnaire to measure their awareness of sustainability after receiving the problem-based learning treatment with the ESD approach.

The participants in this study are 11th-grade students from a public high school in Bandung, majoring in MIPA (Mathematics and Natural Sciences), consisting of one class with a total of 38 students. Participants are active students aged 16-18 years. The population in this study is 11th-grade MIPA students at a public high school in Bandung. The sample was taken using convenience sampling from 11th-grade MIPA students in the even semester of the 2022/2023 academic year.

Al-Najdi et al. (2005) explain that the PBL strategy consists of four learning steps: identifying students' prior knowledge, dividing tasks among students after splitting them into subgroups, supervising and observing students in the classroom, and initiating dialogue with students. Finally, each group presents their proposed results and explanations for the problem.

Broadly, Wheatly (1991) explains that the PBL strategy consists of three main basic elements: assignments, cooperative groups, and sharing. PBL assignments are the foundation of the problem-based learning strategy. The proper and accurate selection of tasks is the parameter for the success or failure of this strategy. Therefore, according to Al-Huthaifi (2002), the tasks given should be simple: direct students to explore, guide students to make decisions, encourage students to ask questions, promote discussion, dialogue, and

communication, be engaging, and be attractive.

Furthermore, according to Al-Syahrani (2010), to apply the principles of cooperative learning, students will be divided into small groups of three to six people. Based on scores from one of the performance tests, each group should have students with diverse academic achievements. This allows them to work together to plan or propose appropriate solutions to the problem.

Sharing is the third phase in the Wheatly model, where all cooperative groups participate. The teacher guides them to discuss the students' solutions, evaluate them, and integrate them into the scientific results known to all members (Abdul-Jaleel, 2000).

The instruments used in this study consist of three types: an instrument to measure critical thinking skills, an instrument to measure the profile of sustainability awareness, and an instrument to measure the implementation of learning.

The instrument for implementing learning is an observation sheet for the implementation of the learning model used. The observation sheet is used to check whether the problem-based learning model with the ESD approach is applied and how the students react. An observer fills out this observation sheet using a checklist and a notes column. Indicators that are implemented are scored 1, and indicators that are not implemented are scored 0. To determine the category of treatment implementation, it can be interpreted as shown in Table 2.

Table 2 Interpretation of the percentage of learning activity implementation

Percentage of Implementation (α)	Criteria
$\alpha \leq 20$	Very weak
$20 < \alpha \leq 40$	Weak
$40 < \alpha \leq 60$	Moderate
$60 < \alpha \leq 80$	Good
$\alpha > 80$	Very good

In addition to using percentages, the implementation of learning can also be seen by analyzing the notes provided by the observer who directly observes classroom learning.

The research instrument used to measure students' critical thinking skills in this study is a pretest and posttest in the form of multiple-choice questions totalling 20 questions on global warming material to determine the application of the PBL model with the ESD approach to critical thinking skills.

Facione (1990) states that critical thinking is a process aimed at proving, interpreting, and solving problems. Core critical thinking skills include interpretation, analysis, inference, evaluation, and explanation. Therefore, critical thinking encompasses five core skills: (1) interpretation, which is understanding the meaning of something; (2) analysis, which is evaluating something in depth through data and information; (3) inference, which is concluding the data collected; (4) evaluation, which is assessing the credibility of the conclusions drawn; and (5) explanation, which is conveying truth, reasons, and evidence. Based on Facione (1990), the distribution of aspects of ability in the critical thinking skills instrument is shown in Table 3.

Table 3 Distribution of aspects of critical thinking skills in the critical thinking skills instrument

Aspect of Critical Thinking Skill	Question Number
Interpretation	1,7,11,17
Inference	2,3,12,13
Explaining	4,8,14,18
Analyzing	5,9,15,19
Evaluating	6,10,16,20

These questions are given during the pretest and posttest, with each correct answer scored one and each incorrect answer scored 0. The results from the pretest and posttest are analyzed using normalized gain (n-gain) developed by Hake (1999).

The test results obtained from the pretest and posttest are processed according to the results of the data normality test. The criteria shown in Table 4 are used to interpret the normalized gain (n-gain) values obtained from the above calculations.

Table 4 Normalized gain (n-gain) criteria

<g>	Criteria
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Students' sustainability awareness is obtained from filling out a checklist questionnaire consisting of 54 statements, processed using the Guttman scale. The Guttman scale is a measurement method that can be used for multiple-choice questions. This scale can also be applied in the form of a checklist and will result in definite answers such as "true-false," "positive-negative," "yes-no," etc., with interval data. In the Guttman scale, answers can be scored with a maximum of one and a minimum of zero, with a score of 1 for yes and 0 for no. From the 54 statements in the sustainability awareness questionnaire, the sustainability awareness profile consists of 3 categories, each represented by several statement items with the distribution shown in Table 5.

Table 5 Distribution of question items in sustainability awareness categories

Sustainability Awareness Category	Items
Sustainability Practice Awareness	1 – 18
Behavioural and Attitude Awareness	19 – 54
Emotional Awareness	37 – 54

In this study, sustainability awareness is categorized into three categories, according to a journal adopted by Fang et al. (2022): sustainability practice awareness, behavioural and attitude awareness, and emotional awareness.

Hanisch and Eirdosh (2023) explain that sustainability practice awareness or awareness of actions and practices that support sustainability helps students analyze and evaluate sustainable development practices, impacting their critical thinking skills for long-term understanding of their actions. Meanwhile, behavioural and attitude awareness or awareness of how behaviour and attitudes affect others and the environment relates to critical thinking involving reflection and analysis of behaviour and attitudes in helping students consider the various impacts of their actions from different perspectives. Lastly, emotional awareness or awareness of one's own or others' emotions and the ability to manage these emotions relates to critical thinking by helping students control emotional responses to think more objectively and reduce bias in decision-making. These three aspects enhance critical thinking skills because they require deep analysis, good reflection, and objective decision-making.

The meaning obtained from the percentage of each sustainability awareness category can be shown in Table 6.

Table 6 Percentage of sustainability awareness

Percentage Respon Sustainability Awareness	Meaning of Response Percentage
0.0 – 50.0 %	Practices that seldom or dislike to be done
51.0 – 70.0 %	Practices that are done/happened moderate/medium
71.0 – 100 %	Practices/feelings that are most likely one/happened

Fang et al. (2022) explained that the percentage of responses "Practices that seldom or dislike to be done" in the Sustainability Awareness response refers to the percentage of individuals who rarely or do not like to engage in practices that support sustainability. This reflects the number of people who could be more involved or more interested in actions to maintain social, economic, or environmental sustainability. The percentage of responses "Practices that are done/happened" refers to the percentage of individuals who engage in sustainable practices with moderate frequency or occurrence. This means that people in this category sometimes engage in actions that support sustainability, but only sometimes. Meanwhile, the percentage of responses "Practices/feelings that are most likely done/happened" refers to the percentage of individuals who frequently engage in sustainable practices. This means that people in this category often or always consistently engage in actions supporting sustainability.

RESULTS AND DISCUSSION

Two observers assess the implementation of learning through an observation sheet. The observation assessment data are processed to calculate the percentage of learning implementation. The following is a recapitulation of the implementation of the PBL model with the ESD approach shown in Table 7.

Table 7 Recapitulation of the percentage of learning implementation

Meeting	Percentage of Learning Implementation by Observer (%)				Average of Percentage Implementation (%)	Category
	Observer I		Observer II			
	Teacher	Student	Teacher	Student		
1	86.76	94.23	76.47	75	83.11	Very Good
2	82.35	96.15	80.88	92.30	87.92	Very Good
Average					85.51%	Very Good

The assessment results of the learning implementation by student activity in the first meeting were 94.23% and 75%, with an average of 84.61%, categorized as "Very good" according to Table 2. This was because the students were still adapting, resulting in confusion and less conducive group discussions. In the second meeting, the learning implementation by student activity was 96.15% and 92.30%, with an average of 94.22%, categorized as "Very good". The increase in percentage from the first to the second meeting was due to the students adapting to the learning activities and the learning environment becoming more conducive as the teacher was stricter than in the first meeting.

Based on Table 7, the overall average percentage of learning implementation was 85.51%. The overall learning implementation category falls into the "Very good" category. Thus, this study executed PBL with the ESD approach to the global warming topic very well.

The advantages and disadvantages of PBL with the ESD approach to global warming are as follows. The advantages of this learning activity include that students become more active because they work in groups, share ideas, respect each other's opinions, and face real-life problems they encounter daily. This also enhances students' understanding of the material and critical thinking skills, deepens comprehension, makes learning more meaningful, and improves communication and collaboration skills useful in everyday life. The disadvantage is that this learning activity takes more

time than traditional methods because students must go through several stages, such as problem identification, information gathering, and data analysis. Therefore, if the teacher cannot motivate students in this learning activity, students who lack motivation or have difficulty managing time may struggle to effectively follow the PBL with the ESD approach.

Data to determine the profile of students' critical thinking skills were obtained from the results of the students' pretest and posttest answers using multiple-choice instruments. The profile of students' critical thinking skills after the implementation of the PBL model with the ESD approach is shown by calculating the N-Gain <g> values based on the average pretest and posttest scores in Table 8.

Table 8 Recapitulation of students' critical thinking skills test results

Average of Pretest	Average of Posttest	<g>	Category
67.63	84.61	0.524	Medium

Based on Table 8, the overall N-Gain value from the critical thinking skills test results is 0.524, categorized as "Moderate", according to Table 3 by Hake (1999). Thus, it can be concluded that, in general, students' critical thinking skills improved after the implementation of the PBL model with ESD approach. This is because the PBL model with the ESD approach encourages students to be more active and to use their critical thinking skills. Students are required to be more active in formulating problems and finding solutions, thereby enabling them to think more critically as they do not just passively receive explanations from the teacher.

According to Facione (1990), critical thinking skills include several aspects: explaining, inferring, analyzing, and evaluating. Each aspect is represented by many questions included in the pretest and posttest. The N-Gain results for each aspect are examined to understand the application of PBL with the ESD approach to the global warming topic on each aspect of critical thinking skills. The following are the N-Gain results for each aspect of students' critical thinking skills based on the pretest and posttest results, as shown in Figure 1.

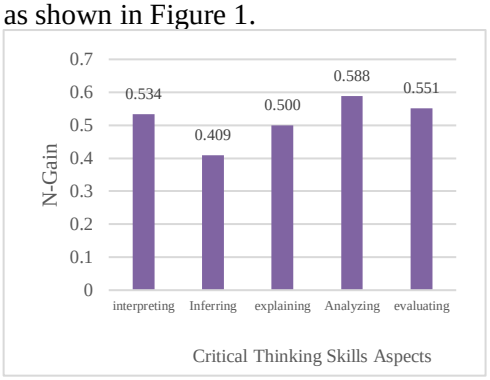

Figure 1 Improvement in students' critical thinking skills in each aspect

The N-Gain values for the evaluating, interpreting, and explaining aspects are approximately the same: 0.551 for the evaluating aspect, 0.534 for the interpreting aspect, and 0.5 for the explaining aspect.

Despite the variation in the N-Gain values obtained by each aspect after the implementation of PBL with the ESD approach, all aspects of critical thinking skills fall into the "Moderate" category. Therefore, it can be concluded that the application of PBL with the ESD approach can improve each aspect of critical thinking skills on the global warming topic, with a "Moderate" category in each aspect.

The profile of students' sustainability awareness after the PBL process with the ESD approach was obtained using a sustainability awareness questionnaire. This questionnaire contains 54 statements divided into three categories: sustainability practice awareness, behavioural and attitude awareness, and emotional awareness. Each category includes statements addressing

sustainable development's environmental, economic, and social aspects. The recapitulation of respondents' responses to the sustainability awareness questionnaire is shown in Table 9.

Table 9 Recapitulation of students' responses to the sustainability awareness questionnaire based on aspects of sustainability awareness

Aspect of Sustainability Awareness	Percentage
Sustainability practice awareness	66.94%
Behavioural and attitude awareness	70%
Emotional awareness	84.86%

Based on Table 9, the percentage for sustainability practice awareness, or conscious efforts and sustainable practices, is 66.94%. According to Fang et al. (2022), the category of sustainability practice awareness after the implementation of PBL with the ESD approach falls into the "Moderately Done" category. This means that students' conscious efforts and sustainable practices are still in the habituation stage and must be consistently done.

Based on Table 9, the percentage for behavioural and attitude awareness, or behaviour and attitudes towards sustainable development, is 70%. According to Fang et al. (2022), the category of behavioural and attitude awareness after the implementation of PBL with the ESD approach falls into the "Moderately Done" category. This indicates that students' behaviour and attitudes towards sustainable development are still in the habituation stage and still need to be consistently done.

For the category of emotional awareness, or concern for sustainable development, based on Table 8, the percentage is 84.86%. According to Fang et al. (2022), the category of emotional awareness after the implementation of PBL with the ESD approach falls into the "Often Done" category. This means students' concern for sustainable development is frequently and consistently done.

CONCLUSION

PBL with the ESD approach to global warming was implemented very well, achieving an average of 85.51%. This implementation also improved students' critical thinking skills with an N-Gain of 0.524 (moderate category). Moreover, PBL with the ESD approach positively impacted students' sustainability awareness. This is because PBL with the ESD approach plays a role in integrating learning with sustainability values, developing problem-solving skills, and encouraging students to actively participate in learning, which impacts their concern for environmental, social, and economic sustainability. Additionally, PBL with the ESD approach encourages students to think critically and creatively when faced with real problems. This is evidenced by the average total sustainability awareness of students being 73.94%, indicating that students often or always consistently engage in actions that support sustainability.

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