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Application of PBL Model Differentiated Learning to Improve Critical Thinking Skills in Work and Energy Materials in Junior High School

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Abstract. This study aims to test the effect of the application of the Problem Based Learning (PBL) learning model based on differentiated learning on the improvement of students' critical thinking skills in work and energy materials at SMP Negeri 2 Selakau Timur. This study uses a quantitative method with a pre-experimental experiment design, namely by using one pretest-posttest group. The results of the study show that the application of the PBL model based on differentiated learning is able to significantly improve students' critical thinking skills. The average score of the pretest students was 17.25, while after the implementation of PBL learning, the posttest score increased to 84.83. This increase is evident with an N-gain value of 0.81, which indicates a high category of improvement. In addition, the implementation of differentiated learning with the PBL model reached an average of 90-92%, indicating that the learning went well and as expected. Based on the results of this study, it can be concluded that differentiated learning with the PBL model is effective in improving students' critical thinking skills, especially in work and energy materials.

Keywords: problem based learning, differentiated, critical thinking

1. Introduction

Natural sciences are a broad learning material and integrated with the fields of chemistry, biology, and physics. Science is active learning that involves students to play an active role in the search and development of knowledge. At the junior high school level, science learning is taught in an integrated or intact manner and cannot be separated [1]. The science learning process in each educational unit should be held in an interactive, inspiring, fun, challenging, motivating students to participate actively, and providing sufficient space for initiative, creativity, and independence in accordance with the talents, interests and physical and psychological development of students [2].

Critical thinking refers to the ability to analyze information, determine the relevance of collected information, interpret it, and solve problems [3]. Students who are less involved in learning and students who have difficulties in understanding this learning material result in a lack of critical thinking skills in science subjects. Critical thinking means that they are able to solve problems both in daily life and case studies (science questions) that are able to make them think about the concepts they are facing.

In physics learning, there are still many students who lack critical thinking skills and low learning outcomes [4]. This is because students are still not actively involved in observing and understanding the physical phenomena around them, and there is still a traditional learning system that hinders students from learning actively and creatively [5].

Based on the results of an interview with one of the science teachers of SMP Negeri 2 Selakau Timur, informationwas obtained that students had low learning outcomes under the minimum completeness criteria (KKM). due to the lack of students' understanding of the concept of the material taught. This is because teachers still use conventional learning models, so students are still unable to analyze problems

that occur in daily life. Students who are less involved in learning and students who have difficulties in understanding this learning material result in a lack of critical thinking skills in science subjects.

This *problem-based learning* (PBL) model is a student-centered learning model in contextual problems, which requires investigation efforts in an effort to solve problems [6]. However, the application of the PBL model alone may not be enough to accommodate the learning needs of each student. Therefore, a learning strategy is needed that is able to accommodate the learning needs of each student or what is called a differentiated learning strategy. Differentiated learning is suitable for science learning, such as physics subjects, because it is able to accommodate the learning needs of students by paying attention to the learning readiness of the students [7].

The results of previous research stated that differentiated learning with the PBL model was able to improve students' learning outcomes and mathematical creativity, but previous researchers had not measured critical thinking skills using differentiated learning with the problem-based learning model, especially in physics materials [8]. This study aims to measure critical thinking skills and the implementation of learning before and after applying the Problem Based Learning model on work and energy materials at SMP 2 Selakau Timur.

2. Method

The model used in this study is a quantitative research model with an experimental research method [9]. The results of *the pre-experimental design* research are dependent variables (bound) and not solely influenced by independent (independent) variables. The design used in this study is *a one-group pretest-posttest design* [10].

Table 1. One-group pretest-posttest research design.

Pretest	Treatment	Posttest
O_1	X	O_2

Through *the pre-experimental design one-group pretest-posttest* can produce more accurate experimental results because at the beginning of the study the *pretest* is carried out first before being given treatment and given *a posttest* after being given treatment, so that researchers can compare before and after treatment.

This study's population is all class VIII B students in junior high school for the 2024/2025 school year. The sampling technique uses simple random sampling, then *Simple Random Sampling* is the taking of sample members from a population that is carried out randomly without paying attention to the strata in that population[10]. The sample used in this study is one class with a total of 31 students.

There are three techniques used for data collection, namely measurement techniques, documentation study techniques, and observation techniques. The measurement technique used in this study is in the form of scoring the answers to the initial test questions for before and after. The documentation used is in the form of photos of activities in learning that use learning strategies. The observation technique used uses direct observation techniques. The observation that was directly carried out in this study was learning activities in the classroom.

The research instruments are in the form of modules, student worksheets (LKPD), and test questions that have been validated by two physics education lecturers and one junior high school science teacher. The test questions used have also been tested for reliability using the SPSS program with the Alpha Cronbach formula, so that the test instrument can be used repeatedly to collect data.

In quantitative research, data analysis activities are grouping data based on variables and types of respondents, tabulating data based on variables and types of respondents,presenting data for each variable being studied, performing calculations to answer problem formulations, and performing calculations to test the hypothesis that has been put forward [11].

The application of differentiated learning is carried out through mapping learning needs to help teachers develop activity plans that are appropriate and in accordance with student needs. This mapping is based on the student's learning readiness, which is the capacity to learn new material. Students' readiness levels are factored into tasks that push them out of their comfort zones, but with the right learning environment and adequate support, they can still grasp new material.

The learning process that uses the PBL learning model consists of 5 syntax, namely student identification of problems, organization of student study groups, guidance of investigation, development and presentation of work results, and evaluation of the problem-solving process or conclusion. The steps of the PBL model are as follows: (1) orient students to problems; (2) organizing students to learn; (3) guiding individual and group investigations; (4) developing and presenting works; (5) analyze and evaluate the problem-solving process [12].

Questions and indicators of critical thinking are shown in Table 2.

Table 2. Questions and indicators of critical thinking.

No.	Critical thinking indicators	Questions
1.	*Elementary clarification* (focusing on the question)	Two people were presented who conducted the experiment. Students were asked to explain the efforts made by the two people.
2.	*Basic support* (Building basic skills), (Observing and considering a report of observation results)	Presented with illustrations, students can give reasons why there are differences in styles in two people who walk on different tracks.
3.	*Inference* (Making and determining the value of consideration)	Presented with narratives and graphs of potential energy and kinetic energy, students can draw conclusions about the relationship between potential energy and kinetic energy appropriately.
4.	*Advanced clarification*	Presented with data, objects that fell at different heights, students were able to provide an explanation of which objects fell deeper.
5.	*Strategies and tactics*	Presented a narrative about roller coasters, students analyze the minimum speed of roller coasters in certain positions.

3. Results and Discussion

To analyze the profile of critical thinking skills before and after the application of differentiated learning with the Problem Based Learning model, it can be seen in Table 3.

Table 3. Descriptive statistical data.

Descriptive Statistics	N	Minimum	Maximum	Mean	Std.Deviation
pretest	31	5	40	17,26	9,56
Posttes	31	75	95	84,84	5,08
Valid N	31				

Table 3 shows the descriptive statistics of students' critical thinking skills scores in *the pretest* and *posttest*. In *the pretest*, the **N** score was 31, with a minimum score of 5 and a maximum score of 40, and a mean of 17.26 which indicates a low level of critical thinking skills before the treatment, with a standard deviation of 9.56 indicating considerable variation among the students. Meanwhile, in the *posttest*, the **N** score remained at 31, with a minimum score of 75 and a maximum score of 95, as well as an average (mean) of 84.84, showing a significant increase after the implementation of differentiated learning with the Problem Based Learning model. The standard deviation in the *posttest* was 5.08, which was lower than the *pretest*, indicating that most students achieved higher and more even scores after learning. Thus, these data show a significant improvement in critical thinking skills after treatment, which will be further analyzed in Table 4.

Table 4. Pretest and posttest score data.

No.	Critical thinking skills indicators	Experimental Classes		
		Pretest	Posttest	$((\Delta\bar{x}))$
1.	Giving a simple explanation	29,03	87,90	58,87
2.	Build basic skills	7,26	80,65	73,39
3.	Conclusion	4,03	77,42	73,39
4.	Providing further explanation	43,55	92,74	49,19
5.	Setting up strategies and techniques	2,42	85,48	86,06

Table 4 shows the score data of each indicator of critical thinking skills of students in the experimental class before (*pretest*) and after (*posttest*) were given treatment. From the table, it can be seen that each indicator has experienced a significant improvement after the implementation of differentiated learning with the *Problem Based Learning* model. For example, in the indicator "Providing a simple explanation," the average score of students increased from 29.03 in *the pretest* to 87.90 in *the posttest*, with an increase of 58.87. The "Building basic skills" indicator also showed a significant improvement, with the score rising from 7.26 on the *pretest* to 80.65 on *the posttest*, an increase of 73.39 points. Likewise, the "Conclusion" indicator, which increased from 4.03 to 77.42, as well as the "Providing further explanations" and "Managing strategies and techniques" indicators, each increased by 49.19. This significant improvement shows that the application of the problem-based differentiated learning model is effective in improving students' critical thinking skills[13]. This model allows teachers to tailor learning to the individual needs of learners, which in turn stimulates their ability to think more critically and deeply [14].

Furthermore, the Wilcoxon Signed Ranks Test was used to analyze whether there was a difference between the pretest and posttest scores because the data was not normally distributed. The results of the Wilcoxon Signed Ranks Test can be seen in Table 5.

Table 5. Wilcoxon Signed Ranks Test.

Test Statistics[a]	
	Postes - Pretest
Z	-4,871[b]
Asymp. Sig. (2-tailed)	,000
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

Based on the results of the Wilcoxon Signed Ranks Test, a Z value of -4.871 was obtained with an Asymp value. Sig. (2-tailed) by 0.000. Because of the value of Asymp. Sig. < 0.05, it can be concluded that there is a significant difference in students' critical thinking skills before and after the implementation of differentiated learning with the PBL model.

After knowing the difference in *pretest* and *posttest* scores, the next step is to use the N-gain formula to find out the difference in improving students' critical thinking skills. The data on the category of improving students' critical thinking skills can be seen in Table 6.

Table 6. N-gain score.

N	Experimental Classes		
31	Minimum	maximum	*N gain Score*
	70,59	94,44	0,81

Based on Table 6, the results of the calculation of the N-gain score show that the average N-gain value of 0.81 is in the high category. So that students' critical thinking skills have experienced a significant increase after the implementation of learning. This shows that differentiated learning with *the Problem Based Learning* model is effective in improving students' critical thinking skills in Work and Energy materials.

Before the implementation of differentiated learning, of course, researchers identify the learning needs of students. At the beginning of the learning activity, the researcher carried out a cognitive diagnostic test in order to find out the student's learning readiness through the pretest. That way the results of the learning readiness test from each student can be seen directly. Learning Readiness refers to the level of ability or readiness of a student to receive and understand the learning materials given [15]. Learning readiness is influenced by various factors, such as prior knowledge, cognitive skills, and student motivation [16]. Based on the results of diagnostic tests, students' learning readiness can be grouped into three categories [17]:

1. Newly Developed
   Students at this stage have a limited basic understanding and require a lot of guidance and repetition of the material to strengthen their understanding. They may have difficulty in connecting new information with previous knowledge.
2. Growing
   Students at this stage can understand and work on most of the material with little guidance. They have developing cognitive skills and are beginning to be able to apply knowledge in simpler contexts.
3. Proficient
   Advanced students have a deep and broad understanding of the material. They can apply their knowledge independently to more complex problems and have high critical thinking skills.

The PBL approach with differentiation begins with an initial assessment to understand the student's needs, followed by a flexible project design that allows for the choice of content, processes, and products. During the implementation, teachers manage heterogeneous groups, provide scaffolding, and monitor progress with formative assessments. The project concluded with product presentations in a variety of formats of students' choice, accompanied by feedback and reflection that strengthened students' skills and understanding, as per recent research demonstrating its effectiveness in supporting meaningful learning. the implementation of differentiated learning with the *Problem Based Learning* (PBL) model on Work and Energy materials, the implementation of learning activities can be calculated using the formula [18]. The following table 7 presents the average learning implementation at two different meetings.

Table 7. Implementation of learning.

No.	Activity Stages	Percentage Per Meeting	
		Meeting -1	Meetings - 2
1.	Introduction	100 %	100 %
2.	Problem Orientation	100 %	100 %
3.	Organizing students into groups	100 %	100 %
4.	Guiding Group Investigations	100 %	100 %
5.	Interpreting the results of group discussions	83,33 %	66,66 %
6.	Analyzing and Evaluating	50 %	75 %
7.	Cover	100 %	100 %
	Average	90 %	92 %

The implementation of differentiated learning with the promulgation-based learning model of students can also be seen based on the percentage of implementation. Based on the results of the percentage of implementation obtained 90%-92%. With this value, it shows that differentiated learning with a problem-based learning model can be categorized as well implemented. Through the implementation of differentiated learning, it aims to facilitate students with learning that suits their characteristics and needs. According to [19] differentiated learning based on initial readiness provides opportunities for students to participate in learning activities as they wish and helps them learn efficiently. Problem Based Learning can be used to help students develop critical thinking skills or problem-solving skills.

The PBL model aims to improve students' critical thinking skills[20]. This model involves five steps, namely:

1) Problem reformation

At this stage, the educator ensures that each student actively participates in the learning process by forming small groups consisting of five to six students. Differentiated learning is applied to align with the students' learning readiness. The students search for information and strategies through group discussions to solve the given problem. Each student shares their thoughts and records the discussion results in the Group Discussion Support Worksheet (LKPD). The aim of this group discussion is to help students understand the problem more easily and deeply, as well as to enhance their critical thinking skills and ability to retain the information received.

2) Organizing students into groups

At this stage, the teacher ensures that all students actively participate in the learning process by using a differentiated learning approach. The researcher forms small groups (5-6 students) to help them understand the given problem and share ideas. During the group discussion, students search for information and strategies to address the problem, while also recording their thoughts in the Group Discussion Support Worksheet (LKPD). This group discussion helps students understand the material more easily and aids them in retaining the information they receive.

3) Providing assistance to students in the implementation of tasks,

At this stage, the researcher provides direct assistance to the students as they carry out their tasks, such as offering additional explanations, examples, or questions to help students think more deeply. This assistance is tailored to the needs of each student, both individually and in small groups, to ensure they can understand and complete the task effectively.

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4) Developing the results of the discussion,

In this study, each group was asked to write a report in the form of a poster that clearly explained the results of the group discussion. Each group then gave a poster presentation in front of the whole class. Presentations follow a specific numerical order, and each learner must present his or her work in a group or participate in a presentation. However, in the learning process, even though each group is asked to make a poster and present it, there are problems such as lack of involvement of all students, ineffective time management, and presentations that do not always follow the prescribed order, thus hindering the optimal development of discussion results. Therefore, improvements are needed in time management, a more equitable division of roles, and stricter supervision from researchers to ensure that every student actively participates and the presentation takes place in a structured manner.

5) Analyze and evaluate.

In this phase, the researcher supports students in analyzing and evaluating problem solutions and research results. For example, about roller coasters, students are asked to analyze the effort and energy that occurs during the roller coaster ride. They evaluated the solutions found regarding potential and kinetic energy changes. Problems that arise include a lack of in-depth understanding of physics concepts, an imbalance of contributions to discussions, and difficulties for groups who are not present to provide constructive responses. Nonetheless, students who attended gave responses and evaluations to the presentations of other groups, while those who did not attend were given the opportunity to ask questions after the presentation, which strengthened the evaluation process and improved overall understanding of the material.

4. Conclusion

The learning with the PBL model implemented through a differentiated approach successfully enhanced students' critical thinking skills. This is evidenced by the significant difference between the pretest score (17.25) and the posttest score (84.83), which indicates a very high improvement. The N-gain value of

0.81 indicates the effectiveness of the learning model in promoting students' critical thinking skills. Differentiated learning with the PBL model is able to accommodate each student's learning needs, in accordance with their interests, learning styles, and readiness. Observation results show that this learning was carried out effectively, with an implementation level of 90%-92%, indicating that the application was effective and provided space for students to learn actively and creatively.

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