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Differentiated Learning Through Problem Based Learning Model to Improve Students' Critical Thinking Skills on Heat and Its Transfer

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Abstract. This study aims to determine the profile of skills and improvement of critical thinking of students before and after implementing differentiated learning through the Problem Based Learning model on the material of heat and its transfer. The method used is a Pre-Experimental Design with a One Group Pretest-Posttest Design. The research sample consists of one class with 31 students. The research data were obtained by providing a critical thinking skills test in the form of pretest and posttest questions consisting of 5 essay questions. The results show that the average score for the pretest is 47.90% (medium category) and the posttest is 69.03% (high category). Based on calculations using paired sample tests, a sig (2-tailed) value of 0.00 < 0.05 indicates a significant improvement in posttest scores after treatment with differentiated learning through the Problem Based Learning model. Therefore, it can be concluded that differentiated learning with the Problem Based Learning model can enhance students' critical thinking skills on the topic of heat and its transfer.

Keywords: differentiated learning, problem based learning, critical thinking

1. Introduction

Education is an effort that is carried out consciously and planned, namely to create a pleasant learning atmosphere so that students can actively develop their potential [1]. One of the challenges in education is that education must be able to produce human resources who have the ability to face various challenges of life. Quality human resources, namely being able to think critically, creatively, systematically, being able to solve problems, and having noble character [2]. One way to improve the quality of human resources is to improve the quality of education first. One of the government's efforts to improve the quality of education is through the independent curriculum which is currently being implemented in schools. Where one of the characteristics of the independent curriculum is implementing a more interactive and collaborative learning method [3].

Natural science (IPA) is one of the main subjects in the current education curriculum in Indonesia. Science learning is a teaching and learning activity that emphasizes the process of investigating natural phenomena to develop the attitudes, skills, and knowledge of students [4]. The objectives of learning Science (IPA/Physics included in it) are to improve students' thinking skills so that students are not just memorizing, but also being able and skilled in the psychomotor field [5]. This means that science learning does not only make students just know and memorize but is designed so that students become individuals who are skilled in critical thinking. The special characteristic of science learning is carrying out scientific work so that it can produce a product and process, from there various thinking skills and critical thinking skills emerge [2]

However, in reality, science/physics learning in schools only emphasizes the aspect of concept mastery and is carried out with conventional learning models. This causes a lack of implementation of skills training so that learning to do in learning has not been achieved [6]. Then there are several other

factors that cause problems in learning physics, namely activity learning Which boring and activities learning in in class No notice need participant educate in Study. Besides that, Teacher teach according to the learning style he wants without caring about the participants educated as a subject of learning [7]. This is in line with research Previously, teachers dominated learning in the classroom. even though students want physics learning activities to be more active and to be able to discuss with friends [8]. Then other factors are explained that learners experience difficulty breakdown problem physics. Matter This due to by a number of factors, including the material they study, learning activities in class, and style teach Teacher [9].

Reason low critical thinking skills of students because students have not been trained to analyze a problem and facts that are found so that the result is productivity that obtained learners in that school very little [10]. This statement is in line with the results of research by Rahmawatiet al. which shows the achievement of students' critical thinking skills measured from five aspects, namely: providing simple explanations, building basic skills, providing conclusions, making further explanations and making estimates and integration. The average percentage of the five aspects of critical thinking skills achieved by students is 45.09 and is included in the very low category [11]. Then from the results of other studies, the critical thinking skills of class IX A junior high school students on biotechnology material are still lacking in critical thinking skills with an average result of 40.62%. Therefore, this needs to be considered by teachers at school, the lack of critical thinking skills in students is not something that can be considered trivial [2].

In addition to the above studies, based on the results of interviews with science teachers, it was obtained that students' critical thinking skills were still below average. In addition, students were still less active in asking questions, only one or two people asked questions and the questions were not continuous. The method often used by teachers is direct learning where teachers use lectures or demonstrations to convey material to students. This means that students are not directly involved in the learning process so that the skills in doing and critical thinking skills of students have not been trained. In relation to these problems, a learning model is needed that can improve students' critical thinking skills. One of the learning models that can be used by teachers is the application of differentiated learning with the problem-based learning model Differentiated learning referred to in this study is a differentiated process that refers to students' learning styles and investigates the improvement of students' critical thinking skills in solving problems on the material of heat and its transfer. By mapping learning groups of students who have auditory, visual and kinesthetic learning styles in one learning group, so that these students will become learning resources for other students. Learning style is the way a person tends to choose to receive, process, and store information from their environment [12]. Students rely on information from oral explanations given by the teacher or can be called an auditory learning style. Then students who rely on information from interesting learning media or are called visual learning styles. As well as students who rely on information from direct practice and relate it to everyday life or can be called a kinesthetic learning style [13].

Differentiated learning is a teaching strategy that focuses on the individual learning needs of students. Differentiated learning includes a teaching approach that is responsive to the needs of students in understanding the subject matter, taking into account the characteristics, abilities, interests, learning styles, and academic potential of students [14]. The application of differentiated learning strategies is able to show learning process activities that are in accordance with the needs of students both in terms of learning readiness, learning interests and learning styles of students. So that the fulfillment of students' learning needs can be met properly [15].

Model problem based learning is a learning model with students as a center in learning activities (student-centered) [16]. The problem based learning model provides problem directly or real Which happen on life daily For made into as material in analyzing so that find A solution in problem With problem based learning, it is expected that students can solve problems with various alternative solutions, and can identify the causes of existing problems [17]. From the results of several Previous research says that the application of the problem based learning model is able to improve participants' critical thinking skills educate [18] [19] [20] [21] [22].

Differentiated learning with the problem-based learning model can have several positive impacts on students and the learning process. Differentiated learning strategies accommodate the learning needs of

each individual student. While the problem-based learning model can help students become more actively involved in class, able to collaborate with friends, independent and can improve critical thinking skills and problem-solving abilities.

Based on the explanation above, researchers need to conduct further research on the application of differentiated learning using problem-based learning models. Increase the critical thinking skills of students. The purpose of this study is to determine the profile of critical thinking skills of students before and after implementing differentiated learning with the problem based learning model. Then to see the increase in critical thinking skills of students after implementing differentiated learning with the problem based learning model. In this study, the author sets several limitations to clarify the direction of the study. The research variables are divided into three categories. The independent variables in this study are the problem based learning model and the differentiated process approach that refers to the learning style of students. The dependent variable is critical thinking skills, which are influenced by the independent variables. Meanwhile, the control variables are heat material and its transfer, and teachers to ensure that the influence of the independent variables is not influenced by external factors. By setting these limitations, the author can maintain the focus of the study and ensure that the study runs in a directed and effective manner. With this research, it is hoped that it can be used as a consideration, reference and solution to improve students' critical thinking skills in learning in class and in their surrounding environment.

2. Method

This research is a quantitative experimental research with the form of research used in this research, namely pre-experimental design with one pretest-group posttest design, which uses one research sample, only the experimental group without any comparison group. Thus the results of the treatment can be known more accurately, because it can be compared with the conditions before and after being given treatment [23].

Table 1. Design study one-group pretest-posttest.

Pretest	Treatment	Posttest
O_1	X	O_2

This study was conducted by SMP Negeri 2 Pontianak in the 2024/2025 academic year with a sample study of Class VII B students, consisting of 31 people. Taking a technique sample in the study, this uses random sampling (simple random sampling). The data collection techniques used in this study are: Measurement techniques in pretest and posttest, unstructured interviews, questionnaires, observation, and documentation. The data collection instrument in this study was a pretest and posttest essay test consisting of 5 questions and was created and adjusted to the indicators of students' critical thinking skills being measured.

Test data analysis technique using the N-gain test score and paired sample t-test assisted by SPSS version 25, by collecting the results of the initial test (pretest) and the final test (posttest) of each student's critical thinking skills. Calculating the percentage of the total score of each student and each indicator of the student's critical thinking skills using the following equation

$$\text{Interpretation of score} = \frac{\text{score obtained}}{\text{total score}} \times 100\% . \quad (1)$$

Table 2. Critical thinking skills category.

Range Score Percentage	Category
≤ 20%	Very Low
21%-40%	Low
41%-60%	Currently
61%-80%	Tall
81%-100%	Very high

As for seeing the increase in critical thinking skills of students after implementing differentiated learning with the problem based learning model , you can use equation 2 namely:

$$\text{N} - \text{gain} = \frac{\text{score posttest} - \text{scorepretest}}{\text{score Maximal} - \text{score pretest}} \times 100\% \quad (2)$$

Table 3. Criteria Index N-Gain [1]

Percentage	Interpretation
$-1.00 \leq g < 0.00$	Happen decline
$g = 0.00$	No happen decline
$0.00 < g \leq 0.30$	Low
$0.31 < g \leq 0.70$	Currently
$0.71 < g \leq 1.00$	Tall

Percentage results pretest and posttest obtained Then served in bar chart form based on category skills think critical participant educate. While For skills think critical every indicator served in form table.

3. Results and Discussion

This study aims to determine the critical thinking skills of students before and after implementing differentiated learning with the problem based learning model on the material of heat and its transfer. Then to find out the increase in critical thinking skills of students after being given treatment. Differentiated learning referred to in this study is differentiated learning that refers to learning styles (visual, audio and kinesthetic) which are integrated in the problem based learning model.

Based on the learning that has been carried out by implementing differentiated learning with the problem based learning model, the results of the study show that there are differences before and after the implementation of differentiated learning through the problem based learning model and there is an increase in critical thinking skills of students in class VII B of SMP Negeri 2 Pontianak after being given treatment.

3.1. *Critical thinking skills of students before and after implementing differentiated learning with the problem based learning model*

To find out the critical thinking skills of students before and after the treatment, namely using pretest and posttest. The pretest is given before the treatment while the posttest is given after the treatment. The results of the pretest and posttest of students are categorized in 5 categories that is very high, high , medium , low and very low . It can be seen from the results of the data analysis presented in the form of a bar chart in Figure 1 which shows that there are differences and there is a significant increase in students' critical thinking skills after implementing differentiated learning with the problem based learning model.

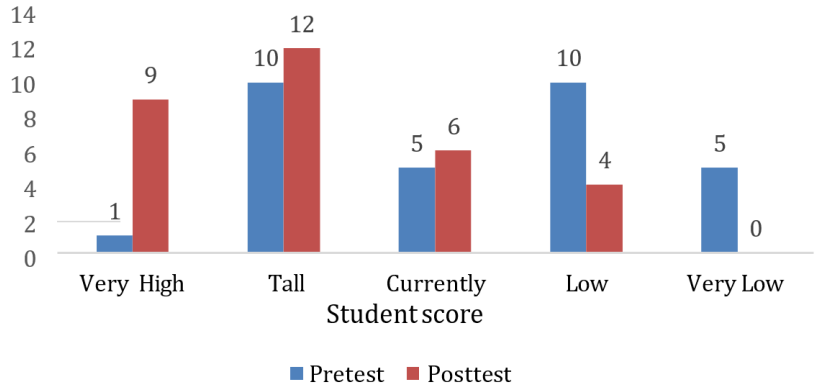

Figure 1. Comparison of pretest and posttest scores of students.

Figure 1 shows the distribution of critical thinking skill scores of each student before and after implementing differentiated learning with the problem based learning model, this can be seen in the pretest and posttest scores obtained by students. Where the most significant category increased was in the very high category, before being given treatment, there was 1 student in the very high category, while after being given treatment it increased to 9 people. While in the very low category, before being given treatment, there were 5 students in that category, after being given treatment, there were no students in the very low score. This shows that the application of differentiated learning with the problem based learning model can have a positive impact on the development of students' critical thinking skills. Not only through the scores of each student, in each indicator of each student's questions also experienced an increase. This increase occurred in all indicators that can be seen in Table 4.

Table 4. Pretest and posttest score data for each indicator.

No.	Critical Thinking Skills Indicators	*Pretest (x)*	Postest (x)	Δx	Improvement category
1.	Analyze	33.06%	54.03%	20.97%	Low
2.	Classifying	50.81%	72.58%	21.77%	Low
3.	Conclude	54.03%	77.42%	23.39%	Low
4.	Ask	40.32%	58.06%	17.74%	Very Low
5.	Compile Strategy	61.29%	83.06%	21.77%	Low
	Average	47.90%	69.03%	21.13%	Low

Based on the indicators of critical thinking skills, students experienced an increase where the analyzing indicator increased by 20.97%, the Classifying indicator increased by 21.77%, the Concluding indicator increased by 23.39%, the Asking indicator increased by 17.74% and the Strategy Formulation indicator increased by 21.77%. With an average pretest score of 47.90% in the moderate category while the posttest score was 69.03% in the high category.

3.2. *Improving students' critical thinking skills after differentiated learning through the problem based learning model*

Based on the results obtained from the pretest and posttest scores of class VII B students of SMP Negeri 2 Pontianak, the first normality test was conducted. The results of the normality test showed the values of the pretest and posttest Probability (sig) > 0.05. This means that Ho is accepted or the data is normally distributed in class VII B. The results of the data normality test can be seen in Table 5.

Table 5. Results of calculating data normality using the Shapiro Wilk test.

	Statistics	df	Sig.
Pretest	,939	31	,079
Posttest	,943	31	,102

Furthermore, because the data is normally distributed, it is continued with a parametric statistical test, namely the paired sample t-test. Based on the calculation through the paired sample test, the sig value (2-tailed) is 0.00 <0.05, so H0 is accepted, so it can be interpreted that there is a significant increase in the posttest value after being treated with differentiated learning with the problem-based learning model. This can be seen from the results of the paired sample t-test in Table 6.

Table 6. Results of the paired sample t-test

t	df	Sig: (2-tailed)	Result
-9,047	30	,000	There was a significant increase in the posttest score because the sig value (2-tailed) was 0.00 < 0.05.

To find out the category of increasing students' critical thinking skills. The results of the N-gain analysis calculation can be seen in Table 7.

Table 7. N-gain calculation results

	N	Mean
Gain_Score	31	,43
Gain_Percent	31	43.11
Valid N (listwise)	31	

N-gain analysis calculation in Table 7, it shows that the increase in critical thinking skills in students has increased by 0.43, which means it is in the moderate category because it is in the N-gain index criteria of $0.31 < g \leq 0.70$ (moderate). Improving critical thinking skills in students cannot be separated from the important role of the 5 steps of the problem-based learning model with differentiated learning strategies. The five steps are orienting students to problems, organizing students to learn, guiding individual and group investigations, developing and presenting work results, analyzing and evaluating.

The first step: orienting students to the problem, in this step the teacher focuses on giving students a problem to analyze. In the problem based learning model, the problems presented are certainly very related to the daily lives of students. In this step, of course, it will train students' critical thinking skills in the analysis indicator. Skills This related with the individual's ability to determine the parts of a problem and show the relationships between the parts, see the causes of an event or provide arguments that support a statement. Students who have good analytical skills will be able to achieve good learning outcomes, while students who have poor analytical skills can hinder the achievement of their learning outcomes [26]. Skills in analyzing are not only able to complete physics calculations but are able to interpret the answers (evaluation) [27]. In this step, teachers can also motivate students to be actively involved in learning and defining problems. Students' critical thinking skills are very much needed in solving a problem. Students who experience the critical thinking process will easily solve a problem [28].

The second step: organizing students to learn, this step begins by dividing students into several groups where one group consists of students who have visual, auditory and kinesthetic learning styles. The goal is for students to help each other and collaborate in solving the problems given, so that these students will become a source of learning for other students. The teacher provides Student Worksheets (LKPD) to each group, this LKPD contains problems that will be solved by students. LKPD already covers all learning styles needed by students. In the visual learning style focuses on sight, then the auditory learning style is a learning style that relies on hearing, in both learning styles the researcher provides videos related to the material. Kinesthetic learning style is a learning style that involves movement such as practicums, the kinesthetic learning style the researcher provides simple practicums by following the steps given in the video. Previous research shows that grouping students affects learning outcomes. The average value of learning outcomes of students who are grouped based on learning styles is higher than students who are grouped not based on learning styles [29]. After dividing students into groups, students discuss in groups to find information or ways to deal with problems that have been given. In this step, it indirectly trains students' critical thinking skills in the indicators of asking and developing strategies. In the indicator of asking, this skill is related to the individual's ability to express questions clearly, questions related to the topic being discussed. This is trained when the teacher gives students the opportunity to ask questions related to problems in the LKPD that are not yet understood by students. While the indicator of developing strategies is related to activities that are carried out consciously and in a planned manner to determine what will be done, for example creating a strategy that can solve a problem, this is trained in group discussion activities. In line with previous research which states that in the second step of problem-based learning, students are able to develop strategies to solve problems and teachers provide students with feedback on strategies [30].

Step three: guiding individual and group investigations, in this step the teacher encourages and guides students to collect information from various sources such as books, the internet and conduct appropriate experiments to obtain explanations and solve problems. At this stage, students with their respective

learning styles will seek solutions then discuss and share information to solve the problems presented. The solutions sought by students are then collected and conclusions are drawn. This activity gives students the opportunity to develop investigation skills so that students' critical thinking skills will emerge and develop. In this step, all indicators of students' critical thinking skills can be trained as an example to solve problems in the LKPD about "melting ice cream" students are trained to find appropriate information to provide solutions to eczema sellers so that the ice cream sold does not melt easily and lasts a long time. In the context of seeking solutions to this problem, students must be able to analyze, apply strategies, classify, ask questions (group discussions) and for the final result conclude. With these skills, of course, students will find it easier to solve the problems given. Problem based learning is a learning model that encourages students to develop critical thinking skills by responding to and seeking solutions to various problems they face [31].

Step four: developing and presenting the results of the work, at this stage each group representative will present the results of their report in front of the class. So that in learning students can respond to each other and share information. This can train the ability to ask questions, provide suggestions or responses. In problem based learning students must be fully involved to solve problems. This is in line with previous research which states that problem based learning is a learning model that accommodates student involvement in learning and problem solving [32].

Fifth step: analyzing and evaluating, in this step the researcher helps students to analyze and evaluate the problem solving and the results of the investigation that has been done. Each student has a different idea according to what is in their mind. This can allow students to experience misconceptions, therefore, the teacher explains or reviews the related material and relates it to problems that have previously been solved by students so that misconceptions do not occur. Then conclude or align the perceptions of each student. Through problem based learning participant educate to obtain experience in handle realistic problems, and emphasizes the use of communication, cooperation and existing resources For formulate ideas and develop skills reasoning [33].

Thus it can be concluded that differentiated learning through the problem based learning model is able to improve students' thinking skills. Because differentiated learning strategies can accommodate differences in students' needs in learning. This is in line with previous research which states that differentiated learning strategies are able to show learning process activities that are in accordance with students' needs both in terms of students' learning styles [34]. Differentiated learning is a concept for organizing learning in order to facilitate the interests and talents of students in the class with diverse needs and abilities. Where in differentiated learning, it tries to adjust the learning process in the classroom in order to meet the individual learning needs of each student [35]. While the problem based learning model is able to train students' critical thinking skills in the learning process, because this model is more student- centered so that students are more active in solving the problems given. This is in line with what was expressed by previous researchers, the use of the problem based learning model is able to foster students' interest in learning because it involves active participation of students in the learning process, causing greater interest in understanding the subject matter. Through problem solving, students are motivated to learn and explore information [36].

4. Conclusion

Based on the results of the analysis and discussion conducted, it can be concluded that differentiated learning through the problem based learning model can improve students' critical thinking skills in the material of heat and its transfer at SMP Negeri 2 Pontianak. With an average pretest score of 47.90% in the medium category for a posttest score of 69.03% in the high category. Meanwhile, students' critical thinking skills in each indicator increased where the analyzing indicator increased by 20.97%, the Classifying indicator by 21.77%, the Concluding indicator by 23.39%, the Asking indicator by 17.74% and the Strategy indicator by 21.77%. Based on the calculation through the paired sample test, the sig value (2-tailed) of 0.00 <0.05 can be interpreted that there is a significant increase in the posttest value after being given differentiated learning treatment through the problem based learning model. Then, seen from the results of the n-gain analysis, it shows that critical thinking skills in students have increased by 0.43, which means it is included in the moderate category.

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