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Differentiated Learning on the Topics of Temperature and Heat to Determine the Effect of the PBL Model on Student Learning Outcomes

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Abstract: Differentiated learning is an attempt to adapt the learning process in the classroom to meet the individual learning needs of each student. This research aims to determine the effect of the Problem-Based Learning (PBL) model through a differentiated approach to temperature & heat topics on student learning outcomes. This research is experimental research, with the research design being One Group Pre-test and Post-test Design. The population of this study was class VII students of SMP Negeri 1 Tilongkabila. The sample consists of 3 classes, namely experimental class, replication 1, and replication 2 with the Cluster Random Sampling technique. The instruments used in this research are learning style tests, teaching modules, student worksheets, teaching topics, and written tests (pre-test and post-test) to see student learning outcomes. Then, the data is analyzed using descriptive and inferential statistics, including normality tests, hypothesis tests, and n-gain analysis. The average score for class VII students is greater than the criteria for achieving learning goals, shown by the average score of the experimental class of 83.92, replication 1 at 83.67, and replication 2 at 82.92, compared to the criteria for achieving learning goals of 70. Based on the hypothesis testing criteria for the class, experimental t-count 14.009 is more significant than t-table 2.035, replication 1 t-count 11.417 is more excellent than t-table 2.035, and replication 2 t-count 12.084 is more remarkable than t-table 2.035, so it can be said t-count is more prominent than t-table. Thus, the PBL model, through a differentiated approach, affects student learning outcomes.

Keywords: Differentiated Learning; Heat; PBL Model; Student Learning Outcomes; Temperature.

Introduction

Education is a process of humanism, which is then known as humanizing humans. Therefore, we can respect the human rights of every human being [1-2]. However, students are not human machines that can be controlled at will; they are a generation that we need to help and care for in every reaction to change towards maturity so that they can form people who think critically and have good moral attitudes. For this reason, education not only forms a person who is different from other people who can carry out eating and drinking activities, dress, and have a house to live in; this is what is called humanizing humans [3-4].

Science is a science that studies natural phenomena, including living and non-living things. Natural science knowledge is obtained and developed based on research by scientists seeking answers to natural phenomena and their application in technology and everyday life [5-7]. Science has been studied since receiving education in elementary school. Still, many students have difficulty learning and understanding science concepts, resulting in low learning outcomes, including difficulty solving problems related to science concepts [8-10]. One innovative learning model that can overcome learning difficulties in understanding science concepts to improve learning outcomes is the Problem-Based Learning (PBL) model. PBL is a learning model focused on regulated learning experiences, including investigation and solving contextual problems [11-14]. Teachers must be innovative and creative in choosing and developing learning methods as time passes. The aim is for the learning to be implemented to be effective, meet learning needs, and maximize the potential for student learning outcomes [15-17]. Learning outcomes in science subjects can be achieved if the teacher uses learning models appropriate to the learning topics and can increase student activity in the learning process. Learning outcomes play a critical role in the learning process because they can provide information to teachers about students' progress in achieving learning goals through learning activities [18-19].

Differentiated learning is an attempt to adapt the learning process in the classroom to meet the individual learning needs of each student. The adjustments in question are related to students' interests, learning profiles, and readiness to achieve improved learning outcomes [20-22]. Differentiated learning recognizes and teaches according to students' talents and learning styles [23]. Teachers facilitate students according to their needs because each student has different characteristics, so they cannot be treated equally. Differentiated learning is not individualized learning [24-25].

Based on the results of interviews with the teacher at SMP Negeri 1 Tilongkabila and the science teacher in class VII, The teacher said students consider science learning to be complicated, student learning outcomes are still relatively low, and teachers have not used the PBL model through a differentiated approach in Temperature and heat topics. The solution to the problem above is using the PBL model through a differentiated approach, which seeks to

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improve student understanding to influence student learning outcomes in the Temperature & Heat topics because there are still those who do not understand the issues. The advantages of the PBL model through a differentiated approach in the student learning process can improve the ability to solve problems so that students can be actively involved in the learning process, and also differentiated PBL can help teachers to adapt learning to the needs, interests, and abilities of different students to create a learning environment that is active and collaborative, which can increase students' motivation to learn [26-27]. Research has found that differentiated PBL significantly influences student learning outcomes. Thus, using the PBL model through a differentiated approach to the Temperature and heat topics is essential so that students can understand the content. The PBL model is effective on temperature and heat topics because this learning focuses on learning experiences that involve investigation and problem-solving, especially those related to everyday life, so that students can develop problem-solving skills and build new knowledge [28-29]. Based on the background description above, the author is interested in researching temperature and heat topics using a differentiated approach to determine the influence of the PBL model on student learning outcomes.

Research Methods

The type of research is experimental, and the research design used is the One Group Pre-test and Post-test design. The steps taken in the experimental study were: 1) giving a pre-test to the three classes; 2) providing the same treatment to the three classes using the PBL model through a differentiated approach; and 3) giving a post-test to all three classes. The research population was class VII students of SMP Negeri 1 Tilongkabila for the 2024/2025 academic year. The selected samples were class VII-A as the experimental class, VII-C as the replication 1, and class VII-E as the replication 2. The instruments used in this research are learning style tests, teaching modules, student worksheets, teaching topics, and written tests (pre-test and post-test) to see student learning outcomes. The replication class was a repetition of the experiment to ensure the consistency of the student learning results obtained [30]. The number of students in each sample group consisted of 34 students and a total sample of 102 students, with the sample group selected using a cluster random sampling technique.

This research uses a learning outcomes test, an essay with 10 questions covering the cognitive domain from levels C2 to C4. The aim is to determine student learning outcomes. The values obtained from the learning outcomes tests are then subjected to data analysis, including normality tests, hypothesis tests, and n-gain tests, to determine the effect of the PBL model treatment through a differentiated approach.

Results and Discussion

The average student learning outcomes are shown in Table 1, showing a difference between the average Pre-test and Post-test scores for each experimental class, replication 1 and replication 2. The average learning outcomes in the post-test for both experimental and replication classes exceed those in the pre-test. The average score for class VII students is greater than the criteria for achieving learning goals, shown by the average score of the experimental class of 83.92, replication 1 at 83.67, and replication 2 at 82.92, compared to the criteria for achieving learning goals of 70. Achievement of learning objectives can be seen from the learning outcomes obtained by students. Success is associated with the high and low grades students achieve, student absorption capacity and student learning outcomes after participating in the teaching and learning process. One can be seen in student learning outcomes, namely the learning process using the PBL model [31].

Table 1. Calculation Results of Average Student Learning Outcomes

Class	Pre-test	Post-test
Experiment	44.92	83.92
Replication 1	47.42	83.67
Replication 2	42.33	82.92

The experimental class had a higher average post-test score than the replication class because the experimental class students' enthusiasm for learning was very good as long as the researchers taught using the PBL model. So, it was concluded that from the average score of the three classes' learning test results, both the experimental class, replication 1 and replication 2, had higher post-test scores than the Pre-test scores. The results of this research align with the results of research from [30], which showed that the average post-test score for the experimental class was 91.62, replication 1 was 91.80, and replication 2 was 87.65.

Students' cognitive domain learning outcomes are obtained from the results of tests carried out by students. The average achievement of each student's cognitive domain from cognitive level C2 to C4 in the experimental class is shown in Figure 1.

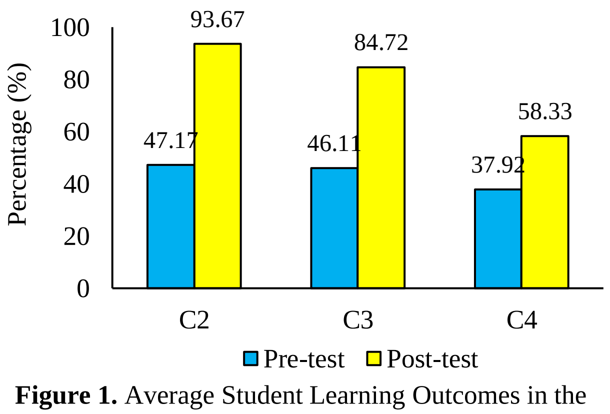

Figure 1. Average Student Learning Outcomes in the Experimental Class

Based on Figure 1 in the experimental class, it can be seen that the average calculation results for each achievement of cognitive levels C2 to C4 have increased from the pre-test to the post-test. C2 cognitive level, there was an increase of 46.50; at cognitive level C3, there was an increase of 38.61; and at C4, 20.41. So, a higher increase occurred at the cognitive level of C2. On C3, it is more significant than on C4. This is in line with research [32]; in the cognitive domain, C4 has a relatively low average percentage value of cognitive ability compared to C2 and C3; this is because in the cognitive analyzing domain (C4), the average value is 0.553 with a percentage of cognitive ability 53% is categorized as low, this is because C4 is the ability to think at the high order thinking skill level. It can be seen from the results of students' work on questions that students have difficulties in solving C4 questions, namely that students experience errors in translating the questions, lack of understanding of students in solving questions and conceptual errors, as can be seen from the answers of students who do not understand and apply equations correctly, calculating errors, and strategic mistakes in analyzing result in students not understanding how to work on questions wholly and correctly. Then, the average achievement of each student's cognitive domain from level C2 to C4 in replication 1 can be seen in Figure 2.

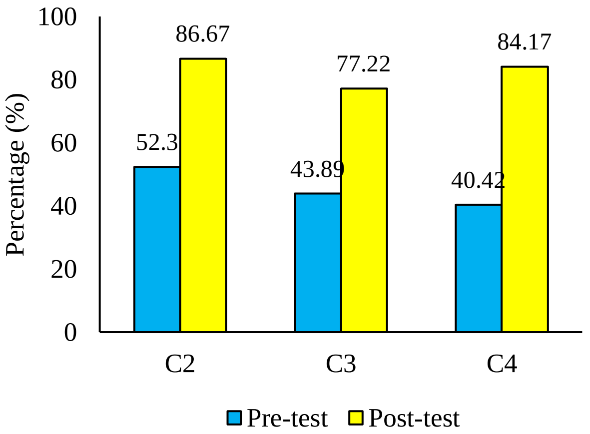

Figure 2. Average Student Learning Outcomes in Replication 1

Based on Figure 2, in the Replication 1 class, it can be seen that the average calculation results for each achievement of cognitive levels C2 to C4 have increased from pre-test to post-test. C2 cognitive level increased by 34.37; C3 cognitive level increased by 33.33; and C4 by 43.75. So, in replication 1, a higher increase occurred at cognitive level C4 and mental level C2 had a more significant increase than C3.

The average achievement of each student's cognitive domain from cognitive level C2 to C4 in replication 2 can be seen in Figure 3. Based on Figure 3, Replication 2 shows an increase from the pre-test to the post-test in calculating the average achievement of cognitive levels C2 to C4. In cognitive C2, there was an increase of 43.00; C3 cognitive level increased by 45.56; and C4 experienced an increase of 27.09. So, in replication 2, a higher increase occurred at cognitive level C3, and C2 had a more significant increase than C4. This is in line with research conducted by [33-34], showing that after being given treatment or treatment, the average score at the C3 cognitive level has increased because, with the help of the teacher, students can train themselves to use the concepts they have learned, learned through experimental activities in answering calculation questions. At cognitive level C3, namely, the ability to apply, connect, calculate, solve, use temperature topics related to formulas, and calculate quantities from principles, concepts or laws quantitatively [35].

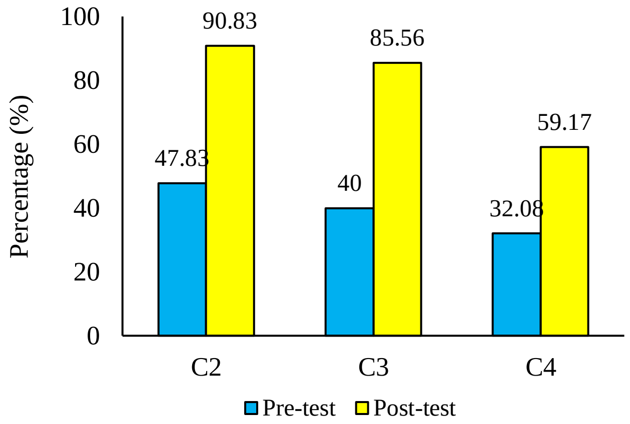

Figure 3. Average Student Learning Outcomes in Replication 2

Test of N-gain

The n-gain analysis of the test results using the course average normalized gain per class can be seen in Table 2.

Table 2. N-gain Test Results

Class	N-gain	Criteria
Experimental	0.71	High
Replication 1	0.68	Medium
Replication 2	0.70	High

Based on Table 2, the n-gain category in the experimental class and replication 2 falls into the high criteria, while replication 1 falls into the medium criteria. This is in line with previous researchers, where the average standard score in the three classes is that the post-test score is higher than the pre-test score because the topics studied are related to events in the surrounding environment, making it easier for students to understand the learning topics [36]. Analysis of n-gain per indicator was also carried out to determine the increase in student's conceptual understanding of each indicator question in the temperature and heat topics.

The results of the n-gain analysis per indicator can be seen in Figure 4. Figure 4 shows that the average calculation result of the N-gain test for the experimental class is 0.71 or includes high criteria. In replication 1, 0.68 is included in the medium criteria, and replication 2, which is 0.70, is in the high criteria. Students in the experimental class have higher initial abilities than replications 1 and 2.

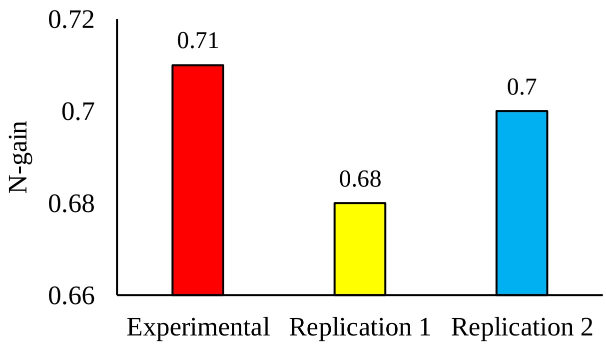

Figure 4. Average N-gain per indicator in the Experiment, Replication 1 and Replication 2

This influences changes in students' pre-test and post-test scores. Apart from that, there are also significant differences between the experimental classes, replication 1 and replication 2, in the n-gain indicator test, which can occur because it is influenced by variations in students' initial abilities and the level of student participation during the learning process. Replication 1 and 2 classes face different problems. Students in replication 1 have higher pre-test results than students in replication 2, so the increase in their learning outcomes tends to be more limited. This happens because they already have a better initial understanding, so the room for improvement or increased value is smaller. As a result, the n-gain value in replication 1 tends to be lower. In contrast, in replication 2, students with lower pre-test results had more significant opportunities for improvement because there was more room to improve their understanding and skills. This condition allows the n-gain value in replication 2 to be higher than in replication 1.

Normality Test

This research uses the Kolomogrof-Smirnov normality test formula using Microsoft Excel. The results obtained from statistical tests can be seen in Table 3 of the following data normality test.

Table 3. Results of Data Normality Testing

Class	F_i	K	Status
Experimental	0.482	0.241	Normally distributed
Replication 1	0.482	0.241	Normally distributed
Replication 2	0.480	0.241	Normally distributed

Based on Table 3, the results of data normality testing show that Fi ≥ K for the actual level α = 0.05. The data obtained for all samples in the three experimental classes, replication 1 and replication 2, were usually distributed to test data normality. Thus, statistical testing is continued using the t-test because the data is typically distributed.

Hypothesis Testing

Hypothesis testing aims to determine whether the PBL model is influenced by a differentiated approach to temperature and heat topics in the experimental class and the replication class given on student learning outcomes. Hypothesis testing in both the experimental class, replication 1 and replication 2, can be seen in Table 4.

Table 4. Hypothesis Testing Results

Class	t-count	t-table	Status
Experimental	14.009	2.035	H_a accepted
Replication 1	11.417	2.035	H_a accepted
Replication 2	12.042	2.035	H_a accepted

Based on Table 4, the calculation of the hypothesis test shows that for the experimental class, the t-count was 14.009; for replication 1, the t-count was 11.417; and for replication 2, it was 12.042 with the t-table for the three classes being 2.035. So it can be concluded, based on hypothesis testing in the experimental class, replication 1 and replication 2, namely, that the t-calculated is more prominent or greater than the t-table for the α = 0.05 level. Ha is accepted, and Ho is rejected. This shows that the PBL model influences temperature and heat topics in class VII and student learning outcomes. This is because using the PBL model can be an effort to improve science learning outcomes because the beginning of learning begins by presenting a problem, identifying the problem, continuing with discussions according to students' learning styles, and designing solutions that will achieved at the end of learning by collecting various sources of knowledge obtained from the internet, books, even through observation [37].

Observation of Learning Implementation

Based on the data from the calculation of student learning outcomes above, there is an increase in student learning outcomes after treatment using the PBL model through a differentiated approach. This is supported by the implementation of learning by observers or teachers who support science subjects in class VII. The following are the results of observations of learning implementation using the PBL model through a differentiated approach in each class, both experimental class, replication 1, and replication 2, which can be seen in graphical form in Figure 5.

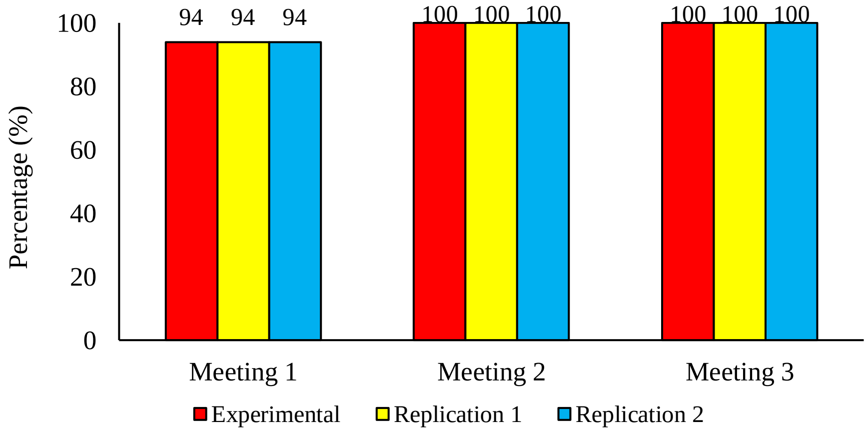

Figure 5. Percentage of Learning Implementation

Based on Figure 5, the percentage of observations on implementing the PBL model using a differentiated approach shows that implementing learning at the meeting and meeting 3 is better than meeting 1. This can be seen from the large percentage at meeting 2 and meeting 3, which shows that it is higher than at meeting 1. The percentage results show that implementing the PBL model through a differentiated approach is very good for learning. This aligns with research conducted by [38], where learning using the PBL model through a differentiated approach is a practical conventional choice, positioning students as the center of learning and encouraging the formation of their knowledge. Differentiated learning is oriented toward interests and needs to achieve optimal learning competence. It is also a very authentic differentiated PBL that is relevant to the world of students because it is easy to understand and adapted to students' abilities.

The problems presented during the learning process range from easy to complex, useful for students as solutions. Differentiated PBL can help teachers adapt learning to different students' needs, interests, and abilities, thereby creating an active and collaborative learning environment, which can increase students' motivation to learn [27]. The obstacle experienced in this research was that students had difficulty finding information or additional reading sources from the internet because some students did not bring cell phones to school or had no internet connection to access various information. Therefore, the researcher distributed teaching topics at the next meeting to help students find information about learning issues.

Conclusion

Based on the research results that have been carried out using experimental research methods and experimental classes, replications 1 and 2 show that the PBL model, through a differentiated approach to temperature and heat topics, can influence student learning outcomes. This is demonstrated by the results of the hypothesis test where for the experimental class, t-count 14.009 is greater than ttable 2.035, for replication 1, t-count 11.417 is greater than t-table 2.035, and for replication 2, t-count 12.042 is greater than t-table 2.035. It can be concluded that testing the hypothesis in each class is calculated to be greater than the t-table, and this can be interpreted as the PBL model, through a differentiated approach, affecting student learning outcomes.

Author's Contributions

Dian Pitaloka Dunggio: Conceptualization, methodology, writing-original draft preparation; Ritin Uloli: Methodology; Tirtawaty Abdjul: Curation, writing-original draft preparation; Muhammad Yusuf: Writing-review and editing; Citron S. Payu: Formal analysis, methodology; Nurhayati: Validation.

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