e-ISSN 2964-4291
https://proceeding.unnes.ac.id/ISET

Development of Problem-Based Learning Teaching Materials on Heat and Temperature to Improve High School Students' Critical and Creative Thinking Skills

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Abstract

Critical and creative thinking skills are part of the High-Order Thinking Skills required by the Independent Curriculum and 21st century education. It is hoped that students will be able to analyze, evaluate, and create creative solutions in learning, especially in science subjects at the high school level. The purpose of this study is to produce problem-based learning tools on temperature and heat materials to improve the critical and creative thinking skills of valid high school students, to find out the practicality and effectiveness of problem-based learning tools on temperature and heat materials to improve the critical thinking and creative thinking skills of high school students. This research is a *development research*. Data collection through tests, observations, questionnaires and documentation. The development model used is 3-D (Define, Design, Develop) which includes the stages of definition, design, and development. The tools developed consist of syllabus, lesson plans, worksheets, student teaching materials, and learning outcome tests. The trial was carried out at SMA Negeri 1 Kudus in the experimental class and the control class. Validation by three validators showed an average score: 3.51 syllabus; Learning Implementation Plan 3.73; student worksheet 3.73; Student Achievement 3.54; Critical Thinking Observation Sheet 3.71; and creativity 3.67 out of a maximum score of 4. The learning outcome test is declared valid, balanced in difficulty, well distinguished, and reliable. Practicality is shown from the teacher's response (average 4.60) and the teacher's ability to manage learning (average 4.59). Effectiveness was shown by an increase in the learning outcomes of experimental students, critical thinking skills by 79%, and creativity by 54%. These devices are proven to be valid, practical, and effective.

Keywords: Learning tools, Poblem-based learning, Critical-Creative Thinking

INTRODUCTION

Natural Sciences (IPA) is a science that emphasizes not only the mastery of concepts, but also the process of scientific discovery through inquiry methods that foster attitudes, processes, products, and applications in real life. In this context, the subject of Physics, especially on temperature and heat materials is a complex subject and requires a conceptual understanding and process skills.

Physics as a branch of science education plays an important role in developing students' ability to understand natural phenomena, solve problems, and think logically. In the context of Indonesian education, Physics, especially the topic of heat and temperature, is often considered difficult and abstract by students. The research results from Yuliati (2009) show that traditional learning methods, especially lecture-based with occasional slide presentations, are not enough to develop students' cognitive and affective potential. Despite efforts to improve teaching through discussion or media integration, this approach has not fully addressed the lack of student engagement and the development of critical-creative thinking.

In Ministry of National Education (2003), that the concept of science learning emphasizes direct experience and scientific inquiry to foster critical and creative competence. However, observations at SMAN 1 Kudus revealed that students faced challenges in understanding thermal concepts, with many achieving scores below the Minimum Competency Criteria (KKM). This shows the need for instructional innovation.

The research results from by Nurhadi (2004) show that Problem-Based Learning (PBL) is an alternative model centered on real-world problems that must be solved collaboratively, promoting student autonomy, reasoning, communication, and teamwork. Previous research supports this; for example, research from Hake (1998) shows that interactive engagement significantly outperforms traditional methods in physics education. Similarly, research from Akinoglu (2006) and Yuliati (2009) show that highlight the impact of PBL on improved academic performance, conceptual understanding, and scientific attitudes. Therefore, this study seeks to develop and validate a comprehensive set of PBL-based teaching materials designed to make physics learning more effective and meaningful.

However, in practice, Physics learning at SMAN 1 Kudus still faces various problems. In general, many students have difficulty understanding Physics due to teacher-centered learning methods, lack of laboratory activities, and lack of training in critical and creative thinking skills. In particular, temperature and heat materials are topics that are considered difficult and tedious, as shown by the low daily and end-of-semester exam scores, as well as complaints from students who have difficulty applying concepts to new contexts. The results of research by Lasmana and Idris (2020) show that students' critical and creative thinking skills are still low.

Several **previous studies** have proven that *Problem Based Learning (PBL)* is effective in improving students' critical thinking skills, creativity, learning achievement, and scientific attitude. Problem Based Learning (PBL) is an educational approach that encourages students to learn independently and work together in groups to solve real problems, with teachers playing the role of facilitators (Nurhadi, 2004). PBL has many advantages, such as emphasizing meaning over facts, improving self-direction, higher understanding, interpersonal and teamwork skills, as well as self-motivation and the quality of teacher-student relationships (Yazdani in Nur, 2011). Hake (1998) showed that interactive learning was more effective than traditional, Akinoglu (2006) found an increase in achievement and understanding of concepts, Yuliati (2009) noted an increase in learning outcomes and environmental skills, and Paidi (2009) highlighted an improvement in metacognition and problem solving. Widiyanti (2011) showed an increase in creativity and high-level thinking, while Rakhmawati (2011) found an increase in character, motivation, activities, and learning outcomes. Nasution (2011) stated that PBL with demonstrations is effective for abstract concepts and increases creativity. Mimbs (2005) emphasized the importance of teachers understanding critical thinking as the basis for problem solving and the need for professional training. Ertmer and Simons (2006) emphasize collaboration as a key component of PBL, while Hmelo-Silver and Barrows (2006) refer to PBL as a method of learning through problem-solving and reflection. Malone (2007) showed that procedural instruction strengthens students' understanding, while Turgut (2008) proved the effectiveness of PBL in the integration of science, technology, and society. Jonassen (2011) emphasized that PBL is a student-centered, reflective, independent, and collaborative methodology in solving problems.

However, **a research gap** that still exists is that there has not been much development of PBL learning tools specific to temperature and heat materials in high school, especially in environments with student characteristics that find Physics difficult and boring. In addition, there is still a lack of research that integrates PBL to improve critical and creative thinking skills and in the material.

Therefore, **the solution offered** is to develop *problem-based learning tools (PBLs)* designed specifically for temperature and heat materials. This learning tool is expected to be able to facilitate students in actively building knowledge, improving conceptual understanding, and developing critical and creative thinking skills.

This research is important because it contributes to efforts to improve the quality of Physics learning that is more meaningful, challenging, and contextual. In addition, the results of this research can be an effective alternative learning strategy for teachers to improve students' learning outcomes and life skills in facing the challenges of the 21st century.

This research aims to develop problem-based learning tools (PBL) on temperature and heat materials that aim to improve the critical and creative thinking skills of high school students. The specific objectives of this study include the development of devices that have certain characteristics, testing their validity, practicality, and effectiveness in improving the quality of student learning processes and outcomes.

The benefits of this research include producing PBL learning tools that can be an innovative alternative in Physics learning, especially in temperature and heat materials. This research also provides a new reference for teachers in designing active and meaningful learning, providing feedback to improve the quality of education, and providing meaningful learning experiences for students through active involvement in solving real problems relevant to daily life, while fostering social skills, collaboration, and courage in speaking.

METHOD

This study uses a development research approach following a modified version of the Four-D Model (Thiagarajan et al., 1974), which includes the Definition, Design, and Development stages.

1. **Define**: This stage includes front-end analysis to determine core problems in current physics teaching, student characteristics analysis, concept analysis about heat and temperature, assignment analysis, and formulation of learning objectives.

2. **Design**: The development of instructional tools begins with building test instruments, selecting appropriate media, determining supporting facilities (such as laboratories and LCD projectors), and preparing the first draft of instructional devices.

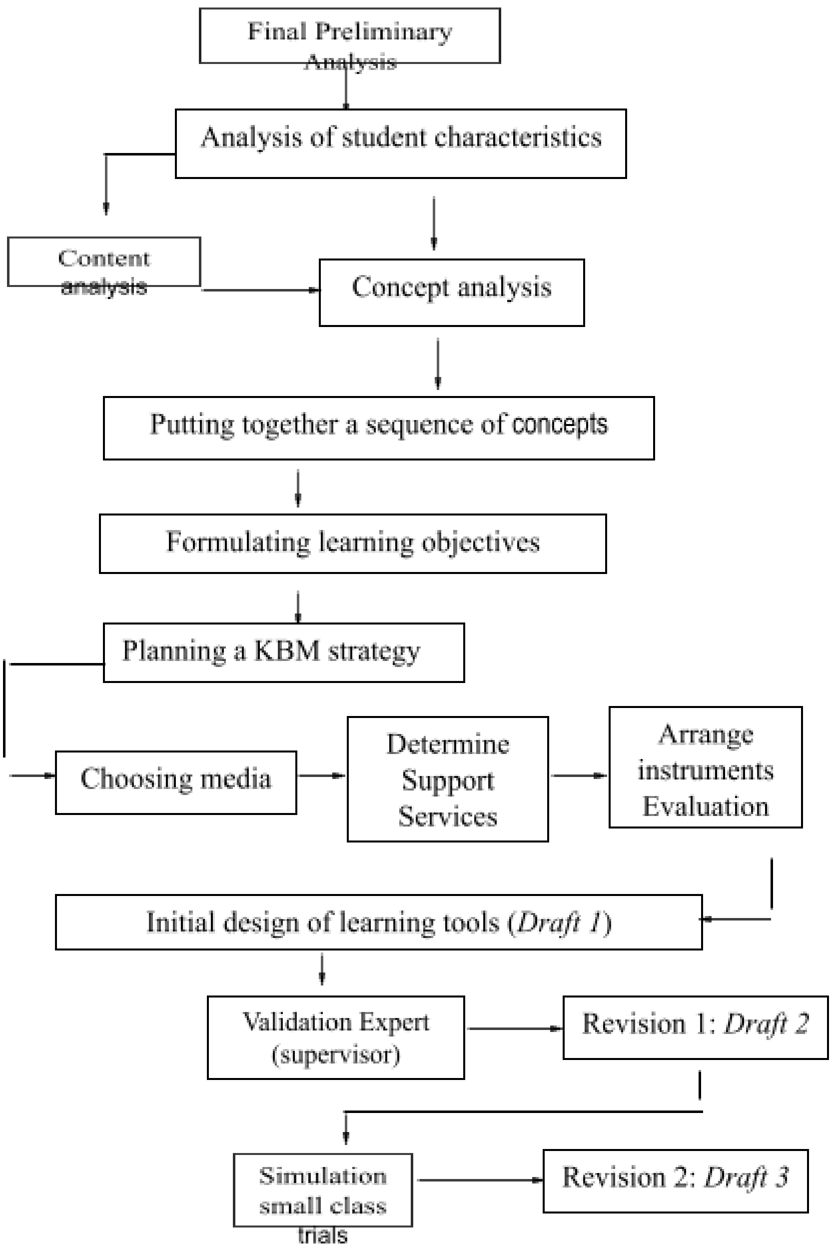
3. **Developing**: Expert validation and small-scale trials are conducted to refine the product. The implementation of the class was carried out in two classes at SMAN 1 Kudus, one as an

experimental group using the developed material, and the other as a control group using conventional methods.

The research was carried out at SMAN 1 Kudus, with the subject of class x students of SMAN 1 Kudus. This research involves 2 different classes. One class is a control class and the other is an experimental class that is subject to treatment.

The research subjects were determined randomly (*random sampling*) from 7 classes of 10 science majors. One class was chosen as an experimental class that was taught using the developed device and the other as a control class. Limited/small-scale trials were conducted on 16 students consisting of 4 students from the upper group, 8 students from the average (middle) group, and 4 students from the lower group. This sample assignment technique aims to find out that the instrument made can be used by all students.

The design of the development of problem-based learning tools Figure 1.



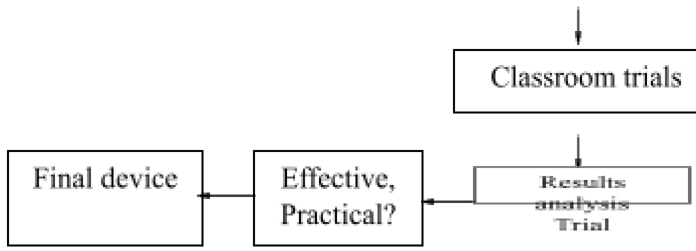


Figure 1. Flowchart of PBL device development design

The types of data taken are in the form of qualitative and quantitative data, which include: the learning implementation process, data from teacher observations, students' critical and creative thinking skills, learning outcomes of student understanding (cognitive learning outcomes), teacher responses, and data from teachers' observations in managing learning.

Data on students' critical and creative thinking skills was taken using a critical and creative thinking ability observation sheet, while data on student learning outcomes was taken using a student comprehension test question sheet.

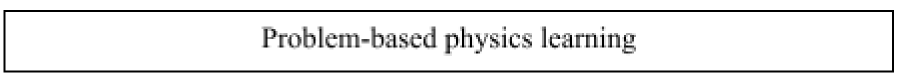
Followed by student analysis, material analysis, task analysis. To determine the validity of the item/question item, statistics are carried out, using the product moment correlation formula. The price r obtained is compared to the product moment table with a significance level of 5%. If the price r is calculated > r the table of the question item is said to be valid.

The reliability price of the test is calculated using the KuderRichardson (K-R-20) reliability test. The price r obtained is compared to the product moment table with a significance level of 5%. The test question set is reliable if r11 > rtable (=0.388).

To determine the level of difficulty of the question, it is indicated by a number called the difficulty index of the question, while the differentiation is classified as follows: a) 0.00-0.20 = poor; b) 0.21-0.40 = adequate; c) 0.41-0.70 = good; d) 0.71-1.00 = very good.

The development stage aims to produce a revised draft of learning tools based on the input of experts and teachers. Activities at this stage include validation of the device by experts and teachers followed by revisions. If the results of the analysis of the considerations of experts and teachers on draft 1 are without revision, or minor revisions, then it is followed by a trial of draft 1 that needs revision, then a revision is held so that a draft 2 is obtained. Draft 2 also requires consideration from experts and teachers. If the results of the analysis of the considerations of experts and teachers are without minor revisions, then it will be continued with the draft 2 trial. However, if the results of the analysis of the considerations of experts and teachers on draft 2 need to be revised, a revision is held to obtain draft 3, and so on so that a cycle occurs. The cycle stops if the results of the analysis of the considerations of experts and teachers on the draft are not revised, meaning that a valid learning tool has been obtained.

The device test used in this study is an experimental research, the design of the device trial can be seen in Figure 2.



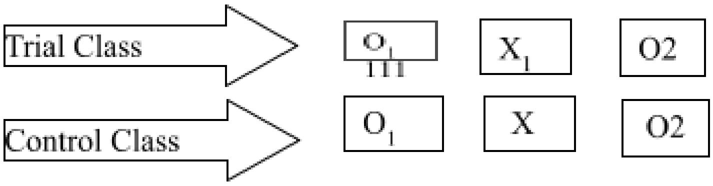


Figure 2. Trial Design

Information:

O_1 : Initial tests *(pre-test)* Temperature and Heat Material

X_1 : Treatment with learning based on temperature and heat material problems

O_2 : Final test *(post test)*

X : treatment with normal/conventional learning models

The first step of the trial implementation was carried out by randomly selecting 2 classes as the control class and the experimental class, which were then given different treatments, for the control class remained with ordinary treatment, namely conventional learning in which laboratory activities were carried out and experimental classes were given special treatment with problem-based learning which involved laboratory activities. After learning is carried out in accordance with the lesson plan, the two classes are then given *a post test* which will later find out if there is a difference in student learning outcomes between the two classes.

The instruments used to collect data in this study Includes: Observation sheets for critical and creative thinking skills, student learning outcome tests. The validity of the problem-based learning tool in this study is the validity of the content. To determine its validity, the researcher asks for consideration and expert judgment. The validity criteria for learning tools based on experts are as follows: a) 1≤ Va <2 are invalid; (b) 2≤ Va <3 are not valid; (c) 3≤ Va < 4 are valid; d) 4≤ Va <5 are valid. (Hobri, 2009)

For a maximum scale of 5. The average for a maximum scale of 4 is as follows: a) 1≤ Va <2 is invalid; (b) 2≤ Va <3 is quite valid; c) 3≤ Va <4 is valid, with Va = average expert assessment.

The analysis of the students' cognitive learning outcomes test uses the following formula:

$$\text{Value} = \frac{\Sigma\ amount\ \ true\ answer}{\Sigma\ amount\ all\ questions}\, x\ 100\% \qquad \text{(Ministry of National Education 2005:17).}$$

The observation data including the data of the results of psychomotor assessment and the affective assessment of students were calculated using the formula:

$$\text{Value} = \frac{\Sigma\ acquisition\ score}{\Sigma\ maximum\ score}\text{x } 100\% \qquad \text{(Ministry of National Education 2005:17).}$$

Analysis Increase in the average score pre and post-test uses *the* normalized average gain formula, which is the comparison of *the actual average* gain with the maximum average gain. The *gain* formula as written by Hake (in Sudarmin, 2007) which is often called the g-factor is:

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle}$$

The magnitude of the g-factor is categorized as follows:

Tall : g >0.7 or expressed in percent g >70

Keeping : 0.3< g <0.7 or expressed in 30 percent <g<70

Low : g <0.3 or expressed in percent g<30

To analyze the significance of improving learning outcomes in cognitive aspects from *pre-test* to *post-test, the* t-test *formula is used* as written by Arikunto (2002:275) with the formula:

$$t = \frac{M_d}{\sqrt{\frac{\sum x^2 d}{N(N-1)}}}$$

Information:

Md = mean of the difference in pre test to post test scores

Xd = deviation of each subject (d - Md)

$\sum x^2 d$ = sum of squares of deviation

N = research subject

The significance of the actual gain is determined through the t-test for paired samples using a specific significance level (α), e.g. α = 5%. If the price *t* Calculate>*t* table, it is concluded that there is a significant increase in the value of the *pre test to post test.*

Practicality data analysis Includes the teacher's response to the learning tool. The data from filling out the teacher response questionnaire to the learning tool was analyzed using the assessment criteria of the teacher response questionnaire consisting of 5 scores. In conducting and providing assessments on the teacher's response questionnaire sheet, assessment guidelines (rubrics) that have been prepared in advance by the researcher are used.

The average teacher response is calculated by summing the average response score of the teacher in each aspect divided by the number of aspects, or formulated as follows.

$R_G = \frac{average\ number\ of\ teacher\ responce\ scores}{many\ aspects}$,

with RG is the average of the teacher's response.

The interpretation of the average score of the teacher's response is as follows.

$1.00 \leq R_G \leq 1.80$ means not good

$1.80 < R_G \leq 2.60$ is not good

$2.60 < R_G \leq 3.40$ is good enough

$3.40 < R_G \leq 4.20$ means good

$4.20 < R_G \leq 5.00$ means very good

Teachers' responses are said to have a positive response if the average teacher's response score is at least good.

To find out the level of teachers' ability to manage learning, the learning process was carried out by 2 observers from peers. The scoring of teachers' ability to manage learning was applied on a scale of five that had been provided by the researcher. The observation data were then analyzed and searched for averages using the formula:

$$KG = \frac{the\ average\ number\ of teacher\ abilities\ for\ each\ RPP}{many\ RPP},$$

with KG is the average ability of teachers to manage learning.

. Based on this, the criteria used to determine the category of teachers' ability (KG) to manage learning are as follows.

Average score of 1.00≤ KG ≤1.80 means very low

Average score of 1.80 < KG ≤ 2.60 means low

Average score of 2.60 < KG ≤ 3.40 means medium

Average score of 3.40 < KG ≤ 4.20 means high

An average score of 4.20 < KG ≤ 5.00 means very high

The average teacher's ability to manage learning is said to be good if it is included in the high or very high category.

The criteria for learning tools are said to be practical if after being tested in an experimental class, the results are: (1) the teacher gives a minimum good response, and (2) the teacher's ability to manage learning is good.

RESULTS AND DISCUSSION

Problem-based learning tools for temperature and heat materials that have been developed to improve students' critical and creative thinking skills consist of a syllabus, lesson plan, student worksheets, and student teaching materials. The development of learning tools based on temperature and heat problems of materials to improve students' critical thinking and creative thinking skills was carried out by following the steps of developing the modified Thiagarajan, S. and Semmel model which consisted of three stages, namely *Define*, design, and develop). The development stage includes expert validation and trial of learning tools, where the data obtained from each of these activities is then used as the basis for the revision of learning tools.

The resulting learning tools are valid and reliable learning tools. In addition, the instruments used in this study were also developed, namely observation sheet instruments, student learning outcome test instruments, teacher response questionnaires, and teacher management instruments. To find out whether a learning tool is valid or not, validation of learning tools is carried out by validators (experts and practitioners).

In general, the results of validation by experts and practitioners of the developed learning tools are shown in Table 1.

Table 1. Recapitulation of Learning Tool Validation Results

Learning Tools	Average Validation of Each Validator				
	V1	V2	V3	Middle	Criterion
Syllabus	3.58	3.21	3.74	3.51	Legitimate
RPP	3.70	3.60	3.90	3.73	Legitimate
Student Work Sheet	3.80	3.50	3.90	3.73	Legitimate
Student Teaching Materials	3.64	3.25	3.72	3.54	Legitimate
Critical Thinking Skills Observation Sheet	3.71	3.57	3.86	3.71	Legitimate
Student Creativity Observation Sheet	3.57	3.57	3.86	3.67	Legitimate

The assessment of the syllabus includes 3 aspects, namely (1) Completeness of the components of the subject's identity syllabus, (2) Conformity with the principles of syllabus development, (3) The language used is in accordance with the good and correct rules of the Indonesian language.

The assessment of the lesson plan includes 10 aspects, namely (1) Clarity of the formulation of learning objectives, (2) Selection of teaching materials, (3) Organization of teaching materials, (4) Selection of learning media/resources, (5) Clarity of learning scenarios, (6) Details of learning scenarios, (7) Suitability of techniques with learning objectives, (8) Completeness of instruments, (9) Completeness of lesson plans, and (10) Language used in lesson plans. .

The assessment of the LKS includes 10 aspects, (1) Can invite students to be active in learning, (2) Emphasizes on the process of finding concepts (3) Has various stimuli through various media and student activities, (4) Using high-level questions, (5) The information provided is clear, (6) The tools, materials, and facilities used support students to be able to find concepts in accordance with the problems posed by the teacher through student worksheets, (7) Not too much information, (8) Too little information, (9) The questions given encourage students to think critically and creatively, (10) Make statements that lead to making good reports.

The assessment of Student Teaching Materials includes 3 aspects, namely (1) Content feasibility component, (2) Language component, (3) Presentation component.

The assessment of students' critical thinking ability sheets includes 12 aspects, namely (1) Focusing questions, (2) Analyzing arguments, (3) Asking and answering high-level questions, (4) Considering the criteria of a source, (5) Observing and considering the results of observations, (6) Making and considering the results of deductions, (7) Making and considering the results of induction, (8) Making and considering the value of decisions, (9) Defining terms, considering definitions, (10) Identifying assumptions, (11) Deciding on an action, (12) Interacting with others. .

The assessment of the observation sheet of students' creativity skills includes 12 aspects, namely (1) Broad curiosity, (2) Deep curiosity, (3) Often asking good questions, (4) Giving a lot of ideas/suggestions on a problem, (5) Being free to express opinions, (6) Having steps in solving problems, (7) Obtaining data in solving problems, (8) Analyzing data obtained in solving problems, (9) Able to see problems from multiple perspectives, (10) Have a broad sense of humor, (11) Have imagination, (12) Be original in expressing problem-solving ideas.

Validation of student learning outcome test questions is based on content validation. The assessment of student learning outcome test questions includes 4 aspects, namely (1) validity, (2) reliability, (3) differentiation, and (4) difficulty level.

Field trials of learning tools aim to find the effectiveness and practicality of learning tools. Testing of learning tools was carried out in experimental classrooms and control classes as a comparator.

Learning tools are said to be practical if after being tested in experimental classes the results are: (1) the teacher gives a minimum good response, and (2) the teacher's ability to manage learning is at least good. The teacher response questionnaire includes teachers' opinions on the components of learning tools in assisting learning activities, teachers' assessments of learning tools and teachers' responses to the feasibility of developing learning tools. The results of filling out the teacher's response questionnaire to the learning tool were then analyzed. The average result of the questionnaire of teachers' responses to learning tools was 4.60 very good.

Observation of the teacher's ability to manage learning was carried out during the learning process by 2 observers from peers. The recapitulation of observation data on teachers' ability to manage learning can be shown in Table 2.

Table 2. Recapitulation of Observation Results of Teachers' Abilities in Managing Learning

Meetings for	Average Rating	
	Observer 1	Observer 2
1	4.39	4.28
2	4.50	4.33
3	4.72	4.39
4	4.72	4.67
5	4.78	4.67
6	4.89	4.78
Average total	4.59	

Criterion	Superior

The total average ability of teachers to manage learning is 4.59, which is in the very good category.

The data on students' critical thinking skills was obtained from observations during the learning process using the critical thinking ability observation sheet instrument that had been made by the researcher. The improvement of students' critical thinking skills in the control class and the experimental class can be seen in Figure 3.

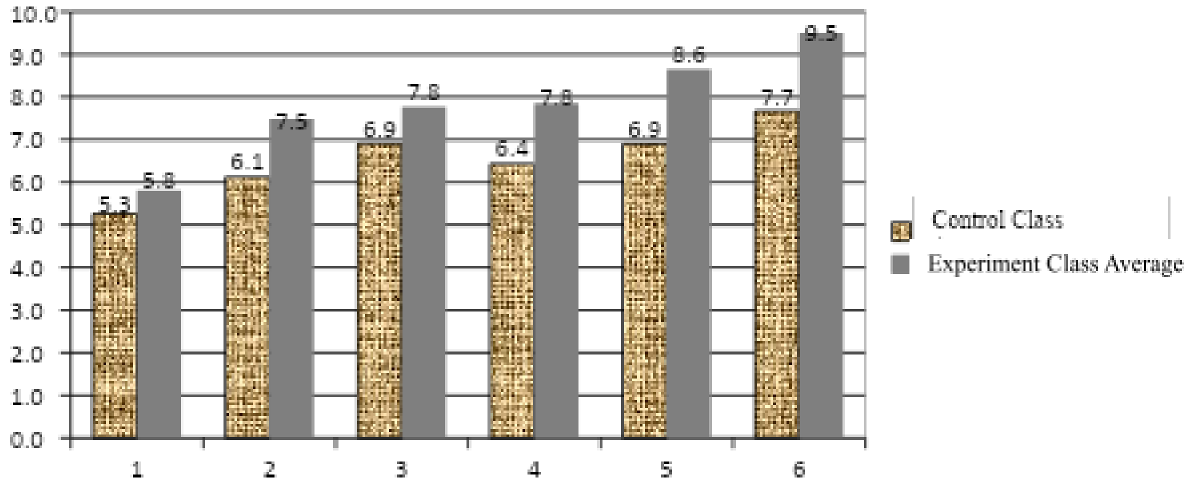


Figure 3. Results of the Critical Thinking Skills Control Class and the Experimental Class.

Data on students' creativity ability was obtained from observation during the learning process using creativity ability observation sheet instruments that have been made by researchers. The improvement of students' creative thinking skills in the control class and the experimental class can be seen in Figure 4.

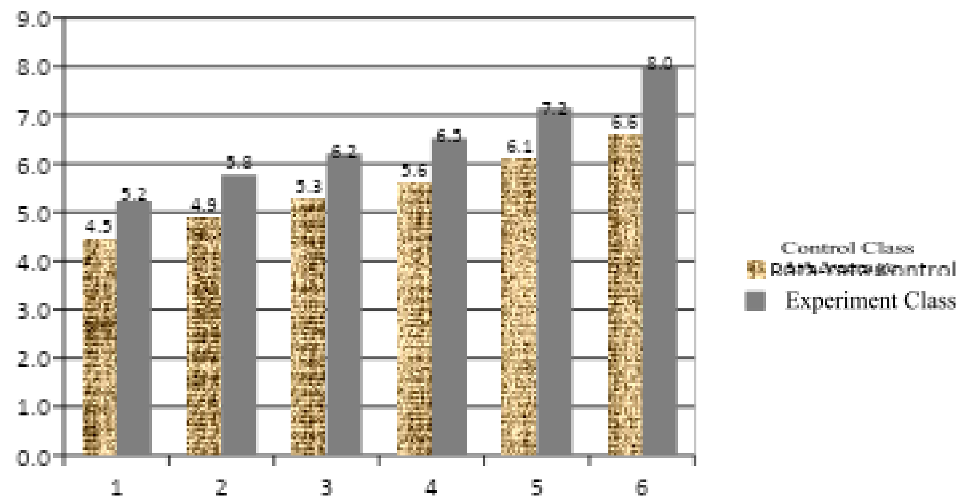


Figure 4. Control Class Creativity Ability Results and Experimental Classes

The learning process is carried out using physics learning tools developed based on problems with temperature and hot materials. Before the learning process is carried out, the learning process using the PBL model is given to students first *Pre-tests*, both experimental classes and control classes. Then the results are compared to *Post-tests*.

Table 3. Recapitulation of student learning outcomes test in the control class

Not e.	Information	*Pre-tests*	*Post-tests*
1.	Lowest value	43.0	67.0
2.	Highest score	63.0	83.0
3.	Average test score	51.094	75.125
4.	Percentage of learning completeness	0.00 %	53.13 %

Table 4. Recapitulation of student test learning results in experimental classes.

Not e.	Information	Pre-tests	Post-tests
1.	Lowest value	50.0	77.0
2.	Highest score	73.0	93.0
3.	Average test score	57.44	81.38
4.	Percentage of learning completeness	0.00 %	100.0 %

Based on the results of the above research, it can be explained that the discussion of the results of the research is divided into two groups, namely the discussion of the results of the device validation and the discussion of the results of the device trial. The average value of the syllabus given by the validator is 3.51 so that in general the validator states that the syllabus is good and can be used for research with minor revisions based on suggestions and input from the validator. The average score of the RPP given by the validator is 3.73 so that in general the validator states that the RPP is good and can be used for research. The average score of the LKS given by the validator is 3.73 so in general the validator states that the LKS is good and can be used for research. The assessment from the validator obtained an average score of 3.54 which means that the students' teaching materials are good and can be used in research. Based on the validation results, an average score of 3.65 was obtained from a maximum score of 4, meaning that the learning tools are good and can be used for research.

Data on students' critical thinking skills was obtained from observation during the learning process using the observation sheet instrument of students' critical thinking skills that had been made by the researcher. Based on the results of observation, it was found that students' critical thinking skills were in the high category.

Data on students' creativity abilities was obtained from observation during the learning process using instruments of observation sheets on students' creativity abilities that had been created by researchers. Based on the results of observations, it was obtained that students' creativity abilities were included in the high category.

Teacher response data to learning tools was collected using teacher response questionnaire sheet instruments that had been provided by the researcher. From the results of filling in the data of filling out the teacher's response questionnaire to the learning tool, it was found that the teacher's response to the learning tool was in the category of very good.

The teacher's ability to manage learning is carried out during the learning process by 2 observers from peers. The average total ability of teachers to manage learning is 4.61, which is in the very good category.

Because the learning tools after being tested in the experimental class obtained the following results: (1) the teacher's response to the learning tool is positive, (2) the teacher's ability to manage learning is very good, the learning tool has met the practicality criteria, so it can be concluded that problem-based learning tools to improve the critical and creative thinking skills of high school students are practical.

Based on the results of the comparison of the average post-test scores of the experimental class and the control class, it can be concluded that the experimental class with an average of 81.38 has a higher average completion score than the average completion score of the control class of 75.13. This shows that problem-based physics learning to improve critical and creative thinking skills is better than conventional learning.

The results *of the pre-test* on temperature and heat materials for the control class got an average score of 51.09 with a percentage of 0% of students completing their studies and *the results of the post-test* got an average score of 75.13 with a percentage of 53.13% of students completing their studies. Meanwhile, *the results of the pre-test* on temperature and heat materials for the experimental class got an average score of 57.44 with a percentage of 0% of students completing their studies and *the results of the post-test* got an average score of 81.38 with a percentage of 100% of students completing their studies. Based on the analysis of the t-test, it was obtained that the price of $\mathbf{t_{count}}$ = 3.457 and $\mathbf{t_{table}}$ = 1.697. Since $\mathbf{t_{count}} > \mathbf{t_{table}}$ it can be concluded that there is a difference between the control class and the experiment class. Based on the average value of N-gain between the two groups, it can be concluded that mastery of the concepts of temperature and heat after learning for the experimental class was better than that of the control class.

The analysis of the increase in pre-test and post-test average scores after implementing learning using the problem-based learning model was calculated using the normalized average N-gain formula and obtained the results:

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle} = \frac{81.38 - 57.44}{100 - 57.44} = 0.56$$

The value (g) = 0.56 which means that the increase in the average score of the pre-test and post-test is in the medium category, where the value for the medium category is $0.3 \leq g \leq 0.7$. The increase in student understanding is because PBL essentially provides students with authentic and meaningful problem situations that can make it easier for students to conduct investigations and investigations. The role of teachers in this model is to raise problems, facilitate students' inquiry and dialogue and support their learning. The model is set around real-life situations that avoid simple answers and invite a variety of competing solutions.

From observations and results during the learning process, it was obtained that problem-based physics learning to improve critical and creative thinking skills has met three effectiveness criteria, namely (1) the value of student learning achievement has reached completeness, (2) the ability to understand the physics of temperature and heat materials between experimental classes is better than the control class, so it can be concluded that physics learning tools based on temperature and heat materials for improving the critical and creative thinking skills of high school students has been effective.

Based on the results of observation and the data collection process during the research, there are several limitations of the research, including: 1) in this study it is explicitly not assessed the attitude of students during the learning process with PBL devices developed on temperature and heat materials to improve students' critical and creative thinking skills. 2) In practicum/experiment activities in the laboratory, there are still students who arrive late. This has an impact on reducing the concentration of friends in their group in the learning process. 3) The implementation of research that follows the school lesson schedule and sometimes during the day makes students at certain meetings less enthusiastic and enthusiastic in participating in learning activities.

The novelty in this study lies in the application of a fully integrated PBL package specifically for thermal topics, filling in the gaps in existing physics teaching practices. The materials also promote collaborative learning and reflective thinking, preparing students for the challenges of the 21st century (Jonassen.2011).

CONCLUSION

This research has succeeded in developing a learning tool based on the Problem-Based Learning (PBL) model on the subject of temperature and heat for secondary school physics education. This material has demonstrated strong validity, practicality and high effectiveness as evidenced by the improvement of student outcomes during classroom implementation.

The integration of real-world problem scenarios in learning encourages students to engage more actively in the learning process, enhancing their capacity for critical and creative thinking and promoting a deeper understanding of basic physics concepts, particularly temperature and heat materials. The results of this study reinforce the potential of PBL as a transformative instructional strategy that not only supports student-centered learning but also prepares learners to face complex challenges in both academic and real-life contexts.

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