PILLAR OF PHYSICS EDUCATION
Vol. 17 (1), 2024, page.63-72
ISSN (Print) : 2337-9618
ISSN (Online) : 2684-8880

Effect of the Problem Based Learning Models Assisted by Learner Worksheet to Improve High School Students' Critical Thinking Skills on the Nature of Physics and Measurement

Delia Syawitri Rahmatullah[1], Yurnetti[1*]

[1] *Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia*
Corresponding author. Email:deliasyawitri13@gmail.com

ABSTRACT

Education in the 21st Century guides the development of education. One of them is the ability to think critically. A learning model that can improve students' critical thinking skills is the Problem Based Learning model. The Problem Based Learning model that is applied must have supporting teaching materials, namely worksheet. This research aims to see the effect of the problem based learning model assisted by worksheet on the critical thinking abilities of class X Senior high school students. The type of research is quasi experimental with posttest only Control Design. The research population was the entire class X of the Senior High school in Lubuk Sikaping. Sampling was taken using purposive sampling technique. The research took two sample classes which were used as the experimental class and the control class. Providing critical thinking final test essay sheets to the two sample classes revealed differences in students' critical thinking abilities. Data analysis shows that the average critical thinking skills of the experimental class is greater than the control class, namely 76.23 > 68.8. The results of the test analysis showed that the two sample classes were normally distributed and had homogeneous variances. The t_h test result of 2.91 with a t_t 2.00 shows that the t_h is outside the Ho acceptance area, meaning that H1 is accepted at a real level of 0.05. So it can be concluded that there is an influence of using the Problem Based Learning model assisted by worksheet to improve students' critical thinking skills.

Keywords : Problem Based Learning; Learner Worksheet; Critical Thinking Skills

I. INTRODUCTION

The development of science and technology in the 21st century has changed the order of human life. The rapid development of science and technology demands an increase in the quality of education [1] . Education is something important and must be given to citizens in order to improve the quality and quantity of knowledge and improve the functioning of the brain so that they can think and reason. Education is highly demanded to play a role in improving the quality of Human Resources (HR) which can keep up with the times and developments in science and technology.

To face the 21st century, humans are required to have four skills, namely 4C skills (Critical Thinking, Creative Thinking, Collaboration, and Communication). One of the important and expected skills is the skill to think critically. Critical thinking skills are very important so as not to be left behind with the development of time. The ability to think critically is intellectual capital as the most important part of thinking maturity [2] . Good critical thinking skills can form rational attitudes and behavior [3] . A reliable critical thinker will have the

ability to find problems and formulate questions precisely and clearly, convey relevant information with logical thinking, valid conclusions and be able to implement them practically [4] .

In realizing the skills demanded in the 21st century, especially critical thinking skills, the government has made various efforts to improve the quality of education in the era of globalization, one of which is curriculum development in each period. The curriculum is the most important aspect of education so that the goals of education are achieved . Curriculum development in each period, namely from the Education Unit Level Curriculum (KTSP), K-13 and now the Independent Curriculum which is currently being implemented . The Independent Curriculum aims to encourage students to hone their thinking patterns, requiring them to play an active role and dig up information , be able to observe, reason, analyze and conclude what is obtained or known after receiving learning, so as to improve students' thinking abilities.

Among the subjects studied in formal education, one of them is Natural Sciences (IPA) and one of them is Physics. Physics learning required in the Independent Curriculum is student centered learning. Students learn to find problems, make hypotheses, design simple experiments, conduct experiments, analyze data, draw conclusions and communicate experimental results to train critical thinking skills , working together, working together and reasoning [5] . In order for Physics learning to run well, it must be in accordance with the process standards that are carried out in order to serve as a guide in carrying out an effective, optimal and efficient learning process [6] . One of the process standards that must be carried out is that teachers must be clever in choosing the learning model to be used. One learning model that is in accordance with the Independent Curriculum and is student center oriented is the Problem Based Learning Model. The Problem Based Learning model is a learning model that presents various real problems related to certain material so that it stimulates students to learn actively and find solutions to these problems in order to improve their critical thinking skills [7] .

The Senior High School in Lubuk Sikaping is one of the schools implementing the independent curriculum used, but the demands for an independent curriculum have not been fully implemented. The learning process still uses a direct learning model. Students tend to be passive in learning Physics, especially in the Nature of Physics and Measurement material . An analysis of students' critical thinking abilities is still relatively underdeveloped. This can be seen from the results of the analysis of the critical thinking test instrument which uses physics questions about material on Physics and Measurement which was given to all students of class X of the Senior High School in Lubuk Sikaping . The results of the analysis of the average critical thinking skills of class X :

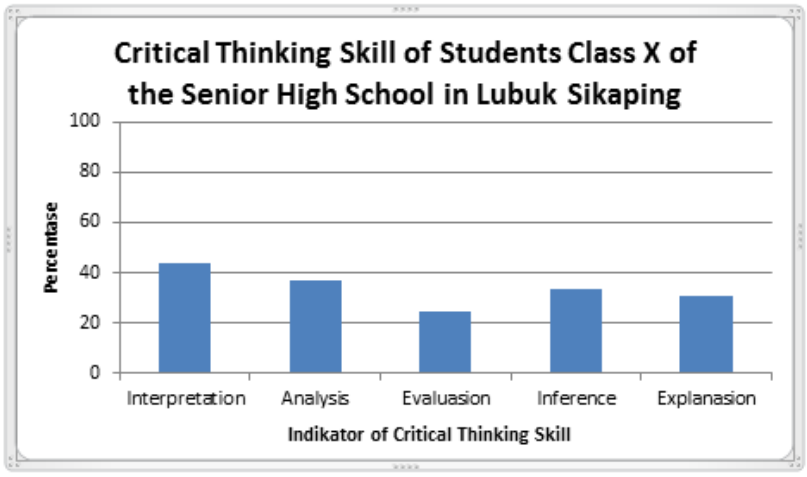

Fig 1. Graph of critical thinking skills of class X Senior High School in Lubuk Sikaping

In Figure 1, it can be seen that the critical thinking skills of class X Senior High School in Lubuk Sikaping is still in the undeveloped category and needs to be improved. It can be seen that the average value is still below 50% . Based on these real problems, the solution needed is to use appropriate learning models and teaching materials that can increase students' learning motivation so they can think critically and logically. One of the learning models chosen is the Problem Based Learning model .

In order for learning using the Problem Based Learning model to take place well, it must have teaching materials that support students being able to think critically and logically. Teaching materials are an important

part of learning because they can be used as a learning resource for both teachers and students in the learning process [8] and arranged regularly, showing the complete figure of the competencies that students will master in learning activities [9] . One of the practical and operational teaching materials in the Problem Based Learning learning model is the Student Activity Sheet (Learner Worksheet).

Learner Worksheet is a teaching material that contains material, instructions and steps in solving tasks or problems that are adapted to the learning model used as a guide for students in the learning process which is packaged in the form of investigation or problem solving activities according to indicators of learning achievement to facilitate interaction between students and teachers . The presentation of learner worksheet can be developed with various innovations according to the learning model applied [10] . Worksheets can help and train students to be active in learning because students will be used to discovering concepts through these activities. Through the use of the Problem Based Learning model assisted by learner worksheet , students can hone their thinking or reasoning skills in solving problems with their scientific thinking skills so that they can increase their critical thinking abilities.

Based on this explanation, researchers are interested in conducting research with the title " Effect of The Problem Based Learning Models Assisted by Learner Worksheet to Improve High School Students' Critical Thinking Skills on the Nature of Physics and Measurement ".

II. METHOD

Type study wow used in study t his is experimental or quasi experimental research . Study experiment t his examines the influence or effects of manipulation or systematic treatment of a variable or more variables another way to see the effect of treatment on the samples to be studied [11] . This Study use method or design quasi experiment design using a posttest only Control Design . This research using two sample classes, namely the experimental class and the control class . Two classes will be applied to the research design in the table 4 below:

Table 1 . Posttest Research Design Only Control Design

Group	Treatment	Posttest
R1	X1	O
R2	X2	O

(Source: [12])

Information :

R1 : Experiment Class
R 2: Control Class
O 1: Final Test after beng given treatment in experiment class and control class
X 1 : Learning using learner worksheet
X2 : Learning without using learner worksheets

The population in this study were all classes X of the Senior High School in Lubuk Attitude . The sampling technique in this research was carried out using purposive sampling . Sampling was carried out using a critical thinking test instrument which was given to the entire population which was then analyzed using statistical tests to obtain a sample class of class XE-1 as the experimental class and class XE-3 as the control class. The independent variable used in this research is the influence of the Problem Based Learning model assisted by learner worksheet . The dependent variable is the critical thinking ability of class X one Semester of the Senior High School in Lubuk Attitude and control variables are the learning model, subject teacher, subject matter, learning atmosphere, number and type of questions tested are the same in both classes.

The research was carried out in three stages, namely the preparation stage, implementation stage and completion stage. The research carried out was limited to the cognitive aspect, by providing written test questions at the end of the lesson in the form of essay questions. The questions used contain indicators of critical thinking. This question was given to the two classes used as samples, namely the control class and the experiment class. Before giving the final test questions, a trial of the questions and statistical data instrument analysis on the questions are

carried out. There are four stages of statistical analysis used to determine the final test questions, namely testing the validity of the questions, reliability, differentiation and level of difficulty tested in classes outside the sample class. So we get 6 questions that can be given to both sample classes. Before being given the final test, both classes were given a grid of questions. Then the sample class takes the final test given. After obtaining the final test data from the sample class, statistical data analysis was carried out.

The data used in this research is primary data on critical thinking skills taken through critical thinking questions in the form of essays with indicators of critical thinking skills. The data in this research is the result of an assessment of the knowledge aspect so that students can think critically. The data analysis technique aims to test the truth of the hypothesis proposed in the research. Whether the working hypothesis put forward in this research is accepted or rejected. Analysis of knowledge data begins with a test of the similarity of two averages. There are several conditions that must be met when using it, namely that the data is normally distributed and homogeneous. So before carrying out a test for equality of two means, a normality test and a homogeneity test are carried out first to fulfill the requirements for a test of equality of two means. If the sample from the population is normally distributed and homogeneous, then the appropriate statistic to use is the t - test. If the sample is normally distributed but not homogeneous, then the more appropriate hypothesis test to use is the t' - test statistic. Meanwhile, if the sample is not normally distributed and does not have a homogeneous variance, then the hypothesis test used is the u - test [13] .

From the results of data analysis calculations, it was found that there was a significant influence on the use of the Problem Based Learning model assisted by worksheet to improve students' critical thinking skills in the Nature of Physics and Measurement material for Class X of the Senior High School in Lubuk Sikaping

III. RESULTS AND DISCUSSION

A. Result

The data obtained from the results of this study are data on students' critical thinking skills. Critical thinking ability data is taken through the instrument of critical thinking questions in the form of essay questions that contain indicators of critical thinking ability and assessment is carried out based on these indicators. Data obtained from research through student answers based on descriptors of critical thinking ability indicators. The data is then processed using statistical tests, namely through the equality test of two averages, the data must be tested for normality and homogeneity. If the data is normal and homogeneous, then the equality test can be done to see the critical thinking skills of students. The results of this study state that there is an increase in students' critical thinking skills.

Description of research data in the form of students' critical thinking skills obtained from the results of written tests in the form of essay questions as many as 6 questions. This test was given to both sample classes at the end of learning or the end of the meeting. Based on the results of statistical calculations, the average value ($\bar{x}$) standard deviation (S), and variance (S^2) of experimental class and control class. The average value, highest value lowest value, standard deviation, and variance of the sample classes are as in Table 2 below:

Table 2. Mean Value, Highest Value, Lowest Value, Standard Deviation and Variance of Sample Classes

Class	Highest Score	Lowest score	$\bar{x}$	S	S^2
Experiment	90	56	76,23	9,73	94,67
Control	90	48	68,81	11,31	127,91

Table 2. shows that the average *post-test* score of the experimental class was higher than that of the control class. The average difference between the experimental class and the control class is 7.42. The standard deviation value of the experimental class is smaller when compared to the standard deviation value of the control class, This means that the *post-test* scores of experimental class students are more evenly distributed than the control class. The variance of the control class is greater than that of the experimental class shows that the ability

of students in the control class is more varied than the experimental class students. The difference in the final test results between the two sample classes or not, can be known by conducting an equality test of two means. Data analysis on the improvement of critical thinking skills was carried out through *post-test* at the end of the research meeting. Data analysis was carried out to see the difference in the average of the two sample classes means or not. Before drawing conclusions from the research results, data analysis was carried out through statistical hypothesis testing statistics. Hypothesis testing is done to find out whether the hypothesis is accepted or rejected. Hypothesis testing was carried out through the normality test and homogeneity test of the two sample classes first, then the equality test of the two averages was carried out.

1. Normality Test

The normality test used in this study is the *Lilliefors* test. Test *Lilliefors test* is conducted to see whether the sample comes from a normally distributed population or not. The results of the normality test of the two sample classes can be seen in Table 3 below:

Table 3. Posttest Normality Test Results of Both Sample Classes

Class	N	A	Lo	Lt	Description
X_{E-1}	34	0,05	0,079	0,154	Normal
X_{E-3}	33		0,060	0,156	Normal

Table 3 shows that the results of the normality test that has been carried out obtained L_o value is smaller than the Lt value at the real level of 0.05 for $n_1 = 34$ and $n_2 = 33$. In the table it is obtained that the normality test result of L in the experimental class is 0.079 while the Lo value for the control class is 0.060. The result of the Lt value in the experimental class is 0.154 while the Lt value for the control class is 0.156. So it can be concluded that the data obtained by the value of L0 < Lt which states that the data from the final test results of the two sample classes come from a normally distributed population.

2. Homogeneity Test

The homogeneity test was conducted to see whether the two sample classes had a homogeneous variance or not. The homogeneity test was conducted through the F Test. Test results homogeneity test results of both sample classes can be seen in Table 4 below:

Table 4. Homogeneity Test Results of Postes of Both Sample Classes

Class	N	$\bar{x}$	S^2	Fh	Ft	Description
Experiment $(X)_{E-1}$	34	76,23	94,67	1,35	1,82	Homogeneous
Control $(X)_{E-3}$	33	68,81	127,91			

Table 4 above shows that the Fh result for the sample class was found to be 1.35. From statistical analysis for Ft value is 1.82. Both sample classes have homogeneous variance if the value of Fh < Ft. Dta shows that the sample has a value of *Fh < Ft*. That is 1.35 < 1.82. So it can be concluded that the data of the two sample classes have a homogeneous variance.

3. Hypothesis Test

Hypothesis testing is used to determine whether the hypothesis is accepted or rejected. The hypothesis test used is the two mean comparison test. Based on the normality test and homogeneity test of the final test data, it was found that the two sample classes were normally distributed and had homogeneous variances, so the hypothesis test for the two sample classes used was the *t* test, as shown in Table 5 below:

Table 5. Hypothesis Test Results - t Postets Sample Class

Class	N	S	S^2	t_h	t_t	Description
Experiment $(X)_{E-1}$	34	9,73	94,67	2,91	2,00	There is a difference in improving critical thinking skills
Control $(X)_{E-3}$	33	11,31	127,91			

Based on Table 16, it is obtained that $_{tcount}$ = 2.91 while t_{tabel} = 2.00 at the real level = 0.05 and dk = 65. Ho acceptance criteria, if -t $_{tabel} \leq _{thitung} g \leq t_{tabel}$, or t $_h < t_t$. Because th = 2.91 is outside the Ho acceptance area and t_h is greater than t_t , then the working hypothesis Hi is accepted. These results indicate that the accepted hypothesis is that there is a **significant effect of using the *Problem Based Learning* model assisted by learner worksheet on students' critical thinking skills on the subject of the Nature of Physics and Measurement of Class X Senior High School in Lubuk Sikaping.**

The test questions were made in accordance with the indicators of critical thinking , namely there are 5 indicators, namely: the ability to identify problems (Interpretation), the ability to analyze arguments into other forms with the same meaning (Analysis), the ability to assess the credibility of claims and the strength or weakness of arguments (Evaluation), the ability to draw conclusions (Inference), and the ability to explain something in detail (Explanation) [14] . Based on data analysis, there are differences in students' critical thinking skills in the two sample classes. Based on students' knowledge competencies, the percentage of critical thinking skills of experimental class students is higher than the control class as shown in Figure 2 below:

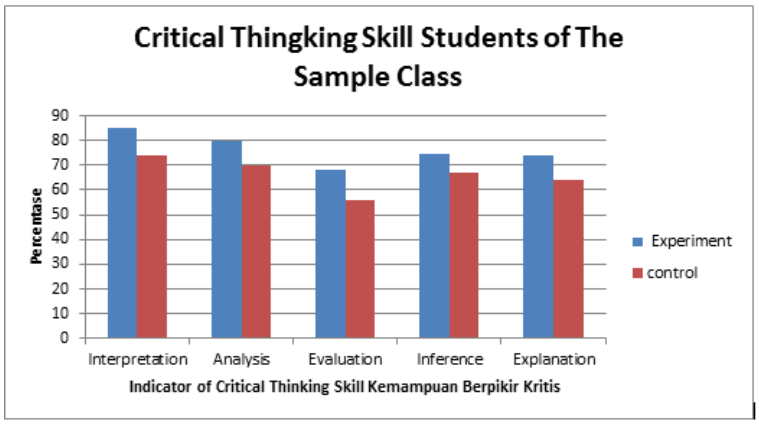

Figure 2. Graph of Critical Thinking Skill of Sample Class Students

From Figure 2 , it can be seen that the value of students' critical thinking skills per indicator is different from the value of critical thinking skills in the experimental and control classes. In each indicator of critical thinking ability , the experimental class students were higher than the control class. In the experimental class, the interpretation indicator was 85%, Analysis 79.9%, Evaluation 67.93%, Inference 74.43%, and Explanation 73.89%. While in the control class the interpretation indicator was 73.67%, Analysis 70.1%, Evaluation 55.88%, Inference 66.8%, and Explanation 63.9%. The difference in the value of this ability occurred because the experimental class was given different treatment from the control class. In the experimental class, learning was assisted by the use of the Problem Based Learning model assisted by learner worksheets while in the control class it was not. The results of critical thinking skills in both sample classes in the initial condition have the same ability. After applying the Problem Based Learning model assisted by learner worksheet to one of the sample classes, namely the experimental class on the material of the Nature of Physics and Measurement, there were differences in critical thinking skills in the experimental and control classes. This difference indicates that there is a significant effect of using the Problem Based Learning model with worksheet to improve the critical thinking skills of students in class X of the Senior High School in Lubuk Sikaping.

B. Discussion

This research was carried out at Senior High School in Lubuk Attitude from 10 July 2023 to 14 September 2023. This research began by conducting initial observations in the form of interviews with the Physics teacher and through a test instrument in the form of 4 Physics essay questions which contained indicators of critical thinking. This initial observation aims to see students' initial critical thinking abilities before being given treatment and determine the sample class that will be used as the class that will be studied in the research. Two classes were taken as samples, namely the experimental class and the control class. The experimental class was obtained, namely class X $_{E-1 \text{ and}}$ the control class, namely XE-$_{3.}$

The results of the research carried out are appropriate and related to the research theory used. In this study, researchers used the Problem Based Learning model which will be taught to the two sample classes, namely the experimental class and the control class. The use of the Problem Based Learning model is related to the theory put forward by several experts, namely by [15] who states that the Problem Based learning (PBL) model is learning that focuses on daily problem solving activities that are student-centered. This is also in accordance with the theory by [16] , namely the Problem Based Learning model is learning that displays various real problems experienced by students in everyday life, so that it functions as a stepping stone for investigation. The PBL model used is supported by Gagne's learning theory which states that the learning process increases with increasing age and the practice an individual obtains, and learning will be faster if cognitive strategies can be used to solve problems more efficiently [17] . The Problem Based Learning model in this research is in accordance with the theory put forward by experts, namely that during the learning process students are very active in solving or finding solutions to the daily problems they are given. Students discuss in groups to find information and solutions to a given problem while the teacher acts as a facilitator. During learning, the teacher provides an introduction (orientation) to students' lives in accordance with the related material. Then, the teacher (organizes) the students regarding the problem. Then, the teacher encourages students to obtain information by experimenting (investigation). With the experiments that students have carried out, the teacher guides students to make reports (presentation of results) and publish them (evaluation) in the form of presentations. The main goal of the Problem Based Learning model is to develop students' critical thinking skills and problem solving abilities in building their own knowledge [18] .

In this research the experimental class and control class used the same learning model, namely the Problem Based Learning model on the Nature of Physics and Measurement material but with different teaching materials. In the experimental class, Problem Based Learning based worksheet teaching materials were used plus student textbooks, while in the control class the teaching materials used were school worksheet teaching without P roblem Based Learning -based and student textbooks. Learning with learner worksheet teaching makes students learn independently with their groups and carry out learning steps according to the worksheet teaching. Students in groups will discuss solving a problem contained in the learner worksheet teaching and then present it. This is in line and related to the theory by [19] which states that Student Worksheets can be used to develop cognitive aspects in the form of investigation or problem solving activities according to the indicators to be achieved. The worksheet used in this research contains sheets of paper containing summaries, implementation instructions and material that must be worked on by students in reference to the goals to be achieved [20] .

The role of worksheets is very large in the learning process. Worksheets can improve students' problem solving skills, critical thinking, and mastery of concepts, especially in the field of physics learning [21] . Worksheet can direct students to solve Physics problems through problem solving steps [22] . Worksheets can also increase student motivation and be able to build student arguments in learning [23] . Worksheets are very good to use to increase student involvement in the learning process which guides students to discover concepts, one of which is Problem Based Learning (PBL). The use of Problem Based Learning based worksheet in experimental classes provides many benefits in the learning process teaching, especially in an independent curriculum which emphasizes active students, including making it easier, faster and improving students' ability to master the subject matter.

Learning with the help of Problem Based Learning-based Worksheet can improve students' critical thinking skills, especially in physics learning because it can produce graduates who are in line with the needs of technology and information development [24] . The Problem Based Learning-based worksheet in this research contains material about the Nature of Physics and Measurement. At each meeting, Problem Based Learning - based worksheet will be given to the experimental class according to the sub-material to be studied. This worksheet contains learning steps according to the syntax of the learning model used. Because this research uses the Problem Based Learning model, the worksheet used must be adapted to the syntax of the Problem Based Learning model, namely orientation, organization, investigations guiding, developing and presenting work results and evaluation.

Through the use of the Problem Based Learning model assisted by Problem Based Learning-based worksheet , it has the effect of honing students' thinking skills and activeness so that they can increase students' critical thinking abilities. In line with theory [25] which states that critical thinking is an active activity that involves the process of manipulating and changing information in memory. Based on the theory put forward by this expert, it turns out to be related and proven to be the learning process that took place during the research.

During the learning process, researchers saw that students were actively and competitively searching for solutions in solving a problem given through worksheets in their respective groups. Students discuss and exchange ideas together and state their reasoning and hypotheses to solve problems in the worksheet which they will then present.

It was proven that the average value of the critical thinking abilities of class, the average score of experimental class students who used Problem Based Learning-based worksheet was much higher than the average score of control class students who used non-Problem Based Learning-based school worksheet . This can be seen from the results of the worksheet answers and the posttest results that have been given, the average student score is better than before, especially the average score of experimental class students is much higher than the average score of the control class. Based on the results of observations, the quality of student learning is increasing day by day. This is in accordance with the expectations of the Merdeka Curriculum, namely that learning is student center oriented, which is the dominant learning activity for students, the teacher only guides and facilitates the learning process to be carried out. Research conducted by [26] concluded that teachers and students need to apply the Problem Based learning model and worksheet in learning. Because of this, the use of teaching materials such as Student Worksheets is an alternative for improving students' critical thinking skills. The effectiveness and efficiency of Problem Based Learning -based worksheet is able to support student learning, especially in Physics subjects, especially in the Nature of Physics and Measurement material.

The results of this research were to see how the use of the Problem Based Learning model assisted by worksheets had an effect on the critical thinking abilities of Class Based on the results of the final test analysis (posttest) , it showed that the average critical thinking the ability of students in the experimental class is higher than that in the control class, the experimental class average is 76.23 and the control class average is 68.81. The sample is normally distributed and the variance is homogeneous so that a t-test is carried out, at the 5% level of significance the $t_{h\ value}$ is in the Ho rejection area. This shows that the two classes have differences in average, the difference in average critical thinking abilities between the experimental class and the control class occurs due to the influence of the treatment given to the experimental class in the form of the use of the Problem Based Learning model assisted by Problem Based Learning - worksheet . So it can be concluded that there is an influence of using the Problem Based Learning model assisted by worksheet on the critical thinking abilities of class

This research has been carried out as best as possible, but there are still several obstacles in conducting research. The first obstacle is limited class hours when testing questions at Senior high school in Lubuk Suhuing . The solution is to ask the next subject teacher for permission to add more hours to the Physics lesson that day. The second obstacle is that students are not used to using worksheets in learning. This can be seen at the first meeting, students still have difficulty understanding or using the worksheet . The solution is to provide guidance and direction to students in using workseet regarding the nature of Physics and Measurement material. The next obstacle is that the class conditions during learning are a bit noisy because students in each group start discussing and are enthusiastic in expressing their opinions. The solution is to remind students to maintain a more conducive learning atmosphere, and invite students to respect each other in group discussions.

IV. CONCLUSION

Based on the data analysis that has been carried out, conclusions can be drawn. That the application of the Problem Based Learning model assisted by worksheet in the experimental class and the application of the Problem Based Learning model without the assistance of worksheet in the control class, obtained differences in the results of critical thinking abilities in the two sample classes. The average critical thinking ability score of experimental class students was higher than that of the control class. The results of the hypothesis test show that this situation occurs because there is a significant influence of the Problem Based Learning model assisted by worksheet on the critical thinking abilities of class X Senior High School in Lubuk Sikaping on the Nature of Physics and Measurement

ACKNOWLEDGMENT

I am grateful to the supervisor Dra. Yurnetti, M.Pd, to the Departement of Physics at Universitas Negeri Padang, the Pillar of Physics Education Journal , and all the other contibutors who helped to make this paper possible. Hopefully, many readers will find this helpful material.

REFERENCES

[1] AF Islamiah, S. Rahayu, N. Nyoman, and S. Putu, "Effectiveness of the LKS-Assisted Problem Based Learning Model on the Physics Critical Thinking Ability of SMAN 1 Lingsar Students in the 2016 / 2017 Academic Year," vol. 6, no. 1, pp. 29–36, 2018.

[2] I. Al-fikry and M. Syukri, "The Influence of the Problem Based Learning Model on Students' Critical Thinking Ability in Heat Material," vol. 06, no. 01, pp. 17–23, 2018, doi: 10.24815/jpsi.v6i1.10776.

[3] EE Wahyudi and N. Siti, "Learning Geometric Optics Through Problem Based Learning (PBL) in View of Students' Critical Thinking Ability and Creative Thinking Ability of Class X High School Students 2014 / 2015," vol. 6, no. 3, pp. 49–60, 2017.

[4] ZP Utama and F. Festiyed, "Effectiveness of Developing Student Worksheets Based on 4C Skills Through the Research Based Learning Model for Physics Learning," *J. Perelit. Physics Learning.* , vol. 11, no. 2, pp. 179–184, 2020, doi: 10.26877/jp2f.v11i2.6232.

[5] K. Education, AND Technology, B. Standards, and DANA Education, *Ministry of education, culture, research and technology* , no. 021. 2022.

[6] Minister of Education and Culture Regulation, "Regulation of the Minister of Education, Culture, Research and Technology of the Republic of Indonesia Number 16 of 2022 concerning Process Standards for Early Childhood Education, Basic Education Levels and Secondary Education Levels," 2022.

[7] D. Paradina and R. Medriati, "The Influence of the Problem Based Learning Model on Class X Student Learning Outcomes," vol. 2, no. 3, pp. 169–176, 2019.

[8] PB & D. Marsa, "Analysis of Media, Learning Resources, and Teaching Materials Used by High School Physics Teachers on Wave Material in West Sumatra in View of 21st Century Learning Needs," vol. 4, 2020.

[9] Asrizal, *Hw* . 2012.

[10] L. Nurliawaty, I. Yusuf, SW Widyaningsih, P. Physics, and U. Papua, "Learner Worksheet (LKPD) Based on Polya Problem Solving," vol. 6, no. 1, 2017.

[11] Setyosari, *Education and Development Research Methods* , 4th ed. Jakarta, 2016. [Online]. Available: Prena Media Group

[12] Sugiyono, *Quantitative, Qualitative and R&D Research Methods* . Bandung: Alfabeta, 2017.

[13] Djamas, *Physics Education Research Methodology* , 1st ed. Padang, 2015.

[14] PA Facione, “Critical Thinking : What It Is and Why It Counts,” 2011.

[15] EDE Graaff, “Characteristics of Problem-Based Learning,” vol. 19, no. 5, 2003.

[16] RI Arends, *Learning to Teach* , 9th ed. New York: Mc Graw Hill Companies, 2001.

[17] AA Sulaeman, "Continuous Professional Development Module".

[18] A. Farisi, A. Hamid, and Melvina, "The influence of the problem based learning model on critical thinking skills in improving student learning outcomes on the concepts of temperature and heat," pp. 283–287, 2017.

[19] O. Brian Pramesti, S. Supeno, and S. Astutik, "The Influence of the Guided Inquiry Learning Model on the Scientific Communication Ability and Physics Learning Outcomes of High School Students," *J. Physical Sciences. and Learning* , vol. 4, no. 1, pp. 21–31, 2020.

[20] ME Nurazri, F. Mabruroh, YT Samiha, and Apit Fathurohman, "Development of Student Worksheets Based on Contextual Teaching and Learning (CTL) on Heat Transfer," no. May, 2023, doi: 10.23960/jpf.v10.n1.202212.

[21] Syafwan, Mahrizal, and Z. Kamus, "Creating Class X High School Physics Student Worksheets (LKPD) Oriented to IDEAL Problem Solving Strategies," vol. 8, pp. 33–40, 2016.

[22] CT Noprinda and SM Soleh, "Development of Student Worksheet Based on Higher Order Thinking Skill (HOTS)," vol. 02, no. 2, pp. 168–176, 2019.

[23] Y. Ramadhani, Akmam, and L. Dwiridal, "Comparison of Students' Science Competencies Between Think-Pair-Share (TPS) Cooperative Learning Model and Snowball Trowing in Class VII SMPN 11 Padang," vol. 8, pp. 57–64, 2016.

[24] M. Pulungan, N. Usman, Suratmi, VA SM, and B. Harini, "LKPD in K13 Thematic Learning," pp. 29–36, 2013.
[25] YN Nafiah, W. Suyanto, and UN Yogyakarta, "Application of the Problem Based Learning Model to Improve Critical Thinking Skills and Student Learning Outcomes," no. c, pp. 125–143.
[26] F. Aulyana, A. Putra, and Yurnetti, "The Effect of Using LKPD Oriented to Content Complexity and Cognitive Processes in the Problem Based Learning Model on the Achievement of Physics Competency for Class X Students at SMAN 7 Padang," vol. 9, no. April, pp. 41–48, 2017.