Improving Students’ Critical Thinking Ability Using Problem Based Learning (PBL) Learning Model Based on PhET Simulation

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Abstract – The ability to think critically is one of the abilities of High Order Thinking that must be possessed by students, but in reality the mastery of this ability is still low. Therefore, this study aims to produce physics learning and research instruments that are feasible to use in learning physics by using PBL learning models, knowing the effectiveness of learning media in the form of PhET simulations in physics learning, and knowing the improvement of students’ critical thinking skills. The subjects of this study were 62 grade 10 students. This research was a development research with 4D model. The define phase is done by defining the problems contained in learning so that appropriate learning and research instruments can be formulated. The design stage is carried out by developing physics learning and research instruments in accordance with what has been formulated at the define stage that implements the syntax of the PhET-assisted PBL learning model. The develop phase is done by producing revised learning instruments and physics research instruments based on designs that have been prepared at the design stage. The dissemination phase is carried out by disseminating development products in the form of learning instruments and physics research. The results showed that the physics learning and research instruments developed were feasible to be used in physics learning as evidenced by the results of validity and reliability. The learning media in the form of PhET were effectively used in physics learning, and the improvement of students’ critical thinking skills in the modeling and implementation classes were included in the medium category.

Keywords – Instrument Development, PhET, Problem Based Learning, Critical Thinking Ability

1. Introduction

In the implementation of education there are various kinds of challenges, one of which is the demand for technological progress. Challenges that arise from the development of human life become a demand for teachers to adjust their learning to those demands [1]. In line with this explanation, [2] states that technological advances in education are growing with the use of smartphones by students during learning. This is consistent with the data obtained by [3] that the use of smartphones by students in MAN 3 Sleman, Yogyakarta is 52.35%. However, the use of smartphones by students has not given a positive impact in achieving the desired learning goals [2].

Most students misuse smartphones in learning such as playing games, watching videos, and even exchanging messages. According to [4,5] students tend not to realize that the use of smartphones in learning can also facilitate them in understanding the material taught by the teacher, such as through various kinds of applications and physics learning simulations found on smartphones. In line with the statement, [6,7] that learning media in the form of physics-based physics and comic laboratory simulations based on Android deserve to be used as learning media for students of senior high school. [8] also proves that Android-based physics games can improve student learning outcomes and critical thinking skills.

Technological advances in education must also be integrated with the curriculum that is currently used in physics learning in schools, namely the 2013 curriculum. In the 2013 curriculum, with the delivery
of the material to the students using a scientific approach, students are trained to observe problems, analyze and solve, communicate them in writing or verbally with the help of technology [9]. In addition, students are also required to be skilled in reasoning, processing, and presenting effectively, collaboratively, communicatively, and solely [10].

Physics has an important role in advancing education, thus attracting the interest of educators to carry out the planned physical education based on existing physics concepts. However, in the implementation of physical education it becomes better if the physical material taught by the teacher is packaged using practical technological assistance and linking material with phenomena in everyday life [11]. In line with these findings, [12] found that the results of the assessment of concept understanding and critical thinking of students towards mechanics material based on the experience of daily life is higher than textually.

Meanwhile, through preliminary observations there were problems such as lack of innovation in learning media used by teachers in delivering physics material to students and learning only focused on the teacher, so that students were not enthusiastic about the material presented by the teacher. Therefore, centralized learning is needed for the students, and one of them is the Problem Based Learning model [13]. PBL learning models offer a problem solving guided by educators to help students obtain material concepts through problem solutions [14].

PBL provides students with the opportunity to be more fully involved and assume greater responsibility for learning. In line with the previous statement, [15,16] stated that the implementation of learning using PBL learning models can develop students' thinking ability through information processing, critical thinking, and instilling in students themselves to be responsible. Meanwhile, [17] mentions that PBL is recognized as the development of student-centered active learning, which uses unstructured problems as a basis for learning.

Meanwhile, high-order thinking skills need to be possessed by the students. High-level thinking can teach them the habit of critical thinking. Thus, students are able to solve problems in everyday life by utilizing technological progress [18]. Students who have critical thinking skills are able to make solutions to the problems faced [18,19]. [20,21] stated that exploration of phenomena in daily life conducted by students through questions and hypotheses can help them to think critically.

The critical thinking ability referred to in this study is the cognitive abilities of students during and after the learning process. Their critical thinking abilities include the ability to analyze (C4) and combine (C6) [22]. [23,24] that the ability to analyze is the main ability in the aspect of critical thinking and the analyzing ability of high school students is still low. Meanwhile, the ability to combine is the ability of the students to combine multiple data or input into a concept of learned material [24].

Therefore, one of the instruments used to determine the improvement of students’ critical thinking skills is a test instrument with a multi-response format [25,26]. [27,28] state that if to measure critical thinking skills students use multiple choice response formats, then measured is only the understanding or level of knowledge and not able to measure their critical thinking skills. When using a reasoned multiple choice format, it is not able to reveal the reasons underlying the choice of answers [29]. Meanwhile, when using a test instrument in the form of a combination of multiple choices and essays, it allows students to fill it spontaneously [30].

Therefore, in this study the instrument to measure the increase in critical thinking skills of students uses a combination of essays with multi responses so that students answer them based on their knowledge without spontaneous thinking. Regarding this problem, the purpose of this research is to produce physics learning and research instruments that are suitable to be used in physics learning by using PBL learning models, knowing the effectiveness of learning media in the form of PhET simulations in physics learning, and knowing the students’ critical thinking skills.

2. Methods

This research was conducted in MAN 3 Sleman in the even semester of 2018/2019 school year in February-May 2018. MAN (State Madrasah Aliyah) 3 Sleman is an Islamic high school under the policies and responsibilities of the Ministry of Religion, Sleman Regency, Special Region of Yogyakarta, Indonesia. MAN Sleman 3 is one of the pilot Islamic high schools in Sleman Regency, Yogyakarta. Meanwhile, the subjects in this study were 32 students of class X MIPA 1 as a modeling class and 30 students of class X MIPA 3 as an implementation class. The research method used is Research and Development (R & D) research method. [31] states that the R & D research method is a method used to produce certain products and test the feasibility of these products. Therefore, a research design that is consistent with this study adapts the 4D model [32]. The research design consists of four main stages, namely define, design, develop, and disseminate.
a. Define Stage

This define stage consists of five main steps.

1) Preliminary Analysis

The results of the preliminary analysis showed that the academic activities at MAN 3 Sleman were quite solid and the implementation schedule of the End of Year Assessment was advanced, making the teacher speed up the delivery of physics material in class X. Finally, the solution was to convey Impulse and Momentum material first, then deliver Energy material. Meanwhile, the results of interviews with physics teachers stated that the learning method used was lectures. It is rare for teachers to deliver material using simulation, only some abstract material. In addition, the aspects of critical thinking are less noticed, more attention is on the cognitive learning outcomes of students.

2) Student Analysis

The analysis results of students showed that students in class X MAN 3 Sleman were in average 15-16 years old. Their cognitive development characteristics are in the formal operational stage which has many creative and innovative ideas. In addition, students begin to be able to think logically about abstract ideas, be able to distinguish the concrete from the abstract, and they evaluate what they have learned.

3) Curriculum Analysis

The results of curriculum analysis produce several indicators and learning objectives that are in accordance with Energy material. The learning indicator is analyzing potential energy in objects, analyzing kinetic energy in objects, combining the relationship between potential energy and height in objects moving into the graph, and forming a graph of the relationship between kinetic energy and velocity on moving objects.

4) Concept Analysis

The results of the concept analysis are expressed by forming a concept map for the Business and Energy material of the Energy subject in accordance with the physical material used in the study.

b. Design Stage

This design phase consists of four main steps.

1) Preparation of Research and Learning Instruments

The preparation stage of the research instrument was carried out by compiling instruments for measuring students' critical thinking abilities. The measurement instrument used to measure students' critical thinking skills consists of 5 items essay questions with indicators used are analyzing (C4) and combining (C5). The learning instrument was compiled in the form of a physics learning device based on a PhET simulation using PBL learning model and its feasibility questionnaire.

2) Determination of the Type of Learning Instrument

The learning instruments used include the Learning Implementation Plan (RPP) for the second meeting of two meetings for 2 Learning Hours and 1 discussion sheet for the Student Worksheet (LKPD) by applying some syntax of the PBL learning model consisting of 7 issues.

3) Selection of Learning Media

The learning media selected in this study were PhET simulations about skate board games, laptops, android smartphones and projector LCD screens, and skate board video games. The media was chosen because it supports the implementation of the PhET simulation. Learning media in the form of PhET simulation is chosen because the learning media is able to explain events related to the Business and Energy material in everyday life practically and able to foster self-reliance in students so that they are able to think critically.

4) Preliminary Design of Learning and Research Instruments

The development of the initial design of this instrument focused on the syntax of the PBL learning model in the form of organizing students to learn, developing and presenting the work, as well as analyzing and evaluating the problem solving process. In addition, aspects of students' critical thinking skills are focused on the cognitive aspects of analyzing and combining.

c. Develop Stage

This develop phase is in the form of elaboration of operational indicators and indicators of critical thinking ability test items that are in accordance with the syntax of PBL learning models shown in Table 1. Furthermore, compiling the development matrix according to this research is shown in Table 2.
Table 1. Operational Indicators and Test Points for Critical Thinking Ability

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Operational Indicator</th>
<th>Item Indicator</th>
<th>Item Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Knowledge</td>
<td>Analyzing potential energy in an object.</td>
<td>Analyze the position of the skate board game movement that matches the energy diagram correctly.</td>
<td>[1]</td>
</tr>
<tr>
<td></td>
<td>Analyzing kinetic energy in an object.</td>
<td>Analyze height, speed, potential energy, and advanced kinetic energy from the movement of the skate board game into the table provided.</td>
<td>[2]</td>
</tr>
<tr>
<td></td>
<td>Combine the relationship between potential energy and altitude on moving objects into a bar graph.</td>
<td>Combine positions and apply friction or not from the four skate board games that match the energy diagram. Form in graphical form the relationship between height and potential energy as well as the relationship between speed and kinetic energy of the skate board game in certain positions. Form and explain the location of potential and kinetic energy when reaching the maximum and minimum values in skate board.</td>
<td>[3]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4]</td>
</tr>
</tbody>
</table>

These operational indicators and item indicators are indicators of critical thinking abilities adapted from Bloom's revised taxonomy [22]. Aspects of critical thinking skills used in this study are only aspects of C4 (Analyzing) and C6 (Combining), not using the C5 aspect (Evaluating). This is because the ability of students towards aspects of analysis and combination is still low [23].

Meanwhile, the development matrix in this study is shown in Table 2.

Table 2. Research Development Matrix

<table>
<thead>
<tr>
<th>Syntax of Problem Based Learning Models</th>
<th>Indicator of Tests for Critical Thinking Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1: Student orientation on problems</td>
<td>Analyze the position of the skate board game movement that matches the energy diagram.</td>
</tr>
<tr>
<td>Phase 2: Organizing students to learn</td>
<td>Analyze the height, speed, potential energy, and advanced kinetic energy of the movement of the skate board game.</td>
</tr>
<tr>
<td>Phase 3: Guiding individual and group investigations</td>
<td>Combine positions and apply friction or not from the skate board game that matches the energy diagram. Form a graph of altitude relationships with potential energy and the relationship between speed and kinetic energy of the skate board game in a particular position. Form and explain the location of potential and kinetic energy when reaching the maximum and minimum values in skate board games.</td>
</tr>
<tr>
<td>Phase 4: Develop and present work</td>
<td></td>
</tr>
<tr>
<td>Phase 5: Analyze and evaluate the problem solving process</td>
<td></td>
</tr>
</tbody>
</table>
The check mark in Table 2 indicates that the indicator of critical thinking ability points appears in the appropriate PBL phase. Indicators of these points do not appear in phases 1, 2, and 5, but appear in phases 3 and 4 because in both phases the students begin to do core activities in learning by applying the five indicators to the point of critical thinking skills. After developing the instrument, then is done the initial design validation by expert validators and practitioners. After obtaining input and improvement on the instruments developed, then they are revised according to the input and improvement. Both revised instruments are then applied to students.

d. Disseminate stage

The disseminate stage is carried out by disseminating learning instruments and research results from development to students, teachers, or other schools. In addition, scientific articles from this study are also published in scientific journals so that they can be useful for researchers or readers in general.

Product Specifications

Product specifications developed in the study consist of two types, namely learning instruments and research instruments.

a. Learning Instrument

1) RPP PBL is based on PhET simulation

The RPP used contains a teacher's guide consisting of preliminary, core and closing activities that are adapted to the PBL learning model syntax. This RPP is expected to be able to support learning with PBL models based on PhET simulations, so that learning objectives in the form of improving students' critical thinking skills can be achieved.

2) PhET simulation

Learning media used by applying existing media in the form of PhET simulations. This learning media is used as a stimulus given to students so that they can easily learn the Business and Energy material. This learning media is a medium that simulates events in daily life in the form of skateboarding games that are related to the Business and Energy material.

3) LKPD PBL Based on PhET Simulation

This LKPD is used to determine the achievement of students in understanding the Business and Energy material. In the part of organizing students to learn, they were asked to identify physical quantities in the video game skate board, in the section developing and presenting the work, they were asked to analyze problems and form charts related to Energy material in skate board games. Then in the section of analyzing and evaluating the problem solving process, they were asked to draw conclusions based on a skate board game simulation related to the concept of Energy.

b. Research Instruments

The validation questionnaire was used to obtain a review along with improvement suggestions from expert validators and practitioners on learning and research instruments. In addition, other research instruments in the form of good test questions pretest and posttest are composed of aspects of analyzing (C4) and combining (C6) which correspond to Bloom's taxonomy. Critical thinking ability test instrument consists of 5 essay questions by applying problems from the skate board game simulation related to Energy material.

Data Analysis Technique

The feasibility of learning instruments and research is obtained from the validation score given by two validators and analyzed using the Aiken's V equation shown by equation 1.

\[
v = \frac{s}{n(c - 1)} = \frac{\sum (r - l_o)}{\sum n(c - 1)}
\]

\(s\) is an appraiser to \(n\), \(l_o\) is the lowest rating score, \(c\) is the highest rating score, and \(r\) is the number given by the appraiser to \(n\).

Meanwhile, [33] states that the criteria for the validity score of an assessment instrument are divided into 5 as shown in Table 3.

<table>
<thead>
<tr>
<th>Validity Score</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8 ≤ V ≤ 1.0</td>
<td>Very Good</td>
</tr>
<tr>
<td>0.6 ≤ V ≤ 0.8</td>
<td>Good</td>
</tr>
<tr>
<td>0.4 ≤ V ≤ 0.6</td>
<td>Enough</td>
</tr>
<tr>
<td>0.2 ≤ V ≤ 0.4</td>
<td>Bad</td>
</tr>
<tr>
<td>V ≤ 0.2</td>
<td>Very Bad</td>
</tr>
</tbody>
</table>

The next step is to analyze the reliability scores of the test instruments that students have done. This analysis was obtained using the equation percentage of agreement (PA). This method is done by assessing
the results of the test questions of the students by two assessors and then testing the level of approval using the PA equation shown by equation 2 [34].

\[
PA = \left(1 - \frac{A - B}{A + B}\right) \times 100\% \tag{2}
\]

PA is a large percentage of agreement, A is a higher total assessor score, and B is a lower total assessor score. Based on the PA value the level of approval of critical thinking test questions can be known, provided the PA value ≥ 75% can only be stated as two agree/reliable assessors.

Meanwhile, the effectiveness of the PhET simulation is determined using one-sample t-test technique by reviewing the improvement of critical thinking skills according to the Minimum Completeness Criteria (KKM) of 75. The decision criteria used are Ho rejected if the sig value, which was obtained less than the significance level (α) of 0.05. The hypothesis for testing one sample t-test in the modeling and implementation class is H₀: the PhET simulation is not effective in terms of increasing students’ critical thinking skills. H₁: PhET simulation is effective in terms of increasing students’ critical thinking skills.

Increased critical thinking skills can be seen through the results of the work on pretest and posttest questions analyzed using standard gain equations. This technique is done by calculating the gain value first [35]. The standard gain equation used is shown by the following equation 3,

\[
\text{std gain} < g > = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \tag{3}
\]

g is a standard gain, posttest and pretest scores are the posttest and pretest scores obtained by students, and maximum score is the possibility of students to get the biggest score. The maximum score in this test is 43. Meanwhile, the interpretation of the standard gain is shown in Table 4.

<table>
<thead>
<tr>
<th>Value of g</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>g &gt; 0.7</td>
<td>High</td>
</tr>
<tr>
<td>0.3 &lt; g &lt; 0.7</td>
<td>Medium</td>
</tr>
<tr>
<td>g &lt; 0.3</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 4. Standard Gain Value Criteria

3. Results

The results of the development of learning and research instruments that apply the PhET-based PBL learning model are shown in Figure 1. and Figure 2.

The question asked the students to form an energy diagram of the skate board game movement. Questionnaires are adjusted to aspects of critical thinking skills which are forming or combining, phase 4 PBL learning model syntax about developing and presenting work, as well as PhET simulation images.

The question asked the students to analyze the amount of physics that changes with the movement of the skate board game. The question item is adjusted to the aspect of the critical thinking ability which is analyzing and simulating PhET images.

The results of the validity of PBL learning instruments based on PhET simulations are shown in Table 5. These results indicate that in general the developed learning instruments are very good.

Table 5. Learning Instrument Validation Results

<table>
<thead>
<tr>
<th>No.</th>
<th>Learning Instrument</th>
<th>Validity (V)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Lesson plan</td>
<td>0.82</td>
<td>Very Good</td>
</tr>
<tr>
<td>B.</td>
<td>Learning media</td>
<td>0.81</td>
<td>Very Good</td>
</tr>
<tr>
<td>C.</td>
<td>PhET simulation</td>
<td>0.80</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Student Worksheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learning Instrument</td>
<td>0.81</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Validity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on Table 5., all learning instruments developed have very good or valid categories, but learning instruments that have the lowest validity scores are Student Worksheets (V = 0.80).

Meanwhile, the results of the validity of the research instrument to measure the improvement of students’ critical thinking skills in the form of tests are shown in Table 6. These results indicate that in general all aspects of the research instrument developed are very good, except in the aspect of quality of the material (good).

Table 6. Results of Validation of Research Instruments

<table>
<thead>
<tr>
<th>No.</th>
<th>Assessment Item</th>
<th>Validity (V)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aspects of the Learning Guide</td>
<td>0.83</td>
<td>Very Good</td>
</tr>
<tr>
<td>B</td>
<td>Quality Aspects of Material in Problem</td>
<td>0.78</td>
<td>Good</td>
</tr>
<tr>
<td>C</td>
<td>Image and Linguistic Aspects</td>
<td>0.87</td>
<td>Very Good</td>
</tr>
<tr>
<td>D</td>
<td>Appropriate Aspects of Critical Thinking Questions</td>
<td>0.80</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Validity of Research Instruments</td>
<td>0.82</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Based on Table 6., all aspects of the research instrument have a validity score at 0.80 intervals which are included in the very good category, but the material quality aspect in the question has the lowest validity score of 0.78 with good category.

In addition to considering the results of the validity, the test instruments to measure the improvement of critical thinking skills of students also consider the results of the reliability shown in Table 7.

Table 7. Results of Reliability of Research Instruments

<table>
<thead>
<tr>
<th>Class</th>
<th>Percentage of Agreement (%)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>Pretest</td>
<td>96.54</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>97.18</td>
</tr>
<tr>
<td>Implementation</td>
<td>Pretest</td>
<td>95.62</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>96.26</td>
</tr>
</tbody>
</table>

These results indicate that in general all aspects of the research instrument developed are very good, except in the aspect of quality of the material (good).

Table 8. Effectiveness of Media in the Form of PhET Simulations

<table>
<thead>
<tr>
<th></th>
<th>Test Value = 75</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td>Modeling Class</td>
<td>-15.370</td>
</tr>
<tr>
<td>Implementation Class</td>
<td>-8.054</td>
</tr>
</tbody>
</table>

These results indicate that the PhET simulation in the effective modeling and implementation classes is used in terms of increasing students’ critical thinking skills towards KKM. PhET simulations are effectively used in physics learning because of sig values of 0.00 which is less than 0.05, then H₀ is accepted or the PhET simulation is effective in terms of increasing the critical thinking skills of the students in the modeling and the implementation classes.

The results of LKPD workmanship for modeling and implementation classes are shown in Table 9.

Table 9. Results of LKPD Work on Both Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Score</th>
<th>%</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>37.94</td>
<td>48.00</td>
<td>19.00</td>
</tr>
<tr>
<td>Implementation</td>
<td>45.47</td>
<td>51.00</td>
<td>41.00</td>
</tr>
</tbody>
</table>

These results indicate that in general the achievement of the students in working on LKPD in the two classes is still low. This is shown by the achievement of the students in the two classes that have not been good. In addition, the difference in achievement of the results of the LKPD workings of the two classes was relatively large, amounting to 12.76%, so it can be stated that the results of the LKPD work in the implementation class were better than the modeling class. Meanwhile, the achievement of each class was obtained from the calculation of the LKPD average work divided by the maximum score then multiplied by one hundred percent, also applicable to the achievement of the aspects of critical thinking skills.

The improvement of students’ critical thinking skills in the modeling class is presented in Figure 3.

Figure 3. Increased Critical Thinking Ability of Students in Modeling Classes
Figure 3. shows the difference between pretest and posttest results for the aspects of analyzing and combining in the modeling class. However, the results of combining aspects are much higher than the results of the analyzing aspects of both the pretest and posttest. This is in accordance with the opinion of [23] that the ability to analyze is the main ability in the aspect of critical thinking and high order thinking skills whose authority is still low. The improved aspects of analysis are by 8.12% and the combining aspects by 30.99%, so that the improvement of students’ critical thinking skills in the modeling class- by 39.11% was obtained from the sum of the increase in both aspects. In addition, the standard value of the gain is 0.35 which is included in the medium category.

The increase in critical thinking in the implementation class is presented in Figure 4. The results shown in Figure 3. and Figure 4 generally show that the results of the pretest and posttest for the aspects of analyzing and combining in the implementation class are larger, except the results of the pretest aspects combine which are smaller than the modeling class.

![Figure 4. Improvement of Critical Thinking Ability of Students in Implementation Classes](image)

Figure 4. shows an improvement in the aspects of analyzing by 36.66% and combining by 43.52%, so that the improvement of students' critical thinking skills in the modeling class by 80.18% is obtained from the sum of these two aspects. These results indicate that the improvement of critical thinking skills in the implementation class is much greater than the modeling class with a difference of 41.07%. Meanwhile, the standard value of the gain is 0.61 which is included in the medium category.

4. Discussion

In connection with the first research objective, the feasibility of physics learning and research instruments was obtained through the results of validation from expert validators and practitioner validators. The expert validator who validates the instrument resulting from this development is a physics education expert lecturer and the one who acts as a practitioner validator is a teacher of physics subjects. The learning instruments validated by the two validators are RPP, LKPD, and PhET simulation media. The results of the validation conducted by the two validators on the three learning instruments are generally valid or have a very good category.

Meanwhile, there are four aspects of validity that are assessed from the test instrument to measure the improvement of critical thinking skills, namely the guiding aspects of learning, the quality of the material in test instruments, images and linguistics, and the appropriateness of critical thinking ability instruments. The results of the validity of the students’ critical thinking ability test instrument showed that in general all aspects of the research instrument were very good, except in the aspect of material quality in the questions which were in good category. This is because the possibility of the developed test instrument has low Energy material quality, the application of material in daily life in the form of skate board games that are less familiar, less precise representation of phenomena in everyday life used in the formulation of test items, and formulation of the test instrument items are unclear. [36] state that if there are deficiencies or weaknesses in some aspects of the research instrument, it causes an influence on the variables to be studied.

In addition to considering the results of validity, the test instrument also considers the results of reliability obtained from the results of the test questions of students and tested using PA equations [34]. Based on the assessment of the two assessors on the results of the work on the test questions in the modeling and implementation class, it was shown that in general the research instruments were developed reliably. These results indicate that the research instrument in the form of a test instrument can be used to measure the improvement of students' critical thinking skills in other schools whose characteristics are homogeneous. [25] state that appropriate instruments are used in research, if instruments are valid and reliable.

Meanwhile, in connection with the second objective of the study, the effectiveness of this learning media was obtained through the one sample t-test. In the implementation of this research, the class used was divided into two groups, the first group was the modeling class and the second group was the implementation class. Based on the use of the simulation media, it was found that the percentage of achievement of LKPD workmanship and improvement of students’ critical thinking skills in the implementation class was greater than the modeling class. However, the results of the achievement of LKPD work and the improvement of
critical thinking skills of both classes have not been at a high level. However, these results are consistent with the research conducted by [33], which states that in general the results of the pretest and posttest of the experimental and the control classes are low.

Although the pretest and posttest results of the two classes were not at a high level, the results were able to ensure that the PhET simulation media used in effective learning as a stimulus of students' critical thinking skills. These results are in accordance with the results of [35] that PBL learning tools with the help of technology in the form of Blogs and effective simulation software are used to improve critical problem solving. [36] also stated in their research that psychomotor results of experimental class students using PhET simulations can complete student learning outcomes rather than print KIT.

The learning media is one way of utilizing technology in education, so that various information and communication technologies can be effectively used to support inquiry learning of the students [36]. In addition, [37] stated that the use of information and communication technology in problem-based learning (PBL) is very effective to improve the basic competencies of science students. Therefore, the effectiveness of instructional media in general depends on the active participation of students during learning, the atmosphere in learning, and the suitability of the media used.

In connection with the final research objective, the improvement of students' critical thinking skills is obtained through analysis using the standard gain equation and its achievement. In general, the results of the pretest and posttest for aspects of analyzing and combining in the class of modeling and implementation there are differences. However, the results of the pretest and posttest modeling classes in the aspect of combining are higher than analyzing. Meanwhile, the improvement of critical thinking skills in implementation classes is higher than the modeling class.

This is because the results of the pretest and posttest obtained by the students in the implementation class are higher than the students in the modeling class. However, in the implementation class students who get the lowest score are more than students in the modeling class, but the number of students who get the highest score from both classes is the same. However, in general an increase in critical thinking skills in both classes is still moderate. This result is not in accordance with the research conducted by [37] that the percentage of pretest and posttest results in critical thinking skills in the experimental and control classes in general is low.

In addition, [36] stated that students' critical thinking skills improved well in physics learning using board game android games. In accordance with the results of the study, [37] stated that the model of mass-based learning has a good influence on improving students' critical thinking and critical thinking skills. Different results can occur due to several factors, one of which is the teacher has been able to situate the learning atmosphere in the implementation class better than in the modeling class. In addition, students from both classes generally seldom follow learning with PBL models, but most use the lecture model. Students certainly need a longer adaptation to learning by using PBL models so that the learning objectives can be achieved optimally. [38] stated that the superiority of PBL models rather than lectures is being able to grow high order thinking skills, one of which is critical thinking and fostering the ability to solve problems in everyday life scientifically.

5. Conclusion

Based on the results and discussions related to research on improving students' critical thinking skills using PBL learning models based on PhET simulations, it was concluded that the physics learning and research instruments developed were suitable for learning by using PBL learning models to improve students' critical thinking skills, proven by the results of validity and reliability. Learning media in the form of PhET simulations are effectively used in physics learning that uses PBL learning models to improve students' critical thinking. Meanwhile, the improvement of students' critical thinking skills in the modeling and implementation classes is 39.11% and 80.18% respectively with the standard gain values of 0.35 and 0.61 which are included in the medium category.

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