The Improvement of Critical Thinking Skills Through Problem Based Learning Models Assisted by Trackers Video on Parabolic Movements

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Abstracts. This study aims to improve critical thinking skills using a problem-based learning model assisted by video tracker on parabolic movements. This research was conducted in class X Senior High School Pandeglang. This study uses one group pretest-posttest design with paired sample t-test analysis technique. Learning is done by conducting demonstration activities of parabolic movement based on problem based learning. The results of the video footage of the parabolic motion demonstration were then analyzed using a video tracker application. Based on the results of the study obtained the average score of critical thinking skills increased by 53.936% with a moderate N-Gain average (0.536) at a confidence level of 95%. These results show that learning using a tracker can improve critical thinking skills well. Based on the test results obtained significance of 0.00, it can be concluded that there are significant differences in critical thinking skills before and after learning using the tracker.

1. Introduction

Physics is often thought of as a subject that contains problem solving work by remembering formulas and performing some mathematical calculations. This phenomenon often occurs causing physics to be considered abstract and a difficult subject [1]. Physics learning must be equipped with experimental activities and fundamental in building understanding of the concepts associated with its application in everyday life. However, the availability of appropriate and adequate laboratory equipment in every high school is sometimes considered a luxury, let alone to present a good science experiment. In terms of the availability of suitable laboratory equipment, the experimental data produced is meaningless without proper processing and analysis. So, it is very important that high school students have good skills in processing and analyzing experimental data. Experimental data can be presented in various ways (multiple representations), such as by tables, graphs, or diagrams [2]. Students must be proficient in making cross-representations in order have a basis for scientific reasoning to solve physics problems [3] [4] and conduct physics experiments. Ironically, based on the case study [5], it was found that the problem solving skills of students with a multi-representational approach were still low.

Visual information, such as the chart is an easy way to display the information in a large amount to a form that is easily understood [6]. Graphs are commonly used in many gateway subjects (mathematics and science) to convey important information [7]. Students’ understanding of graphs is
discussed in many Physics Education Research (PER) studies [8][9]. The first is how the PER studies student difficulties in connecting the graph with the physical concept of a [9]. Graphs in the topic of kinematics help students explain the comparison between position, velocity, and acceleration versus time [9][10]. But in fact, students have difficulty in understanding the graph [10]. Some students experience problems with motion graphs even when they understand mathematical concepts [11].

In this study, in the use of video-based learning analytics as an alternative tool for students to practice the skills of critical thinking and multi-representation. Technological advances have provided many better ways to teach physics, one of which is that physical quantities can be presented interactively in a dynamic format [12]. Open Source Physics (OSP) is one of the computational modeling software that is suitable to be applied in high school to improve students' exploration abilities at the application level in the learning cycle [13]. The tracker is one of the video analysis and modeling software built with the OSP Java Framework, which is designed as a supporter to meet various needs in physics learning [14]. Tracker video analysis is free software and can be downloaded from the open source physics website. The benefits of using video analytics tracker are inferred value of video analysis is consistent with the data real-world acceleration due to gravity at Earth's surface [15].

The tracker provides data analysis tools such as graphs and tables, curve fittings, where we can understand examples of particle motion during the experiment. Behavior in interpreting is a way for students to identify and understand the main ideas contained in the information presented, and understand the relationship between ideas or ideas. Interpretations in relation to physics learning include: a) the ability to interpret verbal statements; b) the ability to interpret pictures, graphs, diagrams, and mathematical equations; c) ability to interpret different types of data; d) ability to make appropriate qualifications in interpreting data; and e) ability to distinguish contradictory conclusions from data arrays [16].

Previous studies have reported the results of video analysis Tracker to solve the problems of education Physics related to everyday life like a pendulum [17], projectiles [18], and the free fall motion [19]. Results from previous studies [18][19] in the report that, when teachers deliver lessons using video analysis Tracker Physics and is linked to the concept of physics, the teacher got a lot of positive response from students.

Learning physics using tracking video analysis can be combined with learning models. One model of learning that can improve the ability of students to find the answer to a question is in model problem based learning. The main principle of the problem based learning model is the existence of a problem, student-centered learning, and learning in small groups.

Based on the things mentioned above, a research was conducted that aims to determine the improvement of students' critical thinking skills through the use of Problem Based Learning-based video trackers on Parabolic Motion material.

2. Method
The population of this study, namely all students of class X Senior High School Pandeglang who were distributed into 8 study groups in the odd semester of the 2020/2021 academic year. The sample in this study is class X MIPA totaling 35 students. The design used in this study is the One Group Pretest Posttest Design. The class will be given a pretest to measure the students initial abilities. Then, given the treatment by using a video tracker based on problem based learning on the parabolic motion material. Then the class was given a posttest in the form of the same questions as the initial test. To measure the difference in the results of the critical thinking skills assessment, students conducted pretest and posttest. The learning tools, namely syllabus, lesson plan, worksheet, were validated by experts. The question instrument consists of 10 questions with reasoned descriptions and tests the validity and reliability of the students of Class X Senior High School Pandeglang.
Research data in the form of the use of a video tracker of parabolic motion learning of critical thinking skills obtained by calculating the N-Gain between pretest and posttest through the equation:

\[ g = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \]

| N-Gain (g) | Interpretation Criteria |
|------------|-------------------------|
| 0.7 < g    | High                    |
| 0.3 ≤ g ≤ 0.7 | Medium                |
| g < 0.3    | Low                     |

Normality test and hypothesis testing were carried out using statistical tests. Hypothesis testing using Paired Sample T-test.

3. Results and Discussion

3.1. Instrument Trial

This research was conducted from September to October 2019 at Senior High School Pandeglang in the class X MIPA as many as 35 students. Prior to use in the implementation phase of the research instrument pretest and posttest tested to determine the feasibility of it. The question instrument was tested on 35 respondents. Based on the results of the validity and reliability test, of the 10 questions that were tested for validity, only 8 questions had a Pearson correlation > 0.361 and in the reliability test, 8 valid questions were obtained with a reliability value of Cronbach’s Alpha 0.674, meaning it has a high degree of reliability. So that the question instrument is feasible to use.

3.2. Application of Video Tracker Analysis in Learning

In Figure 1a, the teacher demonstrates a parabolic motion by throwing a ball from a certain height in a horizontal direction. The activity was recorded using a camera. The recorded video was analyzed using a video tracker. The results of the ball motion analysis using a video tracker are shown in Figure 1b. The shape of the trajectory of the ball is a parabolic graph.
Table 2 shows the summary data for mass A, namely time (s), position on the x-axis (m), position on the y-axis (m), and velocity components in the x-axis (v_x m/s), and velocity components in the direction of the y-axis. (v_y m/s)). Based on Table 2 it is known that the magnitude of the velocity component in the direction of the x-axis (v_x) from 0.100 second to 0.400 second has the same relative value, which is 1.2 m/s. This means that the velocity component in the direction of the x-axis of parabolic motion is constant and the trajectory is straight or can be said to be moving in a straight line. The velocity component in the sumby y direction (v_y) from 0.100 second to 0.400 second has a greater value with the increase in speed every time interval of almost the same magnitude or constant acceleration. This means that the velocity component in the direction of the y-axis of the parabolic motion is uniformly changing or can be said to be moving in a straight line and changing uniformly.

| t (s) | x (m) | y (m) | v_x (m/s) | v_y (m/s) |
|------|-------|-------|-----------|-----------|
| 0.100| 0.102 | -5.09 | 1.337 | -1.400 |
| 0.133| 0.144 | -0.110| 1.274 | -1.910 |
| 0.167| 0.187 | -0.178| 1.337 | -2.101 |
| 0.200| 0.233 | -0.250| 1.209 | -2.419 |
| 0.233| 0.267 | -0.339| 1.209 | -2.863 |
| 0.267| 0.314 | -0.441| 1.337 | -3.183 |
| 0.300| 0.356 | -0.552| 1.274 | -3.631 |
| 0.333| 0.399 | -0.683| 1.210 | -4.075 |
| 0.367| 0.437 | -0.823| 1.273 | -4.392 |
| 0.400| 0.484 | -0.976| 1.273 | -5.157 |

3.3. Research Data Analysis
Quantitative data on the results of the pretest carried out at the beginning of the lesson, while the results of the posttest carried out at the end of the lesson can be seen in Table 3. The results of the N-Gain value is shown in Table 4. Based on Table 4, it is known that there is an increase in the average value of the pretest and posttest of 23.97, from 56.89 to 80.86.

| Parameter | Pretest | Posttest |
|-----------|---------|----------|
| Total students | 35 | 35 |
| Lowest value | 35.00 | 70.00 |
| The highest score | 76.00 | 93.00 |
| Maximum value | 100.00 | 100.00 |
| Average score | 56.89 | 80.86 |

| Parameter | Information |
|-----------|-------------|
| Highest Gain | 58.652 |
| Lowest Gain | 48.576 |
| Average Gain | 53.614 |
| Increase in average scores | 53.936% |
| Average N-Gain | 0.536 |
| Interpretation Criteria | Medium |
Based on Table 4, the value of N-Gain obtain an increase of 53.936% with an average N-Gain 0.536 which shows in the medium category. Based on the category of effectiveness interpretation N-Gain is known that the average value of n-Gain amounting to 53.614 are at intervals of 56 to 76 with less affective category.

Based on the average critical thinking skills data in Table 5, it is known that the highest N-Gain on the indicator determines the name of the variable at coordinates (x, y) of 0.80 and the lowest N-Gain on the indicator determines the independent variable and the dependent variable into the graph. of 0.43.

| Indicator                                                      | Pretest | Posttest | N-Gain |
|---------------------------------------------------------------|---------|----------|--------|
| Identifying graphs from data                                  | 39.43   | 86.29    | 0.77   |
| Determine the independent variable and the dependent variable in the graph | 10.29   | 49.14    | 0.43   |
| Specifies the name of the variable at the coordinates (x, y)  | 5.14    | 81.14    | 0.80   |
| Determining the value of a physical variable/quantity from the graph | 4.00    | 69.71    | 0.67   |
| Determine the relationship between variables                   | 12.00   | 77.71    | 0.75   |

Based on Table 6 in the data normality test is known that the significance of pretest sig. (0.154) > α (0.05) and posttest sig. (0.20 0) > α (0.05), so that both the data normally distributed.

| Kolmogorov-Smirnov                                              | Shapiro-WI k |
|---------------------------------------------------------------|--------------|
| Statistics          df       Sig.     Statistics          df       Sig.     |
| Pretest Score       0.129          35  0.154     0.970          35  0.431      |
| Posttest Score      0.122          35  0.200     0.973          35  0.531      |

Hypothesis testing in this study used the paired sample t-test technique. Test paired sample t-test aims to determine differences in average-average results of critical thinking skills before and after being treated. After being given treatment, there was an increase in students' critical thinking skills. Based on the results of hypothesis testing using a paired sample T-test to see the difference in average critical thinking skills before and after the learning using video tracker in Table 7 obtained value sig. (0.00) < α 0.05. So it can be said that there is a difference average-average critical thinking skills before and after the learning using video tracker.

This is in accordance with the research conducted by Fitriyanto and Sucahyo which stated that the analysis of the pretest and posttest question sheets, learning using a video tracker improved skills with
a medium gain category [19]. So it is clear that learning using tracker can improve students’ critical thinking skills. This is because by using a video tracker, you can display results in the form of images, tables, graphs and find the equations of motion of objects with great precision. The tracker has the ability to track the motion of an object, so that various information needed in the analysis of a motion event can be obtained [20]. After going through the activity of recording a real motion phenomenon using a video recorder, the recording results can be processed on the tracker application. One use of video tracker contributes to practicing the ability to interpret or interpret a representation of data. The interpretation of the data that can be seen on the video tracker is the interpretation of images, tables, graphs and equations of motion [19].

In physics learning, interpretation includes the ability to interpret pictures, graphs, diagrams, mathematical equations, and the ability to interpret various types of data [19]. Based on the test results, students' critical thinking skills have increased. The result is consistent with the understanding of the link between verbal and visual capabilities to improve knowledge of the concept and the process of science. The following are the results of the critical thinking skills test on the pretest and posttest scores. The very significant difference in the average pretest and posttest indicators is supported by student activities in the learning process in class. Activities carried out by students ranging from observing a problem, conducting live demonstrations, recording demonstrations, analyzing demonstration data using a tracker application, for communicating demonstration results. Based on the results of the attitude assessment, which is 82.5%, it shows that student activities during the learning process are active. This is because the tracker application is relatively new to be applied in physics learning, so students feel very interested in knowing the tracker application in various physics demonstrations [19].

Learning activities emphasize the process of thinking critically and analytically to find the answer to a problem for yourself. This learning leads to a problem based learning model that focuses more on real life problems and is meaningful for students. Students must be able to use and integrate the knowledge that they already have or seek the knowledge needed in order to overcome the problem. Problem based learning is able to provide opportunities for students to be active in interacting, reflecting, and taking the initiative in discussion activities. (1) Students better understand the concepts being taught because they themselves discovered the concept; (2) involves actively solving problems and demands students' higher thinking skills; (3) embedded knowledge based on students' schemas so that learning is more meaningful; (4) students can feel the benefits of learning because the problems that are solved are directly related to real life, this can increase students' motivation and interest in the material being studied; (5) make students more independent and mature, able to give aspirations and accept the opinions of others, instill positive social attitudes among students; and (6) student conditioning in group learning that interacts with students and their friends so that the achievement of student learning mastery can be expected.

Students conduct critical thinking at the time of air discussions by analyzing data from the results of the demonstration. Students are guided by the teacher to read the table and compare it with the graph formed on the tracker. Based on this stage, students can know that the graph is a representation of the table data. Skills of critical thinking that exist on items divided into five indicators, namely (1) identify the graph of the data, (2) determine the independent variables and the dependent variable in the graph, (3) determine the variable name at coordinates (x, y), (4) determine the value of the physical variable/quantity on the graph, and (5) determine the relationship between variables. The average critical thinking skills on each indicator after learning can be observed in Table 5.

Based on Table 5. It is shown that the highest critical thinking skill indicator is indicating (1) with an average value of 86.29. Critical thinking skills are high due to the students have been able to identify the shape of the graph parabolic motion there are currently analyzing the data demonstration using the video tracker, explaining the amount indicated, and understand the relationship between variables so that students can take information from a chart very well. Critical thinking skills are defined as the
ability to translate from graphs to verbal expressions. Students can extract the information from graphs they need to solve problems and make different types of interpretations or focus on different aspects of graphs [19].

Critical thinking skills in indicator (2) show the lowest critical thinking skill indicator, namely determining the independent variable data and the dependent variable in the graph, obtaining an average value of 49.14. This is because students have difficulty understanding between the independent variables and the dependent variable contained in the critical thinking skills test questions.

Meanwhile, the results of Subekti's research show that there is a significant increase in learning outcomes of cognitive aspects of physics and science process skills in terms of initial physics abilities in the problem based learning model through the experimental method [19]. The science process skills studied are conducting research/experiments such as carrying out experiments related to the subject of parabolic motion in accordance with the independent variables, controlled variables and dependent variables that have been determined and can test the hypotheses that have been made. This process skill is not understood by students so they cannot solve the problem if the variable is changed.

Critical thinking skills in indicator (3) determine the name of the variable in the coordinates (x,y) to obtain an average value of 81.14. This indicator is in the second rank of the five critical thinking indicators observed. This happens because students can determine the name of the variable in the coordinates (x,y) which is presented on the parabolic motion graph in the video tracker analysis. The graph shown in the video tracker analysis is a vertical line that shows the deviation axis (y) and the horizontal axis which is the time axis (t). The use of video tracker analysis also shows the ability to interpret the equations of motion so that students can find out the mathematical interpretation.

Critical thinking skills in indicator (4) determine the data value of the variable obtaining an average value of 68.71. This value is the second lowest value because students have not been able to determine the value of physics quantities on the graph variables presented to be able to find the required data information. If the concepts and interpretations are not good, then students will find it difficult to solve parabolic motion graph problems. Prasetya argues that it is impossible to draw and think critically without understanding the concept of the quantity in question. Therefore, to determine the variables of a graph, an understanding of the concept is needed and finding the required information [19].

Critical thinking skills in indicator (5) determine the relationship between variables obtaining an average value of 77.71. This is because students already understand the relationship between variables so that students can take the information from the graph very well. However, students have not been able to describe it in graphical form. Therefore, this indicator is in third place.

4. Conclusions
The conclusions of this study are learning to use a video tracker-based problem-based learning in a parabolic motion effectiveness, improve critical thinking skills of students with a significance of 0.00. Achievement of critical thinking skills of students learning parabolic motion on problem based learning to identify the graph of the data reaches N-Gain 0.77; the ability to determine the independent variable data and the dependent variable into the graph reached N-Gain 0.43; the ability to determine variable names in (x, y) coordinates reaches N-Gain 0.80; the ability to determine the data value of the variables reached an N-Gain of 0.67 and the ability to determine the relationship between variables reached an N-Gain of 0.75.

Video-based learning using the Tracker video analysis is very good to be developed in learning Physics. This method could be an alternative solution though experiments do direct activity in the absence of a complete laboratory equipment and adequate. The tracking software provides facilities for the representation of some experimental data. Video tracking analysis using Tracker software can train students' multiple representation skills in the context of Physics.
Based on the research that has been done, it is suggested that a sovereign, when teachers or researchers else wants to train critical thinking skills, then can use the video analytics tracker as an alternative to learning physics. A video tracker analysis is used as a way to process data to get graphs, tables, and equations of motion. The video tracker analysis has very high accuracy. Video recording in analysis uses trackers to practice graphic interpretation skills. Students must gain experience in processing their respective data even though the implementation is carried out in groups.

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