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The Effect of Problem-Based Learning Models with Phet Simulation on Critical Thinking Ability on Parabola Motion Materials

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Abstract— This study aims to examine the effect of problem-based learning model with PhET simulation on critical thinking skills on parabolic motion material. This type of research is quasi experiment with non-equivalent control group design. The population in this study were all students of class XI SMAN 6 Mataram. The sample of this study was taken using purposive sampling and selected XI.2 class of 32 people consisting of 14 boys and 18 girls as the experimental class and XI.4 class of 34 people consisting of 16 boys and 18 girls as the control class. The experimental class was treated with problem-based learning model with PhET simulation and the control class was treated with conventional learning. The research instrument in measuring critical thinking skills in the form of a description test of 6 questions. The research hypothesis was tested using the Twin-Sample t-test with a significance level of 5%. The Twin Snippet t-test resulted in the t_{count} of students' critical thinking skills of 4.65 greater than the t_{table} which is 1.66 so that Ho is rejected and Ha is accepted. So, it can be concluded that there is an effect of problem-based learning model with PhET simulation on critical thinking skills on parabolic motion material.

Keywords— Problem Based Learning Model; PhET Simulation; Critical Thinking Ability; Parabola Motion
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Introduction

Physics is one of the most basic sciences in science and a fundamental science that can help to understand, study and develop other sciences in various fields. Physics learning includes many concepts and principles that are generally still abstract (Juniartini *et al*., 2017). According to Fathurohman (2014), abstract physics material is often difficult to visualize directly, making it difficult for students to learn and understand abstract physics concepts, which makes students think that physics is difficult and boring. According to Rokhmat, J. (2023), the phenomenon that often occurs is that students rarely master physics concepts thoroughly. The impact not only reduces the ability to understand physics concepts, but also worsens critical thinking skills which have a very strong correlation with student learning outcomes (Saparuddin *et al.*, 2021).

Critical thinking is the process of searching, creating, analyzing, collecting, and conceptualizing information with personal awareness and the ability to increase creativity when facing problems (Yildirim & Ozkarahman, 2011). The importance of critical thinking skills that students must have is emphasized in research conducted by Arifah *et al*., (2021), which states that learning physics requires students' ability to think critically because the lesson includes theories about nature and life. In line with that, Prayogi, S., Yuanita, L. & Wasis (2018) who said that the ability to think critically is a skill to face a variety of more complicated challenges, which requires the use of deeper mindsets and standards.The indicators of critical thinking skills used in this study are; (1) interpretation; (2) analysis; (3) evaluation; (4) inference; (5) explanation; and (6) self-regulation (Facione, 2020). One way to improve students' critical thinking skills and make them interested in physics learning can be developed by applying appropriate and innovative learning models so that learning objectives can be achieved.

Improving learners' critical thinking skills and making them interested in physics learning can be developed by applying appropriate and innovative learning models so that learning objectives can be achieved. Innovative learning models are important because they help learners acquire the skills needed in an increasingly complex and fast-changing world. This model also helps learners learn more effectively by increasing their participation in the learning process and providing meaningful real learning experiences (Salamun *et al*., 2023). With regard to the learning model needed, many innovative learning models can be applied to improve physics critical thinking skills, such as problem-based learning models, *Creative Problem Solving* models, *Project Based Learning* models and *Discovery Learning* models in order to achieve maximum results (Setyorini *et al*., 2011).

The implementation of learning models alone is not enough to improve physics critical thinking skills, including some abstract material so that if the explanation is not supported by good media, students will experience obstacles due to differences in abstract thinking abilities and imagination of each student (Sari *et al.*, 2018). On the other hand, in physics lessons students must do practicum, which means they must apply the material in real-world situations (Purwoko, 2018). However, some practicums cannot be done directly in the laboratory for several reasons, not only because of the minimal availability of equipment, but due to the unique nature of physics material which involves abstract processes and concepts that cannot be observed directly (Medica *et al*., 2021). Therefore, the use of virtual laboratories such as *PhET* (*Physics Education Technology*), *Go-Lab*, *Physics Lab*, and *Microscope* are alternatives to laboratory experiments (Oktaviani, 2016).

Based on the results of observations and interviews with Mr. Boby Hadi Kurniawan, S.Pd. as a physics teacher in class XI, it shows that the conventional approach is still used to teach in class. In this situation, teachers are more likely to use conventional learning by using lectures and question and answer as the main method. Researchers also found that the physics learning process still relies on teachers, textbooks, and homework packaged in LKPD. In addition, the use of practicum methods to support physics learning at school is rarely done, due to the limited tools and materials used in practicum. This results in low physics scores obtained by students, which indicates that their critical thinking skills are also low. To improve students' critical thinking skills, a learning model that supports it all is needed. The learning model that supports is a problem-based learning model.

Based on the description above, an innovative learning model is needed in order to overcome the problems and obstacles faced by students. One of the learning models that can be applied to help students practice critical thinking skills is the problem-based learning model. The problem-based learning model is considered to have an important influence on students' critical thinking skills, this is supported by previous research from Dianawati (2017) which states that the problem-based learning model makes students actively seek their own knowledge in solving problems so that it can affect their critical thinking skills. According to Untari *et al*., (2018) the problem-based learning model is a learning model that encourages students to research and work together in groups to solve problems that exist in the real world. This model utilizes examples of problems from everyday life to arouse the interest of learners before they start studying a particular topic.

Suharta & Putri, (2013) stated that the use of problem-based learning models in learning activities makes learners think more than remember, better understand the lesson through discussion, and accept the learning model. The principle in the problem-based learning model is that learners actively seek solutions to problems given by the teacher. The teacher acts as an intermediary and facilitator in helping learners construct their knowledge (Gunawan *et al*., 2021). According to Anam (2022), the two main components of the learning process that must be considered include the learning model and learning media. With the help of learning media, educators can more easily convey lessons and participants can better understand what is being taught.

One type of learning media that can be used today is the virtual laboratory-based PhET simulation. According to Prihatiningtyas *et al*., (2013) by using static and dynamic visualizations, PhET simulations can make abstract concepts concrete. This makes it more interesting especially in the field of physics, where concepts are mostly abstract as well as providing voltmeters, thermometers, rulers, and stopwatches. PhET simulations are designed to allow learners to explore and improve their conceptual understanding of physics. The characteristics of this PhET simulation are that the PhET simulation is very interesting, the experimental model is easy to understand, the PhET simulation can overcome misconceptions, learners can try new knowledge independently without the help of a teacher, the PhET simulation can be accessed easily and there is no charge (Wieman *et al*., 2010).

Amalia *et al* (2022) explained that the problem-based learning model assisted by PhET simulation can improve students' physics critical thinking skills. Therefore, researchers are interested in conducting research on the effect of problem-based learning models with PhET simulations on critical thinking skills. The objectives to be achieved in this study are to examine the effect of problem-based learning models with PhET simulations on critical thinking skills.

Method

This type of research is a quasi-experiment with a non-equivalent pretest-posttest control group design because the number of control and experimental classes is not the same. The place of research was SMAN 6 Mataram. The population in this study were all students of class XI of SMAN 6 Mataram in the academic year 2023/2024 which amounted to 131 people. The samples used were class XI.2 and XI.4. The sampling technique used purposive sampling technique. Class XI.2 of 32 people consisting of 14 boys and 18 girls as the experimental class and XI.4 of 34 people consisting of 16 boys and 18 girls as the control class. The experimental class was treated with a problem-based learning model with PhET simulation, while the control class was given conventional learning. The variables used in this study are independent variables and dependent variables. Problem-based learning is the independent variable and critical thinking ability is the dependent variable.

This study used a test instrument in the form of a description test used to measure critical thinking skills. Data collection techniques by giving test instruments in the form of 6 items of description questions to students who have been selected according to the results of validity, reliability, differentiation of questions and difficulty level of questions. Learners are given an initial test (pretest) and a final test (posttest) to analyze critical thinking skills.

Research data analysis uses normality, homogeneity, and hypothesis. The normality test aims to determine whether the data obtained is a normal distribution or not using the chi squared test. The homogeneity test aims to determine whether the objects studied have the same variance or not (Siregar, 2017) using the variance test or F-test. Hypothesis testing to determine whether or not there is an effect of problem-based learning model assisted by PhET simulation on critical thinking skills using t-test.

Result and Discussion

The results of this study consist of instrument test results, hypothesis prerequisite test results and hypothesis test results.

Instrument Test Results

Before the test instrument was given to the experimental class and control class, the researcher first tested the instrument as many as 6 questions in class XII MIPA 3 SMAN 6 Mataram. The data from the test results of this instrument was then carried out validity test, reliability test, differentiator test and difficulty test. The validity test is a description test of parabolic motion material related to critical thinking skills. Furthermore, the reliability test is carried out to determine the level of trust in the instrument, so that the instrument can be said to be reliable. Then the differentiating power test is carried out to determine the ability of a problem to be able to distinguish between high-ability students and low-ability students, as well as the difficulty test to determine the existence of a problem whether it is considered difficult, moderate, or easy to work on.

Validity Test

The validity test is a measure that shows how valid or valid an instrument is. The instrument validation process is carried out to evaluate how suitable the designed tool is for research. The validity test is sought using *product moment* correlation. The validity test results are presented in table 1 below.

Table 1 Critical Thinking Ability Instrument Validity Test Results

Question Instrument	Number of Items	Valid Question Items	Invalid Question Items
Critical Thinking Ability	6	6	-

Based on Table 1, it is known that in the critical thinking ability question instrument all question items are valid. Valid question instruments are suitable for measuring critical thinking skills.

Reliability Test

The reliability test is carried out to determine the level of trust in the instrument. In other words, a reliable test is a test that when used repeatedly to measure the same object, provides consistent or similar data. For the reliability test, the *Cronbach Alpha* formula is used. The reliability test results are presented in table 2.

Table 2 Critical Thinking Ability Instrument Reliability Test Results

Question Instrument	r_{11}	r_{table}	Description
Critical Thinking Ability	0,63	0,36	Reliable

Based on Table 2, it is known that the critical thinking ability instrument is said to be reliable, meaning that the instrument can be used to measure students' physics critical thinking ability.

Problem Difficulty Level

The level of test difficulty is the ability of the test to filter the number of students who answer correctly. A good test is a test question whose difficulty level is moderate. The results of the test of the level of difficulty of the items can be seen in Table 3.

Table 3 Results of the Level of Difficulty of Critical Thinking Ability Instrument Questions

Question Categories	Number of Items	Description
Difficult	-	-
Medium	6	1,2,3,4,5,6
Easy	-	-

Question Distinguishing Power

The differentiating power of the question is the difference between high and low ability students in the proportion of correct answers. The results of the test of the differentiating power of the items can be seen in Table 4 below.

Table 4 Results of Differentiability of Critical Thinking Ability Instrument Questions

Question Categories	Number of Items	Description
Bad	-	-
Fair	6	1,2,3,4,5,6
Good	-	-
Very good	-	-

Based on the results of the instrument trial, all question items were declared valid and reliable. The results of the differentiating power test stated that all questions were in the sufficient category. While the results of the difficulty test stated that all questions were in the moderate category. So the researcher concluded to take the six questions to do the pretest (initial test) and posttest (final test) in the experimental class and control class.

Critical Thinking Ability Test Results

Critical Thinking Ability Pretest Data

Pretest is given to determine the homogeneity of the initial ability of students in experimental and control classes. The results of the pretest of students' critical thinking skills can be seen in Table 5 below:

Table 5 Critical Thinking Ability *Pretest* Results of Experimental Classes and Control Classes

Class	Number of Students (N)	Lowest Score	Highest Score	Average	Category
Experiment	32	25	58,33	41,40	Low
Control	34	29,17	62,50	44,11	Low

Based on Table 5, the number of students in the experimental class is 32 with the highest score and the lowest score obtained are 58.33 and 25, while the number of students in the control class is 34 with the highest and lowest scores obtained are 58,33 and 29.17. The average score for the experimental class was 41.40 and 44.11 for the control class.

The initial ability of critical thinking in both classes (experimental class and control class) based on the initial test (pretest) is still low. This can be seen from the average critical thinking ability test in both classes, in the experimental class obtained an average of 41.40 and the control class obtained an average of 44.11. The low value of the initial test of critical thinking ability is caused by several factors, including the two classes have not obtained parabolic motion material so that the average students in both classes answer according to what they know (carelessly) and this causes some others to be lazy to answer the questions given. In addition, students are not used to answering questions using critical thinking skills indicators.

Critical Thinking Ability Posttest Data

After conducting a pretest to both classes, then the two classes were given different treatments. The treatment in the experimental class followed the syntax of the problem-based learning model which consists of five learning phases, namely: (1) the phase of orienting students to the problem, (2) the phase of organizing students to learn, (3) the phase of guiding individual and group investigations, (4) the phase of developing and presenting work, and (5) the phase of analyzing and evaluating the problem-solving process. In the first phase the teacher conveys learning objectives, motivates students to be involved in critical thinking activities and presents examples of phenomena related to parabolic motion material that will be discussed, in the second phase the teacher helps students to distribute learning groups and distributes LKPD. Furthermore, in the third phase the teacher directs students to work on LKPD, and guides students in conducting experiments, looking for explanations and solutions. In the fourth phase the teacher assists students in planning and preparing appropriate experimental results and helps them to convey them to others and in the fifth phase the teacher helps students to reflect on their investigations and the processes they use.

The treatment in the control class followed the syntax of the direct learning model which consists of five learning phases, namely: (1) the phase of conveying objectives and preparing students, (2) the phase of demonstrating knowledge and skills, (3) guiding training, (4) the phase of checking understanding and providing feedback, and (5) providing opportunities for further training and application. In the first phase the teacher provides apperception in the form of questions about the causes of a phenomenon, and in the second phase the teacher summarizes the material. Furthermore, in the third phase students are given exercises in the form of LKPD that have been prepared by the teacher. In the fourth phase the teacher asks representatives of students to write the results of the solution on the board then corrects the students' answers. In the fifth phase the teacher summarizes the material that has been learned.The results of the posttest of students' critical thinking ability after treatment can be seen in Table 6 below:

Table 6 *Posttest* Results of Critical Thinking Ability of Experimental Classes and Control Classes

Class	Number of Students (N)	Lowest Score	Highest Score	Average	Category
Experiment	32	54,17	100	85,41	Critical
Control	34	33,33	91,67	72,67	Medium

The final ability of students after being given treatment has a different average score between the experimental class and the control class which is 85.41 and 72.67 respectively. Students' physics critical thinking ability scores for the experimental class were higher than the control class for all indicators measured. The results obtained by researchers are in line with research conducted by Idris (2020) students taught using a problem-based learning model assisted by PhET simulations with students taught using direct learning models have different levels of achievement in critical thinking skills caused by the application of problem-based learning models assisted by PhET simulations given can confront students with real problems and require them to actively participate in solving problems. Zahara *et al.*, (2015) stated that the use of PhET simulation affects the critical thinking ability of students, because of PhET simulation can involve students in learning activities that require higher cognitive skills.

The stages of the problem-based learning model require students to think actively in the learning process. Learners are guided in finding concepts, understanding and applying these concepts to everyday life. The process of involving learners to think actively in learning will stimulate their critical thinking skills. Students' critical thinking skills can be trained at each stage of the problem-based learning model.

In the first stage, the teacher presents a problem that is close to the learners' lives through the angry birds game video. Then, in the video, learners are invited to observe how birds in the game are launched to destroy enemy fortresses by forming parabolic trajectories. The teacher then provokes learners to think and ask: “How can the bird's trajectory reach the target? What factors influence the trajectory?”. The indicator of critical thinking skills trained in this phase is interpretation, where learners are asked to relate the video footage to the concept of parabolic motion. At this stage, learners are trained to express their initial interpretation of the concept of parabolic motion, which then becomes the basis for further learning.

In the second phase, the teacher organizes learning activities by directing students to read the teaching material book that has been provided. The book contains an in-depth explanation of the concept of parabolic motion, complemented by illustrations and examples of applications in everyday life. This activity aims to encourage learners to re-access their prior knowledge while starting to analyze the problems given. The critical thinking indicator trained in this phase is analysis, where learners are invited to break down the concept of parabolic motion into components, such as the effect of launch angle and initial velocity on trajectory results. Through analysis, learners are invited to evaluate the relationship between variables in parabolic motion. The teacher also connects the material in the teaching materials book with the context of everyday life, so that learners can see the relevance of the physics concepts learned. This stage helps learners hone their analytical skills through in-depth understanding and text-based problem solving.

In the third stage, learners are directed to actively conduct independent or group investigations using PhET simulations on parabolic motion. The teacher acts as a facilitator, providing direction as necessary and motivating learners to explore concepts through interactive exploration. Learners are given Learner Worksheets (LKPD) designed to train critical thinking skills. Through the PhET simulation, learners can manipulate variables such as launch angle, initial velocity, and gravitational acceleration to observe how these factors affect the trajectory of parabolic motion. This can train learners to analyze their experimental results. Next, learners are asked to provide explanations based on the data they obtained, such as explaining the pattern of relationships between the variables tested in the simulation. At this stage, learners learn to integrate their observations with relevant physics concepts, so their critical thinking skills develop simultaneously. This simulation-based activity also strengthens learners' understanding of the concept of parabolic motion in a real context.

In the fourth stage, learners are asked to compile and present the results of their work in the form of a group report or presentation. Learners explain the concept of parabolic motion using their own understanding and words, and clarify the results of the analysis that has been done previously. The teacher encourages them to draw conclusions from the data obtained during the investigation process, so that critical thinking skills, especially in the inference indicator, can be honed. In this process, students are trained to integrate observations from PhET simulations or other activities, by interpreting the relationship between the observed variables. The presentation of the results of this work also trains learners to convey ideas in a logical and structured manner in front of their peers. This stage ensures that learners not only understand the material deeply, but are also able to make appropriate inferences from the data and situations they have analyzed.

In the fifth stage, learners are invited to evaluate the problem-solving process that has been done previously. They are asked to analyze the accuracy of the concepts used, the effectiveness of the strategies applied, and the suitability of the results with the theory of parabolic motion. The teacher provides guidance to help learners identify the strengths and weaknesses of the solutions they have made, so that critical thinking skills, especially on the evaluation indicator, can be trained. This stage also encourages learners to apply the concept of parabolic motion in new relevant situations, such as analyzing the trajectory of a ball in sports or predicting the distance of a shot in a particular game. In addition, they are invited to reflect on the understanding that has been built and consider how the concept can be applied more widely. Through this activity, learners not only improve their in-depth understanding of concepts, but also their ability to evaluate and improve the learning process independently, so that their critical thinking continues to develop.

Based on the series of lessons applied in the experimental class, there is a process to train students' critical thinking skills, because critical thinking skills will not develop if they are not trained. As stated by Snyder & Snyder (2008) critical thinking skills require practice, practice, and patience. Critical thinking skills do not occur outwardly, but need to be trained with the aim of preparing students to become critical thinkers (Rahma, 2012).

Hypothesis Prerequisite Test

Prerequisite tests are carried out before analyzing data and the aim is to see data that is normally distributed and has a homogeneous variant. The data obtained from the calculations are as follows.

Homogeneity Test

The data homogeneity test is a test that functions to determine whether or not the data from the pretest and posttest results of the experimental class and control class are homogeneous using the F-test. The homogeneity test can be seen in Table 7 below.

Table 7 Homogeneity Test Results of Critical Thinking Ability

Class	Test	Number of Students (N)	Variant (s^2)	F_{count}	F_{table}	Description
Experiment	*Pretest*	32	94,01	1,06	1,80	Homogenized
Control		34	88,51			
Experiment	*Posttest*	32	134,39	1,31	1,81	
Control		34	175,92			

Based on Table 7 above, it shows that it is smaller than the 5% significance level, namely for the pretest 1.06 < 1.81 and 1.31 < 1.81 for the posttest. Based on the decision-making criteria, the research data is homogeneous.

Normality Test

The data normality test is a test that serves to determine whether or not the data from the pretest and posttest results of the experimental class and control class are normal using the *Chi Kuadrat* test. The normality test can be seen in Table 8 below.

Table 8 Results of the Critical Thinking Ability Normality Test

Class	Test	x^2_{count}	x^2_{table}	Criteria
Experiment	*Pretest*	7,46	11,07	Normally Distributed
Control		6,59		
Experiment	*Posttest*	7,19		
Control		7,88		

Based on Table 8 above, it shows the normal distribution of data so that the type of research used is parametric statistics.

Hypothesis Test

Hypothesis testing is a test that aims to determine whether the hypothesis that has been determined in this study is accepted or rejected. The data used to test the hypothesis is the data from the pretest and posttest results which are normally distributed and homogeneous using the twin-sample t test. The results of the hypothesis test are presented in Table 9 below.

Table 9 Hypothesis Test Results of Critical Thinking Ability

Class	Number of Students (N)	Average Results Per Group	Deviation of Each *Pretest* and *Posttest* Score	t_{count}	t_{table}
Experiment	32	44,14	4300,67	5,23	1,66
Control	34	28,55	5074,04		

After conducting a homogeneity test and normality test on the initial test (*pretest*) and final test (*posttest*), then hypothesis testing is carried out. Based on the data, it is known that the number of experimental class students is not the same as the control class ($n_1 \neq n_2$). The number of experimental class students is 32 people and the control class is 34 people. Hypothesis testing in this study used paramertic statistics in the form of a twin-sample t-test and obtained the price. This price is greater than the price. Thus, the null hypothesis ($_{H0}$) is rejected and the alternative hypothesis (Ha) is accepted. So it is concluded that the problem-based learning model with *PhET* simulation affects critical thinking skills. The results of this study are supported by previous research conducted by Amalia, R., Kosim, K., & Gunada, I. W. (2022) which states that the problem-based learning model assisted by *PhET* simulation can improve students' physics critical thinking skills. In line with that, Rohmawati, L., Wulandari, R., & Wulandari, F. E. (2023) in her research concluded that there was a very good effect of the problem-based learning model integrated with PhET simulation media on critical thinking skills. The PhET integrated problem-based learning model is a systematic learning approach that allows students to describe and solve problems using PhET. Learners are given contextual problems and encouraged to describe the problem and provide explanations based on their knowledge to develop the right problem formulation. Fedi, *et al.* (2019) in his research stated that the problem-based learning model (PBL) has a positive and significant influence on the development of critical thinking skills in students because the PBL model can train students to think scientifically, students are more active, independent, responsible, confident in expressing ideas, able to work in groups, successfully solve problems presented by the teacher, create a good learning environment, can also encourage students to develop and improve critical thinking skills.

Based on this discussion, the results show that the use of problem-based learning models with PhET simulations can be used as an alternative in physics learning. In addition, based on other relevant research that has been presented and based on data analysis calculations, it has been proven that problem-based learning moduel with PhET simulation has a significant effect on students' critical thinking skills on parabolic motion material.

Conclusion

Based on the results of research conducted at SMAN 6 Mataram, data analysis and hypothesis testing at a significant level of 5% and discussion, it can be concluded that there is an effect of problem-based learning model with PhET simulation on critical thinking ability on parabolic motion material. Learning by using problem-based learning model with PhET simulation is better in solving real problems by using PhET simulation to understand the concept of parabolic motion so as to improve the critical thinking ability of students on parabolic motion material compared to conventional learning.

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